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International Handbook of Health Expectancies



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International Handbook of Health Expectancies

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International Handbook of Health Expectancies



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Preface

In 1989, an international group of researchers met together to discuss health expectancy, and so the International Network on Health Expectancy and the Disability Process, known by its French acronym REVES, was born. Over the years following, REVES met at least annually but was a closed network. Then, in 1991, the meeting in Leiden was open to any researcher interested in the topic, and REVES has continued to grow from then on.

In the early years of REVES, subgroups were formed to focus on the key issues around the, then relatively new, population health indicator: conceptual harmonization, methods, and policy relevance. Although the subgroups no longer exist, these three issues have remained the primary focus of REVES. The first book on health expectancy, *Determining Health Expectancies*, was published in 2003 and catalogued research from the first 10 years of the REVES network. It has become a key reference for teaching and research on this topic. A few years ago a group of us decided it was time for a second book since the quantity and quality of research had grown so much. So, here is the *International Handbook on Health Expectancies*.

We have structured the book into four parts, reflecting, as in the first book, the three pillars of the REVES Network but also, in the final section, adding important new research areas on this topic. Many chapters provide in-depth reviews of the literature on, and look forward to future developments in, the specific area. In Part I, *Monitoring Trends and Gaps*, Chap. 1 reviews the conceptual models of health, disability, and frailty that have developed in the last 15 years and how these have changed the operationalization of health and disability for population health indicators. After a detailed description of how life and health expectancy can coevolve in relation to the three theories of compression or expansion of morbidity and dynamic equilibrium, Chap. 2 then describes the trends in health expectancy worldwide. In the last decades, work of REVES has moved from simply documenting trends in, and estimates of, health expectancies to understanding the underlying drivers of such trends. The final two chapters of Part I cover this in terms of inequalities or gaps by socioeconomic status, at the level of countries or regions within countries (Chap. 3) and at an individual level (Chap. 4).

Developing and disseminating methods have always been one of the pillars of the REVES network, and Part II, *Advances in Data and Methodology*, addresses the progress made since the first book. Chap. 5 details the substantial increase in data sources for calculating health expectancy, particularly the increase in harmonized longitudinal studies worldwide. Chaps. 6, 7, and 8

document the progress made in methods to understand the underlying drivers of gaps and trends in health expectancies, specifically attributing the causes of disability (Chap. 6), decomposing the gaps in health expectancies (Chap. 7), and assessing the impact of risk factors (Chap. 8). One of the methods to assess the impact of risk factors includes microsimulation, and this is covered in more detail in Chap. 9, with Chap. 10 describing this method to produce forecasts of health expectancies.

The REVES network has always seen the relevance for public health policy of a population health indicator that reflects both the quality and quantity of remaining life, rather than just the quantity. Part III, *Quantity and Quality of Life: Synergy or Trade-off*, reflects the importance of this topic. Chap. 11 brings new analyses to help understand why women live longer than men but spend a higher proportion of their remaining years in poorer health. Self-rated health is one of the main health measures used for health expectancy, and Chap. 12 discusses the discrepancies between this subjective and more objective measures of health status, proposing practical recommendations for using self-rated health in future studies on ageing. Perhaps the biggest change since the last book is the way that the governments in many countries now understand the value of health expectancy and are using it in targets. The final three chapters in the section document this rise in the uptake of the Healthy Life Years indicator in Europe (Chap. 13), Japan in the area of health promotion (Chap. 14), and the evaluation of health care and health systems (Chap. 15).

Part IV, *Assessing New Dimensions*, comprises six chapters on new dimensions of health or new thoughts on existing ones. The disablement process, rather than health expectancy per se, is the focus of two chapters: Chap. 16, which looks at the role of pain in the process, and Chap. 20, which takes a fresh view of the process in the context of other conceptual models. Mental health has always been a key health dimension considered for health expectancy estimates and, in cognitive impairment, has benefitted from much greater harmonization across studies. However, the growth in surveys, including measures of cognition and mental health, since the first book requires that evidence is reassessed, and Chap. 17 consolidates the findings from across the world on cognitive and mental health expectancies. With continued increases in life expectancy, countries are seeing the need to extend working life and delay the statutory retirement age. Working life expectancy is an existing indicator to monitor developments in this area, and Chap. 18 brings a novel approach for viewing working life expectancy alongside health expectancy to ascertain whether extending working life is possible given the population health around retirement. The remaining two chapters in this section cover new health dimensions of subjective well-being (Chap. 19) and oral health (Chap. 21).

The final chapter in the *International Handbook on Health Expectancies* brings an overall conclusion and consolidation of the research and looks ahead to where future developments in health expectancy might lie. We hope

this book will become, as the first book, a key teaching and research tool for current and future generations, as well as for those already well-versed in health expectancies and those new to the topic.

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Abbreviations

| | |
|---------|--|
| ADL | Activities of Daily Living |
| CIFLE | Cognitive Impairment-Free Life Expectancy |
| DALY | Disability-Adjusted Life Years |
| DemFLE | Dementia-Free Life Expectancy |
| DFLE | Disability-Free Life Expectancy |
| DLE | Disability Life Expectancy |
| DSM | Diagnostic and Statistical Manual of Mental Disorders |
| EC | European Community |
| EU-SILC | European Union Statistics on Income and Living Conditions |
| GALI | Global Activity Limitation Indicator |
| GBD | Global Burden of Disease |
| GDP | Gross Domestic Product |
| HALE | Health-Adjusted Life Expectancy |
| HE | Health Expectancy |
| HLE | Healthy Life Expectancy |
| HLY | Healthy Life Years |
| HRQL | Health-Related Quality of Life |
| IADL | Instrumental Activities of Daily Living |
| ICD | International Classification of Diseases |
| ICIDH | International Classification of Impairments, Disabilities, and Handicaps |
| ICF | International Classification of Functioning, Disability and Health |
| LE | Life Expectancy |
| MEHM | Minimum European Health Module |
| OECD | Organization for Economic Cooperation and Development |
| QALY | Quality-Adjusted Life Years |
| REVES | Réseau Espérance de Vie en Santé/International Network on Health Expectancy and the Disability Process |
| SES | Socioeconomic Status |
| SRH | Self-Rated Health |
| ULE | Unhealthy Life Expectancy |
| UN | United Nations |
| WHO | World Health Organization |
| YLD | Years Lived with Disability |
| YLL | Years of Life Lost |

Part I

Monitoring Trends and Gaps



Operationalization of Concepts of Health and Disability

1

Renata Tiene De Carvalho Yokota
and Herman Van Oyen

Introduction

For a long time, the concept and measurement of health has focused on pathology. The disease-oriented definition was related to one of the main challenges of societies – disease control (Breslow 1972). The concept of health as “absence of disease”, defined in the medical model (Larson 1999), was closely linked with the high impact of infectious diseases on morbidity and mortality in the nineteenth century. At the same time, pathology advanced and diseases were better defined, with the identification of their etiologic agents and pathogenesis. Although it seems contradictory, it was natural to define health based on disease, owing to the expansion of medical sciences (Breslow 1989).

Advances in medical therapies and improvement of living standards, work conditions, personal hygiene, food access, public sanitation, and

immunization contributed to the control of infectious diseases at the beginning of the twentieth century. Population ageing accompanied by the insidious increase of chronic diseases and disability became a reality around the globe (Breslow 1989; Omran 2005). In the face of the shift in mortality and morbidity patterns, the World Health Organization (WHO) proposed a new concept of health – “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (International Health Conference 1946). Even though the WHO definition of health was considered innovative, as it, for the first time, focused on positive health (Breslow 1989), it has received numerous criticisms. For instance, a complete state of well-being is not achievable with the ageing of populations, which are growing older with chronic diseases and disability (Huber et al. 2011; Godlee 2011; Huber et al. 2016). Most individuals would not be considered healthy by the WHO definition, as anything less than this “complete state” is considered unhealthy (Smith et al. 2009). Yet, after 70 years of its proposal, it remains the most popular definition worldwide.

The concept of disability and its operationalisation has also evolved over time (see Chap. 20). Until the 1970s, the medical model was the dominant theory used to define disability, the focus being mainly on the individual, with disability considered a medical problem that requires treatment (Goering 2015). A first disablement model

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was proposed by Nagi (Nagi 1965), with the distinction of pathology, impairments, functional limitations, and disability. In 1980, the WHO proposed the International Classification of Impairments, Disabilities and Handicaps (ICIDH), as a taxonomy for disease impacts, in parallel to the International Classification of Diseases (ICD), the standard taxonomy of diseases (Verbrugge and Jette 1994). The ICIDH distinguished three dimensions on the disablement process: impairment, disability, and handicap (World Health Organization 1980). In 1994, Verbrugge and Jette (Verbrugge and Jette 1994) combined and extended the Nagi's and WHO ICIDH models, by considering the role of risk factors for chronic diseases, and intra- and extra-individual factors to the disablement process. In 2001, the WHO endorsed the International Classification of Functioning, Disability and Health (ICF) (World Health Organization 2001). The ICF is a result of the important shift from the medical model to the "biopsychosocial" model of disability that integrates environmental factors and emphasizes participation – the ultimate step on the disablement process. Within the ICF framework, disability became the umbrella term for impairments, activity limitations and participation restrictions. Participation restriction denotes the negative aspects of the interaction between an individual's health condition(s) and the individual's contextual factor (environmental and personal factors) (Jette 2009). As such, it refers to the performance of roles and social involvement in activities such as work, employment, school, parenting, community, social and civic life (Dijkers 2010). Recognizing that disability is an evolving concept and that it results from the interaction between persons with impairments and attitudinal and environmental barriers that hinder their full and effective participation in society on an equal basis with others, the ICF is in line with the definition of disability of the United Nations Convention on the Rights of People with Disabilities (United Nations 2006).

Another important concept emerged with population ageing in the 1990s, that of frailty. The first definitions of frailty were close to multimorbidity and disability (Hamerma 1999), but cur-

rently it has been used to describe vulnerable older individuals (Fried et al. 2004). Several operationalisations of the concept of frailty have been proposed: (i) the phenotype of frailty (Fried et al. 2001) which defines frailty as a clinical syndrome with three or more of the criteria: unintentional weight loss, weakness, self-reported exhaustion, slow walking speed and low physical activity; (ii) accumulation of deficit approach (Mitnitski et al. 2001), based on the frailty index, obtained by counting deficits, defined as health problems such as symptoms, signs, laboratory abnormalities, diseases, and disabilities (Rockwood and Mitnitski 2011); and (iii) integral conceptual model (Gobbens et al. 2010c), which defines frailty as a dynamic state affecting an individual who experiences losses in one or more domains of human functioning (physical, psychological, social) that increases the risk of adverse outcomes.

As health covers different domains (physical, mental, social) and each can be defined in different dimensions ranging from positive health, ill health, disease and disability there is no single measure of health but a range of measures that may tell (in)consistent stories about the health of the population as each of them cover different dimensions. This introductory chapter aims to review existing methods that operationalize the concepts of health, disability, and frailty in population health research. Several other chapters in this book cover these concepts in more detail, e.g. Chap. 5 discusses how, within different data sources, the concepts of health are brought into practice using appropriate instruments to fit particular research or policy questions.

Health

The measurement and operationalization of health has become increasingly important, as health is the aim of healthcare and research (Godlee 2011). The operational definition of health is crucial for: (i) evaluating public health interventions; (ii) assessing the quality of care; (iii) estimating the needs of a population; (iv) informing clinical decision-making; (v) allocating health-related

resources; and (vi) facilitating patients' autonomy (Ware et al. 1981; Huber et al. 2011).

Health is a complex concept that includes a wide range of dimensions such as risk factors, disease, impairment and disability. Health encompasses what is happening within the body (the biomedical approach) and the impact of pathology or abnormal functioning of organs and body structure on the individual's ability to participate in society. As mentioned earlier, there is no single measure of health, but these different health constructs may reflect different operational needs. A first step in developing summary measures of health is to identify which aspects of health should be captured and to be clear on the choices made. We present definitions and operationalisations proposed by the medical model, the World Health Organization (Card 2017), EuroQol group (EuroQol Group 1990), Huber et al. (2011) (Huber et al. 2011) and self-rated health.

The Medical Model

The medical model uses a negative concept of health, as health is defined as the absence of disease and infirmity. The diseases are detected in accordance with standard accepted procedures, such as medical examinations, diagnostic tests, and symptoms. This model is considered narrow and incomplete (Huber et al. 2011) for: (i) excluding mental and social problems in the definition of health; (ii) focusing on negative aspects of health rather than the individuals' abilities and strengths; and (iii) discouraging patient empowerment (Swaine 2011). In the medical model and following the ICD taxonomy, health is measured by disease-specific incidence or prevalence and/or disease-specific death rates, which are insufficient to measure population health.

WHO Definition

In contrast to the medical model, the WHO definition of health – a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity – was considered

visionary when it was proposed in 1946 (Card 2017), as health was not only considered the absence of diseases, but also included physical, mental and social components with a focus on positive health (Huber et al. 2011).

Nonetheless, this definition has been criticized for more than 70 years, owing to the epidemiological transition that the world is facing with the ageing of populations and the change in the disease pattern from infectious to non-communicable chronic diseases. The main limitations of the definition include: (i) an emphasis on "complete wellbeing" which is unachievable, leaving most of the population unhealthy, unintentionally contributing to the medicalization of societies (e.g. most individuals would be eligible for unnecessary screening or expensive interventions, resulting in higher medical dependency); (ii) the current global phenomenon of population ageing accompanied by the burden of chronic diseases and disability would classify older individuals with these conditions definitively as ill, ignoring the capacity to adapt and to be able to live independently with chronic diseases and disability; and (iii) the lack of operationalization of the definition (Huber et al. 2011; Godlee 2011). Despite these numerous criticisms, the WHO definition of health remains the most popular definition worldwide (Larson 1999; Card 2017).

In 2002, the WHO proposed a conceptual basis for reporting and measuring health (Chatterji et al. 2002). In this report, health is a multi-dimensional concept, distinguished from well-being, that is comprised of states or conditions of human body and mind and is considered an attribute of an individual person, although aggregate measures of health may be used to describe populations or aggregates of individuals. Health is classified based on two WHO frameworks: (i) the International Classification of Diseases and Related Health Problems (ICD) (World Health Organization 2011a) to classify causes of death; and (ii) the International Classification of Functioning, Disability and Health (ICF) (World Health Organization 2001), to classify health states. The health states are described based on the following core domains: affect, pain, mobility, cognition, self-care, and usual activities (Chatterji et al. 2002).

EuroQOL

The EQ-5D instrument was developed by the EuroQol group and created in 1987 by multidisciplinary researchers with interest in health care evaluation (Cabasés and Rabin 2014). The EQ-5D instrument is a health-related quality of life questionnaire, which includes two components: (i) the EQ-5D descriptive system and (ii) EQ-Visual Analogue Scale (VAS). The EQ-5D descriptive system comprises five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression, and is available with three (EQ-5D-3L) and five (EQ-5D-5L) level response options. The EQ-VAS is a vertical visual analogue scale used to capture self-rated health, with endpoints ranging from “best imaginable health state” to “worst imaginable health state”. The responses to the EQ-5D instrument can be used to obtain a simple and generic measure of health status with a single index value (EQ-5D index) for all health states described by a 5-digit number. The EQ-5D index values can be used to estimate composite measures such as Quality Adjusted Life Years (QALYs), which are often used in economic evaluation to inform priority setting in health care, in clinical studies, and in population health surveys (Cabasés and Rabin 2014).

Health Concept Proposed by Huber

Huber et al. (2011) proposed the following concept of health: the ability to adapt and to self-manage, in the face of social, physical and emotional challenges. This definition contrasts with the WHO definition by emphasizing the ability of individuals to cope with chronic diseases and disability.

This definition has also received criticism, mainly related to the emphasis on adaptation and self-management which: (i) could encourage reactive instead of proactive actions for health, as the life challenges are unknown until they occur (Becker 2011); and (ii) also denies the fact that some social determinants may preclude the ability of individuals and communities to adapt to

their circumstances (Macaulay 2011). A qualitative study conducted with public health and health care professionals from the Netherlands highlighted that this definition does not focus on the relation between individual and population health, resulting in a low priority of prevention measures; secondly, it may promote socioeconomic inequalities in health, as individuals are not equally capable of taking care of their own health (Jambroes et al. 2016). Similar to the WHO definition, the definition proposed by Huber et al. also neglects socioeconomic, cultural, and environmental determinants of health.

Self-Rated Health

Self-rated health (SRH) is a self-reported measure of general health, which asks individuals to evaluate their health status (“In general, would you say your health is...”) based on a scale (“excellent,” “very good,” “good,” “fair,” or “poor” (Jylhä 2009; Bombak 2013) or “very good”, “good”, “fair”, “poor” or “very poor” (De Bruin et al. 1996)). SRH is a well-known global or single item instrument with a satisfactory reliability (Cox et al. 2009) and validity (DeSalvo et al. 2006). It is one of the most used health indicators in sociology, epidemiology and economic studies, often being part of health and non-health surveys (Jylhä 2009; Wu et al. 2013). It has also been used in comparisons of health status between populations (see Chap. 12 for further discussion of the use of SRH in population surveys), in risk assessments and clinical practice and as an outcome variable in clinical trials (Jylhä 2009).

SRH is considered an independent predictor of mortality probably for being a very inclusive measure of health, reflecting aspects related to survival that may not be covered by other health indicators (Mackenbach et al. 2002). It has also been associated with morbidity and disability (Crimmins and Saito 1993; Bailis et al. 2003). SRH is also a comprehensive, inclusive and non-specific global measure of health status of populations. Nevertheless, these advantages can also be seen as limitations since the lack of specificity

results in a lack of control of the aspects of health to be considered in individual assessments. Also, SRH is not necessarily comparable between cultural and distant age groups, as e.g. older individuals tend to report more positive SRH than younger individuals (Jylhä 2009).

Disability

The remarkable increase in longevity observed worldwide has been followed by a shift in causes of mortality and morbidity in the past century. Populations are growing older in parallel with the burden of chronic diseases and disability. This has considerable social and economic consequences for societies, posing public health challenges for the next decades especially related to the health care of people with disability (World Health Organization 2011b). Measuring disability becomes crucial to monitor population health and to promote healthy ageing.

The measurement of disability is challenging, as it is a complex, dynamic, and multidimensional experience (World Health Organization 2011b). To better understand the disablement process, several models have been proposed. Nagi's model was proposed in 1965 (Nagi 1965). In this model (Fig. 1.1), pathology is the interfer-

ence with normal processes; impairment refers to a loss or abnormality at the tissue, organ, and/or body system level; functional limitations refer to restrictions in the performance of specific tasks by a person; and disability is defined as limitation in performance of socially defined roles and tasks within a sociocultural and physical environment (Jette 2009).

In 1994, Verbrugge and Jette (Verbrugge and Jette 1994) proposed an extension of Nagi's model, by using a similar main etiological pathway from diseases to disability, but also considering the role of risk factors for chronic diseases, intra-individual factors (e.g. lifestyle and behavioural changes; psychosocial attributes and coping; and activity accommodations) and extra-individual factors (e.g. medical care and rehabilitation; medical therapy; external support; and built, physical and social environment) factors, which can affect the level and pace the disablement process (Fig. 1.2). Chap. 20 further discusses these models.

Despite the difference in terminology, the framework used in the WHO International Classification of Functioning, Disability and Health (ICF) (World Health Organization 2001) describes the aetiology of decrements in functioning and disability not only in association with underlying health conditions, in line with the pre-

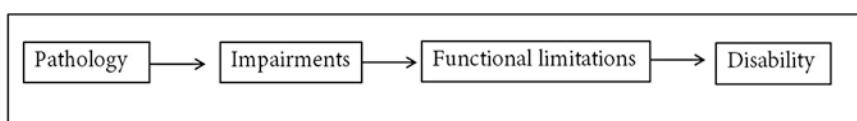


Fig. 1.1 Representation of the disability model proposed by Nagi (1965)

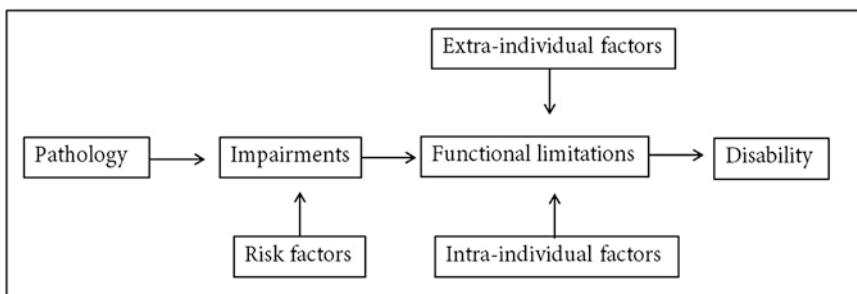


Fig. 1.2 Representation of the disability model proposed by Verbrugge and Jette (1994)

vious two models. Similar to the disablement model proposed by Verbrugge and Jette (Verbrugge and Jette 1994), it also takes into account the association with personal and environmental factors, i.e. disability is the result of the interaction between health conditions (such as diseases, disorders, injuries) and contextual factors – environmental (social attitudes and architectural characteristics) and personal (gender, age, education) factors (Jette 2009). The main difference is the bi-directionality of the associations in the main etiological pathway (Fig. 1.3).

The different domains covered by the disability models have, with the exception of impairments, been operationalized by different survey instruments as shown in Fig. 1.4. These instruments are discussed below.

Washington Group Questions

Since the ratification of the United Nations Convention on the Rights of Persons with

Disabilities (CRPD) in 2001 (United Nations 2006), the Washington Group (WG) was assigned to develop a culturally neutral and standardized instrument to measure disability suitable for censuses and surveys (Madans et al. 2011). According to the CRPD, disability is the result of the “interaction between persons with impairments and attitudinal and environmental barriers that hinder their full and effective participation in society on an equal basis with others” (United Nations 2006). The WG questions focus on measuring functioning in six basic actions or activities: seeing, hearing, walking/climbing, cognition, self-care and communication, with the aim to identify individuals with high risk of experiencing functional limitations in the population studied. The short set question is “Do you have difficulties in ...?”, with response options: no, no difficulty; yes, some difficulty; yes, a lot of difficulty; and cannot do it at all (Madans et al. 2011). The WG set with six questions and the WG short set with four questions (seeing, hearing, walking/climbing, and cognition) has been widely adopted in censuses and surveys (Verbrugge 2016) and cog-

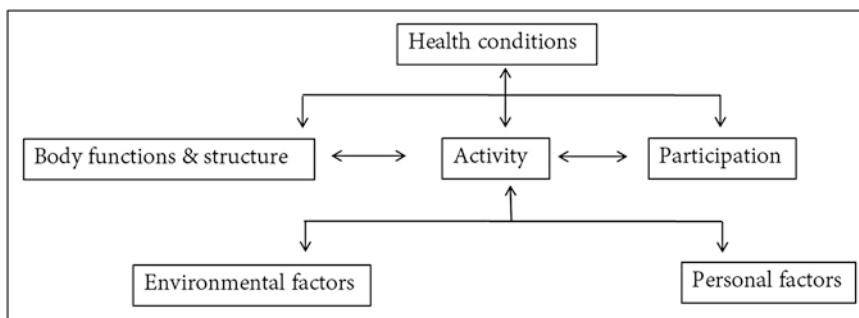


Fig. 1.3 Representation of the disability model proposed by the International Classification of Functioning, Disability and Health, World Health Organization 2001

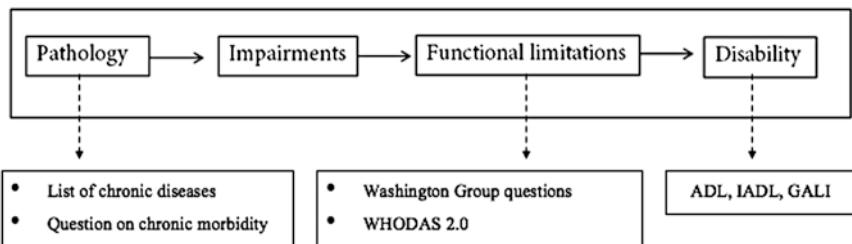


Fig. 1.4 Operationalization of the Nagi's (1965) and Verbrugge's (Verbrugge and Jette 1994) models

nitive interviewing was performed in several countries (Miller 2016).

WHO Disability Assessment Schedule (WHODAS) 2.0

The WHODAS 2.0 is a practical and generic assessment instrument to measure health and disability at a population level or clinical practice, directly linked to the WHO ICF (World Health Organization 2001), corresponding to the activity and participation dimension in the ICF (Üstün et al. 2010a). It captures the level of functioning in six domains of life: (i) cognition – understanding and communicating; (ii) mobility – moving and getting around; (iii) self-care – attending to one's hygiene, dressing, eating and staying alone; (iv) getting along – interacting with other people; (v) life activities – domestic responsibilities, leisure, work and school; and (vi) participation – joining in community activities, participating in society. Similar to the ICF, in WHODAS 2.0, health and disability are placed on a continuum, with disability defined as "a decrement in each functioning domain" (Üstün et al. 2010a).

The instrument includes questions related to difficulties in functioning experienced by the respondent in the six domains of life during the previous 30 days, with response options: none, mild, moderate, severe and extreme. Two versions are available: with 12 and 36 items and both versions can be self, interviewer or proxy-administered. Summary scores using the WHODAS 2.0 can be obtained by two methods: (i) simple – the scores assigned to each item are summed without recoding or collapsing any response category and without weighting of individual items; and (ii) complex – based on item response theory, which takes into account the level of difficulty in responding each item of the instrument. The resulting summary score of the complex approach is linear-transformed into a metric scale ranging from 0 (no disability) to 100 (full disability). WHODAS 2.0 has good psychometric properties, such as good reliability, being robust to different cultures and populations, and

concurrent validity compared to other disability measures (Üstün et al. 2010a, b).

WHO Model Disability Survey

According to the WHO ICF (World Health Organization 2001), disability involves problems in one or more dimension: impairment, activity limitation, and participation restriction (Fig. 1.3). In 2011, the WHO and the World Bank proposed the use of the Model Disability Survey (MDS; <https://www.who.int/disabilities/data/en/>) with an extensive questionnaire including several dimensions related to disability grounded in the ICF (Sabariego et al. 2015). The MDS aims at providing detailed information on the lives of people with disability. It explores disability as the experience of a person with a health condition or impairment encountering a facilitating or hindering environment, instead of solely focusing on the individual's health status.

In line with the conceptual framework of the ICF, the MDS considers that: (i) disability is not an internal attribute of a person but an experience; (ii) disability is etiologically neutral; (iii) disability is a continuum, a quantity, and a matter of degree, ranging from no disability to extreme disability; (iv) disability is universal, meaning every person can be located on the disability continuum.

The MDS questionnaire includes modules on socio-demographic characteristics (18 questions), work history and benefits (23 questions), environmental factors (79 questions), functioning (48 questions), health conditions and capacity (46 questions), health care utilization (46 questions), well-being (26 questions), and empowerment (20 questions). The MDS has been implemented in several countries, such as Chile, Sri Lanka, Cambodia, Oman and Pakistan. A brief version of the MDS has also been proposed to facilitate integration in surveys. This shorter version includes three modules: environmental factors (15 questions), functioning (12 questions), and health conditions and capacity (13 questions). The brief MDS was recently imple-

mented in the 2019 Gallup Word Poll (Gallup 2019) of India, Laos and Tajikistan.

The MDS takes the approach that disability is a universal phenomenon characterized by a continuum ranging from low to high disability levels. Following an approach similar to the one used in the World Report on Disability (World Health Organization 2011b) and using modern test theory, the functioning questions are used to build a disability scale with metric properties using the Rasch model. The whole general population sample is used to create this metric, which is then linearly transformed to range from 0 (lowest level of disability) to 100 (highest level).

Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL)

The most used definition to assess disability in an older population is based on the ability to perform personal care activities, also known as activities of daily living (ADL) and household management, called instrumental activities of daily living (IADL) (Verbrugge 2016). ADL were originally proposed by Katz (Katz 1963) as a measure of functioning to be used among chronically ill and ageing populations, to assess the degree of independence in six basic tasks: bathing, dressing, going to the toilet, transferring, feeding and urinary continence. The idea behind the use of ADL indicators is that loss of functionality is a result of the biological process of ageing and the social environment (Fuentes-García 2014). The IADL were proposed later by Lawton and Brody in 1969 (Lawton and Brody 1969), which includes more complex tasks than ADL. Those tasks are required for independent living, such as cooking, shopping, using transportation, taking medications and managing finances. Since IADL are usually lost before ADL functions, the assessment of the first may identify incipient decline in older adults. The ADL and IADL questions usually focus on the degree of difficulty to perform the tasks, with possible responses defined as a scale, e.g. no difficulty, some difficulty, a lot of difficulty, ability

to perform only with assistive devices, ability to perform only with personal assistance, and inability. To assess the disability prevalence in surveys, a score can be created based on all the ADL and/or IADL questions and different cut-offs are used to define the prevalence. Another approach is to aggregate the response options of the questions. For example, several studies considered disability present when the respondent replies at least some degree of difficulty in one or more ADL and/or IADL questions (Klijns et al. 2011; Van Oyen et al. 2014).

Global Activity Limitation Indicator (GALI)

In 2001, the Global Activity Limitation Indicator (GALI) was proposed as an indicator of participation restriction to monitor population health (Robine and Jagger 2003). In contrast to previous instruments that use several questions to assess disability, the GALI was developed to be a global measure, with a single question that can be easily introduced to surveys to assess disability, thereby improving international comparability (Berger et al. 2016; Verbrugge 2016). The question used to define the GALI is “For at least the past 6 months, to what extent have you been limited because of a health problem in activities people usually do?”, with possible answers: severely limited; limited but not severely; and not limited at all. The GALI implicitly refers to social participation in different settings (work, leisure activities, and environments) (Berger et al. 2016). The GALI has been used in the calculation of Healthy Life Years (HLY) to monitor population health in Europe since 2000, reflecting the Lisbon strategy (2000–2010) and later the Europe 2020 strategy (2010–2020) (Lagiewka 2012). To assess disability prevalence or the prevalence of participation restriction using the GALI, previous studies have grouped the response options (Jagger et al. 2008; Jagger et al. 2010; Berger et al. 2015b), or analysed them separately to assess different severity levels (Van Oyen et al. 2006; Mäki et al. 2013; Berger et al. 2015a). The GALI has good concurrent and predictive validity, being robust to differ-

ent cultures and populations, and good reliability (Van Oyen et al. 2018; Hsiao et al. 2019).

Importance of Including Disability Severity

Although most studies have defined disability as a dichotomous outcome by grouping response categories of questions, with exception of the MDS, which measures disability as a continuous outcome, the assessment of different severity levels of disability is essential to better capture the disability progress in ageing populations. Information on severity is important for the definition of public health policies to reduce disability at older ages, as severe disability is associated with worse health outcomes, institutionalization, long-term care need, and death (Gill 2010). More importantly, severity information is essential when estimating secular trends in health expectancies and to evaluate the theories of compression of morbidity, expansion of morbidity or the dynamic equilibrium as discussed by Robine et al. in Chap. 2.

Evolution of the Disability Concept and Importance for Public Health Policies

In the last decade, there has been an important shift from the medical model to a “biopsychosocial” model of disability that integrates environmental factors and emphasizes participation – the ultimate step in the disablement process. As a higher order functional dimension, participation encompasses and involves body functioning and structure, and activities (Madans et al. 2004; Mont 2007).

Besides monitoring the UN CRPD (United Nations 2006), the use of a harmonized measure of disability is essential for public health policy. For instance, the MHADIE project (Measuring Health and Disability in Europe: Supporting policy development) at the European Union level recently highlighted the “need for valid outcome measures for EU governments to monitor and

evaluate the effectiveness of their disability policy, in terms of the primary ICF dimension of participation” (Leonardi 2010). Additionally, monitoring disability is particularly relevant in the context of ageing societies, as fostering active and healthy ageing has become a public policy priority. Within the European Union, active and healthy ageing is seen as fundamental to the pursuit of smart, sustainable and inclusive growth and better jobs (Berger et al. 2014).

Most of the operationalisations presented above are complex constructs based on various set of instruments. The lack of parsimony has hampered the use of these instruments; e.g. logistics and cost result in survey developers selecting subsets of the instrument questions with a negative effect on the standardization and comparability (Verbrugge 2016). An example of a parsimonious operationalization of the concepts health, disease and disability is the Minimum European Health Module (MEHM) proposed by the Euro-REVES 2 Project – “Setting up of a coherent set of health expectancies for the European Union” in 1998 (Robine and Jagger 2003). The MEHM consists of a short instrument with three global questions, covering three health domains: self-rated health, chronic (long-standing) conditions and long-term activity limitations measured by the GALI (Cox et al. 2009; Hsiao et al. 2019). The MEHM was developed to collect harmonized information on health-related and non-health related surveys in European countries, being adopted as part of the European Health Survey System by the European Statistical Agency (Eurostat) (Cox et al. 2009). The institutionalization of the MEHM instrument has stimulated the widespread use of especially the GALI as the underlying health measure of the HLY by EU Member States and the European Commission for policy making in different domains such as health promotion, the functional capacity of the work force; impact assessment (impact of healthy life styles on disability) and monitoring in health and social protection (Bogaert et al. 2018). Chapter 13 further discusses the use and uptake of the GALI in policy by EU Member States and the European Commission.

Frailty

The term frailty is often used to describe older populations vulnerable to adverse health outcomes, such as disability and mortality (Fried et al. 2004; Clegg et al. 2013; Tocchi 2015; Dent et al. 2016). The term originated in the 1970s by the Federal Council on Ageing in the United States, with the definition of “frail elderly” (Hogan et al. 2003). With the ageing of populations, the concept has evolved and gained relevance at individual and population levels. Yet, there is no internationally accepted definition of frailty (Dent et al. 2016), hindering its operationalization and measurement. Several conceptual models of frailty have been proposed and most of them consider frailty to be a syndrome of decline at advanced ages, which reflects a multi-systemic dysfunction with dynamic transition rates between severity states, resulting in increased risk of adverse health outcomes, such as falls, disability, long-term care, and death (Fried et al. 2004; Clegg et al. 2013; Dent et al. 2016).

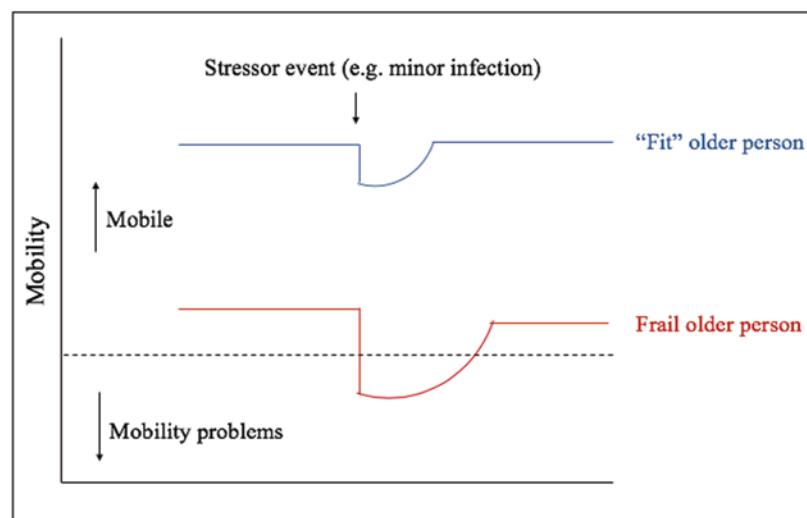
Frailty should be distinguished from the physiological ageing process (Dent et al. 2016). Whilst a gradual decline in the physiological reserve occurs with ageing and most individuals still function well, in frailty this decrease is accelerated resulting in impaired homeostasis (Hogan et al. 2003; Clegg et al. 2013; Dent et al. 2016).

Recent frailty models also distinguish frailty from disability and multimorbidity, although frailty is closely linked to these concepts (Fried et al. 2004; Dent et al. 2016). Multimorbidity is considered an etiologic risk factor for frailty (Gobbens et al. 2010c) and disability an adverse outcome of frailty (Fried et al. 2004; Gobbens et al. 2012).

Figure 1.5 shows a representation of increased vulnerability to a stressor of frail compared to “fit” older people (Clegg et al. 2013). Frailty is presented as a state of increased vulnerability to poor resolution of homeostasis after a stressor event, which increases the risk of adverse outcomes, such as disability. In the diagram, mobility problem is used as example. A stressor event such as a minor infection results in reduced mobility in both fit and the frail older people. In frail older individuals, the event triggers a disproportionate change in the health state – mobility problems. In addition, frail older individuals are not able to recover fully to the baseline state.

In frailty, the decrease in physiological reserves that normally occurs with ageing is accelerated, resulting in impaired homeostatic mechanisms. This decline is determined by genetic and environmental factors and is influenced by the individual physical activity level and nutrition status.

Fig. 1.5 Vulnerable state of frail compared to “fit” older people after a stressor event.
(Adapted from Clegg et al. (2013))



We focus on models that include an operational definition of frailty, i.e. that propose a measurement of frailty in practice and especially in population health research: (i) the phenotype of frailty (Fried et al. 2001); (ii) the accumulation of deficits approach (Mitnitski et al. 2001); and (iii) the multidimensional approach proposed by Gobbens et al. (Gobbens et al. 2010b). Aguayo et al. (2017) compared 35 frailty scores in the general population and showed that the scores based on the accumulation of deficits approach presented the highest agreement while the scores based on the multidimensional approach were the most accurate.

Phenotype Model

This model was proposed by Fried et al. (Fried et al. 2001), based on analysis of the Cardiovascular Health Study in the United States, a prospective study with individuals aged 65 years and older. Frailty was defined as the occurrence of at least three of five criteria: slow walking speed, unintentional weight loss, low physical activity, self-reported exhaustion, and impaired grip strength. Individuals were classified as frail (≥ 3 criteria), pre-frail (1 to 2 criteria), or not frail or robust (no criterion). Frail individuals showed increased risk of adverse outcomes: falls, disability, hospitalization, and death (Fried et al. 2001).

The model is the most widely used as it is very attractive in population health research settings. However, it is difficult to implement in clinical settings, as it includes components that are not measured routinely, such as grip strength (Sternberg et al. 2011). Another limitation is the lack of social components, as this model focuses exclusively on the physical aspects of frailty (Clegg et al. 2013; Dent et al. 2016; Gobbens et al. 2017).

Cumulative Deficit Model

This model was based on the analysis of the Canadian Study of Health and Ageing, a cross-sectional study with a longitudinal component to

investigate the burden of dementia in older individuals (Rockwood et al. 2005). Frailty is considered as the cumulative effect of individual deficits (Rockwood and Mitnitski 2011), including a wide range of health problems, such as symptoms, signs, laboratory abnormalities, diseases, and disability. A frailty index is then calculated as the proportion of existing deficits, i.e. the number of existing deficits/total deficits investigated. For instance, an individual with 20 existing deficits out of 80 investigated has a frailty index of $20/80 = 0.25$. The frailty index is assumed to follow a gamma distribution (Mitnitski et al. 2001). Some studies have shown that the accumulation of deficits contributes to adverse health outcomes, such as institutionalization and death; e.g. a cut-off point of 0.67 is used to identify individuals with high risk of death (Clegg et al. 2013).

This model is attractive in clinical practice as the deficits can be identified in routine clinical assessment. Further, frailty is defined as a continuum instead of a binary outcome (frail/not frail) (Rockwood and Mitnitski 2011), better capturing the dynamic nature of frailty. A major limitation of this approach is that diseases and disability are considered as deficits, and thus included in the definition of frailty. The fact that the range of all possible deficits is variable hampers the standardisation of the instrument and the feasibility for use in (international) population health research.

Multidimensional Model

The multidimensional model defines frailty as a dynamic state affecting individuals who experience losses in one or more domains of functioning (physical, psychologic, social) that increase the risk of adverse outcomes (Gobbens et al. 2010b). The model describes the pathway: life course determinants → diseases → frailty → adverse outcomes (Gobbens et al. 2017). As a dynamic state, frailty is measured as a continuous variable. This model is operationalized in the Tilburg frailty indicator (TFI) (Gobbens et al. 2010b), based on a screening questionnaire for frail community-dwelling older people including only self-reported

information. The TFI has shown good reliability and validity (Gobbens et al. 2017).

The main advantage of this model compared to the previous ones is that it focuses not only on the physical aspects of frailty as the phenotype model, but also includes psychological and social domains (Gobbens et al. 2010a). In addition, frailty is distinguished from multimorbidity and disability.

Importance of Developing a Global Frailty Measure

Although different definitions are needed for different purposes, both clinical practice and population health may benefit from some general guidelines on the definition of frailty (Gobbens et al. 2017). Because frailty is a dynamic process, i.e. it is potentially reversible, and has a pre-clinical stage (Fried et al. 2004), early detection and interventions are essential to reduce it. Additionally, as a pre-disability state, frailty is prone to interventions to reduce the disability burden (Hogan et al. 2003).

Measuring frailty in clinical practice allows health care providers to identify and manage frailty to avoid progression (Dent et al. 2016). For population health, a common frailty definition is needed to compare estimates between populations, to identify high-risk populations, and to develop interventions to prevent, delay and reduce frailty and adverse outcomes in older individuals.

Similar to disability, one important aspect of the frailty definition that should be kept in mind is the possibility to grade it for severity (Clegg et al. 2013). This is important to identify individuals in different risk groups and to target resources and interventions to specific groups.

Composite Health Measures

Composite health measures combine information on mortality and morbidity into a single measure of population health (Hyder et al. 2012). They are used to: (i) monitor population health;

(ii) supply a comprehensive reference for epidemiological estimates; (iii) facilitate health planning; (iv) contribute to decision-making for health policy; (v) guide research priorities; (vi) provide a comprehensive assessment of interventions; and (vii) guide patient care decisions (Murray et al. 2002). The evidence provided by composite health measures contributes to societal debates on questions such as (i) priority setting within health and health care; (ii) quantity versus quality of life; and (iii) whether the investment in longer lives coincides with living longer healthy lives and living less unhealthy lives (Saito et al. 2014).

Two types of composite health measures have been proposed: (i) health gap measures, such as disability-adjusted life years (DALYs) (Murray et al. 2002; Hyder et al. 2012) and quality-adjusted life years (QALYs) (Whitehead and Ali 2010; Saito et al. 2014); and (ii) health expectancies (Saito et al. 2014), such as disability-free life expectancy (DFLE) and life expectancy with disability (LED). Information on deaths, morbidity and disability is used to estimate either (i) the healthy life time lost as a measure of the impact of mortality and non-fatal outcomes; (ii) the healthy life time gained as a measure of a (medical) intervention or (iii) the expectation of duration of life in different health states: the total expectation of life is split over the expectation of life in good health and in different degrees of ill-health.

Each of the composite health measures provides different insight to the interaction between mortality and health-morbidity-disability.

- DALY sums up the loss in healthy life due to disability and years of life lost due to premature mortality. As such it represents, at population level, the years of healthy life lost. DALY is based on the medical model. This enables priority setting through ranking of burden causes in terms of DALY's; mortality and morbidity. At the same time, the disease-driven approach set high data requirements (disease-specific mortality and morbidity data (incidence and duration or prevalence)). The definition of the disability as translated in dis-

ability weights does not necessarily correspond to the different models described in this chapter. A disability weight reflects the severity of the disease on a scale from 0 (perfect health) to 1 (equivalent to death). For each disease, Years Lost due to Disability (YLD) are calculated by multiplying the incident cases by duration/prevalence and disability weight.

- QALY is a summary measure of health outcomes that reflects the years lived in perfect health gained due to a medical or public health intervention. In economic evaluations, it is important to enable comparisons across different disease areas, different types of interventions and different populations to assess the value for money of the interventions. QALY measures the duration in different health states multiplied by a health related quality of life (HRQoL) weight or utility weight. The preference-based measure of utility (a scale from 0 (equivalent to death) to 1 (perfect health)) remains an issue of controversy not only related to equity concerns but also related to underlying theoretical assumptions and methodological problems with the validation techniques (validity, reliability) (Whitehead and Ali 2010; Pettitt et al. 2016).
- In contrast to the DALY and the QALY, the composite health measure health expectancy is very easy to understand and interpret. Health and morbidity data requirements are less especially when the Sullivan method is used. Data are most often survey-based. Morbidity and disability are then self-reported prevalence data. Combined with mortality (incidence), an assumption of steady state is required. Health expectancy allows the study of the interaction of mortality and health through the triangle “duration of life”, “duration of healthy life” and “duration of unhealthy life”. Health expectancy estimates are therefore central in the debate related to (1) quantity versus quality of life and (2) the question if longer living populations are living longer healthy life and at the same time living less long unhealthy life. Chapter 2 discusses this latter question in detail.

Conclusions

In this chapter we described the operationalization of the concepts of health, disability, and frailty in population health research. Given the complexity of the concepts, there is no ‘one size fits all’. In all three domains – health, disability, and frailty – there is an evolution from pure medical models to biopsychosocial models. For each of the domains, differences in the results of the operationalisation can often be linked to differences in objectives and setting. The instruments developed for population health research range from extended multiple question instruments to parsimonious single item instruments. Several instruments are complementary to each other providing different insights to the health of populations.

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Trends in Health Expectancies

2

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Introduction

In the 1980s, the then theories on aging believed that life expectancy was unlikely to increase much beyond the level already reached in the most developed countries, a “ceiling” view explained by two mechanisms: the existence of biological limits due to cell senescence, and the development with age of chronic degenerative diseases. For many biologists, after eliminating the remaining premature deaths, only changing the biological rate of aging could significantly increase life expectancy (Hayflick 1975). Indeed, according to certain biologists, there was much more to be gained by reducing the aging rate rather than by eliminating the “major killers”

such as circulatory and neoplastic diseases (Strelher 1975). A critical evaluation of these theories observed that mortality and morbidity were not necessarily linked as morbidity was generally associated with diseases, and longevity with biological senescence (Manton 1982).

Manton (1982) distinguished a pessimistic perspective, where decline in mortality among old people was due to progress in controlling the lethality, or in retarding the rate of progression, rather than reducing the incidence, of degenerative diseases. The net effect is to raise the prevalence of certain diseases and disabilities by prolonging their duration (Gruenberg 1977), called by Kramer (1980) “a pandemic of mental disorders and chronic diseases”. This perspective of expansion of morbidity was not expected to be

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prolonged given the prevalent views on life expectancy increases. In contrast, Fries (1980) offered a more optimistic perspective where the age at onset of chronic degenerative diseases could be postponed without significantly changing average life expectancy, thereby compressing morbidity into a smaller portion of the life span. This view focused on the postponement of disease due to the adoption of improved health behaviours, fitting into the more general context that, historically, major declines in mortality resulted from decreasing deaths from infectious diseases due to improvements in hygiene, nutrition and other public health factors, and not in medical technology (Omran 1971; McKeown 1976). Such an approach suggested that the most developed nations had entered an “end” stage of the epidemiological transition, the “*Age of Degenerative and Manmade Diseases*” (Omran 1971) and that little could be done to reduce the risks of chronic diseases. Nevertheless there were many inconsistencies between the theories, notably that the rapid decrease in mortality at advanced ages suggested that a biological limit was not close, and that social and clinical markers were not indicating a deterioration in the health status of older people despite significant increases in life expectancy. Manton (1982) concluded “*Therefore, if a pandemic of chronic diseases is occurring [...] something must have been accomplished to reduce the severity and associated disability of these diseases at specific ages.*”

For Manton, reduction in mortality and in the severity of chronic degenerative diseases are linked in a “dynamic equilibrium”. There are two ways to increase the duration of a disease. One way is to eliminate lethal sequelae, e.g., pneumonia, the way observed by Gruenberg in 1977 and theorized by Kramer in 1980 as the “*Rising Pandemic of Mental Disorders and Associated Chronic Diseases and Disabilities*”. Another way is to change the rate of progression of the primary disease process, with life expectancy increased by reducing disease severity. This concept of dynamic equilibrium requires mortality and morbidity to be in equilibrium and population health to be dynamic and multidimensional. In both Fries’ compression of morbidity and Kramer’s

pandemic of mental disorder, morbidity and longevity are partly independent. Moreover, in both visions, there is no level of severity. Morbidity and disability are binary. In the model proposed by Manton, aging is defined in terms of a set of chronic degenerative disease processes. He notes “*as a consequence, medical innovations in the management of chronic disease can continue to extend life span*”.

In the years following Manton’s work, a growing number of researchers, interested by the changes over time in population health, have referred to three major scenarios outlining the possible future of population health: (1) compression of morbidity (Fries 1980); (2) expansion of morbidity (Gruenberg 1977; Kramer 1980); and (3) dynamic equilibrium (Manton 1982). The scenario of longevity extension (Strelher 1975; Hayflick 1975) was not really considered given the unpredictable character of the expected scientific breakthroughs in the fundamental biology of aging. The first of the proposed scenarios is that of James Fries. In its initial version, observed life expectancy should be very close to the maximum possible value. In this scenario, improvement of living conditions and adoption of health-promoting behaviours (smoking cessation, better nutrition, physical activity) could only reduce morbidity without affecting the longevity of populations (Fries 1980). However in subsequent publications, Fries proposed a more flexible version of his scenario, defining it as a stronger reduction for morbidity than for mortality (Fries 2005), though he did not clarify what he saw as morbidity, and his descriptions were mainly anecdotal. The second scenario was constructed by researchers, and initially by Manton, as the scenario opposite to that of compression of morbidity. With reference to Gruenberg (1977) and Kramer (1980), it was first presented as the scenario of the pandemic of chronic diseases and disabilities, but quickly renamed the scenario of expansion of morbidity. By symmetry with the scenario of compression of morbidity, it is first seen as a situation where mortality decreases more rapidly than morbidity. The third scenario, dynamic equilibrium, has never been formally defined. It has often been presented as the “inter-

mediate” scenario between the first two, but such a vague definition does not facilitate its measurement and makes comparisons between studies difficult.

In this chapter we will first define in detail these three health scenarios, and then describe the possible trends in life and health expectancy emanating from them. With this basis we will then review the trends and scenarios observed in different parts of the world, concluding this chapter with an overall summary and indication of the direction of future research.

Defining the Different Health Scenarios

In order to measure the occurrence of these scenarios, it is necessary to take into account the change over time in both mortality and the incidence/prevalence of morbidity. Of the indicators proposed in the 1960s and 1970s (Sanders 1964; Sullivan 1971a), only health expectancies allowed change in morbidity and mortality to be taken into account simultaneously (World Health Organization 1984). Monitoring such changes over time was one of the main reasons for the establishment of REVES, the International Network on Health Expectancies and the Disablement Process, created in Quebec City in 1989 and better known as “Réseau Espérance de Vie En Santé” (Robine and Cambois 2019). Three dimensions of health were identified in the 1960s: (i) the presence or absence of diseases; (ii) the functional dimension corresponding to the presence or absence of disability; and (iii) the perceptual dimension corresponding to self-perceived health status. Of these, the functional dimension was preferred as an indicator of morbidity because it is the least subject to reporting bias or subjective assessment. In particular, it was thought that the diagnosis and therefore knowledge and reporting of chronic diseases can vary over time restricting interpretation of observed trends (Sullivan 1965, 1971b).

The development of health expectancies in the 1980s resulted in the first rigorous definition of these scenarios. Compression of morbidity is the

situation where life expectancy in good health (i.e., without disease, without disability and/or in perceived good health) increases more than total life expectancy, whilst the scenario of expansion of morbidity is the situation where life expectancy in good health (i.e. without disease, without disability, and/or in perceived good health) is growing more slowly than total life expectancy (World Health Organization 1984). Further distinguishing between absolute and relative compression/expansion of morbidity appeared to be a necessary step for specifying these scenarios (Robine 1992; Nusselder 2003). Absolute compression/expansion means that the number of years lived with disability decreases (compression) or increases (expansion) and relative compression/expansion means that the proportion of total years lived that are with disability decreases (compression) or increases (expansion). In this context, dynamic equilibrium corresponds in theory to the situation when the share of years lived with disabilities remains a constant portion of total life expectancy. An absolute compression of morbidity generally coincides with a relative compression, but an absolute expansion of morbidity can coincide with a relative expansion, equilibrium, or compression of morbidity, depending on how life expectancy free of morbidity is changing (Jagger and Robine 2011). Moreover, some authors consider that a relative expansion of disability observed only for the least severe levels of disability indicates a kind of dynamic equilibrium.

Indeed three versions of the scenario of dynamic equilibrium have often been used, all corresponding to the 1982 Manton proposals. The first, the “intermediate” version, corresponds to a situation where mortality and morbidity decrease in proportion, leading life expectancy in good health (or without disability, or without chronic disease) to increase as rapidly as total life expectancy. The second version considers that disability is an indicator of the severity of chronic disease and therefore compares the change in life expectancy without chronic disease to that of life expectancy without disability, dynamic equilibrium then being judged on the basis of three criteria: mortality, chronic disease and disability.

If the increase in the number of years lived with chronic diseases is indicative of an increase in morbidity, a smaller increase in the number of years lived with disability would signal a decrease in the severity of the diseases and, therefore, would point to a dynamic equilibrium between longer life expectancy and the severity of chronic diseases prevalent in populations. This is one of the characteristics of dynamic equilibrium proposed by Manton in 1982. The third version of dynamic equilibrium uses the same reasoning but only the functional health dimension through the introduction of severity levels of disability in a number of ways. One can either conceptually distinguish between several levels of functioning, for example impairments, functional limitations and activity restrictions with, on average, impairments being indicative of less severe disability than functional limitations or activity restrictions. One can also, distinguish severe restrictions from less severe within a functional level such as for example restrictions of activity. Thus, if the increase in the number of years lived with activity restrictions is indicative of an increase in morbidity/disability, a lesser increase in the number of years lived with severe restrictions would signal a decrease in the severity of the disabilities and, hence, would point to the same dynamic equilibrium between the lengthening of life and the severity of the prevailing health conditions in the population.

Possible Trends in Population Health

These reflections on changing population health as well as mortality were accompanied by the implementation of the many surveys to monitor the health status of the population. An assessment carried out at the end of first decade of this century (Jagger and Robine 2011) showed that about 30 studies reporting trends over time in health expectancies had been published in the 2000s. These studies reported on 16 countries in total, including 12 European countries. Seven studies

concerned the United States and four studies China, Japan or Thailand. The first three studies assessing trends were conducted in the 1970s, 18 studies were conducted in the 1980s, seven in the 1990s, and two in the 2000s. Most studies reported trends for perceived health (18 studies) with 13 studies reporting activity restriction, nine studies chronic or longstanding diseases, three studies functional limitations, and two studies functional impairments. Almost all studies used the Sullivan method, only two using a multistate approach. Finally, five studies covered a period exceeding 20 years, including three in the United States. Overall, it was difficult to draw general conclusions in terms of compression of morbidity and/or disability.

Since this review, new papers have been published, and it is these that we focus on here to better clarify trends in health expectancies. We want to know which scenario they support. However, first we need to specify further the scenarios taking into account three key elements: (i) trends in longevity as measured by life expectancy; (ii) the absolute or relative nature of observed changes in morbidity/disability; and (iii) the number of indicators used to define scenarios by distinguishing between situations where only two indicators are used from other situations. In the event that life expectancy tends to increase over time (as is generally the case), it is likely that both the number of years lived in good health and the number of years lived in poor health will increase, leading to the paradoxical conclusion of an increase in healthy life expectancy and a simultaneous expansion of morbidity. It is therefore imperative to see how these increase relative to increases in life expectancy.

Based on two indicators only, here mortality and disability (all levels of disability combined), five main situations can be distinguished alongside life expectancy (LE) increases, as shown in Fig. 2.1. The Figure helps understanding of the differences between these situations, especially for cases 4-1, 4-2 and 4-3, with a baseline where LE at birth, equal to 75 years, is the sum of 65 years free of disability (86.7% of the total) plus 10 years lived with disability (13.3% of the

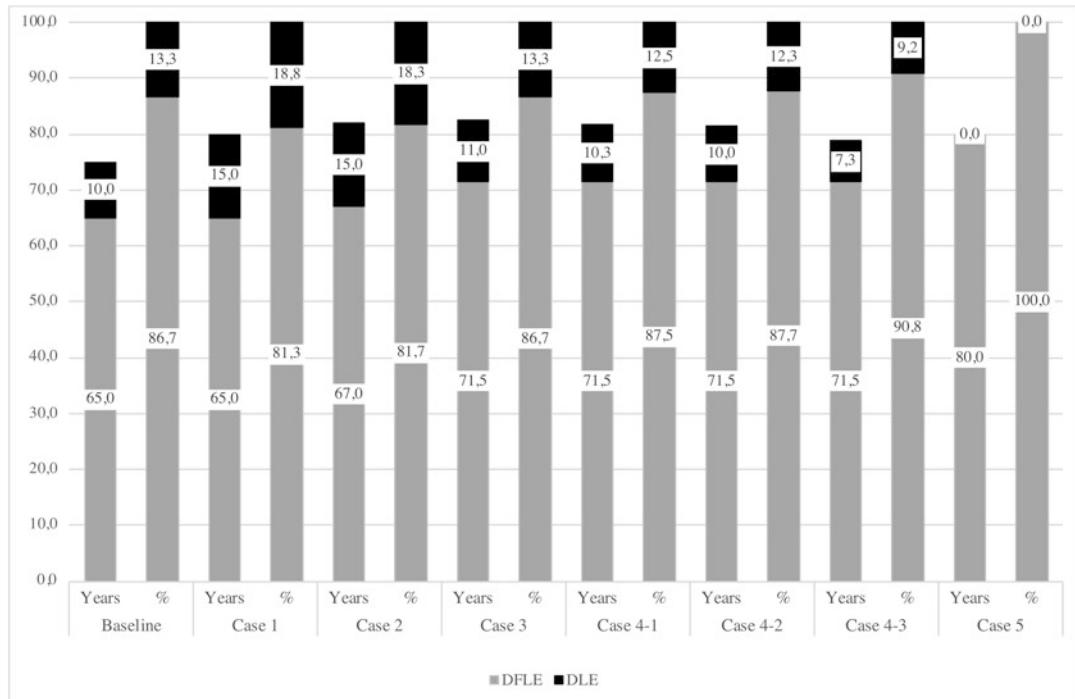


Fig. 2.1 Illustration of the five main scenarios of change over time in population health as assessed by the use of two indicators only, mortality and disability (all levels of

disability combined); total life expectancy (LE) equals disability-free life expectancy (DFLE in grey) + life expectancy with disability (DLE in black)

total LE). Thus the different situations are that LE increases and:

- Case 1: Disability-free life expectancy (DFLE) does not increase, but the number of years lived with disability does (absolute expansion of disability), resulting in a decrease in the proportion of life spent without disability, leading to an *absolute and relative expansion of disability*. Such observations can be explained by the decrease in mortality among those with disease.
- Case 2: DFLE increases less than LE so that the number of years lived with disabilities increases as well as the proportion of life expectancy with disability; this is the most likely scenario of *absolute and relative expansion of disability* assessed in the absence of information on the severity of the disability.
- Case 3: DFLE increases the same as LE with the number of years lived with disabilities

increasing and the proportion of LE without disability constant, leading to the scenario of *dynamic equilibrium* in its simplest version.

- Case 4: DFLE increases more than LE with increases in years lived without disability, both as an absolute, and a proportion, of LE, leading to a scenario of *relative compression of disability*. In this case, the number of years lived with disability can either increase (absolute expansion, see Case 4-1), be maintained (equilibrium, see Case 4-2), or decrease (absolute compression, see Case 4-3) according to the differential increase between DFLE and LE.
- Case 5: DFLE increases more than LE and the proportion of LE lived without disability reaches 100%. This is a limiting scenario of *absolute and relative compression of disability*.

With more than two indicators the scenarios rapidly become complex. Taking the example of severity of disability and three indicators (here

mortality, severe disability and mild disability), we can similarly distinguish the following situations alongside LE increases:

- DFLE does not increase, illustrating an *absolute and relative expansion of disability*, but if
 - Severe disability-free life expectancy (SDFLE) does not increase either, only the number of years lived with severe disabilities does, and thus all years gained are years of severe disability leading to a scenario of an *absolute and relative expansion of severe disability*.
 - SDFLE increases less than LE, with the number as well as the proportion of LE lived with severe disability increasing, again leading to a scenario of *absolute and relative expansion of mild and severe disability*.
 - SDFLE increases by the same as LE, so that the number of years lived with severe disabilities increases, and the proportion of LE lived without severe disability remains constant, leading to a *dynamic equilibrium for severe disability*, and *absolute and relative expansion of mild disability*.
 - SDFLE increases more than LE, with the number of years and proportion of life without severe disability increasing, leading to a scenario of *absolute and relative compression of severe disability*. In this case, the number and the proportion of years lived with mild disabilities will increase. This is a scenario of *absolute and relative expansion of mild disability* but with an *absolute and relative compression of severe disability*.
 - SDFLE increases faster than LE and the proportion of years lived without severe disability reaches 100%, leading to a limiting scenario where *absolute and relative expansion of mild disability* is accompanied by a *total compression of the most severe disability*.
- DFLE increases less rapidly than LE, illustrating a scenario of *absolute and relative expansion of disability*, but if
 - SDFLE does not increase so that all years gained are years of severe disability, and

the number and proportion of years lived with severe disabilities increases, this leads to *absolute and relative expansion of disability where only severe disability increases*.

- SDFLE increases less than LE, the number and the proportion of LE lived with severe disabilities increasing, leading to *absolute and relative expansion of severe disability*, although the rates of increase in the number and proportion of LE lived with severe disabilities or mild disabilities vary.
- SDFLE increases the same as LE, so the number of years lived with severe disabilities does not increase and the proportion of LE lived without severe disability increases, leading to a *relative compression for severe disability* but *absolute and relative expansion of mild disability*.
- SDFLE increases more than LE with the number and proportion of years lived without severe disability increasing resulting in an *absolute and relative compression of severe disability* accompanied by *absolute and relative expansion of mild disability*.
- SDFLE increases more than LE and the proportion of LE lived without severe disability reaches 100%, a limiting scenario of *absolute and relative expansion of mild disability* and *total compression of severe disability*.
- DFLE increases the same as LE is the scenario of *dynamic equilibrium between longevity and disability* in its simplest version, but if:
 - SDFLE does not increase or increases less than LE then the *dynamic equilibrium is based only on the trends in mild disability*.
 - SDFLE increases the same as LE then trends in SDFLE contribute proportionally to the *dynamic equilibrium that equally concerns severe and mild disability*.
 - SDFLE increases faster than LE then the trend in *severe disability contributes more to dynamic equilibrium than the trend in mild disability*.
 - SDFLE increases more than LE and the proportion of LE lived without severe disability reaches 100%, then this is a limiting scenario of *total compression of severe*

disability alongside the overall dynamic equilibrium.

- DFLE increases faster than LE is a scenario of *relative compression of disability*, but if
 - SDFLE does not increase then trends in mild disability explain the whole increase in DFLE.
 - SDFLE increases less than LE then the increase in DFLE rests essentially on the trend in mild disability that must compensate for the smaller increase in SDFLE.
 - SDFLE increases the same as LE, then, even in this case, the increase in DFLE rests more on mild disability than on severe disability.
 - SDFLE increases more than LE then severe disability contributes as much as mild disability to the trend in DFLE, but the pace of increase in SDFLE and DFLE, although higher than LE, may differ.
 - SDFLE increases faster than LE and the proportion of LE lived without severe disability reaches 100% is a limiting scenario where the absolute compression of severe disability plays an important role in the relative compression of disability observed.
- DFLE increases faster than LE and the proportion of LE lived without disability reaches 100% is a limiting scenario of *total compression of disability*. By definition, the proportion of LE lived without severe disability must also reach 100% so there are no further scenarios.

Beyond the apparent complexity due to the abundance of scenarios with only three dimensions (mortality, mild and severe disability), it is worth noting that many of these scenarios are plausible, particularly those where DFLE does not increase, or where the number of years lived with severe disability increases. However scenarios where severe disability decreases while mild disability increases, or vice versa, are also plausible, and have been described or suggested by several authors. Gains in life expectancy are now concentrated at older ages, and they may be accompanied by some form of disability. Mortality gains made among the oldest-old, and more vulnerable people, may be at the expense of

the most severe forms of disability. Conversely, it has been proposed that the effectiveness of current health care systems is not limited to delaying deaths but also reducing the most severe forms of disability. Mild disability may increase because, with a greater variety of activities, individuals may experience more difficulties, as well as individuals with more education and higher expectation being more likely to report activity restrictions.

The scientific literature regularly reports debates about the limits of human longevity (Dong et al. 2016; Vijg and Le Bourg 2017; Olshansky and Carnes 2018; Olshansky 2018). At the same time, several low-mortality countries are experiencing a slowdown in their life expectancy increase (Hiamb et al. 2018; Ho and Hendi 2018). It is therefore appropriate to explore the limiting scenario where life expectancy would cease to increase, especially as it is a very simple scenario. Based on two indicators (here, mortality and disability, all levels of disability combined), we can distinguish the following situations if LE does not increase:

- DFLE does not increase either so that with no further changes no scenario can be verified.
- DFLE increases and both the number and the proportion of LE lived without disability increase, leading to *absolute and relative compression of disability*.

Since the development of the calculation of life expectancy at the end of the nineteenth century (Bertillon 1878), there has been a general tendency for life expectancy to increase. However its pace of increase has varied over time (Vallin and Meslé 2009) and discussions are ongoing today (Dong et al. 2016; Hiamb et al. 2018; Ho and Hendi 2018), as in the 1970s and 1980s (Fries 1980; Manton 1982), on the existence of a limit to this increase. Nevertheless, only a few authors have suggested that, over the long term, life expectancy will decrease, due to environmental factors such as endocrine disruptors, junk food, drug use, pollution or global warming. These possibilities lead us to explore briefly scenarios where life expectancy declines over time.

Based on two indicators only (here, mortality and disability, all levels of disability combined), the following situations can be distinguished if LE declines:

- DFLE also decreases but, depending on whether the rate of decrease is faster, slower or the same as that of LE, all the scenarios described above can occur. Decrease in LE is then accompanied by *expansion, compression or dynamic equilibrium between disability and longevity* as already described in the case of both increase in DFLE and LE.
- DFLE remains constant with only the number of years lived with disabilities decreasing, leading to an *absolute and relative compression of disability*.
- DFLE increases and the number of years lived with disabilities decreases as well as the proportion of LE lived with disabilities, leading to an *absolute and relative compression of disability*.
- DFLE increases and the proportion of LE lived without disability reaches 100%, resulting in a limiting scenario of *total compression of disability*.

Considering that the scenario of decreasing life expectancy is less likely to be realised, we do not consider scenarios based on more indicators, such as the introduction of indicators on the level of severity of disability. We now look at these theoretical scenarios alongside the observed trends.

Trends and Scenarios Observed in Different Parts of the World

We start with the *United States* where the idea of calculating health expectancy began (Sanders 1964; Sullivan 1965) and which has the longest time series on DFLE using reasonably comparable methods and based on the National Health Interview Survey, conducted continuously since 1957 (Sullivan 1971a, b; Crimmins et al. 1989). In the four decades from 1970 to 2010, DFLE and life expectancy with disability (DLE) at birth increased sharply (by 4.5 years for DFLE and

4.7 years for DLE for men, and 2.7 years for DFLE and 3.9 years for DLE for women). However, the proportion of LE spent free of disability (DFLE/LE) remained relatively constant, especially after 1980, illustrating a scenario of dynamic equilibrium. On the other hand, for DFLE and DLE at age 65, there is a relative compression of disability, with the proportion of LE spent free of disability increasing from 47.8% in 1980 to 52.5% in 2010 for men and from 50.5% to 56.7% for women (Crimmins et al. 2016a). While the prior study examined all disability, additional studies have examined more severe disability, often indexed by the ability to perform activities of daily living (ADLs), as well as by instrumental activities of daily living (IADLs) which are generally less severe than ADLs. Indeed, a reduction in the prevalence of more severe levels of disability was observed between 1982 and 2011 for men over the age of 65, resulting in a relative compression of severe disability, with the proportion of LE spent free of more severe disability increasing from 78% in 1982 to 81% in 2011. This scenario was not observed for women who experienced a slight increase both in life expectancy and in disability, with the proportion of LE spent free of severe disability remaining constant, at 70%, between 1982 and 2011, illustrating a scenario of dynamic equilibrium (Freedman et al. 2016). Thus these two studies, using different national surveys, over the period from 1980/82 to 2010/11, show two different scenarios for men and women above the age of 65. For both, DFLE and DLE increased but in slightly different ways. Men experienced both a relative compression of mild and severe disability while women experienced only a relative compression of mild disability, severe disability staying in dynamic equilibrium with longevity. However, the number of years lived with severe disability (three or more ADL difficulties) did not increase over the period, staying at 1.5 years for men and 3 years for women. Therefore, no absolute expansion of severe disability was observed over the last 30 years in the United States over the age of 65 (Crimmins et al. 2016a; Freedman et al. 2016).

Beyond disability, the most remarkable trends are in the prevalence of cognitive impairment

and, consequently, dementia, both declining sharply between 2000 and 2012 in people over the age of 65, the main explanation being the increase in the education seen among older people (Langa et al. 2016; Crimmins et al. 2018). This decline has clearly resulted in a compression of cognitive morbidity over this period, as the years with dementia have decreased markedly and the years without dementia have increased (Crimmins et al. 2016b). These declines in the prevalence of cognitive impairment and dementia continue trends observed in the United States since 1982 (Manton et al. 2005; Langa et al. 2008; Larson and Langa 2017). The Framingham study, which serves as a reference study in this area, shows that since 1975, the incidence of cognitive disorders and dementia has been decreasing in those over age 60 (Satizabal et al. 2016). Several cardiovascular risk factors improved over the period but this cannot fully explain the decline in the incidence of dementia and improved levels of education have played a key role (Zissimopoulos et al. 2018; Crimmins et al. 2018).

In Europe, time series of DFLE are available for a handful of countries: the United Kingdom, Nordic countries (Sweden, Denmark and Norway), Belgium, France, Italy, the Netherlands and Spain. In the *United Kingdom*, between 2000/2002 and 2009/2011, both DFLE and LE increased but at birth DFLE increased more than LE only for men, leading to an absolute compression of disability (Jagger 2015). However, for women at birth the proportion of LE spent disability-free increased, illustrating in all cases a relative compression of disability, although there was also an increase in DLE. At age 65 an absolute expansion of the years lived with disability was observed for both men and women. This was confirmed by another study showing that, in *England* over the 20 years from 1991 to 2011, the expected number of years in a state of high dependency at age 65 increased, although the majority of the years gained were free of dependency or with low dependency (Kingston et al. 2017). As in the United States, the most notable development in England over the last 20 years is a sharp decline in the prevalence of dementia in

the older population (over age 65) between 1989/94 and 2008/2011 (Matthews et al. 2013), explained by a 20% drop in the incidence of dementia (Matthews et al. 2016). Consequently, years of life expectancy free of any cognitive impairment increased by the same amount or more than LE at age 65 (Jagger et al. 2015). Thus, over the last 20 years, LE at age 65 increased for both men and women but more for men, and these gains were accompanied by equivalent gains in years free of any cognitive impairment, illustrating a scenario of relative compression of cognitive limitations for men and of absolute compression of cognitive limitations for women. However, gains in DFLE were much smaller, particularly for women, because of increased years with mild disability. This is considered an illustration of a dynamic equilibrium between increased longevity and disability because mild disability increased rather than severe disability.

For the Nordic countries, between 1992 and 2011 *Sweden* experienced an increase in years lived with moderate and severe disability at age 77 for men and an increase in years lived with moderate though not severe disability in women, as well as an increase in years lived with mobility problems for both men and women (Sundberg et al. 2016). Taking into account the increases in life expectancy, men experienced a relative compression of mild disability alongside a relative expansion of severe disability and mobility problems. Women, on the other hand, experienced a relative compression of disability, including severe disability, as well as a relative expansion of mobility problems. Another study, using disability defined by the Global Activity Limitation Indicator (GALI), suggests that DFLE at age 65 in Sweden increased more than LE between 1980/85 and 2006/2011, resulting in an absolute and relative compression of disability (Lagergren et al. 2016). In *Denmark*, DFLE and years free of severe disability (SDFLE) at age 65 increased faster than LE between 2004 and 2011, leading to a relative compression of disability, accompanied by an absolute compression of mild disability, although years with severe disability remained relatively constant over the period (Jeune et al. 2015). In *Norway*, DFLE and life expectancy

without functional limitations, at age 67, increased more than LE between 1986 and 2008, also illustrating a scenario of absolute and relative compression of disability for both men and women (Moe and Hagen 2011). In total, over the last period and at age 65 (67 in Norway), the Nordic countries experienced an absolute compression of disability. In the Nordic countries therefore the expected number of years lived with severe disability at age 65 remained constant in Denmark but increased for men (at age 77) in Sweden, and the expected years lived with mobility problems at age 77 increased both for men and women in Sweden. It is worth noting that the observed increase in LE, although modest, was larger for men than women over the period in the three countries, as already observed in USA and England. Sweden is one of the countries that has not observed a decline in the prevalence of cognitive impairment or dementia (Winblad et al. 2016; Wu et al. 2017). There is, however, evidence from centenarian studies in Denmark that the most recent cohorts of nonagenarians and centenarians have better cognitive functioning, and score higher in the number of independent ADL activities, than previous cohorts, illustrating a dynamic equilibrium between longevity and functioning (Rasmussen et al. 2017).

The *Netherlands*, until recently, has had a lack of well-established time series on population health status therefore several surveys have been combined to assess the most recent trends. Given the regular reporting of disability indicators proposed by OECD in the 1980s, together with Short Form-36 (SF-36) items, the Netherlands merged data from 5 surveys over the period 1990–2007 via meta-analysis (van Gool et al. 2011). They found that the increase in LE was accompanied by a constant prevalence of disability (for about 10 activities) between the ages of 55 and 84, leading mathematically to an absolute expansion of years lived with disability. Two further points are worth noting. Firstly, between 1990 and 2007, increases in LE at age 55 for women (1.65 years) were much smaller than those for men (3.19 years) (Human Mortality Database 2018). Secondly, the Netherlands has not seen a decrease in the incidence of dementia among GP clients between

1992 and 2014 (van Bussel et al. 2017), in contrast to the decrease seen by the Rotterdam study between 1990 and 2000 (Winblad et al. 2016; Wu et al. 2017). These opposing findings could be explained by either a stability in incidence or a trade-off between better detection and a decline in the incidence of dementia. However, based on the eight waves from the nationally representative Longitudinal Aging Study Amsterdam (LASA), a recent study, combining physical and cognitive measures, showed that the negative trend in physical health expectancies, observed between 1993 and 2016 above the age of 65, is offset by the positive trend in cognitive health, keeping constant the proportion of years lived in poor health above the age of 65 years for both men and women (Deeg et al. 2018; Crimmins 2018).

France also lacks surveys to establish long-term time series. Five surveys have been combined to estimate the most recent trends in DFLE, between 2003 and 2008 (Cambois et al. 2013), extending previous estimates (Cambois et al. 2008), although meta-analyses could not be undertaken because of the diversity of the disability indicators used across the surveys. The earlier period showed dynamic equilibrium at age 65, from increased longevity, expansion of functional limitations and compression of activity restriction. This trend is maintained in the recent period with functional limitations, apart from cognitive limitations for women, increasing for both sexes, while ADL and IADL restriction decreased for both sexes in addition to restriction in usual activities for women. A more recent study showed that, between 2004 and 2015, DFLE at birth increased less than LE for men and remained almost constant for women, leading to a relative expansion of disability for both sexes (Robine and Cambois 2017). As in other countries, LE at birth in France between 2005 and 2015 increased more for men (2.2 years) than for women (1.2 years). The PAQUID study showed that people aged 75 to 84 in 1998/99 lived longer and had less disability over the next 10 years than people aged 75 to 84 in 1988/89. However, while older people in the most recent cohort spend a greater part of their lives without disability, they

also spend more time in the most severe states of disability (Pérès et al. 2013). A recent analysis shows that dementia-free life expectancy at age 70 increased faster than total LE over a ten-year period for both men and women (Grasset et al. 2019).

In Spain, between 1986 and 2007, DFLE at birth increased more than LE for men and women leading to an absolute compression of disability, although at age 65, women experienced only a relative compression of disability, the number of years lived with disability being higher in 2007 than in 1986 (Gutiérrez-Fisac et al. 2010). In the more recent period between 1994 and 2011, there has been a large increase in the number of years lived with chronic disease at age 65 in Catalonia, leading to an absolute expansion of chronic disease (Solé-Auró and Alcañiz 2015). From this study, the increase in LE at age 65 was also accompanied by an almost equivalent increase in the number of years lived with mobility problems, illustrating a scenario of absolute and relative expansion of disability in terms of mobility limitations. Some other European countries such as Belgium (Van Oyen et al. 2008) and Italy (Frova et al. 2010) are also computing series of DFLE but no recent analyses have been published in English. For Belgium, see <https://spma.wiv-isep.be/SitePages/Home.aspx> for updates till 2013, and 2018 in the near future.

For Asian countries, recent time series of DFLE are available for Japan, China including Hong Kong, India, and Singapore. In Japan, DFLE increased more slowly than LE between 1995 and 2004, leading to a decrease in the proportion of years lived without disability. Over this period, both at birth and at age 65, and for men as well as women, Japan experienced an absolute and relative expansion of disability, including more severe ADL type disability (Hashimoto et al. 2010). More recently, from 2000 to 2010, the same scenario of absolute and relative expansion of disability has been observed at birth for both men and women (Sugawara and Saito 2016). For older people, the number of expected years of life in need of care increased: for men aged 65, from 1.4 years in 2005 to 1.6 years in 2009 and in women from 3.0 years to

3.4 years, representing an expansion of severe morbidity (Seko et al. 2012). An increase in the prevalence of dementia has also been observed in Japan in people aged 65 years and over between 1985 and 2005 (Sekita et al. 2010).

In China, DFLE at age 65 has increased faster than LE between 2002/2005 and 2008/2011, illustrating a scenario of compression of disability that, however, is statistically significant only for women (Zimmer et al. 2015). Decline in ADL disability has been observed for participants aged 60 and over, in the China Health and Nutrition Survey over the period 1997 to 2006 (Liang et al. 2015). A recent study showed that the oldest old Chinese experienced both a reduction in mortality and ADL type disability but a substantial increase in cognitive impairment and a worsening of physical performance (Zeng et al. 2017). Note that China is one of the countries with an increase in the age-specific prevalence of dementia in the recent period (Winblad et al. 2016). The self-reported ability of the Chinese population to carry out daily activities increased substantially between 1998 and 2008 for those aged 80 and over (Martin et al. 2014), but large Chinese cities display varied trends. In Beijing, an increasing disability trend occurred for men aged over 70 years between 1992 and 2007, but not for women (Zimmer et al. 2014). In Shanghai, on the other hand, people over 70 experienced substantial improvements in both ADL and IADL disability prevalence, more pronounced for IADL disability, between 1998 and 2008 (Feng et al. 2013). In total, these studies point to a substantial decrease in ADL and IADL type disability for older people in China but without computing health expectancy they do not allow for the assessment of an absolute and relative compression of disability. On the other hand, in Hong Kong, the strong increase in LE between 1996 and 2008, stronger for women than men, has been accompanied by an absolute and relative expansion of severe disability (Cheung and Yip 2010). Between 2001/2002 and 2011/2012, LE at age 65 goes on increasing, accompanied by an absolute and relative expansion of disability, physical and cognitive, for men. For women, the absolute and relative expansion of physical dis-

ability is almost compensated for by the absolute and relative compression of cognitive disability (Yu et al. 2019).

In *Singapore*, the increase in LE at age 65 between 1995 and 2005, again greater for women than men, was accompanied by an increase in the number of years lived with mobility limitations although the vast majority of the years are free of such limitations, illustrating a scenario of absolute and relative expansion of mobility limitations (Yong et al. 2010).

In *Australia*, the increase in LE at birth between 1998 and 2009, again larger for men than for women, is almost entirely due to an increase in the number of years lived without disability leading to a relative compression of disability (Australian Institute of Health and Welfare 2012). However, the number of years lived with disabilities varied little over the period, either for severe or less severe disability. A different picture appears at age 65 where the proportion of LE lived with or without disability, including the most severe limitations, varied very little over the period for men, illustrating dynamic equilibrium. In women of the same age, there is a clearer trend towards relative compression of disability with a slight increase in the proportion of LE spent disability-free and especially a sharp decline in the proportion of LE spent with severe or profound limitations.

Elsewhere, in eastern European countries, the Middle East, India, Africa as well as Latin America, information is very limited. In *India*, according to a recent study, older men (age 60 and over) and older rural persons experienced between 1995 and 2004 an increase in LE without mobility limitation and a reduction in the proportion of remaining life with mobility limitation, suggesting a compression of morbidity. However, over the same period, older women and older urban persons have experienced an expansion of morbidity with an increase in the proportion of remaining life with mobility limitation (Sreerupa et al. 2018). In *South Africa*, at age 50 and older and over the period 2005–2012, unhealthy life expectancy (ULE), based on a

self-rated health measure, decreased, while healthy life expectancy (HLE) increased more than LE (Chirinda et al. 2018). In *Sao Paulo*, in *Brazil*, DFLE at age 60 strongly decreased between 2000 and 2010 while LE has kept increasing (Campolina et al. 2014).

Discussion

From this review of the most recent studies examining trends in DFLE in the different parts of the world, we can extract five general results. Firstly, contrary to expectations in the 1970s and 1980s, LE has continued to increase in the countries studied, illustrating a scenario of extension of longevity without the benefit of major biological discoveries (Hayflick 1975; Strelher 1975; Fries 1980; Manton 1982). In all countries, women's LE is higher than men's but in almost all cases, between 1990 and 2010 men's LE increased faster than that of women, reducing the LE gap between the sexes, with the exception of Japan and Hong Kong, on one extreme of the distribution of LE values, and India and South Africa on the other end. In most countries, men's LE increased by more than 3 months per year from 1990 to 2010, the lowest increase being observed in the United States (1.3 months per year) and the highest in *Singapore* (4.1 months per year). In contrast, in most countries women's LE increased by less than 3 months per year, the highest increase being observed in *Singapore* (3.8 months per year) and the lowest in the United States (0.4 month per year) (Human Mortality Database 2018; World Bank 2018).

Secondly, the majority of countries experienced a relative compression of disability both at birth (UK, Spain) and at age 65 (USA, UK, Sweden, Denmark, Norway, France, Spain, China and Australia) in the context of increased longevity. Dynamic equilibrium has been observed at birth in the USA since 1970, and at age 65 in France when combining increased longevity, worsening functional limitations and

decrease in activity restrictions. On the other hand, relative expansion of disability has been observed in Japan, Hong Kong and Singapore, countries that have the highest LE.

Thirdly, the number of years lived with disability varied little, remaining almost constant in the USA, Denmark (for severe disability) and Australia, slightly increasing (absolute expansion of disability) in the UK, Sweden (for men), the Netherlands, Catalonia (Spain), Japan, Hong Kong and Singapore, and slightly decreasing, and thus an absolute compression of disability, in Denmark (for mild disability) and Norway.

Fourthly, the number of years with severe disability has generally increased (UK, France, Japan, Hong Kong and Singapore), including years with mobility problems (Sweden, Catalonia, Singapore and for women only India) as well as years with care needs (UK, France, Japan). However, a relative compression of the most severe disability has been observed in the US for men and in Australia for women, although in the same countries, the other gender (US women and Australian men) have seen dynamic equilibrium.

Finally, the most unexpected result from the 1970s and 1980s viewpoint (Gruenberg 1977; Kramer 1980; Manton 1982), is the strong decrease in cognitive impairments observed in some countries (USA, UK, Denmark, France, the Netherlands and Australia) but not all (Sweden, Japan and China) (Larson et al. 2013; Winblad et al. 2016; Wu et al. 2017; Larson and Langa 2017). There is no single explanation for this favorable trend where it has been observed but improvements in living conditions, education and health systems could contribute to better cognitive as well as physical health over the life course, leading to a decrease in the risk of dementia at the end of life (Crimmins et al. 2018; Wu et al. 2017). The increase in prevalence of dementia in all Asian countries for which there are studies (Winblad et al. 2016), may be due a phase of economic emergence that would initially favor more cardiovascular risk factors (hypertension, smoking, obesity) (Larson and Langa 2017; Prince et al. 2016). However, these explanations do not fit well with the case of

Japan, Hong Kong and Singapore. For the time being, trends in life expectancy with and without cognitive impairment or dementia are available for only a few countries.

Conclusion

In the 1980s, when research on how to measure the compression of morbidity really began, the question on which dimensions of health should be investigated did not anticipate improvement in cognitive abilities as one of the first indicators to show compression. Another unanticipated trend was the continued increase in LE, which has increased considerably since the 1980s, including in low-mortality countries like Japan and France, which Fries presented as close to the limits of longevity (Fries 1980). This occurred without a significant breakthrough in biology of aging (Hayflick 1975; Strelher 1975) and yet the majority of countries experienced a relative compression of disability, with a larger increase in DFLE than for LE, as detailed in this chapter. The results on DFLE largely support the hypothesis of dynamic equilibrium between the progress of longevity and the state of health of the populations (Manton 1982). Nevertheless, it remains unclear whether this is due to better control of the rate of progression of chronic degenerative diseases, or other unforeseen factors, such as the improvement in cognitive abilities due in part to the considerable improvement in levels of education of the older populations thus allowing them to manage their state of health better.

With the same research question today as 40 years ago, on the future compression of morbidity, the questions now focus mainly on whether LE will continue to increase, on cognitive abilities and on new concepts like that of frailty. Can we imagine that the increase in LE will continue at the current pace for long (Dong et al. 2016; Vijg and Le Bourg 2017; Olshansky and Carnes 2018; Olshansky 2018)? Can we also imagine a continuation of the improvement of cognitive abilities of populations? Is this a one-off effect linked to the development of schooling and the

improvement in early life health? At ages where years of life are now gained, being free from disability does not mean being healthy. It is possible that the years gained in the future are neither years of full health in the true sense, nor years of disability, but something between the two - perhaps what we perceive today as states of frailty or vulnerability (Fried et al. 2001).

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An Analysis of Macro-level Determinants of Geographic Disparities in Health Expectancies

3

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Background

It is well established that life expectancy varies considerably across countries: people in more developed countries enjoy longer lives compared to those in less developed parts of the world. Recent work has suggested heterogeneity, not just in the length of life, but also in the quality of life lived, as measured by health expectancy. The Global Burden of Disease (GBD) project, for instance, weights specific diseases, injuries, and risk factors and calculates the number of years spent in a healthy state (healthy life expectancy, HALE). According to the latest GBD estimates (Kyu et al. 2018), in 2017, HALE at birth was the longest in Singapore (72.6 years for men and 75.8 years for women) and the shortest in the Central African Republic (42.8 years for men and 47.0 years for women). These results illustrate substantial cross-country disparities in health

expectancy and raise a set of important questions: What are the factors that explain geographic differentials in health expectancy? To what extent is health expectancy influenced by a country's socioeconomic characteristics? In addition, do the determinants of health expectancy vary by country?

This chapter seeks to address these questions by summarizing our current knowledge of macro-level factors related to health expectancy measurements in the world. Geographically, we give special attention to Europe and Southeast Asia. Because countries differ significantly in their socioeconomic and political contexts, we explore how the contextual characteristics of countries may be linked to variations in health expectancy in these parts of the world. We begin with a review of research findings from Europe. Although 20 years have passed since the collapse of the communist regimes in the East, there remain marked differences in socioeconomic development levels between Eastern and Western Europe. It is therefore particularly interesting to explore whether and to what extent these socio-economic inequalities may have translated into differentials in population health status across European countries. We then shift our focus to Southeast Asia, namely Japan and China. The populations of these two countries have enjoyed extraordinary health gains over the past few decades; however, evidence indicates emerging heterogeneity in health status among these

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populations. Evidence from Japan and China offers valuable insight into the ways in which health differentials are produced.

Review of Empirical Research Findings

In this section of the chapter we provide an overview of empirical research findings about (1) cross-national/regional inequalities in health expectancy measures, and (2) macro-level socio-economic factors that explain these variations in Europe and Southeast Asia. Table 3.1 provides a summary of major study findings from these parts of the world.

The European Union (EU) Member Countries

With the growing prevalence of chronic conditions, health expectancy has become a standard summary measure of population health in the European Union (EU) member countries. In 2004, the European Commission incorporated a measure of health expectancy, namely healthy life years (HLYs), to the set of structural indicators. The measurement is based on the Global Activity Limitation Index (GALI) questions from the Statistics on Income and Living Conditions (EU-SILC) survey and denotes the number of years expected to be lived without activity limitation. The main objectives of the initiative include: (1) to monitor health as a key economic factor, (2) to introduce the concept of quality of life, (3) to assess the employability of older workers, and (4) to watch progress in access to, and, quality and sustainability of, health care (Jagger et al. 2013).

A cross-country study by Jagger et al. (2008) computed HLYs at 50 years of age and reported substantial inequalities among 25 EU member states. In 2005, the gap in male HLYs at age 50 was 14.5 years (from 9.1 years in Estonia to 23.6 years in Denmark), while female HLYs at 50 had a range of 13.7 years (from 10.4 years in Estonia to 24.1 years in Denmark). An important

question then arises regarding the factors producing variations in HLYs across EU countries. Jagger et al. (2008) noted that GDP per capita and elderly care expenditures (the proportion in total GDP of social protection expenditures devoted to care of the elderly population) were positively related to HLYs at 50 for both genders. Life-long learning (the percentage of the population aged between 25 and 64 years participating in education or training for an extended period of time) was positively associated only with men's HLYs. Further, long-term unemployment rates (the percentage of the unemployed for more than 12 months in the total active population) and low educational attainment (the percentage of those aged 25–64 with lower secondary education) were inversely associated with male HLYs at 50. Among a set of macro-level factors used in the analysis, expenditures on elderly care had the largest impact on HLYs at 50. A one-unit increase in elderly care expenditures was related to a more than two-year increase in HLYs at 50 years of age for both men and women in 25 EU countries. These results suggest that increases in spending on the older population may lead to greater availability of health-enhancing resources, such as medical and care services, thereby contributing to the physical well-being of older persons.

More recent work by Fouweather et al. (2015) used data from 2010 and repeated the same analyses for the 25 EU countries. Two findings are noteworthy. First, cross-national variations in HLYs at 50 have grown over time. Between 2005 and 2010, differences in HLYs at 50 increased by 1.0 year for men and by 2.8 years for women. These results offer evidence of growing health disparities among the EU member states. Second, the results from regression analyses highlight material deprivation as a major predictor of HLYs at 50. In 2010, a 10% rise in the proportion of the population classified as materially deprived was related to a 2.2-year decrease in men's HLYs and a 2.0-year reduction in women's HLYs. Inverse associations between material deprivation and health expectancy were noted in 2005, but the magnitude of the relationship was much larger in 2010 than in 2005. It is a consistent finding that economic hardships have a deleterious effect on

Table 3.1 Studies exploring macro-level factors related to health expectancy measures in Europe and South East Asia

| Author(s) (year) | Area/country (n) | Year(s) of estimate | Measures | Unit | Macro-level factors ^a |
|-------------------------------|-----------------------|--|-----------------------|-------------|--|
| Jagger et al. (2008) | EU member states (25) | 2005 | HLYs at 50 | Country | GDP per capita (+); % of GDP on elderly care (+); long-term unemployment (−, men only); % of those (aged 25–64) participating in education and training (+, men only); % of those (aged 25–64) with lower secondary education (−, men only) ^b |
| Fouweather et al. (2015) | EU member states (25) | 2005/2010 | HLYs at 50 | Country | GDP per capita (+; women only); long-term unemployment (−, men only); % of those classified as materially deprived (−) |
| Gutierrez-Fisac et al. (2000) | Spain | Mortality and disability information is from 1986. | DFLE at birth and 65 | Province | Illiteracy rate per 1000 (−, at birth and at 65); % of the unemployed (−, at birth and at 65); % of smokers (−, at 65) |
| Groenewegen et al. (2003) | The Netherlands | Mortality is from 1995. | HLE at birth and 65 | Region | % of smokers (−, at birth and 65 for men only); unemployment (−, at birth and at 65); |
| | | Health information is from a 1992–1997 survey. | | | % of those with low education (−, at birth and at 65 for women only) |
| Wohland et al. (2014) | United Kingdom | 1991 and 2001 | DFLE at both and 85 | Local areas | Low social class (−); unemployment rate (−, at 65); retirement migration (+); % of non-white population (+) ^b |
| Minagawa (2013) | Eastern Europe (23) | 2008 | HLE between 20 and 74 | Country | Corruption (−); lack of (a) economic freedom (−). (b) freedom in society (−), (c) freedom of the press (−); Terrorist attacks (−); prison population rate (−) |
| Minagawa and Saito (2018) | Japan | 2010 | DFLE at 65 | Prefecture | Income per capita (+); unemployment (−); older worker (65+) rate (+); social welfare Expenditures (+); per-capita LTCI expenditures (−); % of people 65+ relying on public assistance (−, women only) |
| Kondo et al. (2005) | Japan | 1999 | DFLE at 65 | Prefecture | Public health nurses per 100,000 (+); older worker (65+) rate (+); % of good self-rated health (+) |
| Liu et al. (2010) | China | 2006 | DFLE at 60 | Province | GDP per capita (+); proportion of urban residents (+); illiteracy rate among those 60+ (−); % of those without (a) shower (−), (b) water (−), (c) gas/electricity (−); the number of hospital beds per 10,000 (+); the number of clinics/nurses per 10,000 (+) |

^aFactors strongly related to health expectancy measures are listed. Directions of associations (+/−) are in parentheses. Results are significant for both genders unless specified

^bResults are based on multivariate analyses of 2001

the physical as well as psychological well-being of individuals (Mirowsky and Ross 1999). Analysis by Fouweather et al. (2015) demonstrates the inverse relationship between material deprivation and health expectancy in the European context.

In addition, growing evidence suggests health expectancy variations within European countries. Gutierrez-Fisac et al. (2000), for example, found differentials in disability-free life expectancy (DFLE) at birth and at 65 years of age across Spanish provinces. The study reported that socio-economic conditions (e.g., the illiteracy rate and unemployment rate) and health lifestyles (e.g., the percentage of smokers) were linked to regional variations in DFLE values. Similar findings come from Groenewegen et al. (2003)'s study from the Netherlands. In their analysis, the percentage of smokers, unemployment rates, and levels of educational attainment were strongly associated with healthy life expectancy at birth for men and women across 27 Dutch regions. Interestingly, indicators of health-care supply, such as the number of hospital beds and general practitioners per 1000, were not strongly related to health expectancy.

The United Kingdom (UK)

Geographical inequalities in health and mortality are a longstanding issue in England. Thirty years ago the Black Report (Black 1980) highlighted health inequalities across Britain and more recently the Marmot review (Marmot 2010) has brought the topic back to the attention of politicians and policy makers. The Office for National Statistics routinely published life expectancy (LE), healthy life expectancy based on self-rated health (HLE) and disability-free life expectancy (DFLE) at birth and age 65 for various levels of geography and by deprivation. As well as a clear North-South divide, with the North of England generally having lower LE, HLE and DFLE than the South, inequalities do not appear to be reducing. Inequalities in DFLE and

HLE are much greater than those for LE. The Northern regions of England seem doubly disadvantaged compared to their Southern counterparts. Not only do people in the regions of the North have shorter life expectancy and lower disability free life expectancy, but they also spend a higher percent of their lifetime with a disability. This is particularly acute in North East England for both men and women. The latest results comparing the change in LE and HLE between 2012–2014 and 2015–2017 by deprivation decile show statistically significant widening of socioeconomic inequalities in male and female LE at birth and at age 65. Socioeconomic inequalities in male and female HLE at birth and male HLE at age 65 also diverged but not significantly. There was a slight reduction in socioeconomic inequalities in female HLE at age 65 (Office for National Statistics 2019).

Although inequalities in LE, HLE and DFLE between different geographies are routinely reported, further analyses through meta-regression to understand potential correlates of gaps are rare. The only study to date compared inequalities in LE and DFLE at birth and at age 85 across local authorities (LA) in England in 1991 and 2001 (inequalities being measured by the difference between the tenth and 90th centiles of the ordered local authority distribution), and also compared the impact of associated factors through meta-regression (Wohland et al. 2014). Over the period inequalities in LE at birth increased (women 0.3 years; men 0.4 years) but inequalities in DFLE at birth increased even more (women 1.5 years; men 1.3 years). At age 85, inequalities in LE reduced slightly by 0.1 years for women and 0.2 for men, but again DFLE at age 85 increased slightly by 0.1 years for both women and men. A range of area level possible correlates were explored including rurality, deprivation, social class composition, ethnicity, unemployment, and level of retirement migration, with the finding that DFLE at birth across local authorities was most strongly associated with social class composition and unemployment rate. However, all these factors were much less influential by age 85.

East Central Europe and the Former Soviet Republics

While efforts toward greater European integration are in progress, there remain disparities between Eastern and Western Europe in terms of population health status, the phenomenon known as the “East-West health divide” (Bobak and Marmot 1996; Marmot and Bobak 2000). Populations in the East tend to live shorter lives, suffer from a larger number of chronic diseases, and have lower levels of self-rated health compared to those in the West (Bobak and Marmot 1996; Carlson 1998; Marmot and Bobak 2000; Meslé and Vallin 2002). Moreover, evidence suggests a regional divide in terms of health expectancy. In 2010, male HLYs at 50 ranged from 14.2 years in the newly joined countries in the East to 18.6 years in the established 15 EU member states in the West. The range for women’s HLYs at 50 was 3.2 years, from 15.9 years in the East to 19.1 years in the West (Fouweather et al. 2015). Further, using data from the Survey of Health and Retirement in Europe (SHARE), Jagger et al. (2011) calculated a variety of health expectancy measures at age 50 in 13 European countries, including two from Eastern Europe (Poland and the Czech Republic). Men and women in Poland consistently had the lowest levels of health expectancies, such as the number of years spent without chronic morbidity, physical functional limitations, and difficulty in activities of daily living (ADLs) and instrumental ADLs (IADLs).

With persistent health differentials between Eastern and Western Europe, there has been a growing interest in mechanisms behind health disadvantages of the populations in the East. Jagger et al. (2008) identified several macro-level factors related to HLYs at 50 among the 10 new EU member states in the East, including the level of expenditures on elderly care, the mean age of exit from the labour force (men only), and the level of educational attainment. In addition to macro-level socioeconomic factors, broader social circumstances in which populations are

embedded are closely associated with the health expectancies of the populations in Eastern Europe. Using the 2008 European Values Study (EVS) data from 23 countries of East Central Europe and the former Soviet Union (Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, the Czech Republic, Estonia, Georgia, Hungary, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia, and Ukraine), Minagawa (2013) found that several structural variables were closely related to the length of life spent in good self-rated health between ages 20 and 74 (partial healthy life expectancy, HLE). These included levels of corruption (measured by the level of corruption in a country’s public sector), restriction of freedom (measured by the level of freedom in society, economic freedom, and freedom of the press), and violence (assessed according to the number of terrorist attacks and prison population rates per 100,000). Importantly, the relationships between partial HLE and these structural variables remained significant when accounting for macro-economic indicators, namely GDP per capita and the percentage of health care expenditures in total GDP. These results demonstrate that a range of political, economic, and social conditions have an important bearing on the quality of life among populations in Eastern European countries.

Although reducing regional health inequalities has been a pressing public health concern for European countries, population health in Eastern Europe has lagged far behind that in Western Europe. Prior research findings suggest that the political, economic, and social contexts of Eastern European countries hold the key to understanding the health disadvantages of their populations. Continued efforts toward improving the overall social and economic condition in Eastern European countries may lead to improving population health status, thereby narrowing the regional health divide on the European continent.

Japan

The Japanese population enjoys a phenomenal health status. The most recent figures for 2017 show that life expectancy at birth stood at 81.1 years for men and 87.3 years for women, compared with 50.1 years and 54.0 years, respectively, in 1947 (Ministry of Health, Labour, and Welfare 2018). The Japanese not only live longer, but also enjoy healthier lives. According to the GBD estimates (Kyu et al. 2018), in 2017, men and women in Japan had the second longest HALE at birth (71.4 years for men and 74.6 years for women) and at 65 years of age (15.1 years for men and 18.5 years for women) after Singapore. Recent scientific work, however, has noted emerging health inequalities within the country. In 2015, for instance, the gap in life expectancy at birth between 47 prefectures was 3.1 years for men (from 78.7 years in Aomori Prefecture to 81.8 years in Shiga Prefecture) and 1.8 years for women (from 85.9 years in Aomori Prefecture to 87.7 years in Nagano and Okayama Prefectures) (Ministry of Health, Labour, and Welfare 2015a). There is evidence of regional inequalities in health expectancy as well. In 2016, there was a 2.0-year gap in men's DFLE at birth (from 71.2 years in Akita Prefecture to 73.2 years in Yamanashi Prefecture), and women's DFLE at birth had a range of 2.7 years (from 73.6 years in Hiroshima Prefecture to 76.3 years in Aichi Prefecture) (Hashimoto 2017). Further, Minagawa and Saito (2018) found substantial variations in health expectancy at older ages. In 2010, the gap in male DFLE at 65 was 2.0 years (from 11.4 years in Nagasaki Prefecture to 13.4 years in Ibaraki Prefecture), and the result for women reached 2.8 years (from 13.2 years in Tokushima Prefecture to 16.0 years in Shizuoka Prefecture).

The issue of regional health differentials has received growing attention in policy and academic circles, and the second phase of Healthy Japan 21, launched in 2000, incorporated the concept of health expectancy (measured by DFLE at birth) to the nationwide health-promotion agenda (Ministry of Health, Labour, and Welfare 2015b). The program aims to (1)

increase DFLE at a faster rate than growth in life expectancy, and (2) reduce differentials in DFLE across prefectures for the period between 2013 and 2022. In response to government initiatives, researchers have begun to explore the mechanisms behind regional health disparities. Using the 2010 *Kokumin Seikatsu Kiso Chosa* (Comprehensive Survey of Living Conditions) data, Minagawa and Saito (2018) documented a significant relationship between DFLE at age 65 and prefecture-specific socioeconomic indicators, including income per capita, unemployment rates, the proportion of workers older than 65, and social welfare expenditures (measured by the percentage of welfare expenditures in total GDP and per-capita expenditures on the long-term care insurance (LTCI) policy program). Higher levels of a prefecture's wealth and welfare expenditures were positively related to DFLE at 65, while the unemployment rate was negatively associated with DFLE at 65 for both genders. Furthermore, the larger the LTCI-related expenditures, the shorter the length of disability-free life at age 65. Similar findings come from the ecological study by Kondo et al. (2005), who, using prefecture-level estimates of DFLE at age 65 for 1999, found that increases in the number of public health nurses (per 100,000), the proportion of those having good self-rated health, and the percentage of older workers (65+) were associated with longer DFLE at age 65.

Health scholars have investigated the micro-level determinants of mortality (Suzuki et al. 2012) and the probability of reaching 100 years of age (Robine et al. 2012) across Japanese prefectures. Recent work has incorporated a quality-of-life dimension and demonstrated that a prefecture's socioeconomic and policy contexts are important for the health expectancy of the population. Although Japan has long been portrayed as a highly homogeneous society, in recent years, the country has witnessed emerging socio-economic disparities. Importantly, these differences in socioeconomic conditions seemingly have translated into health differentials, as in recent work by Minagawa and Saito (2018). The second phase of Healthy Japan 21 aims to decrease regional differences in DFLE, but

achieving this goal may require policymakers to address much broader issues currently facing the country, namely regional inequalities in socioeconomic development levels.

China

Since the launch of large-scale market reforms under Deng Xiaoping's leadership in 1978, the Chinese population has enjoyed substantial health gains, evidenced by improvements in life expectancy at birth, reductions in infant and maternal mortality, and declines in the prevalence of infectious diseases (Zhou et al. 2016). China seems to stand in stark contrast to Eastern European countries where the transition from communism in the 1990s was accompanied by severe declines in population health (Brainerd 1998, 2001; Watson 1995). Researchers argue that China's gradual economic reforms led to sustained socioeconomic development, characterized by rising incomes, improved living standards, and reduced poverty, thereby enabling the country to avoid large-scale health declines visible in post-communist Eastern Europe (Whyte and Sun 2010).

More recently, however, studies have indicated emerging health inequalities in China, particularly between provinces. Using the GBD estimates, Zhou et al. (2016) analysed the distribution of cause-specific death rates across 33 provinces. Two important findings stand out. First, life expectancy markedly varies by province. In 2013, the range in male life expectancy at birth was 11.8 years (from 68.4 years in Tibet to 80.2 years in Shanghai), and the gap in female life expectancy reached 12.8 years (from 72.4 years in Tibet to 85.2 years in Shanghai). Second, there are regional differences in leading causes of death. Overall patterns of cause-specific mortality have gradually shifted from communicable to non-communicable diseases, but the pace of the progress varies by province. In poor provinces, namely Tibet, Xinjian, and Qinghai, people are at increased risk of dying from infectious diseases and neonatal causes. Furthermore, there are disparities in health expectancy across

Chinese provinces. Liu et al. (2010) reported that, in 2006, there was a 9.6-year gap in overall DFLE at age 60, ranging from 11.2 years in Ningxia Hui Autonomous Region to 20.8 years in Shanghai. Further, province-level differentials in DFLE reflected differences in socioeconomic development levels. GDP per capita, urbanity, and public health resources, such as the number of hospital beds, clinics, and nurses, were positively related to DFLE at 60, while illiteracy and lack of adequate sanitation and hygiene (e.g., access to gas, water, and electricity), were associated with reductions in DFLE at 60 for both genders. This is in line with prior research findings by Zimmer and associates (2010) who identified socioeconomic conditions and access to health services as major contributors to health differences between the urban and rural parts of the Beijing Municipality.

Two decades of market reforms have turned China into one of the fastest growing economies in the world. The rapid transition process, however, has yielded a number of social consequences, as seen in the growing inequality in socioeconomic development levels between rich and poor provinces (Whyte 2014). While China made remarkable progress in improvements of population health status, recent research has shown geographic heterogeneity in terms of mortality rates, cause-specific death structures, and health expectancy measures. The populations in rich large cities tend to enjoy longer and healthier lives, while those in poor remote provinces continue to be faced with health disadvantages. These observations raise the possibility that the benefits of market reforms and drastic health transitions have not been equally distributed within Chinese society.

Summary

With a worldwide rise in chronic conditions, health-related quality of life has become one of the main research topics in demography, epidemiology, and public health. Researchers have made major strides toward computing health expectancy for a large number of countries in the

world, thereby generating an interest in the mechanisms of cross-country health heterogeneity. This chapter provided an overview of prior research findings about macro-level factors related to health expectancy measures in Europe and Southeast Asia. There are marked differences in health expectancy between countries (i.e., Eastern and Western Europe) as well as within countries (i.e., Japan and China). Evidence reviewed to this point clearly suggests that aggregate-level socioeconomic indicators are related to the health expectancy of populations in Europe and Southeast Asia. Overall, people living in countries/places with good economic performance (e.g., higher levels of GDP and higher income) and more generous welfare policies (e.g., higher levels of medical and care expenditures) tend to enjoy both longer and healthier lives. These findings highlight the importance of considering a country/place's socioeconomic and policy contexts to better understand the health status of its population.

Debate continues as to the degree to which geographic inequalities in health are due to differences in the conditions of places or differences in the characteristics of the people living in those places. While it is difficult to empirically separate the effects of places from the effects of individuals, evidence suggests the strong influence of a place, operating above and beyond individual-level demographic and socioeconomic characteristics, on the health of residents (Ross and Mirowsky 2001). The existing demographic literature points to close associations between health expectancy and wealth, labour, and welfare characteristics of a place, suggesting that differences in the socioeconomic environments of a country, prefecture, or province may be the key to explaining geographic variations in health expectancy. Therefore, efforts to promote economic activities, develop medical and care programs, and build public health infrastructure may bring health benefits in the end. In addition, as seen in the case of China, it is important to establish a mechanism through which these resources are equally distributed within society. Overall, investigations into the macro-level determinants of health expectancy can contribute to one of the

headline targets of the United Nations Sustainable Development Goals (SDGs): to reduce health inequalities around the globe for the period 2015–2030. Although cross-national comparisons of health expectancy may suffer from sub-optimal harmonization of, or cultural differences in, the underlying health measure, within-country or regional analyses may be less susceptible to these problems. Continued policy and research attention should be paid to harmonizing cross-national health measures, monitoring the distribution of health expectancy in the world, and investigating the mechanisms behind heterogeneity in health expectancy.

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Monitoring Social Differentials in Health Expectancies

4

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Background

Social inequalities in health and mortality are due to health risks that are closely linked to the social status of individuals and on which public policies are able to act (Navarro and Shi 2001; Marmot 2010; Mackenbach et al. 2013). The reasons for this are that different social groups (more/less education, income, material resources, skilled job...) have different access to or use of care and prevention, particularly for financial reasons, different harmful/protective residential or professional environment, and different practices (tobacco, alcohol, nutrition, physical activity, etc.) that increase or reduce diverse health risks. Poor health and mortality are both associated with social factors operating across the life course

and inequalities grow as health risks differentially accumulate throughout life (Kuh and Ben Sholmo 1997). Poor living conditions, detrimental work conditions, low access to appropriate care and some health related behaviors combine and increase either the risks of life-threatening diseases (for instance cardiovascular diseases, cancers...) or of disabling diseases (for instance mental diseases, musculoskeletal disorders...). Health and mortality are not isomorphic concepts, yet they interact to define the spans of the lifetime spent with and without various health problems. Social differentials in health expectancy summarize and quantify the impact of social factors on both the life expectancy and the healthy and unhealthy life years.

This chapter has a number of aims. First, we discuss the importance of monitoring social inequalities in health expectancy, and how social status is generally measured to reflect such inequalities. Second, we introduce some methodological questions associated with measuring health, and mortality, by social status and we discuss the theoretical association between health, mortality and social status. Third, we present a review of studies on health expectancies by social status, describing and interpreting the patterns revealed by this international literature. The conclusion of this chapter identifies further developments for this research area.

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Health Expectancies by Social Status

Policy Relevance of Measuring Social Inequalities in Health Expectancies

As detailed in Chap. 2, the central question addressed by health expectancies is whether additional years of life expectancy translate into fewer unhealthy years (compression), more unhealthy years (expansion), or mixed effects depending on the type or severity of disability (Kramer 1980; Fries 1980; Manton 1982). When stratified by socio-economic status (SES), health expectancy indicators based on different health and disability dimensions, shed light on the differential population needs and potential policy responses. Analysis of changes over time and differentials within countries may indicate how successful public contexts and policies have been in addressing the unevenly distributed determinants of health and care. Inequalities in health expectancies are also important for the sustainability of social protection systems. Poor health and activity limitations have been found to be major determinants of loss of autonomy at older ages, with a declining social participation and increasing care needs; in mid-adulthood, poor health and activity limitations are also a major reason for labor force exit before the retirement age and low social participation in general.

The measurement of differences in health expectancies between social groups, across different dimensions of health and functional health, is a key public health and social policy indicator that contributes to the debate on the factors of healthy aging, as well as on potentially different retirement ages across population groups. The overview of the literature regarding social inequalities in health expectancy helps to improve our understanding of the mechanisms of expansion or compression of morbidity and the different components of the disablement process across social groups.

Defining and Measuring Social Status

How the Social Situation of Individuals Relates to their Health

Education, income and occupations are broadly used as social criteria to construct SES groups, because these indicators reflect how systems in high-income countries typically stratify the population with regard to risks and resources. Health and education are driven by interrelated mechanisms (Baker et al. 2011). At an individual level, education indirectly provides skills to enhance the capability of detecting health problems and addressing them (Ross and Mirowski 1999; Ross and Wu 1995; Montez et al. 2012). In addition, early life conditions, especially child development and cognitive abilities, explain later educational attainment and adult health (Davey Smith et al. 1998; Power et al. 1996; Hayward and Gorman 2004; Van den Mheen et al. 1997). Education partly determines the socioeconomic situation and work conditions in adulthood as well as related risk factor exposures. Work and life conditions continue to refine the association between early life conditions and health, and adult socioeconomic status can add to or buffer early life health risks (Holland et al. 2000; Hart et al. 1998; Davey Smith et al. 1997; Montez and Hayward; Conti et al. 2010). Considering these educational effects in a life course perspective, we expect that the association between health and education at an individual level depends on three components: childhood health circumstances and child development; the chances of improving the level of education and health skills; and the socioeconomic return of education which might increase or lower the associations due to childhood circumstances.

Low income and poverty have an impact on an individual's health through two main causal pathways (Marmot 2002). More precisely, health is influenced first by the material effect of insufficient income as it limits the quantity and quality of goods and services that people can afford and from which their health should benefit. Second, health is influenced by a psychological effect of insufficient income as it limits the level of control to change and adapt the environment. The

association between health and income is non-linear: once basic needs are covered, the increase in income does not improve health as much as below that level. The threshold depends on the national context and the availability of goods and services provided on a universal basis through a minimum income and free access to a number of goods (including medical care).

Occupation (and also the lack of an occupation) influence a person's health via the risks, rewards, and demands of the work environment (Karasek et al. 1988; Siegrist 1996), both due to the possible health risks associated with physically and psychologically demanding tasks and to the possible impact of lifelong career characteristics. Occupation also impacts health indirectly through the level of income and related living conditions, through material and social support with the professional network and workers' rights (for care provision for instance).

Understanding the Determinants of Social Health Inequality

A model that has been used for understanding the determinants of social health inequality points to central causal mechanisms (Diderichsen et al. 2012). The first is social stratification resulting from social organization; as mentioned above, the stratification process starts early in childhood and influences the individual's social position and health later in life. Differential exposure then covers a wide range of risk factors through work, economic circumstances etc., and thereby residential or work conditions and physical environment. Being exposed to these determinants depends on social position (and paths), and this might mediate the effect of social position on health. In addition, health-related behaviors (physical activities, nutrition, tobacco/alcohol consumption) and a range of biological risk factors are often socially skewed, thus representing differential exposure. Differential vulnerability represents the effect that causes of illness have depending on the clustering and interaction of risk factors and accumulation of exposures. Illness and injuries affect functional ability and health status in general, and the opportunities to participate in working and social life and these

can be expressed as differential consequences of disease. These consequences are influenced by social position through access to treatment, rehabilitation, work and other demands.

Social Status and the Disablement Process

There are unequal risks that a given disease (or accident) lead to functional disorders, and that these functional limitations, in turn, lead to activity restrictions; the risks vary depending on the person's resources and environment, especially technical aids available, and on the home or workplace adaptation to compensate for functional decline and maintain activity (Verbrugge et al. 1997; Agree 1999). SES modifies the probability of pathways within the disablement process: the risk that a disease induces functional limitations; the chance of accessing assistance to compensate for a function lost; the chance of adapting the (work and residential) environment; and the chance of maintaining daily activities. Incorporating several disability measures allows us to recognize that inequalities in health may be generated at different levels of disability through a variety of social health determinants (Marmot et al. 2008).

Differential exposure to diseases, accidents and associated risk factors induce differential risks of *functional limitations*, and by the fact that the chances of recovering from a disease varies (Fig. 4.1). A further step is activity restrictions of which functional limitations are a strong predictor (Jagger et al. 2005; Verbrugge and Jette 1994). This step in the disablement process reveals potential inequalities in exposure to disabling diseases and functional limitation but also to compensation strategies, although adaptations within the home, or even moving to a more suitable environment is not always affordable. Disentangling the different steps of the disablement process allows a better understanding of where differentials between social groups are played out. This is relevant for public health interventions to generalize compensation (technical devices, adapting residential/work environments) to lower the risk of further activity restrictions. Activity restrictions, especially

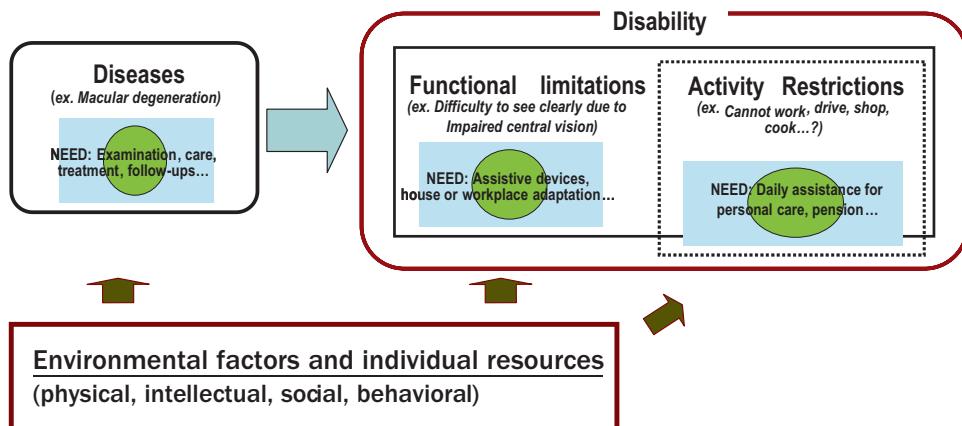


Fig. 4.1 Disablement process, disability concepts and associated needs

personal care activity restrictions, correspond to a complex disability situations in which seriously impaired health prevents an individual from the normal performance of usual activities. Social differentials in activity restrictions relate to differences in the type and severity of health problems and to different ways of coping with them; they reflect unequal chances of independence and work/social participation.

Stratifying a Population by a Social Criterion

Selecting the Appropriate Social Criteria

Most often, social differences are measured by educational level (years of education, degrees obtained), occupational status, or income level, due to their availability in data sources and because their association with health is well documented. However, some limitations need to be taken into account when using these social criteria (Carr-Hill 1990). One issue relates to problems of discontinuity in individuals' belonging to one given status during the life cycle. Income level or occupation depend on the time of career at which individuals are surveyed: some who experienced promotions are characterized by an increase in their skills and wages, some who experienced periods of inactivity and unemployment are characterized by stagnation in the career

and low income. Changes in income or occupation are frequent over the life course, as for instance around family events known to impact women's careers and income (births, small children, relocation, and assistance to a dependent relative). Health problems might also result in progression down the social ladder. Social mobility over the life span means changes in health exposures for good and for bad.

Another issue raised by the measurement of social status concerns changes in categories over time at the population level, which implies both variations in enrolment and in the nature of the categories studied. Analysis of how inequalities evolve over time should keep in mind this temporal evolution and the changing population groups that different categories of education or occupation or income represent over time. For instance, the no-diploma category has become highly selected in high-income countries, being increasingly composed of people who have had major educational difficulties due to either health problems or difficult living conditions in childhood. The increased risk over time of disability or mortality associated with the category "no diploma" is a result of changing population groups (size and social background) behind this no-diploma label.

In total, the issue of discontinuity in individual social category over the life course and that of the evolution of the criteria over time combine when a population is stratified by social status. The

groups created are fictitious insofar as some of the less endowed at younger ages will acquire qualifications and income over their life course with less correspondence in social terms to the group of the less endowed at older ages. However, despite these limitations, stratification upon these criteria is widely used. They are seen as efficient markers of social status to monitor social differentials.

Alternative Approaches to Individual Social Criteria

In order to create stable social groups within the population, some studies use relative categories of education or income stratifying the population by decile, quartile, or third of income or years or months of education (Bossuyt et al. 2004; Brønnum-Hansen and Baadsgaard 2012) or using an index of inequalities (Van Oyen et al. 2011; White and Edgar 2010). Such stratification allows the comparison of groups representing a constant share of the population on the social gradient. In addition, acknowledging that a given status has not the same meaning depending on the age, the period, or the country, the role of social status in health is preferably approached by the life course perspective, and interpreted within a specific time or space context. However, these solutions are not always applicable due to the low level of information available in data sources, and the need to have the same social criteria for health and for mortality data when computing health expectancies. Another option is to use an ecological approach of SES health expectancy differentials, which consists in utilising the SES of cities or regions, usually based on indicators of social deprivation, rather than the SES of the individual (Szwarcwald et al. 2016; Martín and Esnaola 2014; White and Edgar 2010; White and Butt 2015; Wohland et al. 2014; Wood et al. 2006; Geronimus et al. 2001).

Beside the major social markers, there is a growing interest in social vulnerability, which is relevant for certain population groups. However, it may be important to contextualize socioeconomic differences in health and mortality based on other types of intersecting stratification systems. For example, some countries are strongly

stratified along racial and ethnic lines, and thus some studies also highlight racial differentials in relation to the social status to monitor health expectancy differentials (Chan et al. 2016; Wohland et al. 2015; Geronimus et al. 2001; Montez and Hayward 2014; Solé-Auró et al. 2015; Laditka and Laditka 2016). Stratification can also be found at the intersection of the household structure, social origin, area of residence, ethnicity, housing tenure, etc. (Montez and Hayward 2014; Geronimus et al. 2001; Matthews et al. 2006). One study has also focused on a specific socially vulnerable group, that of the disadvantaged travelers' community in Ireland (Abdalla et al. 2013). However, even though such studies are important, information about social situations is not always available in population health surveys, registries and other administrative data, which are required to compute health expectancies.

Measuring Social Status, and Mortality and Health by Social Status

Collecting Appropriate Information on Mortality and Health by Social Status

Availability of Data Stratified by Social Status

One of the major issue when computing health expectancies by social status is the availability of the requested data (Cambois et al. 1999). As explained in Chap. 5, most of the time, health or disability data are obtained from cross-sectional surveys and mortality risk is derived from vital statistics. From these disconnected data sources, one can apply the so-called "Sullivan method" (prevalence-based health life table) to approximate the health and mortality transitions. In that case, data sources are diverse and the computation of health expectancies requires the correspondence in the population groups (i.e. the same definition and criteria for social status) in the two data sources from which mortality and the health outcomes are derived. Health surveys can usually

provide the health information (prevalence) by social groups but routine statistics on mortality rarely provide life tables by social groups. This is why there are many fewer studies on health expectancies by social status than studies on health expectancies overall.

Longitudinal datasets that record the health and mortality status of individuals at different points in time are powerful data sources since the same source of information tracks individuals' health knowing their education, job, income. It is possible to estimate probabilities of transition between health or disability status (incidence and recovery probabilities) and transition to mortality among the individuals of the initial sample for selected population groups. These probabilities of transitions are used to compute the multistate life tables that provide the health expectancy indicators; they can be stratified by the social variables available in the datasets. However, cohorts or longitudinal/panel surveys are scarce and have some limitations: the attrition of this sample due to lost to follow-up, which depends on health status and social status (see below) and the size of the sample, which limits the robustness of the results. Population registers are the most powerful (but extremely scarce) data sources when they record information on mortality and health, together with information on demographic characteristics, work or income.

Collecting Social Status in Surveys or Censuses

Social status is generally self-reported by individual in health surveys or census from which the data are issued (more rarely from registers). The precision of the individual report of their income, job or educational levels depends on a number of issues. For example, the person reporting the information matters: the individual, household respondents, an administrator. At a given time, several answers could be collected for the same person depending on the level of information the respondent has, and his/her perception of what is asked: the most recent job or the longest occupied one? Are resources limited to the income from work, or do they also include pensions and benefits? Is income pre- or post-tax? The quality

of the information collected is variable and depends partly on the survey design and of the mode of administration.

The Measure of Mortality by SES: Linked vs Unlinked Data Sources

Mortality data by social status requires population register data or a mortality follow-up of census or census samples or a cohort that captures deaths occurring in the population groups to compute age specific mortality risk; population and death data are therefore linked at the individual level. Linked data are scarce, and when they exist, they generally need modelling or pooling of multiple years to construct the life table by social status. This is the main reason why health expectancies by social status are not routinely produced.

In some cases, unlinked data have been used: deaths by social status (numerator) and population by social status (denominator) are collected separately. The former comes from information on the death certificate (if provided) and allow stratifying the total death by age and by social status. The latter comes from a population census or registry, providing the population by age, gender and by social status. However, the information related to social status of the deceased person on the death certificate is generally of poor quality inducing frequent inconsistency between what is reported in a census and what is documented on the death certificate (Shkolnikov et al. 2007). Another approach to estimate mortality risk by social status is the population survey follow up (Charafeddine et al. 2014). In principle, this constitutes an interesting approach due to the availability of further data in addition to social status. However, in spite of interesting results obtained in the study of Charafeddine and colleagues, these data have limitations. Health surveys do not usually cover the whole population (being generally limited to the household population), so non-participants may bias the representativeness of the sample. Furthermore, the sample size can be too small to have sufficient deaths when stratifying by age, sex and social status to produce robust mortality estimates.

Measuring Health by Socio-economic Status

Several issues need to be considered when collecting data on health to analyze social health differentials. Health is generally collected by interview surveys (self-administrated or face-to-face-interview) and being included in a sample of a survey is not independent from SES. Participation in a survey is never 100% of the eligible population, and drivers of non-participation include: the willingness of individuals to answer questions; the capacity to participate in terms of health, language; the interview administration mode; availability and sometimes the residence which might not be included in the record from which the sample are drawn. Excluded minorities are obviously missed from the very beginning since they are absent from the initial records. But other drivers may be more likely in less favorable SES groups (Lorant et al. 2007; Brønnum-Hansen et al. 2015). When data collection is being made through cohorts the issue of non-participation to the survey therefore applies to the probability to be lost to follow-up. In addition to the usual drivers of participation, follow-up might be compromised by any kind of change or disruption (geographical move, change at work, in the family). Work instability, inactivity, economic hardship, sources of non-participation and loss at follow-up, are more frequent in less favorable social groups.

The best informed people tend to better identify their health problems, and therefore to better report them (Fried et al. 1996) and various factors influence the propensity to report health and to misreport functional problems. Social status is one such factor due to the greater propensity of more favorable social groups to seek for information on their health (Rodgers and Miller 1997; Kempen et al. 1996). However, the literature has also demonstrated that reporting bias is smaller when measuring functional health than when measuring morbidity (Smith et al. 1990; Rodgers and Miller 1997; Fried et al. 1996). Therefore the size of the difference between social groups across health dimensions might vary not only because of the specific pathways from exposure to the measures of health under consideration,

but also due to varying propensity to identify and report health problems across different measures.

The International Literature on Health Expectancy by Social Status

Characteristics of the Studies: Social Indicators, Country, Method

Knowledge on the magnitude and trends in differentials is accumulating as more data become available and the interest for monitoring health inequalities grows. The first review of the study proposed by the REVES network stopped at the year 1999 (Crimmins and Cambois 2003). For this chapter, we reviewed 56 published studies in the period 2000–2018 presenting health expectancies estimates for different social groups (Table 4.1). These studies covered around 20 countries with either national or regional approaches of social differentials in health expectancies, a few focusing at a city level (Camargos et al. 2007; Kaneda et al. 2005; Martinez-Sanchez et al. 2001) or using data from multi-site surveys (Melzer et al. 2000). The vast majority of studies (3/4) were based on cross-sectional datasets using the Sullivan method; among which five studies used decomposition techniques to relate disability years to diseases. The remaining study reported multi-state life-table based estimations.

In these 56 studies, different measures of social status were used to stratify the population, although the vast majority were based on education (35 out of 56), whilst a small number used income (Alves and Arruda 2017; Kaneda et al. 2005; Lampert and Kroll 2006; Knoops and van den Brakel 2010; van den Brakel and Knoops 2010) or occupation (Brønnum-Hansen 2000; Cambois et al. 2001; Cambois et al. 2011; Magnusson Hanson et al. 2018; Cambois et al. 2008; Melzer et al. 2000). Some studies focused on variation across areas classified by level of deprivation (ecological approach), mixed indicators (education, ethnicity, housing tenure, elementary goods' possession, childhood

Table 4.1 Review of the studies providing estimates of health expectancy by social status, published between 2000 and 2018

| Authors of the studies and year of publication (see reference list) | Countries and within Country sites | Social Stratification indicators ^a | Health and disability indicators ^b | Trends in LE/HLE social gaps ^c | Spatial comparison of HLE gaps ^d | Data and method of estimation ^e |
|---|------------------------------------|---|---|---|---|--|
| Bosstuyt et al. 2004 | BELGIUM | EDUC | SRH | NO | NO | CS / Sullivan |
| Van Oyen et al. 2005 | BELGIUM | EDUC | DISAB | NO | Regions | CS / Sullivan |
| Nusselder et al. 2005 | BELGIUM | EDUC | DISAB (physical FL) | NO | NO | CS / Sullivan/ Decomp |
| Van Oyen et al. 2011 | BELGIUM | EDUC/INDEX | DISAB (ADL-IADL-FL) | ↗ HLE GAP | NO | CS / Sullivan/ Decomp |
| Charafeddine et al. 2014 | BELGIUM | EDUC | DISAB | NO | NO | CS / Sullivan |
| Szwarcwald CL et al. 2016 | BRAZIL | DEPRIVATION AERAS | SRH | NO | Local areas | CS/Sullivan |
| Alves and Arruda 2017 | BRAZIL | EDUC/INCOME | CHRO DIS | NO | NO | CS/Sullivan |
| Camargos MCS et al. 2007 | BRAZIL (Sao Paulo) | EDUC | DISAB | NO | NO | CS/Sullivan |
| Kaneda et al. 2005 | CHINA (Beijing) | EDUC/INCOME/ OCCUP/GOODS | DISAB (ADL-IADL-FL) | NO | NO | Longit / MSLT |
| Børnnum-Hansen 2000 | DENMARK | OCCUP | SRH | NO | NO | CS / Sullivan |
| Børnnum-Hansen and Juel 2004a | DENMARK | EDUC | Smoking => SRH | NO | NO | CS / Sullivan |
| Børnnum-Hansen and Juel. 2004b | DENMARK | EDUC | Smoking => Musculosk. | NO | NO | CS / Sullivan |
| Børnnum-Hansen et al. 2004 | DENMARK | EDUC | SRH | NO | NO | CS / Sullivan |
| Børnnum-Hansen and Davidsen 2006 | DENMARK | EDUC | CHRO DIS | NO | NO | CS / Sullivan/ Decomp |
| Børnnum-Hansen and Baadsgaard 2008 | DENMARK | EDUC | SRH/LSI | → or ↗ HLE GAP | NO | CS / Sullivan |
| Børnnum-Hansen et al. 2015 | DENMARK | EDUC | SRH/DIS | → or ↗ HLE GAP | NO | CS / Sullivan/ Decomp |
| Børnnum-Hansen and Jeune 2017 | DENMARK | EDUC | Smoking => SRH | NO | NO | CS / Sullivan/ Decomp |
| Cambois et al. 2001 | FRANCE | OCCUP | DISAB GAP | ↗ HLE GAP | NO | CS / Sullivan |
| Péres et al. 2005 | FRANCE (S-W region) | EDUC | DISAB | NO | NO | Longit/cohort/ MSLT |
| Cambois et al. 2008 | FRANCE | OCCUP | DISAB (ADL-IADL-FL) | NO | NO | CS/Sullivan |

| | | | | | | | |
|---------------------------|------|---------------------------|---------------------------|----------------------|-------------------------------|-------------|---------------|
| Cambois et al. | 2011 | FRANCE | OCCUP | DISAB | NO | NO | CS / Sullivan |
| Lampert and Kroll | 2006 | GERMANY | INCOME | SRH | NO | NO | CS/Longit |
| Hidajat et al. | 2007 | INDONESIA | EDUC | DISAB (physical FL.) | NO | NO | Longit / MSLT |
| Abdalla et al. | 2013 | IRELAND | VULNERABLE/ ETHNICITY | SRH/DISAB | NO | NO | CS / Sullivan |
| Minicuci and Noale | 2005 | ITALY | EDUC | DISAB (mobility FL.) | NO | NO | Longit / MSLT |
| Yong and Saito | 2012 | JAPAN | EDUC | DISAB | NO | NO | Longit / MSLT |
| Kardal and Lodder | 2008 | NETHERLANDS | EDUC | SRH/CHR DIS/ DISAB | $\rightarrow HLE\ GAP$ | NO | CS/Sullivan |
| Bruggink | 2009 | NETHERLANDS | EDUC | SRH/CHR DIS/ DISAB | $\rightarrow HLE\ GAP$ | NO | CS/Sullivan |
| Knoops and Van den Brakel | 2010 | NETHERLANDS | INCOME | SRH/CHR DIS/ DISAB | NO | NO | CS/Sullivan |
| van den Brakel and Knoops | 2010 | NETHERLANDS | INCOME/POVERTY | SRH/CHR DIS/ DISAB | NO | NO | CS/Sullivan |
| Storeng et al. | 2018 | NORWAY | EDUC | SRH/LLSI | $\searrow LE \nearrow HLE$ | NO | CS/Sullivan |
| Chan et al. | 2016 | SINGAPORE | EDUC/ETHNICITY | DISAB | NO | NO | Longit / MSLT |
| Martin and Esnaola | 2014 | SPAIN (Basque region) | DEPRIVATION AERAS | DISAB | $\searrow LE \nearrow HLE$ | Local areas | CS / Sullivan |
| Martinez-Sanchez et al. | 2001 | SPAIN (Madrid, Barcelona) | EDUC | SRH | NO | Cities | CS/Sullivan |
| Matthews R et al. | 2006 | UK | EDUC, HOUSING TENURE... | DISAB | NO | NO | Longit / MSLT |
| Matthews F et al. | 2009 | UK | EDUC | COGNITION | NO | NO | Longit / MSLT |
| Melzer et al. | 2000 | UK (English cities) | OCCUP | DISAB& DEMENTIA | NO | NO | CS / Sullivan |
| White and Edgar | 2010 | UK England | DEPRIVATION AERAS / INDEX | LLSI&DISAB | $\rightarrow or \nearrow HLE$ | NO | CS / Sullivan |
| White and Butt | 2015 | UK England | DEPRIVATION AERAS | SRH/DISAB | $\searrow LE \nearrow HLE$ | Local areas | CS / Sullivan |

(continued)

Table 4.1 (continued)

| Authors of the studies and year of publication (see reference list) | Countries and within Country sites | Social Stratification indicators ^a | Health and disability indicators ^b | Trends in LE/HLE social gaps ^c | Spatial comparison of HLE gaps ^d | Data and method of estimation ^e |
|---|--|---|---|---|---|--|
| Wohland et al. | 2015 UK England/wales | ETHNICITY | SRH/LLSI | NO | NO | CS / Sullivan |
| Wohland et al. | 2014 UK great Britain | DEPRIVATION AERAS | LLSI | ↗ HLE GAP | Local areas | CS / Sullivan |
| Wood et al. | 2006 UK Scotland | DEPRIVATION AERAS | SRH/LLSI | NO | Local areas | CS / Sullivan |
| Crimmins and Saito | 2001 USA | EDUC | SRH | ↗ HLE GAP | No | CS / Sullivan |
| Gerominus et al. | 2001 USA | AERA/ POVERTY/ ETHNICITY | DISAB | NO | Local areas | CS / Sullivan |
| Lievre et al. | 2008 USA | EDUC | COGNITION | NO | NO | Longit / MSLT |
| Montez and Hayward | 2014 USA | EDUC / ETHNICITY / CHILDHOOD | DISAB (ADL/ IADL/FL) | NO | NO | Longit / MSLT |
| Solé-Auró et al. | 2015 USA | EDUC / ETHNICITY | DISAB | → or ↗ HLE GAP | NO | CS / Sullivan |
| Laditka and Laditka | 2016 USA | EDUC/ ETHNICITY | DISAB | NO | NO | Longit / MSLT |
| Melzer et al. | 2001 USA (state sites) | EDUC | DISAB | NO | NO | Longit / MSLT |
| Majer et al. | 2010 Multiple (10 EU countries) | EDUC | DISAB | NO | Countries | Longit / MSLT |
| Majer et al. | 2011 Multiple (9 EU countries) | EDUC | Smoking/ overweight- DISAB | NO | Countries | Longit / MSLT |
| Beltrán-Sánchez and Andrade | 2013 Multiple (Brazilian/ Mexican sites) | EDUC | DISAB (mobility FL) | NO | Cities/regions | Longit / MSLT |
| Maki et al. | 2013 Multiple (8 EU countries) | EDUC | DISAB | NO | Countries | CS / Sullivan |
| Chiu et al. | 2016 Multiple (USA, Japan) | EDUC | Dis&DISAB | NO | Countries | CS / Sullivan |
| Magnusson Hanson et al. | 2018 Multiple (4 EU cohorts) | OCCUP & JOB STRAIN | SRH/CHRO DIS | NO | NO | Occup cohort / MSLT |

^aStratification by education levels (EDUC), occupational class (OCCUP), income groups (INCOME), poverty level (POVERTY), relative index of social status (INDEX), Household goods' possession (GOODS) ecological approach, in which local areas are classified by the average level of social deprivation (DEPRIVATION AERA), focus on specific vulnerable population groups (VULNERABLE), ethnicity or race (ETHNICITY), Childhood condition (CHILDHOOD), work conditions characterized by high demand and heavy load (JOB STRAIN), ownership or rented housing (HOUSING TENURE)

^bSelf rated health (SRH), mixed of generic disability measure (DISAB), functional limitations (FL), restriction in (instrumental) activities of daily living (ADL IADL), chronic diseases (CHRO DIS), limiting long-standing illnesses (LLSI), cognitive disorders and dementia (DEMENTIA), cognitive functional limitations (COGNITION),

^cNo change (→), increase (↗), decrease (↘) in the life expectancy (LE) and in the healthy life expectancy (HLE) gaps across social groups.

^dComparisons between countries and within countries across local authorities or areas, regions, cities, States, survey sites.

^eCross-sectional data (CS) and use of the Sullivan method, longitudinal or panel data (Longit) or occupation cohorts (Occup Cohort) and use of multistate life table methods (MSLT).

conditions), or specific groups (travelers community). Most studies assessed health using general measures of disability, whilst others focused on specific dimensions such as mobility limitations (Hidajat et al. 2007; Minicuci and Noale 2005; Beltrán-Sánchez and Andrade 2013), and some used self-rated health. Others focused on chronic conditions and a small number integrated specific risks factors (smoking, obesity, job strain). Thirteen out of the 56 studies analyzed time trends and another 10 analyzed spatial differences between or within countries.

Patterns and Trends in Health Expectancy by Social Status

Social Inequalities in Health Expectancies

The general picture from the literature is that social inequalities in disability free or healthy life expectancy are wider than in life expectancy, as shown in earlier literature reviews (Crimmins and Cambois 2003; Pongiglione et al. 2015; Majer et al. 2010). The gaps in unhealthy life expectancy are usually smaller. There is a double disadvantage at the bottom of the social ladder: a larger number of years spent with disability or in poorer health within a shorter life expectancy. Studies usually showed similar patterns whatever the social criteria used: between the qualified and unskilled occupations or between high and low educated. However, most of the estimations were produced in high-income countries, yet, focusing on countries in early stages of development might give another conclusion: in Indonesia, the longer life of the few high educated elderly people translated in more years of disability (Hidajat et al. 2007). Behind these unusual findings, there might be some differences in the type of exposures experienced by the different social group and possibly social differences in the impact of mortality selection.

Direct comparison of these studies is limited, even within a country, due to differences in data sources, disability/health indicators and period of observation. A few studies have compared the magnitude of the gap across different social mea-

sures (Matthews et al. 2006; Kaneda et al. 2005). These studies indicate that the size of the gaps differs between the measures, and results vary by gender. There is no agreement on which SES measure determined the largest gap in health expectancy (Pongiglione et al. 2015).

Varying Gaps According to the Health or Disability Indicator

The magnitude of the gap also varies with the health or disability dimension under consideration. Some countries have a range of estimates using different data sources and health indicators (self-rated health, chronic diseases) highlighting these variations (Brønnum-Hansen et al. 2004; Brønnum-Hansen and Davidsen 2006; Brønnum-Hansen and Juel 2004a). In order to account for these variations, some studies further used a variety of health dimensions from the same dataset in the same analysis: for instance disability and cognitive impairments (Melzer et al. 2000; Brønnum-Hansen and Baadsgaard 2008; Storeng et al. 2018). From a French study using three different dimensions of disability, it is clear that the more common and frequent the disability dimension under consideration, such as functional limitations, the larger the gaps between highly skilled and unskilled population (Cambois et al. 2011; Cambois et al. 2008). As summarized in Fig. 4.2, in the early 2000s, the gaps at age 35 between men in unskilled occupations and in highly skilled occupations were 10 years without functional limitations, 8 years without general activity limitation and 7 years without personal care activity restrictions, and 8 years, 5 years and 4 years respectively for women. It is noteworthy that the gaps in disability-free life expectancy for women were smaller than those for men, though, for years lived with disability the gaps were larger for women than men. Unskilled women could expect to live six more years with functional limitations, three more years with activity limitations and two more years with personal care activity limitations in their shorter lives than women in highly skilled occupations. These figures are respectively 4 years, 2 years, and 1 year more in men.

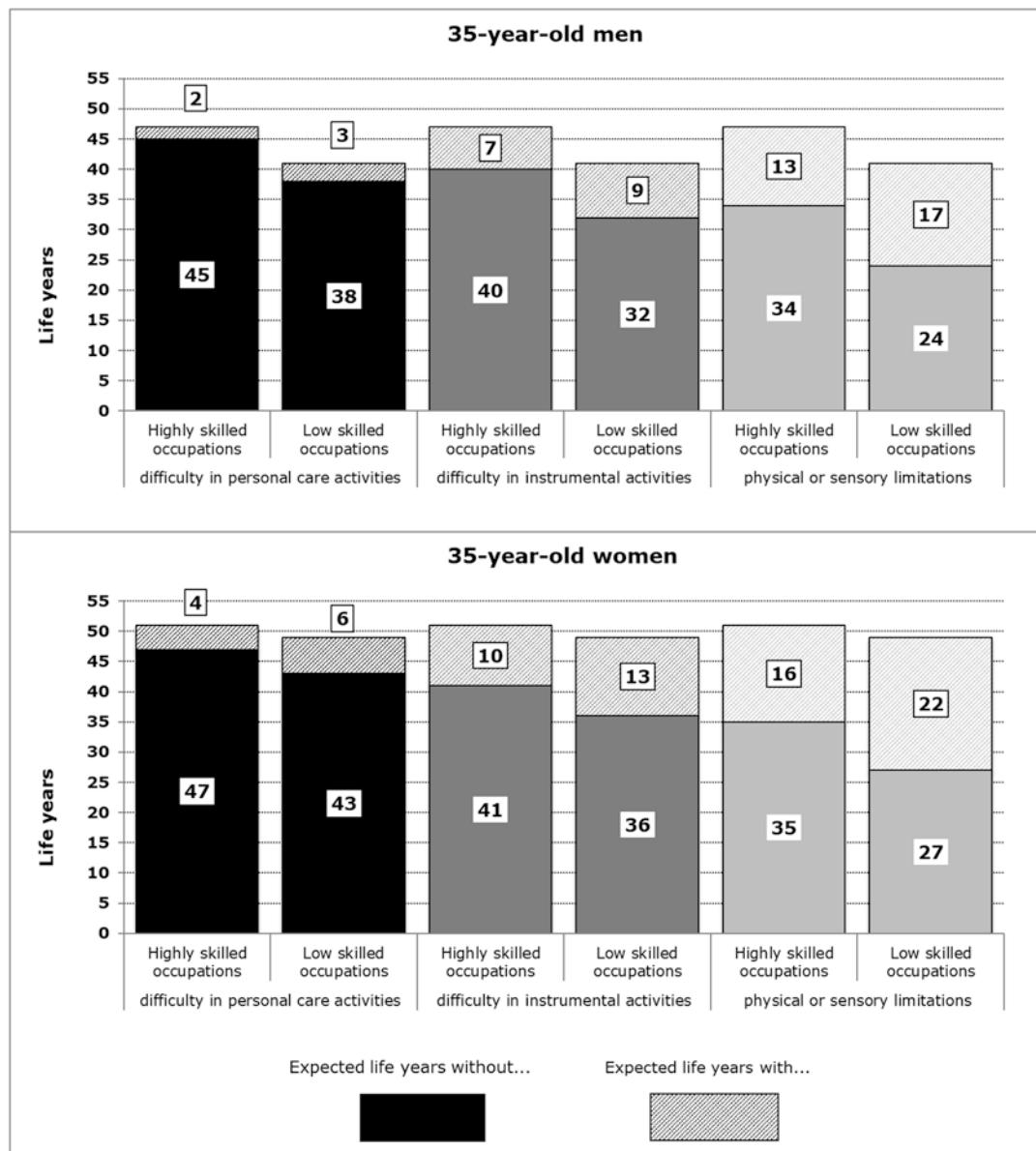


Fig. 4.2 Life expectancy and disability-free life expectancies at age 35 using different disability dimensions, Men and Women, France 2003. (From Cambois et al. 2008)

Social Differences in Health Expectancies Across Age

Some studies provide indicators of health expectancies by social status at different ages and report widening social differences with increasing age (Chan et al. 2016; Kaneda et al. 2005). However, differentials appear to be already present by age 50, indicating that a disability differ-

ential already exists by mid-life. As mentioned in the introduction, there is a growing interest in what happens in mid-adulthood for later disability, with evidence of substantial years to be lived with disability between age 50 and 64 years. A study on 10 European countries shows an important gap between the maximum 15 year span to be lived between 50 and 64 years and the average

number of years to be lived without disability (being hampered in activities due to health or disability problems), and there is evidence of a systematic advantage of the higher educated (Majer et al. 2010).

For the same age range there was some evidence of an expansion of the disability years in the early 2000s in several countries in the population (Cambois et al. 2011; Weir 2007; Parker and Thorslund 2007; Martin et al. 2009), with work conditions a potential explanation for this expansion in disability in young adulthood (Weir, 2007). Interestingly, a study based on data from four European occupational cohorts, indicated that job strain was systematically associated with a shorter healthy life expectancy, especially in unskilled occupational classes (Magnusson Hanson et al. 2018).

Social Differences in Health Expectancies by Gender

Women have longer life expectancies with more years of disability (see Chap. 11). These general findings result in less pronounced social differentials in healthy years in women, although some studies report the opposite (Bossuyt et al. 2004; Brønnum-Hansen and Baadsgaard 2008). As mentioned previously, if women display smaller social gaps in healthy life expectancy compared to men, the gaps in unhealthy life expectancy are actually larger. Women in unskilled occupation or in low education groups have a larger additional number of years with disability compared to women in highly skilled occupation or in high education than men (see Figs. 4.2 and 4.3).

Women's disadvantage in years of disability is largely due to disabling diseases, including musculoskeletal and mental, more common among women (Crimmins et al. 2011; Oksuzyan et al. 2010; Oksuzyan et al. 2008; Nusselder et al. 2019). These results question exposures to gender-specific health risks, including social factors, related to the "gendered" organization. The larger social gap in unhealthy years in women could be due to over exposure to disabling conditions of women in unskilled occupations or with low education. And indeed, the largest contributor to the educational gap in disability-free life

expectancy in women, but also in men, in Belgium was found to be musculoskeletal disorders (Nusselder et al. 2005). In France, the educational gap in the disability prevalence is largely due to musculoskeletal and mental disorders in women and to musculoskeletal, pulmonary and circulatory disorders in men (Palazzo et al. 2019). More research is needed on disease contributions to inequalities in unhealthy years to highlight the gender-specific impact of social factors on disability and mortality risks.

Trends in Health Expectancies by Social Status

Trends studies become increasingly available (Van Oyen et al. 2011; Brønnum-Hansen et al. 2017; Brønnum-Hansen and Baadsgaard 2012, 2008; Brønnum-Hansen et al. 2015; Crimmins and Saito 2001; Cambois et al. 2001; Kardal and Lodder 2008; Bruggink 2009; Storeng et al. 2018; Martín and Esnaola 2014; White and Butt 2015; White and Edgar 2010; Wohland et al. 2014; Solé-Auró et al. 2015). In general, studies found no reduction in the social gap in healthy or disability-free life expectancies but rather an increasing gap. In some studies, the increasing gap contrasted with a decreasing gap in life expectancy. In the United-States, over the 1970s and 1980s, a compression of disability occurred in the high-educated group and an expansion in the low-educated group (Crimmins and Saito 2001).

In Denmark, nationwide register data makes it possible to calculate trends in social inequality in life and health expectancy during the last decades (Brønnum-Hansen et al. 2015, 2017; Brønnum-Hansen and Baadsgaard 2012, 2008). Figure 4.3 shows trends in expected life years without and with disability at age 65 in Denmark for the period 2006–2016. The social inequality seems to persist with no signs of reduction. The gaps in life expectancy increased in both men and women, as did the gaps in disability-free life expectancy in women.

The estimates further indicate that the part of life expectancy lived with severe disability has compressed over time in each education groups and for both sexes whilst years with mild

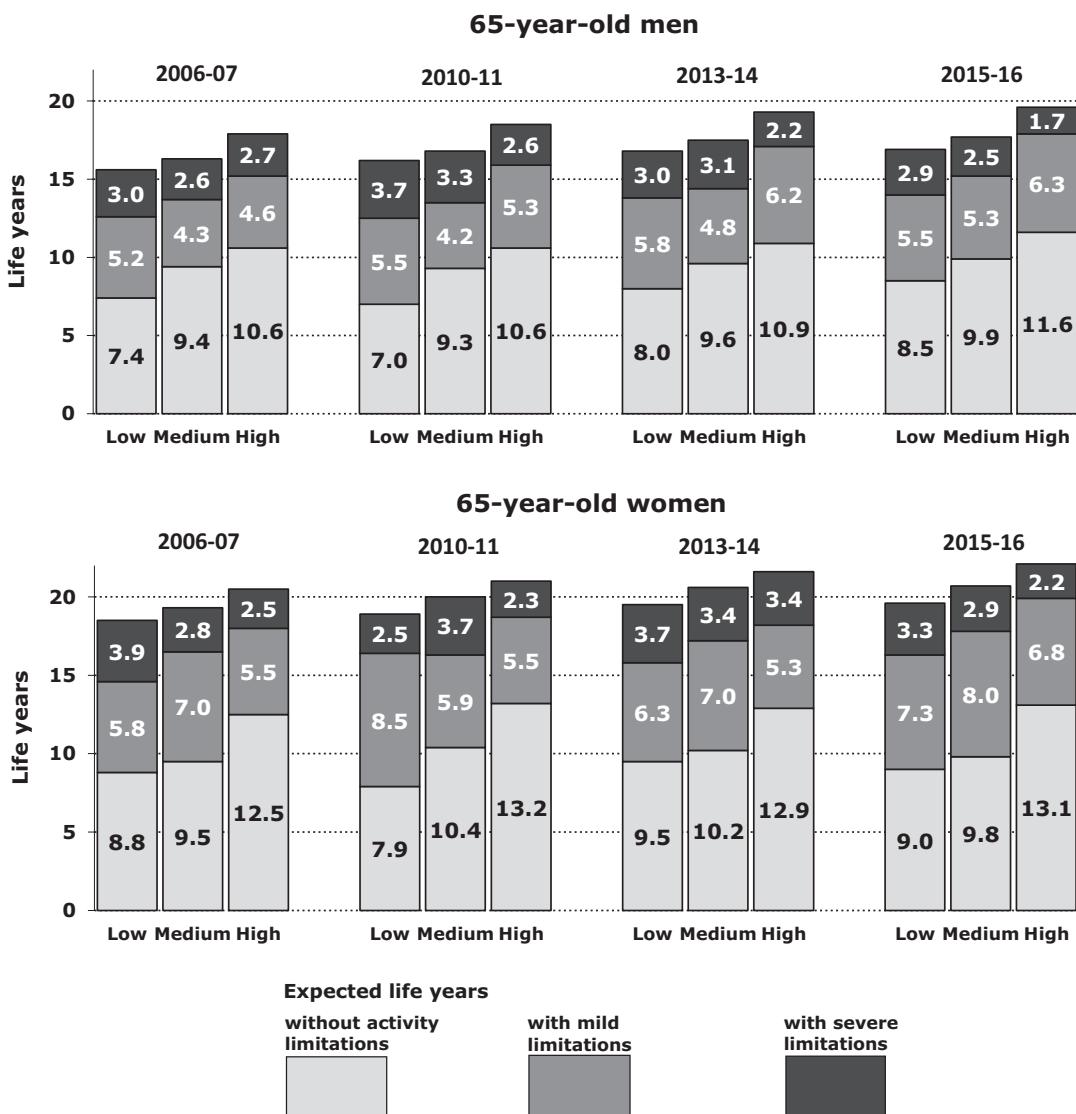


Fig. 4.3 Expected life years at age 65 without and with mild or severe activity limitations in low, medium and high education population groups. Denmark from 2006 to 2016

disability have increased. Overall, in the high- and mid-educated groups, years with disability have increased (or stagnated for high educated men); in the low-educated group, women experienced an expansion of the part lived with disability (due to mild disability) and men benefitted from a compression (due to severe disability). Although these patterns should be viewed with caution due to limited sample size, they show that distinguishing disability levels is useful to better appreciate social differences in trends.

Health Expectancy Within Countries Across Deprivation Areas

The ecological approach deals with analyzing spatial differentials between disadvantaged and advantaged localities within a country to demonstrate what low resources do to health chances. In some countries like the UK with detailed local statistics, or the USA with state statistics it becomes possible to stratify the population into groups with, on average, poor or rich living conditions, generally defined by multidimensional

indicators of deprivation (percentage of unemployed, of low educated,...). These studies show a gradient in health expectancies along the deprivation gradient of the territories (Szwarcwald et al. 2016; Martín and Esnaola 2014; White and Edgar 2010; White and Butt 2015; Wohland et al. 2014; Wood et al. 2006; Geronimus et al. 2001).

Comparing Social Inequalities in Health Expectancy Across Countries or Regions

At a larger scale, the variations in social gaps are also studied across populations. Several studies compared health expectancy differentials in different countries (Majer et al. 2010; Maki et al. 2013; Chiu et al. 2016). Maki and colleagues calculated partial life expectancies, between 30 and 79 years, for eight European Union countries and found differences in life expectancy without activity limitation between primary and tertiary education levels ranged from 4 years for Italian men (2 years for women) to up to 10 years in Lithuania (7.3 years for women) (Maki et al. 2013). As mentioned previously, while educational differences in life expectancy and life expectancy without activity limitation are smaller for women, this is not always the case for differences in life expectancy with activity limitations. In Lithuania, for example, the least educated men can expect to live 1.1 years longer with activity limitations than the most educated, for women the gap is almost 3 years. There have also been studies comparing regions or cities within and across countries (Beltrán-Sánchez and Andrade 2013; Martinez-Sánchez et al. 2001; Van Oyen et al. 2005).

Underlying Mechanisms for Social Differences in Health Expectancies

Living Standard, Work Conditions, Health Related Practices and Risks Factors

The differentials in health expectancies are due to both individual characteristics and the context of life. Living standards, job exposures, health related individual practices (exercise, smok-

ing...) and access to care influence the magnitude of the gap in health expectancies. Regarding job exposures, recent estimates of healthy life expectancy from longitudinal data of European occupational cohorts highlight the role of work conditions, namely the level of job strain, on reducing the healthy life of those in the less skilled occupations (Magnusson Hanson et al. 2018).

Very few studies on social inequality in health expectancy stratify on other determinants or risk factors (smoking, obesity) (Brønnum-Hansen and Juel 2004a, b; Brønnum-Hansen and Jeune 2015; Majer et al. 2011). The main challenge is to estimate death rates in subpopulations categorized by a combination of characteristics. Furthermore, the size of data sources limits the possibilities. Health surveys are seldom large enough to divide data into many dimensions or categories when also relatively small age groups are needed. A study by Majer et al. (2011) used data from 9 European countries to model disability-free life expectancy by body-weight, smoking and education and showed that if high and low educated obese female smokers became overweight non-smokers their gain in disability-free life expectancy would be almost 10 years and 7 years, respectively (Majer et al. 2011).

A study including 10 European countries shows a potential reduction in educational differentials in life expectancy and disability-free life expectancy by improving fruit and vegetable consumption (Baars et al. 2019).

The impact of smoking on health expectancy by educational level has been investigated in Denmark (Brønnum-Hansen and Juel 2004a, b; Brønnum-Hansen and Jeune 2015). Smoking have a substantial effect on life expectancy and life years in good health regardless of educational level. Among women with a low educational level, smoking causes a particularly high loss of life years without longstanding illness and years in self-rated good health.

Country Variations

The variable extent of the social gaps results from the different contexts in European countries in terms of prevention, social protection, access to

care or health-risk practices (consumption of tobacco, alcohol, prevention, etc.) (Marmot et al. 2008; Mackenbach et al. 2013). Thus, part of the European variation in disability gaps between social groups is also explained by variable levels of material advantage (Cambois et al. 2016), although inequalities of different magnitude can be observed within regions with close social protection systems, explained by variations in income gaps (Huijts et al. 2010). It is a complex combination of effects of a country's social system, educational and health care system, economic development, living conditions and health-risk practices that explain social inequalities and the variation in their magnitude across countries (Huijts et al. 2010; Eikemo et al. 2008; Avendano et al. 2009). Macroeconomic indicators such as expenditure in care for the elderly population, age at retirement or the level of material deprivation tend to explain some variation in health expectancies across the European Union (Fouweather et al. 2015; Jagger et al. 2008).

The differences between countries in terms of life expectancy and activity limitations therefore reflect both differences in living conditions that limit exposure to health risks and differences in socio-sanitary conditions that make it possible to manage health problems and limit their consequences in terms of risk of disability and death. Different health and social protection systems from one country to another constitute more or less favorable contexts for the prevention and management of health problems (Rechel et al. 2013; Bergqvist et al. 2013; Brennenstuhl et al. 2012; Lundberg et al. 2008). These contexts (access to care, environment, attitudes towards disability, availability of technical aids) are likely to facilitate or restrict the performance of activities for people with functional disorders; possibly in different ways depending on the social status.

Incidence and Recovery: Differentiated Health Transitions

Country contexts and social status therefore together condition health transitions such as the probability of recovering from a disabling disease, the probability that this disabling disease translates into functional limitation and the prob-

ability to cope with functional limitation and limit further activity restrictions. A study in Italy and the Netherlands showed that among older people, social differences in disability resulted mainly from differences in the risks of these disabilities occurring and very little on the chances of regaining autonomy (adaptation), indicating the importance of prevention and protection against disability risks (Huisman et al. 2005). Education seems to affect mainly the onset of functional problems (from healthy state) but less the other trajectories. In different studies, once functional problems occur education does not appear to influence subsequent improvements in functioning or mortality in the USA, Japan, Taiwan or Indonesia (Hayward et al. 2007; Zimmer et al. 1998; Zimmer and House 2003; Melzer et al. 2001; Yong and Saito 2012; Hidajat et al. 2007). In contrast, significant educational differences in both incidence, and recovery rates were found in Brazil and Mexico settings (Beltrán-Sánchez and Andrade 2013).

Discussion: Perspectives to Monitor Social Gaps in Health Expectancies

Methodological Issues and Data Improvements

There is a need for improving data availability and quality to produce more regular and more comparable health expectancies by social status. In a number of countries, mortality data stratified by social status are not routinely available. This limits the opportunity to produce more regularly disability-free life expectancy by social status or to cover all countries in multi-country analysis (Maki et al. 2013; Majer et al. 2010, 2011; Chiu et al. 2016). As mentioned earlier, alternative datasets such as survey sample follow-up for mortality have been investigated (Charafeddine et al. 2014).

There is also a need for improving implementation of comparative measures across countries in order to draw conclusions based on different countries and contexts (Brønnum-Hansen 2014). Most studies use "homemade" social categories

and disability measure, limiting the opportunity of comparing patterns across countries (Pongiglione et al. 2015). Obviously, comparable data on social status could be established by using international classification systems, such as ISCED, ISCO, or equivalised disposable income, etc.

There is a need for more longitudinal data to better account for various probabilities of onset and recovery and to fully understand inequalities in pathways from the disease to dependence. Multistate life table based probability transitions to compute HLY according to various covariates are powerful indicators to understand disparities within populations. A number of countries have conducted longitudinal studies to permit such estimations. In some countries, specific cohorts on aging have produced information on the differentials in the disability dynamics, however, stratification is limited by the sample size (Jagger et al. 2007; Pérès et al. 2005).

Recently some estimates of health expectancy were produced based on data issued from four European occupational cohorts (Magnusson Hanson et al. 2018). Such cohorts may have some limitations due to a selected population at inclusion and at follow-up, or sample size. However, based on probabilities of transition across health/disability status related to different covariates, these cohorts provide opportunities to compute health expectancy across various types of social groups defined by occupation, activity status, or activity sectors, and assess associated health risks (work condition, job insecurity...).

New Insights

The availability of new datasets would provide an opportunity to go further in analyzing health expectancies by social groups. For instance, looking at health and disability transitions could shed light on understanding the gaps. Also, it could be interesting to document possible social differences in morbidity/disability/mortality patterns by focusing on specific conditions, such as cognitive disorders (Matthews et al. 2009; Melzer et al. 2000; Lievre et al. 2008), or several chronic

diseases (Alves and Arruda 2017; Magnusson Hanson et al. 2018), or by conducting a decomposition approach to assess the contribution of the different diseases to social differences in health expectancies (Brønnum-Hansen and Davidsen 2006; Nusselder et al. 2005; Van Oyen et al. 2011). Studies that used decomposition of health expectancy differences across social groups show the importance of musculoskeletal diseases in the association between social status and the disability years. Including some health determinants into the estimation would also be an important step forward to understand social differences, as illustrated by findings on the association of smoking, obesity or job strain with disability years.

Another promising avenue is to refine the definition of social groups in order to draw attention to specific vulnerable groups. As mentioned in the introduction, improved data sets could help produce health expectancies for groups at the intersection of social disadvantage (i.e. sex, ethnicity, education) (Solé-Auró et al. 2015; Kaneda et al. 2005; Chan et al. 2016; Laditka and Laditka 2016; Geromimus et al. 2001; Montez and Hayward 2014) or for specific groups at risk of disadvantage (Abdalla et al. 2013). A route for improvement would also be to characterize individuals over their life course since the social status of the individuals can change with moves from unskilled to higher skilled jobs or moving from low social background. There has been some evidence of better outcomes for those who are upwardly mobile (Cambois and Laborde 2011; Blane et al. 1999), but questions remain on whether upwardly mobile individuals have similar or better outcomes than downwardly mobile individuals (Montez and Hayward 2014).

Finally, it could be useful to relate health expectancies by social status to significant changes in contexts. Economic conditions in recent years may have exacerbated the effect of the various factors that drive health and mortality with differential impact across population groups (Karanikolos et al. 2013). The impact of the abrupt financial crisis in 2008 on health expectancy in Denmark has been investigated (Brønnum-Hansen et al. 2015), with the argument

for the study being that the health of the well-off part of the population would probably not be affected. However, concerns for loss of pension and savings might lead to worse health among retired persons or persons close to the age of retirement. Moreover, deficits and cutbacks in public budgets might have put a strain on people who lose their jobs. The conclusion was that social inequality in disability-free life expectancy for men and expected lifetime in self-rated good health for both genders increased slightly during the period 2006–2011. Thus, the financial crisis did not change the persistent trend of increasing social inequality in health expectancy in Denmark (Brønnum-Hansen et al. 2015). In a similar vein, sudden changes in sanitary conditions could differentially affect population groups with different access to information or health care. Indeed life expectancy, especially at older ages, seem highly sensitive to episodes of or heat waves, for instance in 2015 in several European countries, and the impact on health expectancies, possibly socially differentiated, is still largely unexplored.

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Part II

Advances in Data and Methodology



Data Sources for Health Expectancy Research

5

Mary Beth Ofstedal

Types of Data

There are two main types of data that are used for health expectancy analysis: cross-sectional and panel. Cross-sectional refers to data for which any given individual is measured at a single point in time. Cross-sectional data can come from surveys, Censuses, and administrative sources. Cross-sectional data sources can either be one-time data collections or repeated cross-sections. Repeated cross-sections generally involve employing the same methodology and measurements at multiple time points on different samples. Examples are the National Health Interview Survey in the United States (conducted annually), the European Social Survey (conducted biennially) and the World Values Survey (conducted about every 4–6 years). A Census is also a type of repeated cross-sectional data source.

One-time cross-sectional surveys can be used to investigate disparities in health expectancy within a population (e.g., by gender, race, ethnicity, socioeconomic status, etc.) and/or for cross-national or cross-survey comparisons at a given point in time. Repeated cross-sectional surveys are valuable for examining trends in health expectancy over time. Some researchers have combined different surveys conducted at differ-

ent time points to assess trends in a specific country or setting (e.g., Freedman et al. 2016; Gu et al. 2009). Whether using the same or different surveys from different time points, it is important to take note of whether the survey design is comparable with respect to the target population, sampling methods, weighting procedures, and the measures used.

Panel data refers to data that provide measurements for a given individual at multiple time points. Surveys are the primary source of panel data, but other sources include epidemiologic surveillance systems, clinical trials, administrative records, and registration databases. Most sources of panel data also provide information on mortality, at least on the fact and timing of death and, in some cases, on the cause(s) of death and circumstances surrounding the death.

As has been discussed by Saito et al. (2014) and illustrated throughout this volume, different analytic methods are used to compute health expectancy depending on the type of data source (cross-sectional vs. longitudinal) and what, if any, information is available on mortality. Multistate life table methods require panel data and individual-level information on mortality, whereas prevalence-based methods, such as the Sullivan method, can be used with cross-sectional data combined with population-level mortality information. The multi-state life table method has some advantages over the Sullivan method as outlined by Saito et al. (2014). Recent

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methodological developments in multi-state life table software programs have made health expectancy analysis more accessible and flexible. Two software programs that are specifically designed for health expectancy analysis using panel data include IMach (Interpolation of Markov Chains) (Lièvre et al. 2003) and SPACE (Stochastic Population Analysis for Complex Events) (Cai et al. 2010). Both IMach and SPACE use a multi-state life table (MSLT) approach constructed from transition probabilities estimated by logistic regression. Laditka and Wolf (1998) also developed a microsimulation model for health expectancy analysis.

Measures Used in Health Expectancy Research

Along with the growth in data sources has been a broadening of the variety of health measures that have been used in analyses of health expectancy. Measures have covered multiple domains of health including self-rated health, disability and functional limitation, chronic disease, cognitive functioning and dementia, and psychological well-being. A discussion of specific measures in each of these domains and examples of how they have been used are provided below. The variety in health measures is also illustrated in other chapters in this Handbook.

Self-Rated Health

Self-rated health is perhaps the most common health measure available in surveys. This item, also referred to as self-assessed health, asks people to rate their health on a scale that generally ranges from very good or excellent to bad or poor. The scale typically contains between 3 and 5 points. Almost all surveys that focus on health and aging include a measure of self-rated health, and it is often included as a “general” health measure in surveys on different topics, such as labour force surveys, household surveys, social surveys, and surveys on values. It is thought to be a composite measure of health, in that people take mul-

multiple domains (physical, emotional, cognitive) into account in their rating. Self-rated health has been shown to be a strong predictor of mortality (Idler and Benyamin 1997), health decline (Ferraro et al. 1997), and health care utilization (Menec and Chipperfield 2001), even after controlling for other health indicators.

Self-rated health has been used in a number of studies of health expectancy in Japan (Yong and Saito 2009), China (Wen and Gu 2012), Bangladesh (Tareque et al. 2015), France (Cambois et al. 2011), and Denmark (Brønnum-Hansen 2005). When used in this context, the measure is typically dichotomized, e.g., into fair or poor versus good, very good or excellent health. A further discussion on the use of self-rated health specifically in studies of older people is provided in Chap. 12.

Disability and Functional Limitation

Disability and functional limitation is the most common domain that has been studied in health expectancy research. In a recent review paper on inequalities in health expectancy, Pongiglione et al. (2015) found that, of the 96 studies included in their review, 74 of the papers used some measure(s) of disability, activity limitation or functional limitation as their indicator of health expectancy.

Most of these measures are based on some combination of Activities of Daily Living (ADL) and/or Instrumental Activities of Daily Living (IADL). ADLs include basic personal care activities like bathing, dressing, eating, using a toilet, getting in and out of bed, and walking across a room. IADLs include activities that are thought to be important for independent living, like preparing meals, shopping for personal items, using a telephone, taking medications, doing housework, and managing money. Another measure of functional limitation that is sometimes used was developed by Nagi (1976). This measure focuses on sensory motor functioning and includes items such as crouching, stooping, kneeling; walking; climbing stairs; lifting; and reaching. ADL, IADL and Nagi measures are included in many

health surveys, particularly those focusing on older adults.

There have been several efforts to develop more parsimonious measures of disability that can be used in cross-national research, such as the Global Activity Limitation Indicator (GALI) and the Washington Group Short Set of Questions on Disability (WG-SS). The GALI is a single-item indicator of disability that was developed by the REVES network as part of a larger effort to develop measures for introduction into European surveys (Van Oyen et al. 2006). The GALI is included in numerous European surveys and has been used to monitor Healthy Life Years (HLY) in the European Union (Bogaert et al. 2018) and in studies of health expectancy (Cambois et al. 2011; Mäki et al. 2013).

The Washington Group Short Set on Functioning (WG-SS) is a set of six questions designed to identify people with a disability (Jones 2017). The Washington Group on Disability Statistics, a UN City Group with representation of over 135 countries, developed the measure. The questions ask whether people have difficulty performing basic universal activities in six domains of functioning: seeing, hearing, walking, cognition, self-care and communication. The WG-SS is designed to provide comparable data cross-nationally for populations living in a variety of cultures with varying economic resources. It has been adopted by numerous censuses and surveys around the world.

Studies that have used disability or functional limitation measures in health expectancy analyses have typically dichotomized the measures into any versus no disability (or limitation). Some studies have combined ADLs and IADLs (and possibly other measures of disability or functional limitation) into a single indicator (Yong and Saito 2012), whereas others have examined ADLs and IADLs or other measurement domains separately (Ishizaki et al. 2002; Ofstedal et al. 2019). To get more nuanced estimates of health expectancy, Jagger et al. (2007) used ADL and IADL measures to classify disability into three levels (none, mild, and moderate to severe), and estimated years free of any disability and years free of moderate to severe disability. Likewise,

Crimmins et al. (2009) estimated models that differentiated between ADL disability, IADL-only disability and no disability. Chap. 1 discusses these measures in more detail.

Chronic Conditions and Diseases

Although less common than disability, chronic conditions and diseases have been the focus of some health expectancy research. Most health and aging surveys include questions about chronic conditions. Respondents are typically asked if they have been diagnosed with a condition (“Has a doctor ever told you that you have had ...”), although some surveys ask about the presence of a condition (“Do you have ...?”). Beyond simple prevalence, some surveys ask additional questions to get at the duration and severity of the condition (whether it limits the person in any way), and whether the person is receiving medical care and/or taking medications or receiving other treatment for the condition.

Commonly queried conditions include hypertension, heart disease, diabetes, arthritis, stroke, and cancer. Many surveys also ask about other chronic debilitating conditions such as lung disease, kidney disease, Parkinson’s disease, Multiple Sclerosis, osteoporosis, and psychiatric problems.

Studies that have utilized chronic conditions as an outcome measure typically focus on the presence of any disease or chronic condition (Cambois et al. 2011; Gu et al. 2009; Leskinen et al. 2018; Stenholm et al. 2016), although some studies have focused on individual conditions (Yong et al. 2011) or on multi-morbidity, that is, the presence of multiple diseases (Jagger et al. 2011). A different, but related line of research has examined the consequences of chronic disease for health expectancy (e.g., defined by disability), for example, by comparing health expectancy for people with and without specific diseases (Jagger et al. 2007; Manuel et al. 2002).

Cognitive Impairment and Dementia

The availability of measures of cognitive function and dementia in population-based surveys is relatively recent, but rapidly increasing. Many surveys of health and aging now include a set of tests to assess different cognitive domains (e.g., mental status, memory, crystallized intelligence, fluid intelligence), as well as questions about diagnosis of Alzheimer's Disease (AD) or other types of dementia or memory disease. Some studies have also incorporated neuropsychological assessments that allow for a dementia diagnosis by a panel of experts. Examples of the latter include the Aging, Demographics and Memory Study (ADAMS) that was conducted as part of the Health and Retirement Study in the United States (Langa et al. 2005), and the Canadian Study of Health and Aging (CSHA), Phase 1 (Canadian Study of Health and Aging Working Group 1994). Information on diagnosis of AD or other dementias may also be available in administrative data sources that are based on medical records.

Items from the Mini-Mental State Examination (MMSE, (Folstein et al. 1975)), such as the date, object naming, person naming (president, vice-president) and counting backwards, are often used to measure mental status. Immediate and delayed word recall are commonly used as tests of memory and vocabulary as a test of crystallized intelligence (Ofstedal et al. 2005). Fluid intelligence is multi-dimensional and can be assessed through tests of quantitative reasoning (e.g., number series test), verbal reasoning (e.g., verbal analogies test), and retrieval fluency (e.g., animal naming test), among others (Fisher et al. 2013).

Several studies have incorporated measures of cognitive function and/or dementia as outcomes in health expectancy analysis. In an early study, Ritchie et al. (1994) used published prevalence rates of dementia along with published life tables to derive dementia expectancies for older Australians. Dubois and Hébert (2006) used dementia diagnoses from the CSHA to examine dementia-free life expectancy among older Canadians. Suthers et al. (2003) used a combination of self- and proxy-cognition measures to

estimate life expectancy with cognitive impairment in a national sample of older adults in the U.S. Several other studies have used various measures of cognitive impairment based on the MMSE to estimate life expectancy with and without cognitive impairment in a variety of settings, including Australia (Nepal et al. 2008), Latin America and the Caribbean (Ashby-Mitchell et al. 2015), and the United Kingdom (Jagger et al. 2016; Matthews et al. 2009).

Psychological Well-Being

Another domain of health that has gained attention in health expectancy research is psychological well-being. This domain encompasses different aspects of mental and emotional health such as depression and depressive symptoms, life satisfaction, loneliness, and happiness. Most health or aging surveys include some measure to assess depression and/or depressive symptoms, such as the Composite International Diagnostic Interview (CIDI), the Geriatric Depression Scale (GDS), or the Centers for Epidemiological Studies Depression Scale (CES-D). These surveys may also include questions about diagnosis or presence of general or specific psychiatric conditions, including but not limited to depression. Measures of life satisfaction, whether a single question on overall life satisfaction or a multi-item scale such as the Satisfaction with Life Scale (SWLS), are also common. Surveys are also increasingly including other measures of psychological well-being, such as satisfaction with specific domains of life (e.g., health, work, family), emotional well-being, stress, and financial strain.

Several studies have examined depression-free life expectancy in Brazil (Alves and Pereira 2018; Andrade et al. 2016), Thailand (Apinonkul et al. 2015) and Canada (Steensma et al. 2016). Perenboom et al. (2004) used the Bradburn Affect Balance Scale to examine trends in life expectancy in well-being in the Netherlands.

Happy life expectancy has emerged as an important social indicator for quality of life (Veenhoven 1996) and has been the focus of

several studies in the U.S. (Yang 2008), Japan (Bardo et al. 2017), South Africa (Chrinda and Phaswana-Mafuya 2018), and Brazil (Lima et al. 2016). It is also used as a metric for ranking countries with respect to quality of life (<https://www.purposeplus.com/world/indicators/happy-life-years/>).

Covariates

At a minimum, information on age and gender is required for health expectancy analysis. However, many studies of health expectancy go beyond this to examine disparities by race/ethnicity, education, socioeconomic position, and so on. In addition, studies are increasingly taking advantage of new methodological developments to control for underlying covariates when examining disparities.

A number of studies have explored sociodemographic and/or SES differences in health expectancy within countries (Chan et al. 2016; Crimmins et al. 1996; Geronimus et al. 2001; Guralnik et al. 1993; Hidajat et al. 2007; Laditka and Laditka 2016; Montez and Hayward 2014; Sihvonen et al. 1998; Yong and Saito 2012) and these are examined in detail in Chap. 4. Other studies have examined the impact of chronic disease (e.g., diabetes) (Andrade 2010), dementia (Dodge et al. 2003; Jagger et al. 2007), life style factors (e.g., smoking, obesity) (Brønnum-Hansen and Juel 2001; Mehta and Myrskylä 2017; Reynolds et al. 2005; Stenholm et al. 2017; Stenholm et al. 2016; Tian et al. 2011), emotional problems (Pérès et al. 2008), and environmental factors such as air pollution and occupational exposures on health expectancy (Platts et al. 2017; Wen and Gu 2012).

Data Sources

This section provides an overview of some of the data sources that have or can be used for research on health expectancy. It is organized around the two main data types: cross-sectional and panel data. The focus is primarily on data sources that

are based on large, representative samples, contain multiple measures of health, and/or provide data at multiple time points (to support trend analysis) or across multiple settings (for international comparisons). This is not an exhaustive inventory, but is rather intended to provide a general sense of the data that is available for health expectancy research from different countries and regions of the world.

Table 5.1 contains a list of the data sources with links to websites that provide information about the data source and data access. All of the sources listed in the table provide public access for at least part of the data (in some cases, certain types of sensitive data are not available for public use). For some sources, the data can be downloaded directly, whereas others require a research application or contract to be in place. For most of the sources, the data are available free of charge, although a few charge a fee to obtain the data.

Cross-Sectional

Cross-sectional data are available from a variety of sources, such as population censuses, administrative databases and population registries, and surveys. As noted previously, cross-sectional data can be collected at a single point in time (single cross-section) or over multiple time points on different individuals (repeated cross-section). Cross-sectional data typically do not provide information on subsequent mortality of study participants. As a result, it is necessary to have an auxiliary data source on mortality for the population under study in order to estimate health expectancy.

Censuses

Most countries conduct a census periodically, typically every 10 years, although some countries conduct them more frequently. Measures of health tend to be limited on censuses, but most contain at least one measure of health or disability. Work or employment disability is commonly measured in censuses, and some contain other health measures such as mental or psychological disability, mobility disability, sensory impairment

Table 5.1 Data Sources Organized by Region

| Region | Study Name | URL |
|---|---|-----|
| <i>Multi-regional</i> | | |
| Cross-National Equivalent File (CNEF) (harmonized household panel surveys from Asia, Europe, North America, Oceania) | https://enef.ehe.osu.edu/ | |
| Demographic and Health Survey's (DHS) (Africa, Asia, Europe, Latin America, Oceania) | https://dhsprogram.com/ | |
| Gateway to Global Aging Data (harmonized HRS international studies) | https://g2aging.org/ | |
| IPUMS—International (harmonized Census data, all regions) | https://international.ipums.org/international/ | |
| Study on Global Ageing and Adult Health (SAGE) (Africa—Ghana and South Africa; Asia—China and India; Latin America—Mexico; Europe—Russian Federation) | http://www.who.int/healthinfo/sage/en/ | |
| World Health Survey (WHS) (70 countries spanning all regions) | http://www.who.int/healthinfo/survey/en/ | |
| World Values Survey (WVS) (80 countries spanning all regions) | http://www.worldvaluessurvey.org/wvs.jsp | |
| <i>Africa</i> | | |
| Health and Aging in Africa: Longitudinal Studies in Three INDEPTH Communities (HAALSI) (South Africa) | https://haalsi.org/ | |
| <i>Asia</i> | | |
| East Asian Social Survey (EASS) (China, Korea, Japan, Taiwan) | https://www.icpsr.umich.edu/icpsrweb/ICPSR/series/486 | |
| China Health and Nutrition Survey (CHNS) | https://www.icpsr.umich.edu/icpsrweb/DSDR/studies/176 | |
| China Health and Retirement Longitudinal Study (CHARLS) | http://charls.pku.edu.cn/en | |
| China Longitudinal Healthy Longevity Study (CLHLS) | https://www.icpsr.umich.edu/icpsrweb/NACDA/studies/36179 | |
| Indonesian Family Life Survey (IFLS) | http://www.rand.org/labor/IFLS/IFLS | |
| Japanese Study of Aging and Retirement (JSTAR) | http://www.rieti.go.jp/en/projects/jstar/index.html | |
| Korea National Health Information Database | https://nhiss.nihis.or.kr/bd/ab/bdaba000eng/do | |
| Korean Longitudinal Study of Ageing (KLOSSA) | http://ssrc.uci.edu/klossa01.jsp | |
| Longitudinal Aging Study in India (LASI) | https://iasi.hspf.harvard.edu/ | |
| Malaysia Ageing and Retirement Survey (MARS) | http://ssrc.umi.edu.my/malaysia-ageing-and-retirement-survey-mars/ | |
| National Survey of Japanese Elderly (NSIE) | https://www.icpsr.umich.edu/icpsrweb/NACDA/studies/6342 | |
| Nihon University Japanese Longitudinal Study of Aging (NUJLSOA) | https://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/156 | |
| Social Environment and Biomarkers of Aging Study (SEBAS) | https://addnet.psc.isr.umich.edu/data/survey-summary/109 | |
| Taiwan Longitudinal Study on Aging (TLSA) | https://www.hpa.gov.tw/EngPages/Detail.aspx?nodeid=1077&pid=6197 | |
| <i>Europe</i> | | |
| European Community Household Panel (ECHP) | https://ec.europa.eu/eurostat/web/microdata/european-community-household-panel | |

| Region Study Name | URL |
|---|---|
| European Health Interview Survey (EHIS) | http://ec.europa.eu/eurostat/web/microdata/european-health-interview-survey |
| European Social Survey (ESS) | http://www.europeansocialsurvey.org/ |
| European Union Statistics on Income and Living Conditions (EU-SILC) | https://ec.europa.eu/eurostat/web/income-and-living-conditions/overview |
| European Values Study (EVS) | http://www.europeanvaluesstudy.eu/ |
| Survey of Health, Ageing and Retirement in Europe (SHARE) | http://www.share-project.org/ |
| British Household Panel Survey (BHPS) | https://www.iser.essex.ac.uk/bbps |
| Understanding Society (US) | https://www.understandingsociety.ac.uk/ |
| English Longitudinal Study of Ageing (ELSA) | http://www.elsa-project.ac.uk/ |
| German Health Interview and Examination Survey for Adults (DEGS) (2008–2011) | https://www.rki.de/EN/Content/Health_Monitoring/Public_Use_Files/public_use_file_node.html |
| German Socio-Economic Panel (GSOEP) | https://www.eui.eu/Research/Library/ResearchGuides/Economics/Statistics/DataPortal/GSOEP |
| Health Survey for England (HSE) | https://www.ucl.ac.uk/epidemiology-health-care/research/epidemiology-and-public-health/research/health-and-social-surveys-research-group/studies-0 |
| Healthy Ageing in Scotland (HAAGIS) | http://www.hagis.scot/ |
| Irish Longitudinal Study on Ageing (TILDA) | http://tilda.tcd.ie/ |
| Northern Ireland Cohort for the Longitudinal Study of Ageing (NICOLA) | https://www.qub.ac.uk/sites/NICOLA/ |
| Scottish Health Survey | https://www.gov.scot/Topics/Statistics/Browse/Health/scottish-health-survey |
| Swiss Health Survey | https://www.bfs.admin.ch/bfs/fr/home/statistiques/sante/enquetes/sgb.html |
| <i>Latin America</i> | |
| Survey on Health, Well-Being, and Aging in Latin America and the Caribbean (SABE) | https://doi.org/10.3886/ICPSR03546.v1 |
| Brazilian Longitudinal Study of Aging (ELSI) | http://elsi.cpqrr.fiocruz.br/en/ |
| Costa Rican Longevity and Healthy Aging Study (CRELES) | http://www.creles.berkeley.edu/ |
| Mexican Health and Aging Study (MHAS) | http://www.mhasweb.org/ |
| <i>North America</i> | |
| Canadian Community Health Survey (CCHS) | http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3226 |
| Canadian Longitudinal Study on Aging (CLSA) | https://www.cls.ca-elcv.ca/ |
| National Health Interview Survey (NHIS) (United States) | https://www.cdc.gov/nchs/nhis/about_nhis.htm |
| National Health and Nutrition Examination Survey (NHANES) (United States) | https://www.cdc.gov/nchs/nhanes/index.htm |
| Panel Study of Income Dynamics (PSID) (United States) | https://psidonline.isr.umich.edu/ |

(continued)

Table 5.1 (continued)

| <i>Region</i> | <i>Study Name</i> | <i>URL</i> |
|--|-------------------|---|
| Health and Retirement Study (HRS) (United States) | | http://hrsonline.isr.umich.edu/ |
| National Long Term Care Survey (NLTCSS) (United States) | | https://www.icpsr.umich.edu/icpsrweb/NACDA/studies/9681 |
| National Health and Aging Trends Study (NHATS) (United States) | | https://www.nhats.org/ |
| U.S. Center for Medicare and Medicaid Studies (CMS) Program Data (enrollment and claims) (United States) | | https://www.resdac.org/cms-data/files/mbsf-base |
| <i>Oceania</i> | | |
| Australian Longitudinal Study of Ageing (ALSA) | | http://www.flinders.edu.au/sabs/fcas/alsaf |
| Household, Income and Labour Dynamics in Australia (HILDA) | | https://www.dss.gov.au/our-responsibilities/families-and-children/programmes-services/the-household-income-and-labour-dynamics-in-australia-hilda-survey |
| New Zealand Longitudinal Study of Ageing (NZLSA) | | http://nzlsa.massey.ac.nz/ |

(vision, hearing), and/or self-assessed health. Also, as noted previously, there has been a recent effort to promote the inclusion of the WG-SS Short-Set (WG-SS) disability measures on censuses, and 27 countries plan to include these measures on their 2020 census. This will be a valuable resource for future health expectancy research.

Census data can be difficult to obtain and unwieldy to analyse. Often data from censuses are available only in tabulated form in published reports. In countries where it is possible to get micro-data, the data are typically released under restricted procedures to protect confidentiality. These restrictions pose challenges for researchers who are interested in using census data to study trends over time and/or for cross-national comparisons. The IPUMS-International database (Minnesota Population Center 2018) is a valuable resource for such purposes. IPUMS-International is an initiative led by researchers at the University of Minnesota, in collaboration with national statistical offices and international data archives. The database contains harmonized data from 365 censuses (dating from 1960 to the present) in 94 countries. IPUMS data can be used for either national or cross-national research. Information on IPUMS-International may be obtained at the website provided in Table 5.1.

Because of their global reach and national representation, census data can be useful for studying health expectancy, particularly in countries where survey data is lacking. The main drawbacks of censuses are that there is generally a long gap between rounds (10 years) and they tend to have limited health measures relative to surveys.

Surveys

Many countries conduct cross-sectional surveys that include measures of health. Some are national surveys that are government sponsored (e.g., health interview or health examination surveys, household surveys, social surveys, labour force surveys), while others are international and designed to be comparative in terms of both the study methodology and survey measures. This section focuses mainly on health and/or aging

surveys, since they provide the most detailed measures of health; however, other types of cross-sectional surveys that have certain advantages for analysis of trends over time and/or cross-national comparisons are also mentioned.

Health interview surveys (HIS) have a long history and have been conducted in a number of countries. Most HIS are cross-sectional, nationally representative, and household-based, that is, they collect information on all members in a household, or at least all adult members. Some are one-time surveys, whereas others have been repeated at least periodically, if not annually. Health interview surveys generally collect self-reported information on prevalence of chronic conditions and diseases, physical, psychological and sensory impairments, disability, risk factors such as smoking, alcohol consumption, weight and height, and use of health services.

The National Health Interview Survey (NHIS) in the United States has been conducted annually since 1957 and is perhaps the longest continuously running health survey. Ongoing health surveys have also been conducted in Canada (Canadian Community Health Survey, since 2001) and Switzerland (Swiss Health Survey, since 1992). In 2006 the international European Health Interview Survey (EHIS) was launched in 17 countries and data collection is planned in 5-year intervals. The World Health Survey conducted a single wave of data collection in 70 countries in Africa, Asia, Europe, Latin America and Oceania between 2002 and 2004.

Another set of health surveys includes health examination surveys (HES). These typically involve both an interview component (with much the same content as health interview surveys) and a medical examination. The medical examination, which is carried out by a doctor or other medical professional, provides extensive biomarker measures, including results from blood assays, blood pressure, anthropometric measurements, and biomedical measurements such as breathing, grip strength, balance, gait speed, and the like. Some key HES surveys include the National Health and Nutrition Examination Survey (NHANES) in the United States, which has been conducted periodically since 1971, the

Scottish Health Survey (SHeS), conducted since 1985, the Health Survey for England, conducted since 1994, and the German Health Interview and Examination Survey for Adults (DEGS), conducted between 2008 and 2011. Medical examinations in NHANES are conducted in a specially designed and equipped mobile centre, by a medical team consisting of a physician, medical and health technician, as well as dietary and health interviewers. DEGS used a similar approach for the medical examinations, except they were conducted in community facilities instead of mobile centres. Both the SHeS and HSE use nurses to conduct medical assessments in respondents' homes.

The Demographic and Health Surveys (DHS) is a program of international surveys that are designed to monitor and evaluate a wide range of population, health and nutrition indicators (Corsi et al. 2012; Rutstein and Rojas 2006). The DHS started in 1984 and is conducted every 5 years, with some smaller-scale interim data collections on specific topics. At least one round of the survey has been conducted in 90 countries, and many countries have multiple rounds. DHS samples are nationally representative and the survey collects information on all members of a household. A key focus of the survey is on maternal and child health, although the survey includes some questions on adult health and health behaviours. The most recent round of DHS includes the WG-SS disability measures.

Most of the aging surveys covered in this chapter are panel surveys and are reviewed in the section on Panel Data. However, one cross-sectional study of population aging is noteworthy, the Survey on Health, Well-Being and Aging in Latin America and the Caribbean (SABE) that was conducted in 1999–2000 in 7 countries. The survey sampled community-dwelling individuals aged 60 or older in the capital cities in Argentina, Barbados, Brazil, Chile, Cuba, Mexico, and Uruguay. The study included a broad range of health measures, including chronic and acute diseases, disability, and physical and mental impairment. Harmonized data files for each country are available through the National Archive of Computerized Data on Aging (NACDA).

Social surveys are also conducted in many countries and provide valuable data for trend and/or cross-national research on health expectancy. The European Social Survey has conducted 8 rounds of data collection since 2001 in 36 countries in Europe. The ESS routinely includes questions on self-rated health and activity limitation and, in some rounds, has included questions on depressive symptoms and psychological well-being. A major strength of the ESS is that it has a strong central coordination and all countries use the same study design and questionnaire. The East Asian Social Survey (EASS) is another cross-national social survey that is conducted in China, Japan, Korea and Taiwan. The survey began in 2006 and conducts interviews every 2 years. A topical module on health was included in the 2010 round.

The World Values Survey (WVS) is an ongoing international cross-sectional survey that focuses on changing values and how they influence social and political life. Seven waves of WVS have been conducted between 1981 and 2014 in nearly 100 countries in all major regions of the world. The survey is designed to be comparable across countries in terms of questionnaire content, though data collection methods may vary. A companion study, the European Values Study, has been carried out across Europe, also since 1981. The WVS and EVS data files are structured in a way to facilitate easy merging. Although the WVS and EVS contain only a single measure of health (self-rated health), the surveys merit mention because of their broad geographic coverage and the availability and usability of the data for cross-national research.

Panel Data

Panel data (same individuals measured at multiple time points), which generally comes from surveys but may also come from administrative sources, usually includes information on mortality as part of the released data. The sections below describe some of the panel surveys that have or can be used for health expectancy research.

Surveys

In recognition of the global force of aging and the importance of panel data for understanding the dynamics of aging, there has been tremendous growth in the number of panel surveys of aging around the world in the past couple of decades. Given that health is often a key focus of surveys of aging and, as such, is measured in some detail, these surveys can be particularly valuable for health expectancy research. As a result, many of the surveys covered in this section are aging surveys (i.e., based on samples of older individuals), but some are broader population and/or household-based surveys.

The Health and Retirement Study (HRS) is a large and comprehensive panel study of aging in the United States. It collects detailed information from middle-aged and older Americans on health and health care use, as well as on economic status, employment and retirement, family circumstances and intergenerational support, and psychological well-being. The study began in 1992 and conducts biennial interviews with participants, as well as supplemental surveys on special topics in between the main interview waves. HRS has served as a model for a growing number of panel studies of aging around the world. These include studies in England (English Longitudinal Study of Ageing), Ireland (Irish Longitudinal Study of Ageing), Northern Ireland (Northern Ireland Cohort for the Longitudinal Study of Ageing), Scotland (Healthy Ageing in Scotland), 27 European countries plus Israel (Survey of Health, Ageing and Retirement in Europe), South Africa (Health and Aging in Africa: Longitudinal Studies in Three INDEPTH Communities), Mexico (Mexican Health and Aging Study), Brazil (Brazilian Longitudinal Study of Aging), Costa Rica (Costa Rican Longevity and Healthy Aging Study), South Korea (Korean Longitudinal Study of Aging), Japan (Japanese Study of Aging and Retirement), China (China Health and Retirement Longitudinal Study), India (Longitudinal Aging Study in India), Indonesia (Indonesian Family Life Survey), Malaysia (Malaysian Ageing and Retirement Survey), and the Study of Global Ageing and Adult Health (SAGE) that is based in China, Ghana, India,

Mexico, Russian Federation and South Africa. These studies use similar sample and study designs and measures that are the same or comparable to support cross-national research. Collectively they are referred to as the HRS international sister studies. Some of these studies are now quite mature, while others are very new. The Gateway to Global Aging Data, produced by the Program on Global Aging, Health and Policy at the University of Southern California, contains harmonized data for many of the HRS international sister studies on specific topics, including health. Extensive documentation, including a variable concordance, questionnaires and codebooks, and links for downloading harmonized datasets are available on the Gateway website (see Table 5.1). These resources are valuable for researchers who are interested in conducting cross-national research with the international HRS surveys.

The National Health and Aging Trends Study (NHATS) in the U.S. and its predecessor, the National Long-Term Care Survey, are also valuable panel data sources for research on health expectancy. A major objective of these surveys is to provide data to help understand trends in late-life functioning and how these vary for different population subgroups. The surveys include extensive measures of disability and functioning. An advantage of both studies is that the samples are not restricted to community-dwelling individuals, which is the case for many population-based surveys, but also include individuals in long-term care facilities. Also, NHATS collects data annually, whereas many panel surveys collect data at 2-year or longer intervals.

There are many other panel surveys of aging that have been conducted in different parts of the world. Australia and New Zealand both conduct panel surveys of older adults. The Australian Longitudinal Study of Ageing (ALSA) conducts biennial interviews with a sample of individuals age 70 and over who were residing in Adelaide when the study began in 1992. The New Zealand Longitudinal Study of Ageing was launched in 2008 and conducts biennial interviews with a national sample of people age 50–84. Canada also has an in-depth panel study on aging, the

Canadian Longitudinal Study of Aging, which began in 2011. Two waves have been completed as of 2018. The study includes an interview component and a physical and neuropsychological assessment that takes place either at a nearby data collection site or in the participant's home.

Japan has a rich history of panel studies of aging. The recent JSTAR study that is modelled after the HRS was preceded by two other studies. The first is the National Survey of Japanese Elderly that surveyed a national sample of individuals age 60 and older every 3 years between 1987 and 1996. The second, the Japanese Longitudinal Study of Aging was conducted by Nihon University (NUJLSOA) from 1999–2003 and is modelled after the U.S. Longitudinal Study of Aging. It collected 3 waves of data at 2 year intervals on a national sample of persons aged 65 and over. Data from both of these surveys are archived in NACDA.

In addition to CHARLS, China also has two panel studies that focus on health for which data are publicly available. The China Longitudinal Healthy Longevity Study (CLHLS) was conducted on a large sample of people age 65 or older. The CLHLS oversampled the oldest old (age 80+) and has a large number of centenarians in the study. A total of seven waves were conducted between 1998 and 2014. A second survey, the China Health and Nutrition Survey (CHNS), provides detailed information on population health. CHNS is a household-based survey that began in 1989 and has collected 10 waves of data.

Taiwan also has a long-standing panel study of aging. The Taiwan Longitudinal Study on Aging (TLSA) began in 1989 and conducted seven waves of data collection through 2011. In the 2000 and 2006 waves, a supplemental study referred to as the Social Environment and Biomarkers of Aging Study (SEBAS) was conducted with a subsample of the panel cohort. For SEBAS, the main interview was enhanced with additional measures of physical, emotional and cognitive health status, physical performance assessments, and a hospital-based physical examination.

In addition to aging and health surveys, household panel surveys often include a number of

measures of health and disability and can be valuable sources for health expectancy research. Examples include Understanding Society (US) in the United Kingdom; German Socio-Economic Panel (GSOEP); Household, Income and Labour Dynamics in Australia (HILDA); and Panel Study of Income Dynamics (PSID) in the United States. A cross-national household panel study in 14 European countries (European Community Household Panel) was conducted annually between 1994 and 2001. The European Union Statistics on Income and Living Conditions (EU-SILC) is another example of a cross-national household survey. EU-SILC began in 2004 in a small number of countries and has since expanded to all 28 EU member states, plus several other countries. A strength of EU-SILC is that it has both a cross-sectional and longitudinal component.

Most of these household surveys include a number of self-reported measures of health status, chronic disease and disability. Although the health measures are not as detailed as many of the aging surveys, advantages of the household surveys are large sample sizes, long duration of survey (PSID has been ongoing since 1968; GSOEP since 1984), and frequent data collection. Similar to the HRS international studies, there have been efforts to harmonize some of the ongoing household panel studies. A project based at Ohio State University has produced the Cross-National Equivalent File (CNEF) for eight household panel surveys, including the US, GSOEP, HILDA and PSID studies mentioned above, as well as similar surveys in Korea, Russia, Switzerland and Canada.

In addition to self-reported health measures, many of the surveys described in this section also conduct physical performance measures (e.g., walking speed, balance, grip strength, peak flow) and collect anthropometric measurements (height; weight; waist, hip and calf circumference; knee length), blood-based biomarkers, and DNA.

Administrative Data

Though less commonly used, administrative databases and population registries can provide

valuable data for health expectancy research. Many health-related administrative databases are based on enrollment and claims data from government programs or medical or health centres. Examples include Center for Medicare and Medicaid (CMS) data in the U.S., health and long-term care insurance databases in several Asian and European countries, and population health registries that are common in Scandinavian countries.

The Research Data Assistance Center (ResDAC) distributes numerous CMS data files, including beneficiary level files, plan or provider files, claims files, and visit or encounter based files for the Medicare and Medicaid programs in the U.S. The beneficiary files, which include information on eligibility, enrolment, service utilization and costs, and diagnoses for individual beneficiaries, would be most relevant for health expectancy research.

Other countries also have administrative databases that have been used for health research, including Taiwan (National Health Insurance Research Database; (Hung et al. 2016)), Japan (National Long Term Care Insurance Data; (Akiyama et al. 2018; Seko et al. 2012)) and Korea (National Health Information Database in South Korea, (Cheol Seong et al. 2017)). The Scandinavian countries have a long history of population registers that cover multiple domains such as education, housing, employment, income/tax, as well as a variety of health and health care issues. An advantage of the Scandinavian registers is that it is possible for researchers to obtain individual-level data that are linked across different registers (Thygesen et al. 2011). This allows for the inclusion of covariates, such as marital or partnership status, household composition, socioeconomic status and work history, that are generally not available in a health register. Examples of studies that have utilized data from multiple registers include one on trends in the association between income and mortality in Denmark (Brønnum-Hansen 2017) and another on the association between trends in age at first hospital admission and trends in life expectancy in Sweden (Karampampa et al. 2013).

Administrative data can either be used as micro data (if available in that form) or as aggregated data. Pinheiro and Kramer (2009) used aggregated administrative data on population, mortality, morbidity, and long-term care to estimate severe disability-free and long-term care free life expectancy in Germany. Seko et al. (2012) also used aggregate data, in their case from the Long-term Care Insurance System in Japan (2005–2009), along with Japanese population, mortality and life-table data to estimate trends in life expectancy with care needs. Most studies that use these sources focus on medical or long-term care service use and costs, though some focus on disease incidence and prevalence.

Many of these administrative databases contain longitudinal data on medical claims or diagnoses over a period of time, however most do not include information on mortality. The CMS data is an exception in that it is linked to the National Death Index and one of the files includes information on date, cause, and underlying causes of death. The Scandinavian health registers can also be linked with death and cause of death registers.

Most aggregated administrative data are readily available in published reports, on government websites or upon request. Micro administrative and registry data can be cumbersome to access and, in some cases, may require researchers to work in a secure computing environment at the government departmental office or other approved facility or collaborate with the institute that holds the data. Some surveys request consent from participants to link their survey records with administrative data. In that case, the linked data are typically made available for research under special protocols for restricted data.

Cross-National Data Sources

A number of the surveys and other data sources mentioned in the previous sections are cross-national. Some are explicitly designed and carried out as cross-national studies. DHS, EHIS, ESS, SHARE, SAGE, SABE, WHS, and WVS are all examples. There is generally a core

questionnaire that is administered in all countries and some additional country-specific content that is tailored to the country's particular policies or circumstances. For these studies, the data is generally disseminated in a way that facilitates cross-national comparisons--either data for all countries is released in a single file that contains a country indicator on the data record or data are released in country-specific files, but with a common variable naming scheme to facilitate merging of variables that are comparable across countries.

Other surveys and data collections may not be carried out or even designed as cross-national studies, but efforts have been made to harmonize the data sources either ex-ante or ex-post. Examples of these include IPUMS-International (harmonized census data), the Gateway to Global Aging Data (harmonized HRS international sister studies), and the Cross-National Equivalent File (harmonized household panel surveys). All of these collections include extensive documentation on the source questionnaires and decision rules that were used for harmonization.

Conclusion

As noted at the outset and illustrated throughout this chapter, there has been tremendous growth in the availability of data resources to study health and aging over the past several decades. In addition, there has been an increasing recognition of the value of producing data that is comparable over time and across settings and of making the data publicly available. The result is a wide array of cross-sectional and longitudinal data emanating from surveys, censuses, administrative databases and population registers that can be used for health expectancy analysis.

This chapter has focused primarily on data sources that can be used for cross-national comparisons or for studying trends over time within a given setting. For researchers interested in conducting cross-national comparisons, there are many high quality data sources that can be used. A number of prior health expectancy studies have undertaken cross-national comparisons. One example is a study by Robine et al. (2002) who

made use of the European Community Household Survey (ECHS) to examine gender differences in active life expectancy across 12 European countries. Another study also focuses on Europe and used data from European Union Statistics on Income and Living Conditions (EU-SILC) to explore educational differences in disability-free life expectancy across 8 countries (Mäki et al. 2013). Yet another used data from the Study on Global Ageing and Adult Health (SAGE) and examined cross-national differences in disability-free life expectancy in six low and middle income countries spanning several regions of the world (Chirinda and Chen 2017).

Repeated cross-sectional data is generally best for studying population trends, although panel data can also be used, especially if the study includes sample refreshment as part of the design. Again, there are many examples of studies that have used data from repeated cross-sections or panel studies to examine trends in active life expectancy over time in Denmark (Brønnum-Hansen 2005), England (Jagger et al. 2016), Greenland (Mairey et al. 2014), Taiwan (Tu and Chen 1994), Japan (Yong and Saito 2009), and the U.S. (Cai and Lubitz 2007; Crimmins et al. 2009; Crimmins et al. 2016; Freedman and Spillman 2016; Freedman et al. 2016; Hagedorn 2008; Manton et al. 2006; Sole-Auro et al. 2014). These studies drew on a variety of data sources, including repeated cross-sectional surveys in Denmark, Greenland, Japan, Taiwan and the U.S., as well as panel studies in England and the U.S. Analysis of trends in health expectancy worldwide are provided in Chap. 2.

With regard to measures, many existing studies of health expectancy have focused on different measures of disability and/or functional limitation, although studies are increasingly using other health indicators, such as cognitive impairment, depression, life satisfaction and other measures of psychological well-being. Data on multiple domains of physical and mental health are becoming increasingly available.

Research on health expectancy is also getting increasingly sophisticated in the inclusion of sociodemographic and health covariates in the estimation of health expectancy. In some cases

these covariates are used as stratification variables, e.g., to examine differences in health expectancy across race and ethnic groups or among people with and without a specific disease. In other cases, they are used as control variables in models that estimate health expectancy.

Surveys and censuses generally provide the most comprehensive information on demographic and socioeconomic characteristics; often this information is very limited or missing altogether from administrative data. Surveys focusing on health provide the best coverage for health indicators and health behaviours and risk factors. Administrative data in the form of geographic linkages can provide valuable information on the environment in which people live and work, allowing researchers to explore issues relating to environmental exposures, such as air pollution.

In sum, between advances in analytic methods and the extensive growth in data availability, there are abundant opportunities for researchers interested in studying health expectancy.

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Attributing Causes to Disability

6

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Introduction

Health expectancy is a summary measure of population health that aggregates mortality and health outcomes across age. Life expectancy with and without disability are the most used examples of health expectancies, but other health measures such as “less than good self-perceived health” are also frequently used. Disability-free life expectancy calculations require mortality and disability data, aggregating fatal and non-fatal outcomes, as a result of a range of causes of death and disability. To better understand differences in health expectancies between populations, subgroups or over time, and to identify priority inter-

ventions or policy measures to reduce disparities or to improve unfavourable trends, insights into the causes of death and causes of disability are needed.

In the context of health expectancies, causes of death and disability have been used for two purposes. First, to identify the diseases that contribute to disparities in life expectancy with(out) disability across specific subgroups (men and women, socio-economic groups) or over time, with causes (of death and disability) then used as input for decomposition analyses of health expectancy variations by cause (Nusselder and Looman 2004). Second, to decompose years with disability by cause (diseases), showing which diseases contribute most to years with disability in a specific population or period (Klijns et al. 2011).

All-cause mortality can simply be disaggregated by causes of death, as the death certificate includes information to derive the underlying cause (disease or injury) that initiated the train of events leading directly to death according to international coding standards. This cause-specific mortality information is generally available in national and international databases. For disability data, similar information on underlying diseases or injury is generally not available. To fill this gap, several methods can be used to derive cause-specific disability. In this chapter we focused on the attribution method proposed by Nusselder and Looman (Nusselder and Looman 2004) and further extended by Yokota

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et al. (Yokota et al. 2017b) that can be used based on widely available cross-sectional survey data. This method is based on the theory of the disablement process (Verbrugge and Jette 1994) that describes the main pathway from pathology to disability. The main advantage of this approach is that it allows partitioning of the disability prevalence into the additive contribution of diseases taking into account that individuals can report more than one disease (multimorbidity) and that disability can be present even in the absence of disease. Originally, the method was developed as input for the decomposition of health expectancies. Since its introduction however it has expanded its use beyond health expectancies, e.g. to obtain insights in the contribution of specific chronic conditions to the disability burden (Klijns et al. 2011, 2014; Strobl et al. 2013; Yokota et al. 2015a, b, 2016a, b, c, 2017a).

This chapter is organized as follows. We first introduce the attribution method with the two variants of the additive hazard model: the binomial additive hazard model for binary responses (absence *versus* presence of disability); and the multinomial additive hazard model for more than two disability states (for example, no, mild, and severe disability). An illustration of the application of the models to the 2013 Brazilian National Health Survey data is also provided. Next, we show how the cumulative hazard rates of disability for diseases and background (model parameters) are interpreted and how multimorbidity and independence is accounted for in the attribution method, using the results of the Brazilian data as example. The previous applications of the method, the contribution of the attribution method to the field, and the limitations and strengths of the approach compared to other methods are also discussed. Finally, concluding remarks and suggestions for future analyses are outlined.

Attribution Method

The attribution method aims to attribute each disability case reported in a survey to a single cause, taking into account that individuals can have more than one disease (multimorbidity) and that

disability can be present in individuals who do not report any disease. Even if a person reports only one disease in the survey, this is not necessarily the cause of disability. Disability that is not associated with the diseases included in the analysis is labelled *background*. Disability in individuals who do not report any disease is entirely attributed to background, while disability in individuals with reported diseases is partitioned between the diseases and the background. The background may reflect the effect of age-related losses in functioning, underreported and undiagnosed diseases in the survey, and causes of disability that were not included in the analysis.

The core of the attribution method is the additive hazard model. Analogous to the analysis of competing risks (Chiang 1961; Manton and Stallard 1984) in which an exponential transformation is applied to a cumulative rate (cumulative force of mortality) to obtain a probability (cause-specific probability of death) under the assumption of independence between the causes of death, in the attribution method the exponential function is applied to the cumulative hazard rate of disability to obtain the cause-specific disability probabilities, assuming independence between the causes of disability (diseases).

Binomial Additive Hazard Model

For binary outcomes, the binomial additive hazard model is defined as shown in Eq. 6.1.

$$\begin{aligned} y &\sim \text{Bernoulli}\left(\hat{\hat{y}}\right) \\ \hat{\hat{y}} &= 1 - \left[\exp\left(-\hat{\eta}\right) \right] \\ \hat{\eta} &= \alpha_a + \sum_m^d \beta_d X_d \end{aligned} \quad (6.1)$$

where y is the observed binary disability outcome, $\hat{\hat{y}}$ is the estimated probability that the participant is disabled, $\hat{\eta}$ is the linear predictor representing the estimated overall cumulative hazard rate of disability, α_a is the cumulative hazard rate of disability for background by age group $a(1, \dots, k)$, β_d is the disease-specific cumulative hazard rate of disability or disabling impact for

each disease $d(1, \dots, m)$, and X_d is the indicator variable for each disease d , indicating presence or absence of disease d .

Here, the terms “cumulative hazard rate”, “cumulative rate” and “hazard rate” will be used interchangeably. The binomial additive hazard model can be fitted with the software developed by Nusselder and Looman for non-experienced R users, available upon request from the authors, and with the R package *addhaz* for R users (Yokota et al. 2016d).

Multinomial Additive Hazard Model

Analogous to the binomial case, the multinomial additive hazard model is defined as shown in Eq. 6.2.

$$\begin{aligned} y &\sim \text{Multinomial}\left(1, \hat{y}_j\right) \\ \hat{y}_j &= \left[1 - \exp\left(-\sum_{c=2}^{j-1} \hat{\eta}_j\right)\right] \left[\frac{\hat{\eta}_j}{\sum_{j=2}^c \hat{\eta}_j} \right] \quad (6.2) \\ \hat{\eta}_j &= \alpha_{aj} + \sum_{m=1}^{d=1} \beta_{dj} X_d \end{aligned}$$

where $y(1, \dots, j)$ is the observed multicategory disability outcome, with y_1 defined as the reference category (not disabled, for example), \hat{y}_j is the estimated disability probability for each category j of the outcome, $\hat{\eta}_j$ is the linear predictor representing the estimated overall cumulative hazard rate of disability for each category j of the outcome, α_{aj} is the cumulative hazard rate of disability for background by age group $a(1, \dots, k)$ and each category j of the outcome, β_{dj} is the disease-specific cumulative hazard rate of disability or disabling impact for each disease $d(1, \dots, m)$ and each category j of the outcome, and X_d is the indicator variable for each disease d .

The multinomial additive hazard model can be fitted with the R package *addhaz* (11). Wald confidence intervals or bootstrap percentile confidence intervals can be estimated for the regression coefficients of the binomial and multinomial models.

Assumptions of the Additive Hazard Models

The following assumptions are required to estimate the cumulative hazard rates of disability with cross-sectional data in the additive hazard models:

1. a causal relationship between diseases and disability;
2. the distribution of disability by cause is entirely explained by the background and the diseases that are still present at the time of the survey;
3. the estimated cross-sectional cumulative rates of disability ($\alpha_a \alpha_{aj} \beta_d \beta_{dj}$) reflect the transition rates that would have been estimated with longitudinal data (stationarity assumption);
4. the recovery rate is zero, i.e. individuals with disability cannot return to the state of (1) not diseased and not disabled or (2) diseased and not disabled;
5. the ratio of the cause-specific cumulative rates to the overall cumulative rate, i.e. $\alpha_a / \hat{\eta}$ and $\alpha_{aj} / \hat{\eta}_j$ for background and $\beta_d / \hat{\eta}$ and $\beta_{dj} / \hat{\eta}_j$ for disease d , is constant over time (proportionality assumption);
6. the onset of the time at risk to become disabled is the same for all diseases;
7. diseases and background act as competing causes of disability.

Absolute and Relative Contribution of Diseases and Background to the Disability Prevalence

The attribution of disability to causes (diseases) depends on the disease prevalence (X_d) and the disabling impacts of the diseases overall and for each category of the outcome (β_d and β_{dj}). The contribution of diseases and background to the disability prevalence can be estimated in three steps for binary and multinomial outcomes.

For binary outcomes, we first estimate the cause-specific disability probabilities for each disease ($\hat{D}_d = \frac{\beta_d X_d}{\hat{\eta}} \times \hat{y}$) and the background

$(\hat{B} = \frac{\alpha_a}{\hat{\eta}} \times \hat{y})$ for each individual, using the proportionality assumption, analogous to competing risks for mortality (Chiang 1961). Next, the number of disabled individuals by each disease ($\hat{N}_d = \sum_n^i \hat{D}_d$) and the background ($\hat{N}_b = \sum_n^{i=1} \hat{B}$) are the sum of cause-specific probabilities in the population studied. Finally, the absolute contribution to the total disability prevalence (\widehat{AC}) of each disease ($\widehat{AC}_d = \frac{\hat{N}_d}{n} \times 100$) and the background ($\widehat{AC}_b = \frac{\hat{N}_b}{n} \times 100$), i.e. the prevalence of disability by cause, can be estimated by dividing the total number of disabled individuals for each cause by the total number of individuals in the population studied. Since the prevalence of disability by cause (\widehat{AC}_d and \widehat{AC}_b) sum to the total disability prevalence ($\hat{P} = \widehat{AC}_b + \sum_m^d \widehat{AC}_d$), the relative contribution (\widehat{RC}) of each disease to the disability prevalence can be obtained by dividing the absolute contribution of each disease ($\widehat{RC}_d = \frac{\widehat{P}_d}{\hat{P}} \times 100$) and the background ($\widehat{RC}_b = \frac{\widehat{P}_b}{\hat{P}} \times 100$) by the total disability prevalence. The relative contributions (\widehat{RC}_d and \widehat{RC}_b) sum to 1.

For the multinomial case similar calculations are made, but for each j category of the outcome. The confidence intervals for the absolute and relative contributions for the binomial and multinomial models can be obtained via bootstrapping (Efron and Tibshirani 1994).

Application of the Attribution Method to the National Health Survey, Brazil, 2013

Data

The National Health Survey in Brazil (NHSB) (*Pesquisa Nacional de Saúde*) is used to illustrate the attribution method. The NHSB was a nationally representative survey of the Brazilian adult

population (≥ 18 years) with approximately 60,000 individuals, conducted in 2013. A multi-stage sampling design with simple random sampling (census tracts) and clustering (households and adults) was used. The response rate was 77%. Survey weights were used to account for the complex design of the sample. Detailed information about the NHSB can be found elsewhere (Szwarcwald et al. 2014; Yokota et al. 2016a).

In the present analysis disability was based on seven activities of daily living (ADL): feeding, bathing, toileting, dressing, transferring from one place to another, getting in and out of chair, and getting in and out of bed. When asked about the degree of difficulty in performing ADL tasks, participants could answer: “1. Unable”, “2. A lot of difficulty”, “3. Some difficulty”, or “4. No difficulty”. The definition of the disability outcomes used in the binomial and multinomial models is described in Table 6.1. The analysis included self-reported medical diagnosis of seven chronic conditions: diabetes, stroke, arthritis, back pain, mental disorders (schizophrenia, bipolar disorder, psychosis, or obsessive-compulsive disorder), chronic respiratory diseases (emphysema, chronic bronchitis, or chronic obstructive pulmonary disease), and cancer. We limited analysis to older individuals (≥ 60 years), as the ADL questions were restricted to this subgroup. Among the 11,177 individuals aged 60 years or older who participated in the NHSB, information on chronic conditions were missing for 592 (5%), resulting in a sample of 10,585 older individuals. Separate models were fitted for men and women. The statistical analysis was carried out in R. The cumu-

Table 6.1 Definition of the binary and multinomial disability outcomes

| Outcome | Outcome category | Answer to at least one ADL question |
|-------------|-------------------|-------------------------------------|
| Binary | No disability | 4 |
| | Disabled | 1,2 or 3 |
| Multinomial | No disability | 4 |
| | Mild disability | 3 |
| | Severe disability | 1 or 2 |

National Health Survey, Brazil, 2013

1. Unable; 2. A lot of difficulty; 3. Some difficulty; 4. No difficulty

lative rates of disability and the contributions were estimated using the R package *addhaz* (Yokota et al. 2016d).

Figure 6.1 shows the prevalence of chronic conditions by gender. Back pain, arthritis, and diabetes were the most common conditions in the older population in Brazil while mental disorders and chronic respiratory diseases were the least frequent. The prevalence of back pain and arthritis was much larger in women than men whilst the prevalence of cancer was larger in men compared to women.

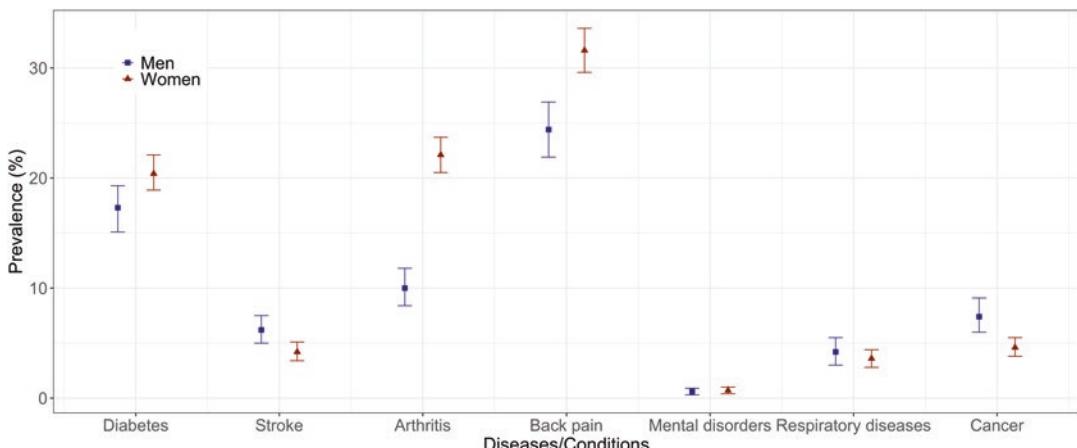


Fig. 6.1 Disease prevalence by gender. (National Health Survey, Brazil, 2013)

Table 6.2 Rank of the cumulative rates of disability (CR) and 95% confidence intervals (CI) for the binomial additive hazard model by gender. National Health Survey, Brazil, 2013

| Rank | Men | | | Women | | |
|------|-------------------------------|-----------------|------------|-------------------------------|-----------------|-------------|
| | Condition | CR ^a | CI | Condition | CR ^a | CI |
| 1 | Mental disorders ^b | 0.67 | 0.14; 1.25 | Stroke | 0.38 | 0.22; 0.57 |
| 2 | Stroke | 0.66 | 0.46; 0.93 | Mental disorders ^b | 0.24 | 0.04; 0.65 |
| 3 | Arthritis | 0.20 | 0.10; 0.34 | Arthritis | 0.13 | 0.08; 0.18 |
| 4 | Respiratory ^c | 0.16 | 0.02; 0.37 | Diabetes | 0.12 | 0.07; 0.18 |
| 5 | Back pain | 0.08 | 0.03; 0.13 | Back pain | 0.08 | 0.04; 0.12 |
| 6 | Diabetes | 0.06 | 0.01; 0.11 | Respiratory ^c | 0.06 | -0.03; 0.20 |
| - | Background ^d | 0.07 | 0.06; 0.09 | Background ^d | 0.09 | 0.07; 0.11 |

^aCR: cumulative rate of disability

^bMental disorders: schizophrenia, bipolar disorder, psychosis, or obsessive-compulsive disorder

^cRespiratory: chronic respiratory diseases (emphysema, chronic bronchitis, or chronic obstructive pulmonary disease)

^dBackground: disability causes not included in the model

Results for the Binomial Model

Table 6.2 shows the cumulative rates of disability for the background and diseases in the binomial models. The top three disabling diseases were mental disorders, stroke, and arthritis in men and women. Diabetes and chronic respiratory diseases showed the lowest disabling impacts in men and women, respectively.

In terms of the contribution of chronic disease to disability prevalence (expressed as a percentage), Fig. 6.2 shows that the background was the

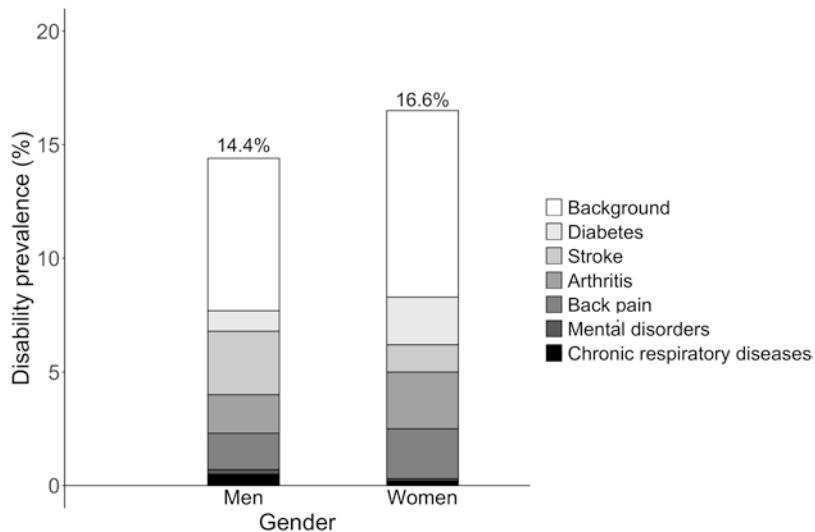


Fig. 6.2 Disability prevalence and absolute contribution of diseases to the disability prevalence. (National Health Survey, Brazil, 2013)

main contributor in men and women. Among the diseases, stroke was the main contributor in men (2.8%) and arthritis was the main contributor in women (2.5%). Mental disorders and chronic respiratory diseases showed the lowest contribution in men and women. The disability prevalence in women (16.6%) was slightly higher than in men (14.4%).

and women. For mild disability, back pain was the condition that contributed most in men and women. For severe disability, stroke was the main contributor in men and diabetes was the main contributor in women. The mild disability prevalence was higher than the severe disability in men and women, with the prevalence of mild and severe disability being slightly higher in women than in men.

Results for the Multinomial Model

The regression coefficients (cumulative rates of disability) of the multinomial model are provided in Table 6.3. For mild disability, the most disabling diseases were stroke, mental disorders, and arthritis in men and stroke, arthritis, and diabetes in women. Chronic respiratory diseases were the least disabling diseases for men and women. For men and women with severe disability, mental disorders and stroke were among the top disabling conditions whilst diabetes (men) and back pain (women) showed the lowest disabling impact.

As for the binomial model, Fig. 6.3 shows that the background was again the main contributor to the mild and severe disability prevalence in men

Interpretation of the Cumulative Rates of Disability and Multimorbidity

In the attribution method, disability is attributed to diseases by comparing disability in similar persons who only differ with respect to the presence or absence of the disease. The cumulative rate of disability for background is estimated based on the presence of disability in individuals without any disease reported from the disease list in the survey. The attribution method assumes that the cumulative rate of disability for background is the same for all individuals within each subgroup, which in the binomial and multinomial examples in this chapter means that the back-

Table 6.3 Rank of the cumulative rates of disability (CR) and 95% confidence intervals (CI) by severity level for the multinomial additive hazard model by gender

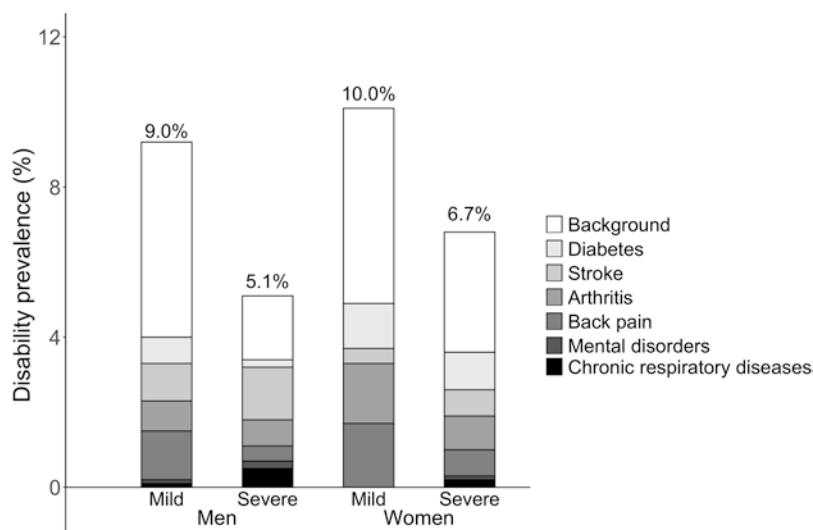
Mild disability

| | Men | | | Women | | |
|------|-------------------------------|-----------------|-------------|-------------------------------|-----------------|-------------|
| Rank | Condition | CR ^a | CI | Condition | CR ^a | CI |
| 1 | Stroke | 0.26 | 0.14; 0.42 | Stroke | 0.14 | 0.05; 0.25 |
| 2 | Mental disorders ^b | 0.20 | -0.04; 0.58 | Arthritis | 0.08 | 0.04; 0.12 |
| 3 | Arthritis | 0.10 | 0.02; 0.20 | Diabetes | 0.07 | 0.03; 0.11 |
| 4 | Back pain | 0.06 | 0.02; 0.10 | Back pain | 0.06 | 0.03; 0.09 |
| 5 | Diabetes | 0.04 | 0.00; 0.10 | Mental disorders ^b | 0.03 | -0.05; 0.20 |
| 6 | Respiratory ^c | 0.02 | -0.04; 0.11 | Respiratory ^c | 0.01 | -0.05; 0.10 |
| - | Background ^d | 0.05 | 0.04; 0.07 | Background ^d | 0.05 | 0.04; 0.07 |

Severe disability

| | Men | | | Women | | |
|------|-------------------------------|------|-------------|-------------------------------|------|-------------|
| Rank | Condition | CR | CI | Condition | CR | CI |
| 1 | Mental disorders ^b | 0.50 | 0.00; 1.13 | Stroke | 0.25 | 0.12; 0.4 |
| 2 | Stroke | 0.39 | 0.24; 0.59 | Mental disorders ^b | 0.23 | 0.04; 0.54 |
| 3 | Respiratory ^c | 0.17 | 0.02; 0.34 | Diabetes | 0.06 | 0.02; 0.10 |
| 4 | Arthritis | 0.10 | 0.03; 0.17 | Respiratory ^c | 0.06 | -0.02; 0.17 |
| 5 | Back pain | 0.02 | 0.00; 0.04 | Arthritis | 0.05 | 0.02; 0.08 |
| 6 | Diabetes | 0.01 | -0.01; 0.04 | Back pain | 0.02 | 0.00; 0.05 |
| - | Background ^d | 0.02 | 0.01; 0.03 | Background ^d | 0.03 | 0.03; 0.04 |

National Health Survey, Brazil, 2013

^aCR: cumulative rate of disability^bMental disorders: schizophrenia, bipolar disorder, psychosis, or obsessive-compulsive disorder^cRespiratory: chronic respiratory diseases (emphysema, chronic bronchitis, or chronic obstructive pulmonary disease)^dBackground: disability causes not included in the model**Fig. 6.3** Disability prevalence and absolute contribution of diseases to the mild and severe disability prevalence. (National Health Survey, Brazil, 2013)

ground was the same for all individuals aged 60 years or older, but differed by gender, since separate models were fitted for men and women. The disease-specific cumulative rates of disability are obtained by comparing two groups: one who reported disability but no disease, and the other who reported disability and disease(s).

To better understand the interpretation of the cumulative rates of disability and how multimorbidity is handled in the additive hazard models, we take a closer look in the results of the binomial model for men, showed in Table 6.2. As an example, we will consider four groups: (1) men without any reported disease (*No disease*); (2) men who only reported stroke (*Stroke*); (3) men who only reported arthritis (*Arthritis*); and (4) men who reported both, stroke and arthritis (*Stroke, arthritis*).

The overall cumulative rate of disability ($\hat{\eta}$) can be obtained using the estimates in Table 6.2 by:

1. $\hat{\eta}_{Men, No\ disease} = \alpha_{Men} = 0.07$
2. $\hat{\eta}_{Men, Stroke} = \alpha_{Men} + \beta_{Stroke} = 0.07 + 0.66 = 0.73$
3. $\hat{\eta}_{Men, Arthritis} = \alpha_{Men} + \beta_{Arthritis} = 0.07 + 0.20 = 0.27$
4. $\hat{\eta}_{Men, Stroke, Arthritis} = \alpha_{Men} + \beta_{Stroke} + \beta_{Arthritis} = 0.07 + 0.66 + 0.20 = 0.93$

In groups 2 to 4, competing risks of disability exist, as the overall cumulative rate of disability is estimated based on more than one cause. It is important to notice that the cumulative rate of disability for background is the same in all groups ($\alpha_{Men} = 0.07$) and that the overall cumulative rate of disability is the sum of the cumulative rates of disability for background and for each disease, i.e. the model is additive. Since the interpretation of the cumulative rate of disability is easier on a probability scale, we convert the overall cumulative rate of disability to the estimated probability of being disabled (\hat{y}) by using the exponential function:

$$\begin{aligned} 1. \quad \hat{y}_{Men, No\ disease} &= 1 - \exp(-\hat{\eta}_{Men, No\ disease}) \\ &= 1 - \exp(-0.07) = 0.07 \end{aligned}$$

2. $\hat{y}_{Men, Stroke} = 1 - \exp(-\hat{\eta}_{Men, Stroke})$
 $= 1 - \exp(-0.73) = 0.52$
3. $\hat{y}_{Men, Arthritis} = 1 - \exp(-\hat{\eta}_{Men, Arthritis})$
 $= 1 - \exp(-0.27) = 0.24$
4. $\hat{y}_{Men, Stroke, Arthritis} = 1 - \exp(-\hat{\eta}_{Men, Stroke, Arthritis})$
 $= 1 - \exp(-0.93) = 0.61$

According to the results above, men without any reported disease had 7% probability or risk of being disabled, while the probability of being disabled in men who reported stroke was 52%, in men who reported arthritis was 24%, and in men who reported stroke and arthritis was 61%.

The probability of being disabled by cause (\hat{B} , for background; \hat{D}_{Stroke} , for stroke; $\hat{D}_{Arthritis}$, for arthritis; and $\hat{D}_{Stroke, Arthritis}$, for stroke and arthritis) can be obtained by:

1. For men without any diseases:

$$\begin{aligned} \hat{B}_{Men, No\ disease} &= \frac{\alpha_{Men, No\ disease}}{\hat{\eta}_{Men, No\ disease}} \\ &\times \hat{y}_{Men, No\ disease} = \frac{0.07}{0.07} \times 0.07 = 0.07 \end{aligned}$$

2. For men with stroke:

$$\begin{aligned} \hat{B}_{Men, Stroke} &= \frac{\alpha_{Men, Stroke}}{\hat{\eta}_{Men, Stroke}} \\ &\times \hat{y}_{Stroke} = \frac{0.07}{0.73} \times 0.52 = 0.05 \\ \hat{D}_{Men, Stroke} &= \frac{\beta_{Men, Stroke} (X_{Stroke})}{\hat{\eta}_{Stroke}} \\ &\times \hat{y}_{Stroke} = \frac{0.66(1)}{0.73} \times 0.52 = 0.47 \end{aligned}$$

3. For men with arthritis:

$$\begin{aligned} \hat{B}_{Men, Arthritis} &= \frac{\alpha_{Men, Arthritis}}{\hat{\eta}_{Men, Arthritis}} \\ &\times \hat{y}_{Arthritis} = \frac{0.07}{0.27} \times 0.24 = 0.06 \end{aligned}$$

$$\hat{D}_{Men,Arthritis} = \frac{\beta_{Men,Arthritis}(X_{Arthritis})}{\hat{\eta}_{Arthritis}}$$

$$\times \hat{y}_{Arthritis} = \frac{0.20(1)}{0.27} \times 0.24 = 0.18$$

4. For men with stroke and arthritis:

$$\hat{B}_{Men,Stroke,Arthritis} = \frac{\alpha_{Men,Stroke,Arthritis}}{\hat{\eta}_{Men,Stroke,Arthritis}}$$

$$\times \hat{y}_{Stroke,Arthritis} = \frac{0.07}{0.93} \times 0.61 = 0.05$$

$$\hat{D}_{Men,Stroke} = \frac{\beta_{Men,Stroke}(X_{Stroke})}{\hat{\eta}_{Men,Stroke,Arthritis}}$$

$$\times \hat{y}_{Stroke,Arthritis} = \frac{0.66(1)}{0.93} \times 0.61 = 0.43$$

$$\hat{D}_{Men,Arthritis} = \frac{\beta_{Men,Arthritis}(X_{Arthritis})}{\hat{\eta}_{Men,Stroke,Arthritis}}$$

$$\times \hat{y}_{Stroke,Arthritis} = \frac{0.20(1)}{0.93} \times 0.61 = 0.13$$

Thus, the probability of being disabled in men who did not report any disease is 7% and this probability is all attributed to background, which can represent the age effect, for example. In men who reported only stroke, the disability probability due to stroke is 47% and in men who reported only arthritis, the disability probability due to arthritis is 18%. However, if we look at the results of the last group – men who reported both, stroke and arthritis – we can see that the probability of being disabled due to stroke is 43% and due to arthritis is 13%. This example shows that: (1) the background contributes to the disability probability in all four groups; (2) the cause-specific disability probabilities (\hat{B} and \hat{D}) sum to the total disability probability (\hat{y}) within each group; and (3) the probability of being disabled due to background (\hat{B}_{Men}), stroke ($\hat{D}_{Men,Stroke}$), and arthritis ($\hat{D}_{Men,Arthritis}$) differed across groups, although the cumulative rates of disability were identical in each of the four groups that included the respective disease. That is, in all four groups $\alpha_{Men} = 0.07$, in the two groups that reported stroke $\beta_{Stroke} = 0.66$ and in the two groups that reported arthritis,

$\beta_{Arthritis} = 0.20$. The explanation for these differences can be seen in the formulas used to define the cause-specific probabilities (\hat{B} and \hat{D}), as these probabilities depend on the overall cumulative rate of disability ($\hat{\eta}$) and the total probability of being disabled (\hat{y}). Here, we can clearly see that the probability of being disabled due to one disease depends on the presence of other diseases and background, i.e. multimorbidity is taken into account, which is analogous to the mortality analysis of competing risks (Chiang 1961; Manton and Stallard 1984).

The interpretation of the cumulative rates of disability in the multinomial model is similar to the binomial model. As an illustration, let's look at the results for severe disability in four groups of women, according to Table 6.3: (1) women without any reported diseases (*No disease*); (2) women who reported only stroke (*Stroke*); (3) women who reported only diabetes (*Diabetes*); and women who reported stroke and diabetes (*Stroke and diabetes*). The results for the overall cumulative rate of disability ($\hat{\eta}_j$), the total probability of being disabled (y_j), and the cause-specific disability probabilities (\hat{B}_j and \hat{D}_j) for mild (disability category $j = 2$) and severe (disability category $j = 3$) disability are summarized in Table 6.4.

The main difference between the binomial and multinomial models is the estimation of the total probability of being disabled, in our case, of being severely disabled ($\hat{y}_{j=3}$). To ensure that valid probabilities will be obtained for all three categories of the outcome (no disability, mild, and severe), this calculation depends not only on the overall cumulative rate of disability of women with severe disability ($\hat{\eta}_{j=3}$), but also on the overall cumulative rate of disability in women with mild disability ($\hat{\eta}_{j=2}$), as can be seen in the definition of the multinomial model (Eq. 6.2).

According to Table 6.4, women who did not report any disease had 3% risk of being severely disabled. This probability was 22% in women who reported only stroke, 8% in women who reported only diabetes, and 26% in women who reported diabetes and stroke. In women without any reported disease, the probability of being severely disabled is fully attributed to back-

Table 6.4 Overall cumulative rate of disability ($\hat{\eta}_j$), total probability of being disabled (\hat{y}_j), and cause-specific disability probabilities (\hat{B}_j and \hat{D}_j) in women with severe disability

| Group | Mild disability ($j = 2$) | | | | $\sum_c \hat{\eta}_j$ | Severe disability ($j = 3$) | | | | | | | |
|---------------------|-----------------------------|------------------|--------------------|--------------|-----------------------|-------------------------------|------------------|--------------------|--------------|-----------|-----------|--------------------|------|
| | α | β_{Stroke} | $\beta_{Diabetes}$ | $\hat{\eta}$ | | α | β_{Stroke} | $\beta_{Diabetes}$ | $\hat{\eta}$ | \hat{y} | \hat{B} | \hat{D}_{Stroke} | |
| No disease | 0.05 | 0 | 0 | 0.05 | 0.08 | 0.03 | 0 | 0 | 0.03 | 0.03 | 0.03 | 0 | 0 |
| Stroke | 0.05 | 0.14 | 0 | 0.19 | 0.47 | 0.03 | 0.25 | 0 | 0.28 | 0.22 | 0.02 | 0.20 | 0 |
| Diabetes | 0.05 | 0 | 0.07 | 0.12 | 0.21 | 0.03 | 0 | 0.06 | 0.09 | 0.08 | 0.03 | 0 | 0.05 |
| Stroke and diabetes | 0.05 | 0.14 | 0.07 | 0.26 | 0.60 | 0.03 | 0.25 | 0.06 | 0.34 | 0.26 | 0.02 | 0.19 | 0.05 |

ground ($\hat{y} = \hat{B} = 0.03$). As in the binomial case, the cause-specific probabilities sum to the total probability of being severely disabled, e.g. in the group of women with self-reported stroke, the probability of being severely disabled due to background ($\hat{B} = 0.02$) and stroke ($\hat{D}_{Stroke} = 0.20$) sum to the total disability prevalence ($\hat{y} = 0.22$). Multimorbidity is also taken into account in the multinomial case, as can be seen by the differences in the cause-specific disability probabilities ($\hat{B}, \hat{D}_{Stroke}$, and $\hat{D}_{Diabetes}$) across groups even though the cumulative rates of disability ($\alpha = 0.03, \beta_{Stroke} = 0.25, \beta_{Diabetes} = 0.06$) were identical in each of the groups that included the respective cause.

Independence Assumption

In the previous section, we showed that even under the independence assumption (no interaction between diseases), the binomial and multinomial additive hazard models take multimorbidity into account. Tests for the violation of this assumption can be represented by including interactions between diseases. In the example for the binomial model, independence could be tested by including an interaction term between stroke and arthritis in the model for men with stroke and arthritis. Suppose this interaction was estimated and was significant ($\beta_{Stroke * Arthritis} = 1.1$). Now the overall cumulative rate of disability ($\hat{\eta}$) is not only the sum of the background and

main effects of these two diseases, but also includes an additional effect due to the disease co-occurrence of stroke and arthritis ($\beta_{Stroke * Arthritis}$):

$$\begin{aligned}\hat{\eta}_{Men, Stroke, Arthritis} &= \alpha_{Men} + \beta_{Stroke} + \beta_{Arthritis} \\ &+ \beta_{Stroke * Arthritis} = 0.07 + 0.66 + 0.20 + 1.1 = 2.03\end{aligned}$$

We can estimate the total disability probability (\hat{y}) by:

$$\begin{aligned}\hat{y}_{Men, Stroke, Arthritis} &= 1 - \exp(-\hat{\eta}_{Men, Stroke, Arthritis}) \\ &= 1 - \exp(-2.03) = 0.87\end{aligned}$$

Note that the probability of being disabled in men who reported stroke and arthritis increases to 87%. The cause-specific disability probabilities (\hat{B} and \hat{D}) can be obtained by:

$$\begin{aligned}\hat{B}_{Men, Stroke, Arthritis} &= \frac{\alpha_{Men}}{\hat{\eta}_{Men, Stroke, Arthritis}} \\ &\times \hat{y}_{Men, Stroke, Arthritis} = \frac{0.07}{2.03} \times 0.87 = 0.03 \\ \hat{D}_{Men, Stroke} &= \frac{\beta_{Men, Stroke}(X_{Stroke})}{\hat{\eta}_{Men, Stroke, Arthritis}} \\ &\times \hat{y}_{Men, Stroke, Arthritis} = \frac{0.66(1)}{2.03} \times 0.87 = 0.28 \\ \hat{D}_{Men, Arthritis} &= \frac{\beta_{Men, Arthritis}(X_{Arthritis})}{\hat{\eta}_{Men, Stroke, Arthritis}} \\ &\times \hat{y}_{Men, Stroke, Arthritis} = \frac{0.20(1)}{2.03} \times 0.87 = 0.08\end{aligned}$$

$$\hat{D}_{Men, Stroke*Arthritis} = \frac{\beta_{Men, Stroke*Arthritis} (X_{Stroke} X_{Arthritis})}{\hat{\eta}_{Men, Stroke, Arthritis}} \\ \times \hat{y}_{Men, Stroke, Arthritis} = \frac{1.1(1)(1)}{2.03} \times 0.87 = 0.47$$

In the above example, a synergistic effect in the co-occurrence of stroke and arthritis is observed, as a positive disabling impact was obtained for the interaction between these two diseases. In other words, the combination of stroke and arthritis results in a higher disability probability than is expected by the individual disease effects. An example of the violation of the independence assumption in the attribution method has been published using the Belgian cross-sectional data (Yokota et al. 2016c). A similar interpretation can be obtained for the multinomial model with significant interaction terms.

Previous Applications of the Attribution Method

The attribution method has been widely used since it was developed, either to assess the contribution of diseases to disparities in health expectancies or years lived with disability, or to assess the contribution of diseases to the disability prevalence. In this Section we present the main characteristics and results of previous studies that have applied the method.

Contribution of Diseases to Gender and Education Disparities in Health Expectancies

The attribution method was first applied to gender differences in disability-free life expectancy in the Netherlands in combination with decomposition analyses with findings that the largest contributions came from non-fatal diseases, such as arthritis and back complaints (Nusselder and Loosman 2004) (Table 6.5). In addition, fatal diseases, such as heart disease, stroke and chronic obstructive pulmonary diseases (COPD) not only

caused death, but were also associated with disability. In women, this was also observed for diabetes mellitus. At that time, an unexpected finding was the large contribution of background, which was labelled as *causes not attributable to reported diseases*. The study focused on gender differences, showing that cause-specific disability from arthritis, diabetes mellitus and back complaints as well as from background were higher in women than in men. The use of these cause-specific disability data in the decomposition analyses indicated that arthritis contributed most to women's longer life expectancy with disability.

The second application of the method was also part of a study on health expectancy disparities, namely educational differences in disability-free life expectancy in Belgium (Nusselder et al. 2005). This study confirmed that largest contributions came for arthritis, back complaints, and heart diseases with higher disability prevalence from arthritis and back complaints observed in women compared to men. In addition, highly educated individuals had both a lower disease prevalence for most diseases and a lower disabling impact for cancer, arthritis, heart disease/stroke, back complaints (only men), and asthma/COPD (only women) compared to the low educated population. Back complaints (men) and arthritis (women) contributed most to the educational difference in years with disability.

Contribution of Diseases to Disparities in Years Lived with Disability

The third application focused on the contribution of chronic diseases to the prevalence of disability and years lived with disability among men and women in the Netherlands (Klijns et al. 2011). Here the focus was not on the contribution of diseases to *differences* by gender or education in the number of years with disability, but rather on the contribution of diseases to years lived with disability. The number of years lived with disability was decomposed into the contribution from different diseases, showing the largest contribution

Table 6.5 Use of the attribution method in prior studies

| Country | Population | Disability measure | Main contributors | Main contributors to disparity | Publication |
|--------------------|--|---|--|--|-------------------------------------|
| Netherlands | Men and women; 15+ | OECD ^a disability indicator | Arthritis, back pain, heart diseases, COPD ^b (men), diabetes (women) | Gender: arthritis, diabetes, back pain | Nusselder and Loosman (2004) (2) |
| Belgium | Educational groups; males and women; 30+ | Functional limitations in mobility | Arthritis, back complaints, heart diseases | Education: men: back pain, heart diseases; women: asthma/COPD | Nusselder et al. (2005) (16) |
| Netherlands | Men and women; 55+ | ADL ^c disability | Musculoskeletal diseases (arthritis, back pain, neck/arm), stroke, heart diseases | – | Klijns et al. (2011) (1) |
| Germany | Men and women; 65+ | HAQ-DI ^d indicator | Joint diseases, eye diseases, heart diseases | – | Strobl et al. (2013) (21) |
| Netherlands | Educational groups; males and women; 40+ | OECD ^b disability indicator | Musculoskeletal diseases (arthritis, back pain, neck/arm), stroke, heart diseases | Education men: back pain, neck and arm conditions, peripheral vascular diseases; women: arthritis, back pain, nonspecific lung disease | Klijns et al. (2014) (18) |
| Belgium | Men and women; 15+ | ADL disability and mobility limitations | Musculoskeletal, cardiovascular and respiratory diseases | – | Yokota et al. (2015a, b) (17) |
| Belgium | Men and women; 15+ | ADL and mobility limitations (separated into mild and severe) | Men: mild disability: back pain Men: severe disability: chronic respiratory diseases Women: mild and severe: arthritis | – | Yokota et al. (2015a, b) (20) |
| Belgium | Smokers and non-smokers; 40–60 years | ADL disability | Musculoskeletal diseases, depression, chronic respiratory diseases | Smokers men: cardiovascular diseases and chronic respiratory diseases Smokers women: cardiovascular diseases and depression | Yokota et al. (2016a, b, c, d) (19) |
| Brazil | Males and women; 60+ | ADL & IADL ^e | Back pain, diabetes, heart disease (men), arthritis (women) | – | Yokota et al. (2016a, b, c, d) (7) |
| Brazil and Belgium | Men and women; 65+ | ADL | Musculoskeletal conditions (men and women, moderate and severe, Belgium and moderate, Brazil), depression (men, severe, Brazil) and heart diseases (women, severe, Brazil) | – | Yokota et al. (2017b) |

(continued)

Table 6.5 (continued)

| Country | Population | Disability measure | Main contributors | Main contributors to disparity | Publication |
|---------|--------------------|--------------------|---|--|-------------------------|
| France | Men and women, 50+ | GALI | Musculoskeletal, heart diseases (men), anxiety-depression (women) | Women: musculoskeletal diseases and anxiety-depression Men: heart diseases, peripheral vascular disease and accidents | Nusselder et al. (2018) |

^aOECD Organization for Economic Cooperation and Development

^bCOPD Chronic obstructive pulmonary diseases

^cADL Activities of Daily Living

^dHAQ-DI Health Assessment Questionnaire Disability Index

^eIADL Instrumental Activities of Daily Living

from musculoskeletal diseases (including arthritis, back complaints, and disorders of neck and arm), cardiovascular diseases, and background. Within musculoskeletal and cardiovascular conditions, back pain, peripheral vascular disease and stroke contributed mainly through their high disabling impact while arthritis and heart diseases were less disabling but contributed most through their high prevalence.

Contribution of Diseases to the Disability Prevalence

Most of the more recent studies applied the method to investigate the contribution of diseases to the disability prevalence. Some of these studies focus on disparities, for instance between men and women (Nusselder et al. 2018; Yokota et al. 2015a, 2016a), educational groups (Klijns et al. 2014), and across smoking categories (Yokota et al. 2016b). All studies used a binary disability outcome (non-disabled and disabled), one study separately assessed the contribution for mild and severe disability, but still using the binomial additive hazard model (Yokota et al. 2015b), and one study investigated the contribution of diseases to moderate and severe functional limitations in Belgium and in Brazil (Yokota et al. 2017a, b).

Comparison of the findings of these studies is limited due to differences in the disability definition, chronic conditions included in the analyses,

and age range included in the study. Despite these differences, musculoskeletal conditions and cardiovascular diseases were among the main contributors. Apart from Brazil, chronic respiratory diseases also had an important contribution. Cancer was not an important contributor to the prevalence of disability in any of the studies.

Regarding gender and educational differences, both the disease prevalence and the disabling impacts explained differences between the groups. The study of Klijns (Klijns et al. 2014) compared these effects on educational disparities in the disability prevalence and found that variations in the disabling impact were more important than the disease prevalence.

Similar to previous findings with binary disability outcomes, the results of the application of the multinomial additive hazard model to the Brazilian and Belgian data highlighted the burden of musculoskeletal conditions in Belgium for moderate and severe disability and in Brazil for moderate disability. Depression and heart disease contributed most to severe disability in men and women in Brazil, respectively.

Alternative Methods

The attribution method should be distinguished from the population attributable fraction (PAF) based on the relative risk (RR) and the outcome prevalence; the PAF based on the counterfactual approach; the average attributable fraction (AAF)

based on logistic regression; and the years lived with disability (YLD) from the Global Burden of Disease (GBD) study.

The PAF can be obtained in two ways. First, it can be estimated using information on the RR and outcome prevalence (in our case, disability), using the formula:

$$\text{PAF} = \frac{\text{prevalence} \times (\text{RR} - 1)}{[\text{prevalence} \times (\text{RR} - 1)] + 1} \quad (6.3)$$

To control for other causes and confounders, the adjusted RR can be used. In cases where the RR is not available, the OR can be used as an approximation of the RR if the outcome is rare. However, the latter is generally not true for disability, especially in older populations. The sum of PAFs across multiple causes may exceed 100%.

A second method to obtain the PAF using available cross-sectional data, using logistic regression but avoiding using the OR as an approximation for the RR, is the counterfactual approach. In this method, a logistic regression is fitted with disability as the outcome and all diseases of interest as predictors. This model is then used to predict the total number of cases that would have been observed in the dataset under the counterfactual scenario that no individual had the disease of interest. This approach has been previously used and is appropriate to obtain cause-deleted health expectancies (Nusselder et al. 1996). Similar to the PAF based on the RR and outcome prevalence, the sum of cause-specific PAFs based on the counterfactual approach can exceed 100%.

To overcome the limitation that the PAFs for each cause can add up to more than 100%, the average attributable fraction (AAF) method was developed (Eide 2008; Eide and Gefeller 1995; Ferguson et al. 2018; Ruckinger et al. 2009). The attributable fractions are obtained by including two additional steps: (1) calculation of sequential attributable fractions (SAFs) based on logistic regression, which represent the additional proportion of the original prevalence that can be eliminated by removing a disease, after having removed other diseases in a specific sequence;

(2) averaging the SAFs to avoid that the order of elimination affects the results. The AAFs are additive and interpreted as attributable fractions adjusted for other risk factors and confounders. The AAF was used by Palazzo et al. (Palazzo et al. 2012) to assess the contribution of diseases to disability in France.

In the disability context, both the PAF and AAF quantify the proportional reduction in disability if the diseases could be somehow eliminated from the population. In the demographic field, the analysis of multiple causes of death distinguishes between multi-decrement and cause-elimination analyses. In multi-decrement analyses the probability of dying from a specific cause in the situation where multiple causes of death act simultaneously (competing risk) also known as *crude probability*, is used (Nusselder and Looman 2004). These causes add up to the probability of dying from all causes and thus, can be used to assess the contribution of each cause to the total mortality. Cause-elimination methods estimate the gain that would be obtained by eliminating a specific cause. In the presence of competing causes, there is an overlap between exposures. For example, in a situation of only two causes *A* and *B*, after elimination of cause *A*, all persons who were exposed to cause *B* including those exposed to both *A* and *B*, remain at risk to die from cause *B*. Similarly, after elimination of cause *B*, all persons who were at risk to die from cause *A*, including those who are exposed to *A* and *B*, remain at the risk to die from cause *A*. This implies that adding the probability of dying after deletion of cause *A* and the probability of dying after deletion of cause *B* yields a probability that exceeds the probability of dying from all causes. In other words, these probabilities are not additive. The PAF based on the counterfactual approach is a cause-elimination analysis. Multiple efforts have been undertaken in the literature to solve the non-additivity (Llorca and Delgado-Rodriguez 2004; McElduff et al. 2002) of which the AAF method was used to study the contribution of diseases to disability. By calculating SAFs and averaging these, is a way to deal with common exposures; the AAF method becomes a mixture of both approaches.

The GBD followed a more complex approach to obtain disease-specific contributions to the disability burden. While the attribution method, PAF, and AAF start from all-cause disability to assess how much each disease contributes to the disability prevalence, the GBD starts from individual sequelae due to diseases and injuries combined with information on cause-specific disability weights to derive a different metric of population health, years lived with disability (YLD). In the GBD terminology, disability is used broadly to refer to departures from optimal health in any health domains and is not related to the definition of disability as given in the International Classification of Functioning, Disability and Health (ICF) (World Health Organisation 2001). Disability weights are used to quantify the severity of disease sequelae and are based on survey responses of the general population (Vos et al. 2012).

Strengths and Limitations of the Attribution Method Compared to Other Methods

The attribution method has some limitations that should be acknowledged, and most of the limitations are related to the use of cross-sectional data. A causal relationship between disease and disability is assumed in the attribution method. Although this assumption is plausible according to the disablement model proposed by Verbrugge and Jette (Verbrugge and Jette 1994), causality cannot be assessed with cross-sectional data. This implies that disability is incorrectly attributed to diseases in cases where disability onset preceded disease onset. Applying the PAF based on the RR from prospective studies could avoid this limitation, but these RR are currently not available. PAF based on the counterfactual approach, AAF based on cross-sectional data, and the GBD have the same limitations.

Another drawback of the attribution method is that the control for confounders is only meaningful if the contributions are stratified by the confounders' levels. Factors such as age, gender or

socioeconomic status can be included in the background hazard and/or the disabling impact using interaction terms. As the full age-interaction term would require many parameters (i.e. the number of age groups times the number of diseases), reduced rank regression can be used to reduce the number of parameters, or broader age groups for the interaction terms can be used (Yee and Hastie 2003).

The assumption that disability is an absorbing state, i.e. like death, individuals with disability cannot recover, is more likely to be violated for mild disability, as a high recovery rate has been previously reported in older individuals with mild limitations in ADLs (Hardy and Gill 2004).

A final limitation is related to the interpretation of the disabling impacts of diseases, as they represent a cumulative rate (disease-specific cumulative rate of disability). The disabling impacts represent the cumulative rate of disability among the individuals with each specific disease (Verbrugge et al. 1989). Therefore, it is not a probability, i.e. it is not restricted to the interval [0, 1], but can range between $-\infty$ to $+\infty$. The interpretation is easier on the probability scale, as discussed previously and as included in table notes or web-appendices of previous publications (Klijn et al. 2011; Yokota et al. 2016b). The AAF presents odds ratios which are generally used, but these cannot be interpreted as disabling impacts.

The attribution method has several strengths. First, the concept of background, which represents disability causes not included in the analysis, can be considered an advantage compared to the alternative approaches, as different from mortality, where each death is assigned a cause, survey data does not cover all potential causes of ill-health. Second, the method is based on the additive hazard model, allowing the partition of the total disability prevalence into the additive contribution of background and diseases, i.e. the contribution of each disease and the background sum to the total disability prevalence, as observed in Figs. 6.2 and 6.3. The additive property of the method facilitates the interpretation of the results. The PAF methods do not yield additive contributions. In the AAF approach, the calculation of SAFs and their average avoids this. The resulting

AAFs are additive in the sense that the sum of cause-specific attributable fractions equals the combined attributable fraction of all diseases, but do not sum to 100%. The difference is the part explained by causes not included in the model, analogous to the background contribution in the attribution method.

A third strength related to using an additive hazard model is that the method takes multimorbidity into account in a transparent way, even under the independence assumption between diseases. Accounting for multimorbidity, or more in general for competing risks, is an important advantage relative to the PAF based on the RR. PAFs based on the counterfactual approach with disability as the outcome and all diseases of interest as predictors do not yield contributions that add to 100% because of overlap in exposure. The AAF corrects for the consequence of competition between the diseases, but does not correct for the competition between background and diseases (Eide and Gefeller 1995). In the attribution method, the background is treated as a competing cause of disability as it can represent unreported diseases. This difference relates to the purpose of AAF which is to help assessing the impact of preventing a cause. It fits conceptually in the cause-elimination perspective. In the attribution method the independence assumption can be easily avoided by including interaction terms between diseases in the additive hazard models, being limited by sample size restrictions. In the AAF approach it is not straightforward to include disease interactions, as depending on the number of diseases considered, it can be a computer-intensive task. The GBD first adjusts the healthy life expectancy estimates for multimorbidity assuming independence between conditions; later, dependent multimorbidity is also taken into account (World Health Organization 2013).

A fourth strength is that the disease-specific cumulative rates of disability, which quantify the disabling impacts, can vary by age and other confounders. By including the interactions between diseases and age in the model, or by using more parsimonious methods, such as reduced rank

regression (Yee and Hastie 2003), disabling impacts can vary by age and other confounders, such as educational attainment or gender. The GBD assumes that the disability weights apply to all ages, both genders, and all populations. No applications of the AAF with age interactions have been published, to our knowledge. While it is not easy to include interactions between age and diseases in the AAF, it allows the inclusion of age and other covariates as confounders in the logistic model.

A strength especially related to health expectancy estimation based on cross-sectional data is that the same disability measure can be used in the decomposition analysis, ensuring consistency of measures. In practice it is virtually impossible to obtain the RR for all diseases. Even if they would be available they would, most likely, be based on a different disability measures. The attribution method uses the same measure.

Finally, a practical strength of the attribution method is that the software to fit the models and to estimate the contribution of diseases to the disability prevalence is publicly available in R for non-experienced-R users (upon request by the authors) and for R users with the R package *addhaz* (Yokota et al. 2016d). Both provide confidence intervals with bootstrapping. The AAF is also available in R with the R package *averisk* (Ferguson et al. 2018), Stata, and SAS (Ruckinger et al. 2009).

Concluding Remarks

In the context of health expectancies, the attribution of causes to disability has helped to identify which diseases contribute most to disparities in life expectancy with(out) disability across specific subgroups (men and women, socio-economic groups) and to identify which diseases contribute most to years with disability in a specific population or period. Increasingly, the attribution method has expended its use beyond health expectancies, e.g. to obtain insights in the contribution of specific chronic conditions to the disability burden.

The main advantage of this approach is that it allows partitioning of the disability prevalence into the additive contribution of diseases taking into multimorbidity and that disability can be present even in the absence of measured disease. Another important advantage is the possibility to identify variations in contributions of specific diseases in terms of disease prevalence and disabling impact. These variations may refer to different determinants and different interventions are applicable to target disease prevalence and disabling impact. The approach uses cross-sectional data, which is an advantage in terms of general data availability and representativeness, but at the same time a major drawback, as causality cannot be established.

The studies that applied the attribution method have yielded different insights, including:

- non-fatal diseases such as arthritis, conditions of the arm, neck and back diseases, which are unnoticed in cause-of-death analyses, yield important losses in disability-free life expectancy and disparities between men and women and socioeconomic groups;
- persons without any (reported) diseases may report disability, implying that these unmeasured causes are also an important contributor to disability in persons with one or more diseases;
- the largest contributors to disability are not necessarily diseases with high disabling impacts, but also diseases with moderate disabling impact and high prevalence;
- disabling impacts of diseases vary between men and women, by age, socio-economic groups, and smoking categories;
- disability not associated with any (measured) diseases (background) varies by age;
- competition between diseases affects the contribution of the diseases and cannot be neglected.

These insights have direct relevance for public health and for the method specifications. For the purpose of studying the contribution of diseases

to disability, important features are that the method:

- allows for binary and multinomial disability outcomes;
- takes into account other reported diseases (multimorbidity);
- takes into account explicitly the disability that cannot be attributed to diseases (background);
- takes into account competition between all causes: diseases and background;
- provides the contribution of each disease and background;
- adds to the total disability prevalence;
- allows background (unspecified diseases) to vary by age and population;
- allows the disabling impact to vary by age and population;
- allows a better understanding of the underlying reasons why a disease contributes differently to the disability burden in two populations: (1) due to the high disease prevalence; (2) due to the high disabling impact; (3) or due to both;
- allows use of the results in the decomposition of differences in health expectancies by causes of disability between two populations.

Suggestions for Future Analyses

The attribution method was developed to attribute disability to diseases based on cross-sectional data. The method can be applied to other health outcomes than disability, such as self-assessed health. However, the assumption that the causes were present before or at the time of the onset of the health outcome may be more problematic in other applications. Within the theory of the disablement process the assumption that diseases causes disability is reasonable, but it will be violated if disability causes a disease (reverse causation). For other health outcomes, such as self-perceived health, the link between diseases and the outcome may be weaker and less grounded in theory.

The use of lifestyle risk factors, such as physical inactivity, alcohol consumption, as causes of disability instead of diseases is even more prone to reverse causation than diseases. For instance, physical inactivity can be the result of disability or ill-health. Whether the method should be used for risk factors also largely depends on the alternatives available and their limitations. Given the scarcity of data on relative risks from prospective studies and the challenge of finding relative risks for similar disability measures, the attribution method may still be useful to complement other approaches, such as assuming similar RR for disability, as reported for mortality. It might also be of interest to extend the method to longitudinal data, as several assumptions would not be required – causality, stationarity, and disability as an absorbing state, although the model will become more complex, as transition rates between all different states will need to be estimated.

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Decomposing Gaps in Healthy Life Expectancy

7

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Introduction

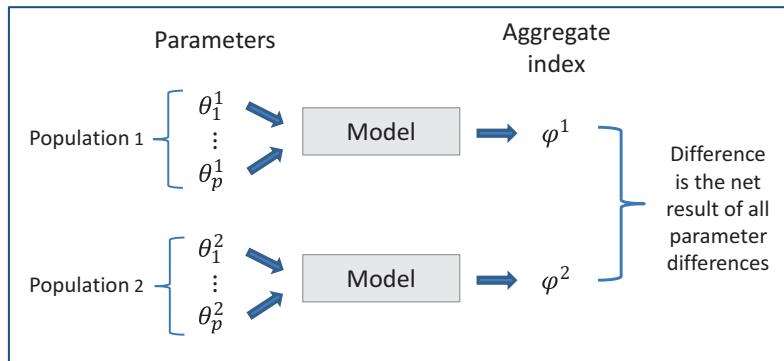
Decomposition is a widely used tool to explain gaps in demographic indices by the underlying changes or differences in its components. Decompositions can be performed either between two populations at a similar time period (a between-population decomposition) or within one population between two time periods (a within-population decomposition). In both cases the central aim, or decomposition problem, is to attribute the difference in an aggregate index into the contribution of differences in the underlying parameters, of the two populations being examined.

In Box 7.1, we present the decomposition problem at its most basic. We start with a set of parameters $\theta_1, \dots, \theta_p$, in each of populations 1 and 2. The parameter vector could take the form of rates, probabilities, population composition, or a combination of forms. These parameters are taken as input to a model, which produces an aggregate index, φ , as output. The model used to calculate φ could for instance be a simple formula, a lifetable, or a multistate model, but must be the same for both populations. Finally φ itself

could be any aggregate index including life expectancy, healthy life expectancy, the crude death rate, an index of lifespan variation, or any other metric which can be expressed as a function of its parameters. The difference in φ is the net result of all parameter differences included in the model. The decomposition problem is how to estimate the contribution of these input parameters to the gap in the aggregate index between populations 1 and 2.

An important feature of any decomposition is that the effects of the parameters are additive, even if the aggregate index itself is not an additive function of the parameters. It is also important to recognize that a larger relative or absolute difference in any given parameter does not necessarily translate into a larger contribution of that parameter to the final difference in φ . This is because indices differ in their sensitivities to the underlying parameters (Keyfitz 1977; Vaupel 1986; van Raalte and Caswell 2013; Caswell 2008). For example, imagine populations 1 and 2 had larger differences in death rates at age 100, but smaller differences in death rates at age 75, and we wish to understand which age was contributing more to the life expectancy gap. The size of the difference in these age-specific rates between the two populations alone does not allow us to know which of the two ages were contributing more to the life expectancy gap. In fact, since more deaths generally occur at age

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Box 7.1 The decomposition problem. (Graphic adapted from Caswell (1996))

75 and since saving the life of an 75 year-old leads to more future years of life gained, life expectancy tends to be far more sensitive to mortality change at age 75 than at age 100. In this case, the smaller difference in death rates at age 75 compared to age 100 could have a larger impact on the overall life expectancy difference, but we would need to decompose this gap in life expectancy into its age-specific contributions to be certain.

In the following, we discuss the developments of decomposition analysis as a tool for understanding demographic change or difference, with an emphasis on its applications in mortality research. We then turn our attention to the description of the step-wise and continuous change methods of decomposition. These are general tools applicable to the decomposition of differences in any aggregate index of mortality, including gaps in healthy life expectancy. We then demonstrate how to decompose healthy life expectancy, with either method, using the newly developed DemoDecomp package (Riffe 2018) in the open-source R statistical software program.

Developments in Decomposition Analysis

Decomposing Change in an Aggregate Index into Direct Versus Compositional Change

The earliest decomposition methods used in Demography aimed to distinguish the role of direct changes in rates from compositional

change in the population (Kitagawa 1955; Das Gupta 1978, 1994). For example, if the crude death rate was increasing in the population these methods could distinguish whether the increased crude death rate was owing to increases in age-specific mortality (direct change) or to an older age structure of the population (compositional change), with individuals more highly concentrated over ages with higher mortality. These methods were designed in discrete time for linear functions such as crude rates, i.e. functions that are the sum of their underlying parameters. These aims were revisited by Vaupel and Canudas-Romo in a decomposition framework developed in continuous time, with a broadened set of applications (Vaupel and Canudas Romo 2002, 2003).

Decomposing an Index into the Contribution of Its Covariates

A separate line of decomposition analysis does not concern itself with compositional differences in group membership, but rather seeks to quantify the contribution of different covariates to the change in an aggregate measure. Age is the most commonly examined covariate in this framework, but decomposition analysis can be applied to other covariates for which the underlying rates are known, for instance the cause of death or the region where the death took place.

Quantifying the contribution of different age categories to gaps in life expectancy at birth is an example of this type of decomposition analysis. Life expectancy is a complicated function to

decompose because it is a non-linear function of its death rates. If we lower mortality in one age interval, we need to consider not only the change in person-years lived in that interval, but also the impact that the changed survival within this age interval has on subsequent ages.

A number of analytic solutions have been derived to do just that, either in discrete (Andreev 1982; Pressat 1985; Arriaga 1984) or continuous (Pollard 1982) time form. The logic behind the life expectancy decomposition can be seen by a close examination of the Arriaga (1984) formula. Arriaga splits the age-contributions into what he terms direct and indirect effects of mortality change.

The direct effects (DE) at each age x are as follows, with ℓ_a^1 being the number of survivors in population 1 at starting age a (e.g., for life expectancy at birth $a=0$), ℓ_x^2 referring to the survivors at age x in population 2, and T referring to the total person-years lived beyond age x or $x+n$, with n being the length of the age interval:

$$DE_x = \frac{\ell_x^1}{\ell_a^1} \left(\frac{T_x^2 - T_{x+n}^2}{\ell_x^2} - \frac{T_x^1 - T_{x+n}^1}{\ell_x^1} \right) \quad (7.1)$$

To interpret these direct effects, it is helpful to recall that $\frac{T_x - T_{x+n}}{\ell_x}$ is equivalent to the tempo

rary life expectancy between ages x and $x+n$, i.e. the expected number of years lived in the interval. Thus the direct effects of age-specific mortality change according to Arriaga are simply the proportion of survivors at each age multiplied by the change in the temporary life expectancy from that age to the subsequent age interval.

The indirect effects and interaction effects (IE) take into account the impact of the increased survivors from an age interval on subsequent age intervals, and is calculated as:

$$IE_x = \frac{T_{x+n}^2}{\ell_a^1} \left(\frac{\ell_x^1}{\ell_x^2} - \frac{\ell_{x+n}^1}{\ell_{x+n}^2} \right). \quad (7.2)$$

In the open-aged interval there are no indirect effects since there are no individuals surviving to subsequent ages. The total age-specific contributions to life expectancy change (C_x) are the sum

of the DE_x and IE_x terms, where all three terms are age vectors.

The three discrete formulas of Arriaga, Andreev and Pressat are equivalent, however Arriaga's version does not consider symmetry, which is the fact that small differences may occur depending on which population is considered population 1 or population 2 (Andreev et al. 2002). To get around this, Andreev and Pressat each proposed to run two decompositions, swapping the populations designated as 1 and 2, and averaging age-specific results over both directions.

More recently, researchers have decomposed other metrics of health and longevity, for instance indices of lifespan variation (Gillespie et al. 2014; Zhang and Vaupel 2009; Shkolnikov et al. 2003, 2011; van Raalte and Caswell 2013; Wilmoth and Horiuchi 1999). Like life expectancy these indices are non-linear functions, and some of these derivations are long and difficult to interpret. However with the general methods described in section “General formulations for decomposition problems”, decomposition of these indices is a relatively straightforward task.

Decomposition of Healthy Life Expectancy

Healthy life expectancy is another metric that has received increasing attention. Returning to the concepts introduced in Box 7.1, when calculated from prevalence data, the input parameters are vectors of age-specific mortality rates and age-specific health prevalence. When using incidence data, the input parameters would include the transition rates or probabilities between states of incidence, recovery and death. The model used to calculate healthy life expectancy from prevalence data could be either a life table (Sullivan 1971) or a Markov chain with rewards matrix model (Caswell and Zarulli 2018). With incidence data containing incidence, death and recovery rates or probabilities, a multistate model would be used (Rogers et al. 1989; Lievre et al. 2003). Regardless of whether prevalence or incidence data is used, the decomposition problem is to attribute the dif-

ference in healthy life expectancy between two populations into contributions from these input parameters.

For prevalence data, two decomposition formulas for splitting the contributions of healthy life expectancy into changing age-specific mortality and age-specific morbidity prevalence have been independently derived. Both are based on the Sullivan method of calculating healthy life expectancy and return similar age-specific contributions from changing mortality and disability (Andreev et al. 2002; Nusselder and Loosman 2004). A misunderstanding of the Nusselder and Loosman (NL) method has arisen concerning the age-specific contributions (Shkolnikov and Andreev 2017). If input vectors using only differences in person-years and changing disability prevalence are used (NL equations 4 and 5), the age-specific mortality contributions will be biased, because they do not account for how changes in person-years in one age group have come about from changes in survivorship from other age groups. Thus in applying the NL decomposition method, the full NL equations 4 to 11 must be used, which additionally account for these indirect mortality effects. A further advantage to the NL decomposition formulas is that they can additionally incorporate the contribution of causes of death.

General Formulations for Decomposition Problems

Deriving an analytic formula to decompose demographic functions is sometimes complex, and the end result are often formulas that do not lead themselves to easy interpretation. For this reason, researchers have increasingly turned to using general decomposition methods which do not require these derivations. To date, there are two main approaches, the step-wise decomposition algorithm and the continuous change (or line integral) method. Both methods are flexible and can be adapted to decomposing different summary measures.

Step-Wise Decomposition Method

Step-wise decomposition is a technique that has been used for many demographic applications and was first described in Andreev et al. (2002). From Arriaga's life expectancy decomposition, we know that when changing one parameter we must consider both the direct and indirect or interaction effects of that parameter on the aggregate index. Step-wise decomposition alters the parameters one element at a time, and after each step, recalculates the index function to estimate the parameter contribution.

A formal description of step-wise decomposition is given in Andreev et al. (2002) and Jdanov et al. (2017). This method can also be understood graphically. In Fig. 7.1 we illustrate the steps necessary to decompose life expectancy at birth for populations A and B with 4 age classes (Ages 0, 1, 2, 3).

In step 1, the age-specific death rates in each population are given by the vectors $M^A = \{m_0^A, m_1^A, m_2^A, m_3^A\}$ and $M^B = \{m_0^B, m_1^B, m_2^B, m_3^B\}$. From these death rates,

life expectancy at birth is e_0^A and e_0^B in the two populations. In step 2, we calculate the gap in life expectancy, i.e. $e_0^A - e_0^B$. In step 3, we first replace m_0^B with m_0^A , then re-calculate life expectancy in population B with this new mixed set of age-specific death rates. This new life expectancy is $e_0^{B'}$, and the contribution of age 0 to the life expectancy difference is $e_0^B - e_0^{B'}$. In steps 4–6, we step-wise replace death rates at ages 1, 2, and 3 respectively, and after each replacement step, recalculate the life expectancy at birth and estimate the contribution of the age interval as the difference in the most recently calculated life expectancy, and the life expectancy calculated in the previous step. After all ages have been replaced, the contribution of each age group to the life expectancy gap has been estimated. These age-specific contributions exactly sum to the gap in life expectancy calculated in step 2.

The estimated age contributions might differ slightly depending on which population is desig-

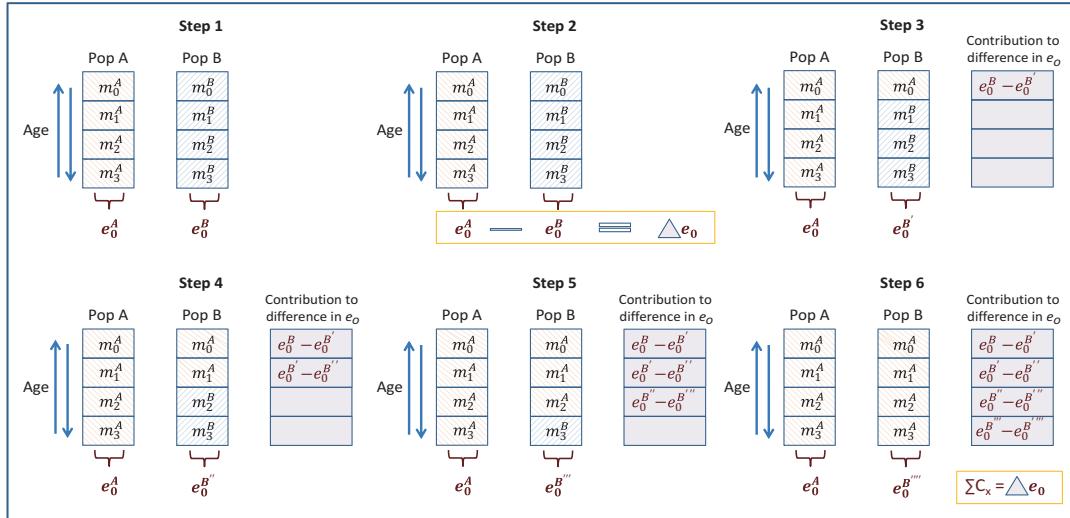


Fig. 7.1 A graphical depiction of the step-wise decomposition algorithm

nated as population A and which population as population B. Good practice is to run the decomposition twice, and to average the results. The replacement order is also a choice that must be made. In this example we used an age ordering from young to old. This guarantees that the contributions will be the same as those from the formulas of Andreev (1982) and Pressat (1985). But other age orderings are possible, for instance from older to younger ages, or a random replacement order. Theoretically all combinations should be computed and averaged, but with large numbers of age classes, this is not computationally possible. Experiments with samples of random replacements have shown that, at least for the case of life expectancy, the ordering of replacement steps for death rates does not make much of a difference to the final contributions (Andreev et al. 2002). It is less clear how to order these parameters when they are not in a logical ordering like age (for instance regional parameters), or if the parameters consist of several vectors such as causes of death, health prevalence, etc. In these cases it is recommended to experiment with different orderings to test the stability of the estimated contributions.

The example of Fig. 7.1 used life expectancy from all-cause mortality. This method can be extended to include other parameters or to calculate gaps in other summary metrics including

healthy life expectancy between populations A and B (or populations 1 and 2, from the notation used earlier). Returning to the concept of Box 7.1, we would need to extend our input vector of parameters, and to create a model (e.g. life table) that takes this vector of parameters as input and calculates the summary measure as output. In the case of healthy life expectancy calculated with prevalence data, our parameter vector would contain both the age-specific death rates as well as the age-specific prevalence of health. Each parameter should be replaced one element at a time, and after each replacement step the contribution of the parameter would be the newly calculated healthy life expectancy minus the healthy life expectancy calculated in the previous step.

If we wanted to additionally split the age-specific mortality contributions by cause of death, we would need to modify our healthy life expectancy formula to take causes of death plus health prevalence as input and return healthy life expectancy as output. Then we would step-wise replace each of the parameters (age-and-cause-specific mortality and age-and-cause-specific health prevalence) and calculate the contributions of each elementary step to the total healthy life expectancy gap, just as we showed for the life expectancy example. Klijns et al. (2011) describes how to estimate the contribution of different diseases to health prevalence.

Continuous Change Decomposition Method

The second general method of decomposition is the continuous change or line integral model developed by Horiuchi et al. (2008). This methodology is equivalent to an independently derived decomposition method in ecology known as regression-based LTRE (life table response experiment) (Caswell 1996, 2001).

The main idea behind the continuous change model is to assume that mortality changes continuously or gradually along a ‘hypothetical or actual dimension’ i.e. between two time periods in the case of a within-population decomposition or between two populations for a between-population decomposition. If we could split the time or space interval into many, many smaller intervals, then we could estimate the changes needed by the covariates (for instance age-specific mortality) to change the aggregate function (for instance life expectancy) from one population to the next. Each of these tiny changes in the aggregate function can be approximated by a linear combination of n partial derivatives of the function with respect to the covariates. These can then be aggregated over time, or across space, using numerical integration to give the total contribution of the covariates to the change in the aggregate function.

A key assumption behind this model is that the changes in the covariates are proportional to one another. In other words, equal proportions of the total change in each covariate are assumed to occur simultaneously. The method itself is flexible to many applications, provided that the function being decomposed is a differentiable function of its covariates.

Comparing Step-Wise and Continuous Change Methodologies

To date, the step-wise and continuous change models have produced similar parameter contributions in all demographic applications that we are aware of in which both methods were applied.

Thus, there is no strong reason to prefer one methodology over the other. The main advantage that we can see for using the continuous change framework is that there is no ordering of covariates. While there is some logic to a young-to-old ordering in stepwise replacement decomposition, the ordering of replacement is more difficult to justify across other covariates such as regions or subgroups. On the other hand a key advantage of the step-wise algorithm has been its application to non-traditional decomposition problems such as decompositions along an age-period contour (Jdanov et al. 2017), decompositions of direct and compositional change in population subgroups (Shkolnikov et al. 2006; Wenau et al. 2019), and decomposition of the total, between, and within-group variance in longevity into contributions from different ages (Timonin et al. 2016).

Software to Decompose Healthy Life Expectancy

Currently we are aware of four software tools that can be used to decompose healthy life expectancy using either the decomposition formula of Nusselder and Looman (2004), the general step-wise decomposition algorithm or the continuous change method.

The first example is the decomposition software developed by Nusselder and Looman (2013) based on their decomposition method (Nusselder and Looman 2004), which is available by the authors upon request. Users provide input data in preformatted .csv or .txt files which are flexible to include various data formats for age classes, as well as causes of death if desired. The decomposition itself is performed by running an R-script. Users would need to install the open-source R statistical program to run the script, but would not need to make any changes themselves to the R-script, apart from modifying the location of their local directory where the input files are stored.

The second is a flexible Excel spreadsheet programmed with a VBA macro that implements the step-wise decomposition method (Shkolnikov

and Andreev (2010). It is user-friendly, modifiable to different problems, and accompanied by examples of decomposition for four different demographic indices in the accompanying technical description. Unfortunately no example was given on healthy life expectancy, so users would need to modify the spreadsheet to the healthy life expectancy calculation. Alternatively, Shkolnikov and Andreev (2017) embedded an Excel spreadsheet in their paper with formulas to calculate and decompose healthy life expectancy based on the Andreev et al. (2002) method.

The third example is the Matlab script given as supplementary material to the continuous change decomposition method (Horiuchi et al. 2008). To implement this script, users must create a function to calculate healthy life expectancy, as well as provide vectors $x1$ and $x2$, which are the input parameters from populations 1 and 2 needed for the healthy life expectancy function.

The fourth example uses the DemoDecomp R-package developed by Tim Riffe (Riffe 2018). This package implements both the step-wise decomposition algorithm and the continuous change decomposition method in a flexible and comparable format. It has a steeper learning curve for researchers less familiar with the R programming language than the Excel spreadsheets for step-wise decomposition. While the Excel-based implementations are fine for decomposing a gap between two populations, it quickly becomes tedious when multiple comparisons are needed, or more parameters added to the model.

In the following, we walk through the steps needed to decompose healthy life expectancy using the DemoDecomp R-package, from installing the package through to calculating and decomposing gaps in healthy life expectancy, and finally to plotting and exporting the results.

Decomposing Healthy Life Expectancy with the DemoDecomp R Package

We demonstrate these methods by estimating and decomposing changes in female healthy life

expectancy among adults aged 65 and older between 1970 and 1990 in the United States, defining HLE as disability-free-life expectancy (DFLE) – the expected number of years lived free of disability. Our prevalence data come from Crimmins et al. (1997), and our mortality data from the Human Mortality Database (HMD 2018).

First, we briefly explain how to install and use the *DemoDecomp* package, then we move on to calculating and decomposing gaps in DFLE. In the example, lines which are shaded in grey are chunks of R code which can be used to replicate the example by coping them into your R workspace.

Installing the Package in R

To install any R package onto your computer, including this one, you use the function *install.packages*.

```
install.packages('DemoDecomp', repos =
  'http://cran.us.r-project.org')
```

To access the documentation file of the package, you can use the function *help*.

```
help(package = 'DemoDecomp')
```

Note that the package needs to be installed onto your computer only once, however, to load and attach the package to your current R session you will need to run the following command:

```
library('DemoDecomp')
```

Installing Other Needed Packages

We will also make use of the tidyverse, data.table and HMDHFDplus packages. Tidyverse and data.table are packages that makes data manipulation and plotting easier. HMDHFDplus is a package designed to read data from the Human Mortality Database directly into R (Riffe 2015).

```
install.packages('HMDHFDplus', repos =
  'http://cran.us.r-project.org')
install.packages('tidyverse', repos =
  'http://cran.us.r-project.org')
install.packages('data.table', repos =
  'http://cran.us.r-project.org')
library('HMDHFDplus')
library('tidyverse')
library('data.table')
```

The Decomposition Functions Built into the DemoDecomp Package

From the *DemoDecomp* package, we use the functions *horiuchi* and *stepwise_replacement*.

Both functions contain the arguments *(i) func*, *(ii) pars1*, and *(iii) pars2*, that correspond respectively to: *(i)* a function specified by the user, *(ii)* a vector of covariates to be passed on as arguments to *func* for time 1 or population 1, and *(iii)* a vector of covariates to be passed on as arguments to *func* for time 2 or population 2.

Returning to the general concept of decomposition introduced visually in Box 7.1 in the introduction: the parameters are age-specific death rates and disability prevalence in time period 1 (*pars1*) and 2 (*pars2*); the model (*func*) is a function which takes each of these parameters vectors as input, and produces DFLE as output. Specifically we will create a function called '*Sullivan.fun*', which calculates DFLE using the Sullivan method.

The arguments *pars1* and *pars2* contain mortality rates and prevalence of disability by age respectively for 1970 (time 1) and 1990 (time 2). Note that *pars1* and *pars2* are each single vectors containing first mortality rates followed by the prevalence of disability. Thus the number elements of each of these vectors should be double the number of age intervals. In this example, we have 5 age groups (65–69, 70–74, 75–79, 80–84, 85+), thus *pars1* and *pars2* should each have 10 elements.

Beyond the *func*, *pars1*, and *pars2* arguments, the *horiuchi* function also contains the argument *N* that is the number of intervals (or time steps) to integrate over. The larger the number, the longer the function takes but the lower the total residuals. Horiuchi et al. (2008) used *N*=20 as a default value which would correspond to estimating

changes over 1/20th of a year interval in a decomposition between two subsequent years.

The *stepwise_replacement* function has additional arguments *symmetrical* and *direction*. The *symmetrical* argument defaults to TRUE. This refers to running the replacement steps in both directions, i.e., first replacing population 1->2 then 2->1 and taking the arithmetic average of the estimated contributions. If this is not desired then set *symmetrical* = FALSE. The *direction* argument defaults to 'up' meaning that the parameter vectors will be replaced in the order from the first to last elements. The other options are 'down' (last to first) or 'both' which takes the average of 'up' and 'down'.

Now, we show the steps to use *DemoDecomp* package in order to decompose the gap of female DFLE in the USA between 1970 and 1990.

Creating a Function to Estimate the Sullivan HLE

The function *Sullivan.fun* is the input for the *fun* argument. The arguments of this function are: *(i)* *rates* (vector with age-specific mortality rates and age-specific prevalence rates of disability), *(ii)* *age* (the age groups corresponding to the data), *(iii)* *sex* = 'f' or 'm' (only needed for life expectancy calculations below age 5). This is a flexible function, which could be used for life tables with different age constellations as input. In our example we have death rates and disability prevalence corresponding to ages 65–69, 70–74, 75–79, 80–84 and an open-ended 85+ age interval. Thus in this function, we have specified our *age* argument to take the form of *age* = seq(start of first interval, start of open-aged interval, length of interval), i.e. *age* = seq(65,85,5). With an older open-ended age interval for abridged data, age 85 would need to be changed to the maximum age. If your data contained, for example, a full abridged life table up to open-ended age 90+ (i.e. ages 0, 1–4, 5–9, ..., 85–89, 90+) you would need to change the *age* argument to be *age* = c(0,1,seq(5,90,5)). If you are using data by single year of age from age 0 to ages 110+ you would need to change the *age* argument to be *age* = seq(0,110,1).

```
Sullivan.fun = function (rates,age=seq(start.age,open.age,5), sex='f') {

# 1) First, we split from our single vector 'rates' the set of age-specific
death rates (mx) and age-specific prevalence of disability (wx)
lengthvec <- length(rates)
mx <- rates[1:(lengthvec / 2)]
wx <- rates[(lengthvec / 2 + 1):lengthvec]

# 2) Calculating period life table functions
# ax
n <- c(diff(age), 1)
ax <- 0.5 * n

# This part of the code is only for calculations when the
# starting age is zero.
# Formulas are from Andreev & Kingkade (2015)
#-----
if (age[1] == 0) {
if (sex == 'm') {
  ax[1] <- ifelse(mx[1] >= 0.08307, 0.29915,
                    ifelse(mx[1] < 0.023,
                           0.14929 - 1.99545 * mx[1],
                           0.02832 + 3.26021 * mx[1]))
  if (sex == 'f') {
    ax[1] <- ifelse(mx[1] >= 0.06891, 0.31411,
                      ifelse(mx[1] < 0.01724,
                             0.14903 - 2.05527 * mx[1],
                             0.04667 + 3.88089 * mx[1]))}

#-----
# probability of dying (qx) and surviving (px)
qx <- (n * mx)/(1 + (n - ax) * mx)
qx <- c(qx[-(length(qx))], 1)
qx[qx > 1] <- 1
px <- 1 - qx
# survivors at age x (lx)
lx <- c(100000,rep(0,(length(mx)-1)))
for (i in 1:(length(mx) -1)){
  lx[i+1] <- lx[i]*px[i]
# deaths between ages x and x+n (dx)
  dx <- lx * qx
# person-years lived between ages x and x+n (Lx)
  Lx <- rep(0,length(mx))
  for (i in 1:length(mx) -1){
    Lx[i] <- lx[i+1]*n[i] + ax[i]*dx[i]
  Lx[length(mx)] <- lx[length(mx)]/mx[length(mx)]}

# 3) Person-years lived without disability
Lx.health <- Lx*(1-wx)

# 4) Healthy Life expectancy at age 0
ex.health <- sum(Lx.health)/lx[1]
return(ex.health)
}
```

Preparing the Inputs

The *rates* argument of the *Sullivan.fun* function must contain the same values attributed to the *pars1* and *pars2* arguments of the *horiuchi* and *stepwise_replacement* functions. For this example,

```
# Defining the variables for the start of the first interval, the start
# of the open-aged interval, and the years

start.age = 65
open.age = 85

year1 = 1970; year2 = 1990

# To extract data from the HMD, you first need to register at
# www.mortality.org. Replace your username and password here:
myusername <- "username"
mypassword <- "password"

# Preparing the inputs for the arguments rates, pars1 and pars2

# 1) Selecting the country
country <- "USA"
# 2) Extracting Female Life Tables from HMD
LTF<- readHMDweb (CNTRY = country,
                      item = "fltpcr_5x1",
                      username = myusername,
                      password = mypassword,
                      fixup = TRUE)
# 3) Extracting Number of Deaths from HMD
Dx<- readHMDweb (CNTRY = country,
                      item = "Deaths_5x1",
                      username = myusername,
                      password = mypassword,
                      fixup = TRUE)
# 4) Extracting Exposures from HMD
Nx<- readHMDweb(CNTRY = country,
                      item = "Exposures_5x1",
                      username = myusername,
                      password = mypassword,
                      fixup = TRUE)
# 5) Getting the female death rates for ages >=65 in 1970 and 1990
mx1 <- filter(LTF,Year==1970 & Age >=65)$mx
mx2 <- filter(LTF,Year==1990 & Age >=65)$mx

# 6) We considered 85+ as the open age interval to match the
# disability data

Dx1 <- filter(Dx,Year==1970)$Female
Dx2 <- filter(Dx,Year==1990)$Female
Nx1 <- filter(Nx,Year==1970)$Female
Nx2 <- filter(Nx,Year==1990)$Female

# y is the last position in the mx1 and mx2 vectors
y = length(seq(start.age,open.age,5))

mx1[y] <- sum(Dx1[19:24])/sum(Nx1[19:24])
mx2[y] <- sum(Dx2[19:24])/sum(Nx2[19:24])
mx1 <- mx1[1:y]
mx2 <- mx2[1:y]
```

the set of age-specific mortality rates used as input for the *pars1* and *pars2* arguments come from the Human Mortality Database (HMD 2018). The function *readHMDweb* comes from the package *HMDHDFplus*.

Alternatively, if you already had own death rates for each year, you could type them in directly separated by commas, i.e.,

```
mx1 <- c(0.0204, 0.0325, 0.0533, 0.0867,
0.1640)
mx2 <- c(0.0161, 0.0246, 0.0384, 0.0646,
0.1410)
```

The set of age-specific prevalence of disability comes from the National Health Interview Survey (NHIS), published in Crimmins et al. (1997). The disability prevalence estimates are allocated in vectors $wx1$ and $wx2$, respectively for years 1970 and 1990.

```
wx1 <- c(0.3000, 0.3657, 0.4552, 0.5285,
0.6822)
wx2 <- c(0.3056, 0.3831, 0.4552, 0.5424,
0.6441)
```

Now we combine age-specific death rates and age-specific prevalence of disability into one vector, as required for the decomposition functions *horiuchi* and *stepwise_replacement*.

```
# Making a single vector of mx followed
# by wx - we need these as input for either
# horiuchi or stepwise_replacement
mxwx1 <- c(mx1,wx1)
mxwx2 <- c(mx2,wx2)
```

Calculating the Gap in Healthy Life Expectancy

After making a single vector of mx and wx for 1970 and 1990, we can calculate the difference in DFLE between 1970 and 1990 using the Sullivan function that we created. In doing so, we see that the DFLE increased among American females from 9.69 to 10.59 years, creating a difference (or gap) of 0.91 years. It is this difference that we will then decompose into its age-specific mortality and morbidity components.

```
# The DFLE in 1970 was
Sullivan.fun(rates=mxwx1)
## [1] 9.691796
# In 1990 it was
Sullivan.fun(rates=mxwx2)
```

```
## [1] 10.5992
# The gap in DFLE was:
Sullivan.fun(rates=mxwx2) - Sullivan.fun(rates=mxwx1)
## [1] 0.9074079
# The observed gap in LE from HMD (for comparison only) was:
filter(LTF, Year==1990, Age==65)$ex -
filter(LTF, Year==1970, Age==65)$ex
## [1] 2.13
```

At age 65, disability-free life expectancy increased 0.9 years for females between 1970 and 1990. Over this period, female remaining life expectancy at age 65 also increased from 16.9 to 19.0 years. Thus, between 1970 and 1990, over 42% of the increase in life expectancy at age 65 was in DFLE.

Decomposing the Gap into Its Age-Specific Mortality and Morbidity Contributions

```
HE_DecomP_sw <- stepwise_replacement(
  func=Sullivan.fun,
  pars1 = mxwx1,
  pars2 = mxwx2)
HE_DecomP_Cont <- horiuchi(
  func=Sullivan.fun,
  pars1 = mxwx1,
  pars2 = mxwx2,
  N=20)
```

Interpreting the Results

Results give the contribution from each parameter to the DFLE gap in the order in which they were inputted. Since our parameter vector was made up of age-specific death rates followed by age-specific disability prevalence, in this example each contribution vector would first contain the age-specific mortality followed by the age-specific morbidity contributions. Results using the step-wise decomposition method can be seen by typing *HE_DecomP_sw*. For results using the continuous change decomposition method we type *HE_DecomP_Cont*.

A good way to visualize our results is through barplots. The code to create Fig. 7.2 is presented below.

```

# 1) Making a matrix of the vectors with the age-specific
# mortality and morbidity contributions
HE_sw <- matrix(HE_Decompo_sw,nrow=(length(HE_Decompo_sw)/2),ncol=2,
byrow=F)
HE_cont <- matrix(HE_Decompo_Cont,nrow=(length(HE_Decompo_Cont)/2),ncol=2,
byrow=F)
colnames(HE_sw) <- colnames(HE_cont) <- c("Mortality","Morbidity")

# 2) Creating a data frame with the matrices and adding
# a column with the beginning of the age interval
HE_sw_df <- mutate(as.data.frame(HE_sw),Age=c(seq(start.age,
open.age,5)))
HE_cont_df <- mutate(as.data.frame(HE_cont),Age=c(seq(start.age,
open.age,5)))
# We will construct barplots by using the package called
# "ggplot2". This package is included in the "tidyverse"
# package previously installed. As input, "ggplot2" requires # data in
the long format. To change our data frames
# "HE_sw_df" and "HE_cont_df" from the wide to long format, # we use
the function "melt" in the package "data.table"

# 3) Making the long data format
HE_sw_res <- melt(HE_sw_df,id.vars="Age")
HE_cont_res <- melt(HE_cont_df,id.vars="Age")
colnames(HE_sw_res) <- c("Age","type","Contribution")
colnames(HE_cont_res) <- c("Age","type","Contribution")

# 4) Checking if the data is in the long format
head(HE_sw_res)
  #   Age    type      Contribution
  # 65 Mortality  0.18388350
  # 70 Mortality  0.21375435
  # 75 Mortality  0.22878292
  # 80 Mortality  0.16562088
  # 85 Mortality  0.14367055
  # 65 Morbidity -0.02677929

# 5) Creating the barplots
# create a vector with the start of first interval,
# the start of open-aged interval, & the length of interval
Age=seq(start.age,open.age,5)

# Fig.7.2-a) Barplot with the stepwise decomposition
Fig7.2a <- ggplot(data=HE_sw_res, aes(x=as.factor(Age), y=Contribution,
fill=type))+  

  geom_bar(stat = "identity", position = "stack")+
  scale_fill_manual(values=c("grey30", "grey60"))+
  scale_x_discrete(labels=c("65-69", "70-74", "75-79", "80-84", "85+"))+
  geom_hline(yintercept=0, linetype= "dashed", color = "gray50",
size=0.5)+  

  scale_y_continuous(breaks=seq(-0.1,0.3,by=0.05))+  

  xlab("Age-group")+annotate("text", x=0.5, y=0.27, label= "a",
fontface =2)+ labs(fill = "Effect", size=8)+ theme_minimal()+
  theme(axis.text.x = element_text(size=8),axis.text.y = element_text
(size=8), legend.text=element_text(size=8))+  

  theme(axis.title.x = element_text(size=8),axis.title = element_text
(size=8), legend.title=element_text(size=8))

# Fig.7.2- b) Barplot with the continuous change decomposition
Fig7.2b <- ggplot(data=HE_cont_res, aes(x=as.factor(Age),
y=Contribution, fill =type))+

```

```

geom_bar(stat = "identity", position = "stack")+
scale_fill_manual(values=c("grey30", "grey60"))+
scale_x_discrete(labels=c("65-69", "70-74", "75-79", "80-84", "85+"))+
geom_hline(yintercept=0, linetype="dashed", color = "gray50", size=0.5)+ 
scale_y_continuous(breaks=seq(-0.1,0.3,by=0.05))+ 
xlab("Age-group")+annotate("text", x=0.5, y=0.27, label= "b",
fontface =2)+ 
labs(fill = "Effect", size=8)+theme_minimal()+
theme(axis.text.x = element_text(size=8),axis.text.y = element_text
(size=8),legend.text=element_text(size=8))+ 
theme(axis.title.x = element_text(size=8),axis.title = element_text
(size=8),legend.title=element_text(size=8))

```

Fig7.2a

Fig7.2b

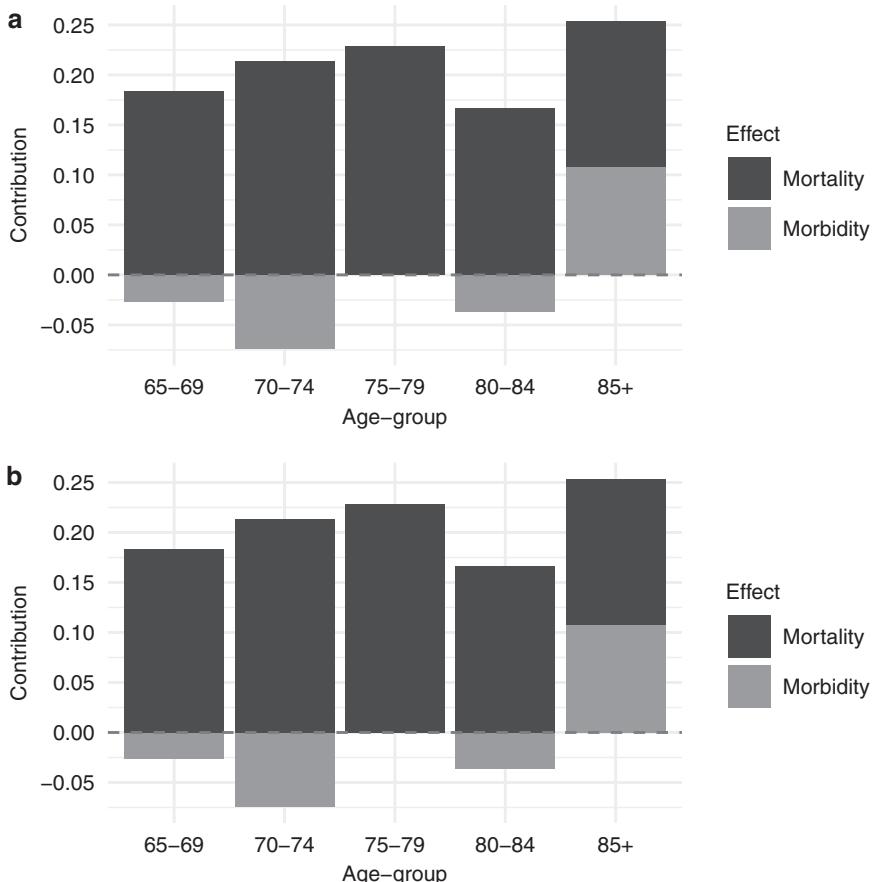


Fig. 7.2 The contribution of age-specific mortality and morbidity change to the decrease in DFLE between 1970 and 1990, calculated using (a) step-wise and (b) con-

tinuous change decomposition methods. These age-specific contributions sum to the total difference in DFLE between the 2 years

Figure 7.2 shows that reductions in mortality were relatively more important than changes in disability prevalence in explaining the increase in DFLE between 1970 and 1990. At ages younger than 85, except the age group 75–79, increases in the prevalence of disability reduced the gap in DFLE (bars are below the zero contribution line). The disability prevalence did not change over ages 75–79 between 1970 and 1990, thus, only changes in mortality contributed to the rise in DFLE from this age group. At ages 85+, decreases in both mortality rates and disability prevalence led to increases in DFLE over the 20-year period. The plots further show that there were no substantive differences between using the stepwise or continuous change decomposition methods.

Checking That Our Contributions Sum to the Gap

```
sum(HE_sw_res$Contribution)
## [1] 0.9074079
sum(HE_cont_res$Contribution)
## [1] 0.9073937
Sullivan.fun(rates=mxwx2) - Sullivan.fun(rates=mxwx1)
## [1] 0.9074079
```

The results from the continuous change method could be made even closer to the gap by changing the argument $N = 20$ to a higher value.

Conclusion and Future Outlook

Decomposition is an important tool used to quantify the contributions of different parameters to changes or gaps in summary health metrics. In this chapter we focused on the specific case of healthy life expectancy using disability-free life expectancy as a worked example. Measures of healthy life expectancy can be decomposed using either the step-wise or continuous change decomposition methods. Both methods are flexible enough to accommodate additional covariates,

such as cause of death or region, by lengthening the input vector and changing the life table function to take the additional parameters as inputs into the calculation of healthy life expectancy.

To date, the calculation and decomposition of healthy life expectancies has relied on binary health outcomes (healthy or not healthy; disabled or not disabled). New advances in the usage of Markov chain with rewards models have opened up the possibilities of extending the health prevalence parameter space to include count data (e.g. the number of limitations in activities of daily living) or quantitative measures that follow an empirical distribution (e.g. grip strength), in the calculation of healthy longevity (Caswell and Zarulli 2018). Such healthy longevity metrics are less straightforward to interpret because they will no longer be the number of expected years in good health—grip strength for example would be the expected remaining grip strength years. However, such health outcomes recognize that there might be important continuums that are lost by reducing health complexities to binary outcomes. Decomposition methods would provide a valuable opportunity to uncover how these continuums differ across age in different populations.

Finally the example used in this chapter used prevalence models, but the decomposition of a full incidence-based model is also possible with either the step-wise or continuous change decomposition methods. Riffe et al. (2019) have used the *DemoDecomp* package to decompose such a model using data from the U.S. Health and Retirement Study. All that is needed are a vector of parameters from each population (i.e. transition rates or probabilities between states of health, sickness or disability, and death), and a multistate life table function to calculate healthy life expectancy based on such a vector of parameters. These type of studies will allow us to explore the relative contribution of changes in disability or sickness onset, changes in recovery to states of good health, as well as changes in mortality out of both healthy and unhealthy states to the overall change or gap in healthy life expectancy.

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Assessing the Impact of Risk Factors on Health Expectancy

8

Henrik Brønnum-Hansen

Introduction

The first estimates of disability-free life expectancy (DFLE) appeared half a century ago (US Department of Health 1969) and was an initial stage towards considering the demand for summary measures of population health that integrate information on health and mortality. The need for a composite measure of morbidity and mortality (in the developed countries) was a consequence of the transition from communicable to non-communicable diseases and the low mortality among people with chronic diseases. This change in the disease pattern and mortality makes life expectancy less suitable as a measure of the health of a population characterized by increasing life years with chronic health conditions. New indicators of population health were needed to support health policy considering this development.

Whereas life expectancy is a simple, uniform and age standardised indicator, estimates of summary measures of population health requires health related data (e.g. disease, impairment, functional limitation, disability, self-rated health, etc.) and to improve international comparability, health data needs to be harmonized. Although

lots of efforts have been done to harmonize concepts, methods, and data to make meaningful comparisons of health expectancy across populations and over time, it is still a challenge for those involved in health monitoring and health data collection and for those who are using the data (Brønnum-Hansen 2014). The refinements by including the associations between specific diseases, disability, and causes of death involve more data and extra efforts to improve harmonization. Thus, it becomes even more complicated when moving one step further by adding an extra dimension to morbidity and mortality when the population is stratified or divided into different risk factor exposure levels. However, the main challenge of expanding the multidimensionality is the heavily demanding data requirements.

Health Expectancy by Risk Factor Exposure

Studies of the impact of risk factor on health expectancy are based on evidence of the association between risk factor exposure and health established from epidemiological studies. In most cases this association involves both health status and mortality. Thus, ideally, what is needed is comprehensive longitudinal data comprising variables to estimate transition probabilities between and within risk factor exposure levels

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and health states, and risk of death for the various combinations of exposure levels and health states. Sufficient statistical power is seldom achieved in (panel) data sets which include these variables and require analysis in a joint multivariate model.

With less optimal data the prevalence-based life table method is more straightforward, but at the expense of not taking into account the underlying dynamics between health states (e.g. where no recovery from unhealthy to healthy is possible) and generally assuming uniform mortality regardless of health status.

Sullivan's Method Stratified by Risk Factor Exposure

With the prevalence-based life table method (Sullivan 1971) as the basis for health expectancy calculation stratified by risk factor exposure we need consistent data on mortality and health status by risk factor exposure levels. Thus, gender- and age-specific death rates and health status prevalence must be available for each level of exposure.

Figure 8.1 describes the steps for the analysis. Relative risks of death (RR) by level of exposure are assumed to be available for each gender at all ages (age groups) or if possible, to be initially estimated from mortality follow-up (using national statistics) of participants in the study survey.

The construction of life tables by level of risk factor exposure utilizes gender- and age-specific population death rates and prevalence of expo-

sure levels. Thus, let P_0 signify the gender- and age-specific prevalence of unexposed persons, P_i the gender- and age-specific prevalence of persons exposed at level i and let RR_i be the relative risk of death for those exposed at level i ($RR_0 = 1$). Then, the gender- and age-specific death rate (d) can be expressed as

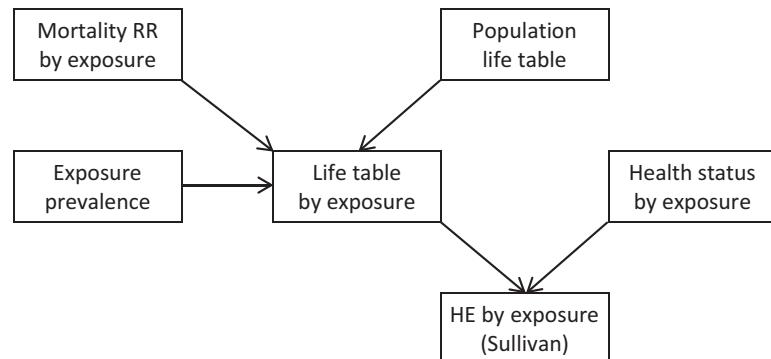
$$d = \sum P_i \times RR_i \times d_0$$

where d_0 is the gender- and age-specific death rate for unexposed. As d is readily accessible from the population life table, the death rate for unexposed, d_0 , can be found by solving this equation. The gender- and age-specific death rate for persons exposed at risk factor level i is $RR_i \times d_0$ and the life table for those exposed at level i can be constructed.

Some adjustments may be necessary as the RR estimates in use might not fully reflect the exposure-mortality association of the study population, e.g. if the estimates are taken from the international literature or if the estimates are too crude and not sufficiently divided up into age groups. Furthermore, prevalence of risk factor exposure might only be available in broad age intervals, but the method will work by carefully constructing abridged life tables.

Smoking is recognized as the most important preventable risk factor and the impact of smoking on health and life expectancy has been studied in several countries. The Sullivan method was used in studies of the Belgium population (Van Oyen et al. 2014), in Denmark (Brønnum-Hansen and Juel 2001, 2003, 2004a, 2004b; Brønnum-Hansen et al. 2007; Brønnum-Hansen and Jeune 2015),

Fig. 8.1 Steps for calculating health expectancy (HE) by risk factor exposure (Sullivan's method)



in The Netherlands (Klijns et al. 2011), for a US population (Peeters et al. 2004), and the male population living in the West Bank of the occupied Palestinian territory (Brønnum-Hansen et al. 2018b).

All these studies estimated a markedly loss of life expectancy due to smoking. However, while also a substantial loss of healthy life years was found, no consistency has been established whether also years in poor health increases by smoking, i.e. whether smokers' shorter lives comprises more, the same or fewer years in an unhealthy state compared with never smokers. The study by Van Oyen et al. (2014) aimed to investigate this explicitly and concluded that "smoking kills and shortens both life without and with disability mainly due to its related excess mortality." However, the question might reach different answers depending on the choice of health indicator (e.g. whether the unhealthy state is related to high or low fatality). In Denmark, expected lifetime with musculoskeletal disease was found to be longer among smokers than never smokers (Brønnum-Hansen and Juel 2003, 2004b). Furthermore, smoking among Danes increased expected years in less than good self-rated health, while the pattern in expected years with longstanding illness is less clear (Brønnum-Hansen and Juel 2004a; Brønnum-Hansen and Jeune 2015).

The impact of other lifestyle related risk factors on health expectancy has been quantified by Sullivan's method, including the effect of obesity, fruit and vegetable consumption, physical inactivity, and alcohol consumption on longstanding illness and active life expectancy etc. (Baars et al. 2019; Brønnum-Hansen et al. 2007; Klijns et al. 2011; Peeters A et al. 2004).

Sullivan's method was applied in a study of the impact of air pollution on life expectancy and various measures of health expectancy among older adults in China participating in the Chinese Longitudinal Health Longevity Survey (Wen and Gu 2012). Air quality was based on five pollutants measured at the prefecture or city level: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PM_{10}), carbon monoxide (CO), and ozone (O_3) and categorised into seven levels. DFLE, cognitive impairment-free life

expectancy, expected lifetime in good self-rated health, and disease-free life expectancy were estimated and the differences between air quality levels presented. For instance, the differences in health expectancies at age 65 ranged from 1.47 years in good self-rated health for men to 5.20 years of DFLE for women (Wen and Gu 2012).

Multistate Life Table Methods

The multistate life table approach aims to include the dynamics of health changes in the population and to incorporate effects of covariates. The method makes use of longitudinal data to estimate age-specific life table transfer rates, and, by that means, allows transitions between health states (e.g. to recover from poor health).

One study based on a fairly harmonized and large longitudinal data set covering various countries (The European Community Household Panel) investigated life expectancy and expected lifetime with disability simultaneously analysed for body weight and smoking groups (Majer et al. 2011). The results were further presented for high and low educated men and women. The size of the data source allowed a multistate Markov model to be fitted to obtain estimates of transition rates between the health states: nondisabled, disabled and dead (including the possibility to recover from disabled to nondisabled). After achieving a satisfactory model fit, multiple life tables were set up for further calculations. The conclusion from the study was that smoking was associated with mortality more than with disability, whereas obesity was associated with disability more than with mortality (Majer et al. 2011). A US study on smoking and obesity reached the same conclusion (Reuser et al. 2009). Cao (2016) used the multistate life table approach to forecast DFLE among older adults in US based on smoking and obesity history. Multistate life table methods used data from the Framingham Heart Study to estimate the effect of smoking (Mamun et al. 2004) and physical inactivity (Franco et al. 2005) on life expectancy without cardiovascular disease. A Markov Chain model was used by Ferrucci et al. (1999) to study the impact of

smoking and physical inactivity among an American population aged 65 and over.

A Dutch multistate life table calculation of the impact of smoking on DFLE concluded that abstention of smoking compresses morbidity (Nusselder et al. 2000). Multistate life tables were estimated to investigate DFLE for selected risk factors (smoking, physical inactivity, and overweight) and chronic conditions in Canadians aged 45 and older (Berlanger et al. 2002). Moreno et al. (2018) used multistate life tables to study nutritional status and DFLE among older people in Santiago in Chile.

The Interpolation of Markov Chains (IMaCh) (Lièvre A et al. 2003) tool for multistate life table method estimation has been used in various health expectancy studies. Reynolds et al. (2005) used the model to estimate effect of obesity on total, active, and disabled life expectancy among Americans aged 70 and older. A more recent study by Leigh et al. (2016) estimated the impact of body weight on healthy life expectancy in old and very old Australian women. They found that the relationship between weight and healthy life expectancy has important implications for nutrition for older people and a questionable benefit of weight loss in obese older women.

In addition to the multistate life table methods various multivariate statistical models have been applied to study the impact of risk factors on health expectancy. Examples are a Finnish study using Cox regression models and analysis of variance to estimate the impact of obesity (Visscher et al. 2004) and a Dutch study using Cox regression and calculation of the “area under the survival curves” to estimate the impact of smoking (Streppel et al. 2007). Multistate models were used to estimate the impact of risk factors on late-life cognitive impairment among Australians (Anstey et al. 2014).

Micro-simulation Modelling

Basically, a micro-simulation model exposes each individual in a population or cohort to probabilities of switches between various levels of exposure and health states and risks of death

(absorbing state). Thus, micro-simulation extends multistate life table methods by more flexible possibilities for including dynamics of population health. Depending on the specific aim of a study simulation models might be expanded by intermediate stages of health deteriorations, covariates, risk factors, etc. However, due to lack of transparency of the mathematics and the complexity of the methods it is a challenge to promote these models. Although a satisfactory model fit with health trajectories and mechanisms of the real population can be rendered probable by comparing observed and modelled marginal distributions of the study characteristics, it is a challenge to convince recipients that the results are reliable.

Micro-simulation models are typically developed for specific purposes and seldom available as a generic and user-friendly tool. However, some models have been developed in preparation for public use. An example is the DYNAMO-HIA model developed as a tool for quantitative health impact assessment. DYNAMO-HIA is a Markov-type multi-state simulation software that estimates the effects of changed risk factor exposure on population health by comparing intervention scenarios to a reference scenario (Boshuizen et al. 2012; Lhachimi et al. 2012). The model requires input data on population size, data on incidence and prevalence of diseases, cause specific and all-cause mortality, prevalence of risk factor exposure, and relative risk parameters for the associations between exposure and diseases and all-cause mortality. Furthermore, the model offers an option to include a matrix of transition probabilities between levels of risk factor exposure as an alternative to the net transition probabilities estimated by the model. A wide range of outcome measures from DYNAMO-HIA includes life expectancy and disease-free life expectancy and other measures of health benefits of reducing exposure to risk factors (Boshuizen et al. 2012; Lhachimi et al. 2012).

DYNAMO-HIA has been used in several studies (Lhachimi et al. 2012, 2013, 2016; Kulik et al. 2012; Holm et al. 2014; Füssenich et al. 2019) to model the impact on health gains by lifestyle interventions. Thus, the model estimated gain in

DFLE by several intervention scenarios on risk of obesity (Lhachimi et al. 2013) and to quantify potential health gains and health losses caused by changes in the prevalence of smoking, alcohol consumption, and overweight in 11 EU countries (Lhachimi et al. 2016). Füssenerich and colleagues used DYNAMO-HIA comprising data for 27 European countries to study various scenarios of potential gains in health expectancy by lifestyle changes, i.e. smoking, overweight and alcohol consumption (Füssenerich et al. 2019). The impact of smoking intervention on mortality and disease-free life expectancy was also studied in the Netherlands and Denmark by use of DYNAMO-HIA (Kulik et al. 2012; Holm et al. 2014).

DYNAMO-HIA was used in a study that estimated life expectancy and disease-free life expectancy and other measures of the health benefits of reducing exposure to traffic-related air pollution in the municipality of Copenhagen, Denmark (Brønnum-Hansen et al. 2018a). Data included in the study was register data on diseases and mortality and exposure-response functions linking nitrogen dioxide (NO_2) concentrations (as measure of exposure) estimated at the residential address with the risk of type 2 diabetes mellitus, cardiovascular diseases, and respiratory diseases. If NO_2 exposure was reduced to the annual mean rural level expected lifetime would increase by 1 year and expected lifetime without type 2 diabetes, ischemic heart disease, stroke, chronic obstructive pulmonary disease, asthma, and lung cancer would be reduced by between 0.5 and 2.3 years (Brønnum-Hansen et al. 2018a).

Conclusion

Knowledge of the impact of risk factor exposure on expected years in healthy and unhealthy states can benefit prioritizing in health planning. Studies that quantifies years in different health states by exposure level are limited because of insufficient data sources. However, the readily accessible prevalence-based life table method (Sullivan's method) is usable if life tables by risk factor exposure can be constructed, for instance

if relative risk for the association between exposure and death can be procured.

More sophisticated methods exist but are heavily data dependent. As in the case of the simple method of Sullivan, multistate life table methods, and micro-simulation modelling have their advantages and disadvantages, but future prospects are promising with the advent of more comprehensive longitudinal data.

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Microsimulation of Health Expectancies, Life Course Health, and Health Policy Outcomes

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Background

Active life expectancy, a central indicator of population health, measures life expectancy and the proportions of remaining life with and without disease or disability. Microsimulation allows researchers to estimate active life expectancy by simulating a population of individual lifetime health biographies, where each individual's status in one or more outcomes is known for each measured unit of life, most often each month or year. Microsimulation is an especially useful tool for life course research. Guy Orcutt (1957) introduced microsimulation to the social sciences in 1957. Researchers have used the method to support many major public policy decisions (Abraham 2013; Citro and Hanushek 1991; Spielauer 2011).

In this chapter we summarize the microsimulation process. We describe how researchers have used microsimulation in the past 20 years to model population health, calculate active life expectancy, and forecast effects of changes in

population health and policies. We illustrate the use of microsimulation in active life expectancy research with a study of "interval need," a measure of need for health care and other services focused on resource utilization. We describe strengths of microsimulation, considerations regarding its use, and directions for future research.

Summary of Microsimulation

Laditka and Wolf (1998) introduced the use of microsimulation to study active life expectancy. They applied maximum likelihood methods and a discrete-time approach to panel data to recover parameters of an embedded Markov chain, using a multinomial logistic Markov model (Laditka and Hayward 2003). The parameters represented monthly transition probabilities, such as the likelihood that an individual would become disabled in the coming month, would recover from disability, or would die. The parameters were the foundation for simulating individual health biographies from a starting age through death. The approach was a random experiment for each month of each individual's life, where each experiment determined the individual's status in the coming month (such as nondisabled, disabled, or dead), conditional on the parameters, a random number draw, the individual's status in the current month, and other characteristics

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included in the model that estimated the parameters. The result was a lifetime biography of monthly functional status for each simulated individual, and a simulated population that approximated the disability dynamics of the actual population (Laditka and Hayward 2003; Laditka and Wolf 1998; Laditka and Laditka 2009).

A given individual contributes to the likelihood function only the limited number of functional status transitions that occur when she or he is surveyed. The estimated parameters and the microsimulation process combine that information from all participants to produce both expected values for measures of interest, such as the percentage of remaining life with disability, and estimates of variation around those values. The simulated population provides lifetime measurements that could be obtained for an actual population only by following all individuals through death.

Contributions of Microsimulation to Active Life Expectancy Research

Studies using microsimulation often report total remaining life expectancy, disabled life expectancy, and disability-free life expectancy (e.g., Laditka and Laditka 2016a, b, c; Laditka and Laditka 2015, 2017). Researchers can also calculate other measures using microsimulated data, such as the age-specific prevalence and incidence of diseases or disability, outcomes for particular periods of life or following life course transitions, or outcomes in the last year of life. Microsimulation is therefore useful for life course studies.

Variation Among and Within Groups

Several studies investigated variability in active life expectancy by producing distributions of years lived in each functional status. For example, in a study of older women, Wolf et al. (2002) found that life expectancy and active life expectancy were distributed relatively symmetrically

around their means. However, remaining years of disabled life were highly skewed, with many women having zero years, and few having many years. Thus, microsimulation revealed a characteristic of active life expectancy that is typically not shown in related research, one that is highly relevant for individuals who are considering long-term care insurance. Laditka and Laditka (2006) found similar results for people with diabetes.

New Measures of Population Health

Focusing on variation in the association of educational attainment with active life expectancy, by sex and race/ethnicity, a recent study reported the average age of first disability, the average age at the beginning of the first continuous disability spell lasting 5 or more years, the average spell length of disability preceding death, and the average percentage of years disabled in each decade of life (Laditka and Laditka 2016a). Microsimulation can also calculate analogous measures for periods of “active” life: periods without disability, functional impairment, or disease. Examining associations of childhood adversity with adult functional status, researchers showed age-specific prevalence of: difficulty with activities of daily living (ADLs) and needing help with ADLs; or being impaired in instrumental ADLs (IADLs) (Laditka and Laditka 2018a). Childhood adversity was significantly associated with poorer outcomes for all of those measures. Examining associations of childhood adversity with moderate and severe work disability, defined as physical or nervous problems that limit work, a recent study showed that people with high adversity reported: their first moderate or severe work disability at significantly younger ages than those with no reported adversities; significantly more spells of moderate and severe work disability; and moderate and severe work disability for significantly greater proportions of life from ages 30 through 65 (Laditka and Laditka 2019). Laditka and Laditka (2018b) found that childhood adversity was also associated with significantly shorter life expectancy.

In another study, researchers calculated the prevalence of work disability at each age, the percentage of people who were ever work disabled, the average number of work disability spells, and measures of recovery from work disability (Laditka and Laditka 2018c). Results suggested that the majority of Americans experience work disability during working life. Most spells of work disability ended with recovery or reduced severity, underscoring the importance of rehabilitation and workplace accommodations. The ability to measure specific patterns of disability spells illustrates the flexibility and power of microsimulation for improving knowledge about disability throughout life.

Policy Simulations

Laditka (1998) estimated lifetime nursing home use under assumptions of better (or worse) health. Lower morbidity produced longer life and more time in both the community and in nursing homes. Laditka and Laditka (2001) examined effects of lower morbidity on long-term care eligibility, finding that more women would be eligible for services than men, with larger effects of reducing functional status decline, highlighting the importance of slowing functional status decline.

Another study highlights the role of health behaviors in functional status outcomes. Laditka and Laditka (2015) studied the association of diabetes, and the individual and combined additional risks for people with diabetes of heart disease and earlier-life obesity and inactivity, with active life expectancy and disability in the last year of life. Being obese or inactive earlier in life or having heart disease greatly reduced life expectancy and active life for people with diabetes. People with diabetes with the other risks had much more disability in the last year of life, a finding that would be difficult to quantify without microsimulation.

Similarly, researchers have used microsimulation to study associations of chronic conditions with active life expectancy, examining eight health conditions individually and in combination (Laditka and Laditka 2016b). Having multi-

ple conditions did not reduce life expectancy more than having a single condition. However, compared with one condition, having combinations of multiple chronic conditions was associated with significantly increased disability. Related research has been largely limited to single chronic conditions, or counts of those conditions, which assume that effects of the conditions are equal and additive.

Another recent study examined work disability from 1968 through 2015 in the United States (Laditka and Laditka 2018c). The 1990 Americans with Disabilities Act (ADA) and the ADA Amendments Act of 2008 addressed discrimination against workers with disabilities. The hypothesis was that these efforts together with more use of assistive devices and better medical control of chronic conditions would have reduced work disability across the nearly five decades. Results supported the hypothesis.

Innovative Models of Population Health

A limitation of most previous studies is their focus on effects of diseases or other risk factors measured only at baseline. Microsimulation lets researchers model the occurrence and timing of events that can vary among individuals and groups. For example, when modeling effects of stroke, microsimulation can retain a memory of stroke events and adjust the probabilities of future transitions to reflect the increased risks of disability and death for people with a previous stroke. Applying a matched cohort analysis to a microsimulated population (Laditka and Laditka 2014a), researchers found that those with strokes had substantially shorter lives and a greater proportion of remaining life with disability.

In another study, researchers followed a cohort from 1992 through 2009 to examine associations between educational attainment and active life expectancy focusing on people who developed cognitive impairment (Laditka and Laditka 2014b). Among those with cognitive impairment more education limited ADL disability and its duration. Given that ADL disability is a criterion

used to diagnose advanced dementia, that finding indicated that people with more education were less likely to progress to that dementia stage, with important implications for developed countries where educational attainment has increased greatly (Crimmins et al. 2018).

Forecasting Disability and Service Needs

Relatively few studies have used microsimulation to forecast active life expectancy or estimate future service needs. Two studies used the Population Ageing and Care Simulation (PACSim) model developed by Andrew Kingston and Carol Jagger for the MODEM project (“a comprehensive approach to MODelling outcome and costs impacts of interventions for DEMentia”). In the first study, the researchers estimated the prevalence of multi-morbidity among people age 65+ in England through 2035 (Kingston et al. 2018a). They estimated that: the proportion of those with 4+ conditions will almost double, from 9.8% to 17.0%; about one-third of those with 4+ conditions will have cognitive or emotional problems such as dementia or depression; and life expectancy will increase 3.6 years for men, 2.9 years for women.

A second PACSim analysis used “intervals of need” (or simply “interval need”) to forecast care required at different frequencies and intensity levels for people in England through 2035 (Kingston et al. 2018b). Interval need refers to the time between each need for help or care. For example, people with advanced dementia who require 24/7 care have need intervals with essentially no elapsed time. The researchers concluded that dependency will decrease among the younger old, ages 65–74. At ages 85+ the number with low dependency will increase by 148% and the number with high dependency will increase by 91.8%.

Six additional forecasting studies used microsimulation. Guzman-Castillo et al. (2017) modelled life expectancy and disability in England and Wales through 2025 using the IMPACT-Better Ageing Model. Although the model

assumed that cardiovascular disease and dementia would decline, the researchers found a 25% increase in older adults with disabilities and care needs, a result that underscores effects of population aging. Manuel et al. (2016) found that the number of people in Canada living with dementia will double by 2031, also largely due to population aging; similar to an earlier study (Laditka and Laditka 2014b) participants developed dementia over time based on projected incidence rates. Using the Future Elderly Model (FEM), Goldman et al. (2005) found that ADL disability in 2030 in the United States ranged from a 5.5% decrease to a 27.3% increase, depending on baseline population health. Zissimopoulos et al. (2018) used the FEM to study how reducing diabetes and hypertension by 50% affected dementia in the United States through 2040. The result was longer lives with more dementia. Chen et al. (2016) used the FEM, finding that by 2040 in Japan more than 27% of older people will have impairments in 3+ IADLs and social functioning; 25% will have difficulty doing 3+ ADLs; and 20% will have cognitive limitations, all largely due to population aging. Lay-Yee et al. (2017) found that in New Zealand in 2021, increasing informal care moderately lowered formal care, and that moderately more informal and community based formal care reduced residential care.

In all of these studies, the researchers examined phenomena involving complex interactions among multiple inputs over extended periods. As illustrated by the results of Zissimopoulos et al. (2018) and Chen et al. (2016), using microsimulation to forecast the results of such interactions can reveal unexpected outcomes that are useful for planning and policy. In Chap. 10 Carol Jagger and Andrew Kingston describe other methods of forecasting health expectancies.

Estimating Interval Need in the United States

A recent analysis is the first to calculate interval need using data from the United States (Laditka et al. 2017). Using data from the Health and Retirement Study (1994–2012, n = 29,933,

146,324 status transitions, 306,997 person-years), we estimated seven-state models predicting six need intervals and death for African American, Hispanic, and non-Hispanic white (hereafter white) women and men. Table 9.1 shows the definitions for the need intervals, which account for both time between needs for help or care and the intensity of the needed help or care.

Figure 9.1 shows distributions of interval need from ages 55 through death for women and men. The top panels show survival and interval need. The bottom panels show the percentage distribution of need intervals for the remaining population at each age. Consistent with previous research, the figure shows that women have much more short-interval needs than men, such as scheduled daily help or the critical needs associated with long-term care or intensive informal caregiving, particularly at the oldest ages.

The figure suggests that even at the oldest ages large percentages of women and men who need substantial care (intervals 5 and 6) require only

periodic scheduled daily help, such as help with dressing or getting into bed, rather than short-interval continuous care. Also of interest are the substantial percentages of both women and men, particularly among the younger-old, who have needs for daily guidance (shown in black), defined by either a diagnosis of a cognitive or memory problem, or a self-report of such problems, without needing help with ADLs. Given that needing help with ADLs is a diagnostic criterion for advanced dementia these individuals have mild to moderate cognitive impairment, or an early-stage dementia.

Table 9.2 shows the percentage of remaining years from age 80 in each need interval group and the percentage of the population in each group at age 80. Hispanic women and men were the most likely to need the highest levels of care. At age 80, 10.0% of Hispanic men used skilled nursing, assisted living, or equivalent care (need interval 6), for 20.6% of remaining life; comparable results for white men were 5.6% and 12.0%.

Table 9.1 Interval of Need category definitions

| Interval Name | Interval length | Definition | Difficulty and help needed |
|--|---|--|---|
| 1. Independent | No interval, no services | No criteria below apply | May have difficulty (not help) bathing, getting in/out of bed, or dressing; may use technology to do ADLs. |
| 2. Periodic assessment and stand-by help | Periodic assessment | Difficulty (not help): Walking in room; and/or eating; and/or using toilet; or doing any 3 or more of: Bathing, getting in/out of bed, using a chair, dressing | Needs regular assessment by caregivers or providers; needs at least stand-by help by phone or lifeline service. Does not need ADL help. |
| 3. Weekly service | Weekly or every several days | IADL: Shopping for groceries and/or managing money | May have ADL difficulty (not help); may have cognitive impairment but no ADL help indicates not severe; prepares meals or meds if needed. |
| 4. Daily guidance | Once daily or periodically | Cognitively impaired but does not have needs of shorter intervals; no IADL or ADL difficulty, no ADL help | Able to prepare meals, take meds. May reside at home or independent living. Daily guidance may be by phone or other technology. |
| 5. Discrete time daily need | Daily help scheduled for discrete times | Cannot prepare meals; and/or needs help with: Medications, bathing, getting in/out of bed, eating, and/or dressing | May reside in nursing home or assisted living. May reside in independent living but typically requires extra scheduled daily services. |
| 6. Critical interval need | Short interval or continuous 24/7 care | Help with 3 or more ADLs; or help with toilet; or help walking in room; or help with any ADL and cognitively impaired | Requires 24/7 care or available nearby; nursing home, assisted living, home care, or continuous caregiver. |

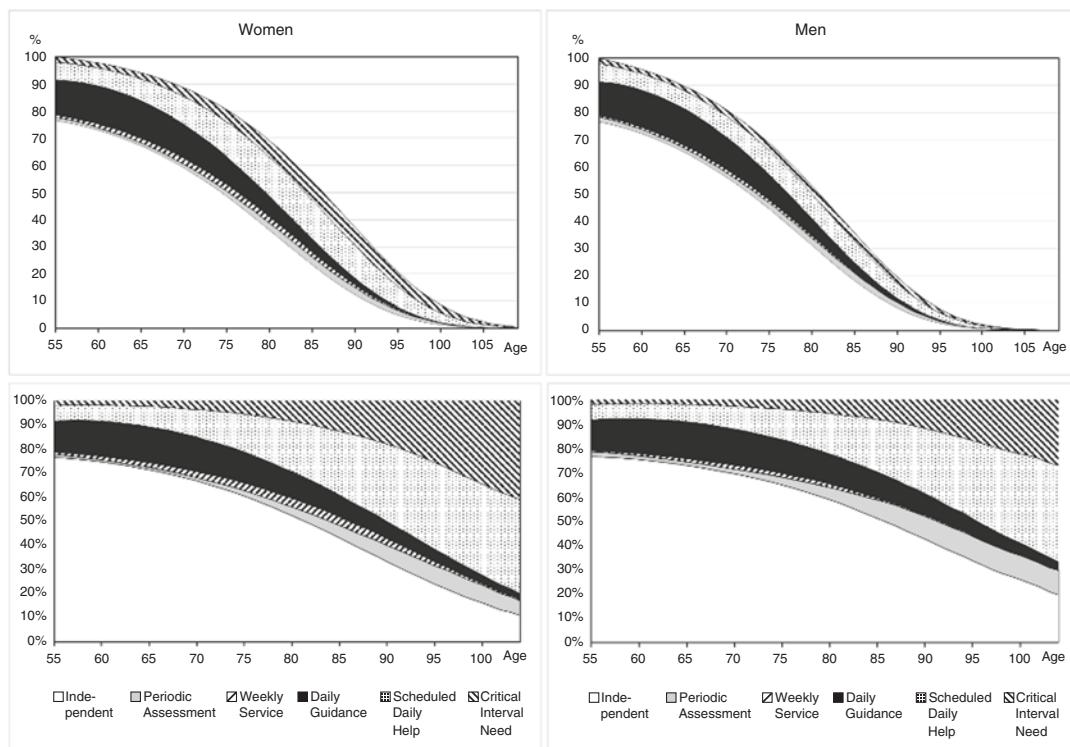


Fig. 9.1 Survival and interval need by age, women and men, education greater than high school; results of microsimulation using data from the Health and Retirement Study

Table 9.2 Intervals of need, results from microsimulated populations, ages 50 through death

| | Men | | | Women | | |
|-----------------------------|------|------|-------|-------|------|-------|
| | AA | Hisp | White | AA | Hisp | White |
| Survival from age: | | | | | | |
| 50 | 74.6 | 78.9 | 76.6 | 79.3 | 83.0 | 81.1 |
| 80 | 87.1 | 88.8 | 87.9 | 89.0 | 90.6 | 89.7 |
| % years from age 80: | | | | | | |
| Interval 2 | 14.3 | 11.1 | 11.6 | 13.5 | 10.4 | 11.7 |
| Interval 3 | 7.6 | 6.3 | 7.0 | 9.5 | 7.7 | 8.6 |
| Interval 4 | 3.8 | 6.1 | 3.2 | 2.9 | 4.4 | 2.6 |
| Interval 5 | 17.0 | 18.2 | 16.4 | 18.2 | 19.2 | 17.6 |
| Interval 6 | 17.0 | 20.6 | 12.0 | 22.6 | 26.9 | 17.5 |
| % at age 80 | | | | | | |
| Interval 2 | 12.6 | 10.0 | 9.7 | 13.2 | 10.4 | 10.5 |
| Interval 3 | 6.3 | 5.0 | 5.2 | 8.1 | 6.3 | 6.3 |
| Interval 4 | 3.1 | 5.9 | 2.5 | 2.4 | 4.4 | 2.1 |
| Interval 5 | 12.2 | 12.8 | 10.4 | 12.9 | 13.7 | 11.1 |
| Interval 6 | 8.7 | 10.0 | 5.6 | 11.1 | 12.6 | 7.6 |

Data source: the 1992–2012 Health and Retirement Study; AA African American, Hisp Hispanic

The interval need analysis illustrates the ability of microsimulation to handle a substantially expanded state space to assess health policy interventions. Results also suggest that many studies of active life expectancy measuring disability dichotomously, based on difficulty with ADLs or receiving help to do them, do not adequately characterize the heterogeneity of needs for help or care.

Conclusions

Strengths

Microsimulation has theoretical, technical, and practical strengths (Spielauer 2011). From a theoretical perspective microsimulation supports life course analysis. Microsimulation lets researchers estimate the entire distribution in a population of time in each health status. This allows researchers and policy makers to better address issues of equity and efficiency in financing and providing health care and other services. For example, microsimulation enabled Lay-Yee et al. (2017) to study how altering the mix of informal and formal care affected older people “at the margins of care,” whose needs could be met equally well—with differing costs—by various combinations of institutional care, home health care, or informal care. A strength of microsimulation from a technical perspective is that it can handle any number of variables of any type (e.g. Laditka et al. 2017), unlike table-based models, which in practice are limited to relatively simple models. Combining the multinomial logistic Markov model with microsimulation also addresses missing-data problems that often affect panel data.

Considerations and Approaches to Address Them

One way to assess the predictive power of microsimulation is to compare its estimates with population data. Many studies described in this chapter have reported estimates consistent with those of established national data, such as life expectancies

calculated by the National Center for Health Statistics (NCHS) (e.g. Laditka and Laditka 2014a, b; 2016a, b), and estimates of chronic disease from other well-established data sources and methods (e.g. Chen et al. 2016; Guzman-Castillo et al. 2017; Kingston et al. 2018a; Manuel et al. 2016).

To provide useful results, microsimulation models of active life expectancy need to be based on parameters of functional status change that reasonably represent population dynamics. Wolf and Gill (2009) compared estimates from data with monthly status measures to results from an embedded Markov chain (EMC) model of monthly transitions (Laditka and Wolf 1998) and an event-history (EH) approach, which assumes that functional status transitions occur only at the mid-point of 12 or 24 month intervals (e.g. Crimmins et al. 1994). They found that although the EMC model performed considerably better than the EH model, both under-estimated: probabilities of becoming disabled; probabilities of recovering from disability; and transitions from unimpaired to dead. However, none of the comparisons of active life expectancy or disabled life expectancy indicated statistically significant differences, and the confidence intervals largely overlapped, suggesting that the results of the three approaches were substantially similar.

A third consideration of microsimulation is its cost. Although microsimulation is straightforward conceptually, the method requires relatively advanced skills in data management, software development, and data analysis. For these reasons microsimulation is most often used by researchers in government agencies or large research centers, limiting its use.

Directions for Future Research

Use High Quality Longitudinal Data

Microsimulation models are empirical, based on panel data. Many researchers who study aging are familiar with high quality panel data such as the Health and Retirement Study. Researchers in this area may be less familiar with the Panel Study of Income Dynamics (PSID). The PSID

(1968-present) represents people of all ages (Johnson et al. 2018). It has measured work disability for five decades, and ADLs since 1992. Deaths are identified using several data sources including the National Death Index. The PSID measures chronic disease onset, duration, and severity. Starting in 2007, for 12 major conditions including asthma, depression, diabetes, and heart disease, the data allow researchers to identify all or most years from birth through the month of interview when the respondent did or did not have the condition. Such dense retrospective data can improve active life expectancy estimates (Laditka and Wolf 2006; Wolf and Gill 2009). PSID supplements measure specific physical and mental health conditions for children and adolescents, who are then followed throughout their adult lives, making it possible for researchers to simulate lifetime health biographies. Researchers can also link participants across families and generations to study family and intergenerational patterns of health and disease (Johnson et al. 2018).

The Survey of Health, Ageing and Retirement in Europe (SHARE) is a cross-national panel study with more than 120,000 participants ages 50 and older with more than 297,000 interviews in 28 countries (2004-present). The large SHARE sample allows modeling of active life expectancy for important but less prevalent chronic conditions such as Parkinson's disease, although mortality data may be incomplete for some countries.

Enhance Reporting of Uncertainty

Some active life expectancy research using microsimulation has reported measures of uncertainty (confidence intervals), typically using bootstrapping (e.g. Laditka and Laditka 2016a, 2016b, 2016c, 2018c; Laditka and Laditka 2014a, b; 2015; 2017). Often, however, measures of uncertainty go unreported. Researchers should more often account for the distribution of model parameters when conducting microsimulations. In a related area, model inputs, which are typically the result of multinomial logistic Markov

models based on panel data with complex survey designs and repeated measures, should more often account for both the survey design effects and the repeated measures.

Extend Active Life Expectancy Research to Younger Ages

Researchers studying active life expectancy have often focused on people who have lived past midlife, often to at least age 65 or 70. That practice may often be due to limitations of available data. However, using data with only midlife and older participants may bias knowledge about active life expectancy, restrict knowledge about health disparities, and overlook problems that policy might otherwise address. For example, current life tables from the NCHS indicate that about 37% of African American men do not survive to age 70, a percentage that would be considerably larger for those with limited educational attainment, and there is evidence of growing mortality gradients associated with education (e.g. Miech et al. 2011). Researchers have shown that it is common for younger adults to have periods of disability, and multiple spells of disability throughout typical working years (Laditka and Laditka 2018c). Increasing opioid addiction and deaths linked with despair underscore high health risks for many Americans in young adulthood and in midlife (e.g., Case and Deaton 2017). All of these factors suggest that researchers should include younger adults in active life expectancy studies. Finally, researchers can use microsimulation to study active life expectancy specifically for people with developmental disabilities or delays and for people with functional impairments or chronic diseases from birth or childhood. Including them in our research would increase knowledge about important population groups and inform service providers and policy makers about needs and intervention opportunities. Representing all ages in active life expectancy studies would improve knowledge about functional status, chronic diseases, and service needs throughout life. Microsimulation makes that possible.

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Forecasting Health Expectancy – What the Future Might Hold

10

Carol Jagger and Andrew Kingston

Background

Many countries regularly produce projections of their populations incorporating trends in the components: births, deaths, fertility and migration. Such projections are generally deterministic rather than stochastic, that is they do not incorporate uncertainty around the individual components. Nevertheless such projections are of immense utility for governments, industry as well as for researchers.

Though we may have estimates of the size of future populations, particularly of older people for planning services, these do not indicate the likely prevalence of ill-health, the numbers of older people with disability, dementia or other care needs, or whether years with disability or ill-health at a particular age are increasing or decreasing. Forecasts of population health or health expectancy are much fewer and these will be the concern of this chapter.

If we have forecasts of the numbers of older people with disability, for instance, is there also a need for disability-free life expectancy (DFLE)? Although service providers and industry might be more interested in knowing how the

actual numbers of older people will change in the future, whether healthy life expectancy or DFLE will keep pace with life expectancy in the future is of equal importance for government in its public health role. The number of older people with disability might increase even if the age-specific prevalence of disability remains constant or decreases, due to larger numbers of the very old who are at the greatest risk of disability. DFLE is independent of population size and takes account of both the prevalence of disability and life expectancy. Thus DFLE may increase even when the numbers with disability have increased if the prevalence of disability falls (Jagger et al. 2016).

This chapter will be concerned predominantly with forecasts of health expectancy. It is worth noting here that papers seem to use the terms ‘forecast’ and ‘projection’ interchangeably though it is understood that the difference between them is in the nature of the assumptions made, those in forecasts being more data-driven. First we will briefly describe the search methods used in the literature review. Then we will review the models found under three headings: cross-sectional, macro-simulation models, and micro-simulation models, and, in the latter we will draw heavily on Chap. 9. We will also discuss simulation models that have the potential to produce forecasts of health expectancies but as yet do not. The chapter will conclude with discussion on where research might next be directed.

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Review of Forecasting Models

For this chapter we updated and extended a previous literature review on dynamic microsimulation models for dependency and care needs which was the focus of that research (Kingston et al. 2018a). We also ran the search algorithm used to produce the regular bibliographic updates for the International Network on Health Expectancy and the Disability Process (REVES) and extracted papers with forecasts or projections. Sixteen papers were identified and these are now reviewed under three headings: cross-sectional methods, macrosimulation models, microsimulation models.

Cross-Sectional Methods

The simplest way of forecasting future health expectancy would be to assume the prevalence of ill-health remains the same (or changes in some predetermined way) and then successively apply these to life tables for future years using the Sullivan method (Sullivan 1971). For example the ratio DFLE/LE has been modelled conditional on age, sex and country, and then used to estimate the adult disability dependency ratio (ADDR), defined as the ratio of the number of adults at least 20 years of age with disabilities divided by the number without disabilities, as a better alternative to the old-age dependency ratio (OADR) which defines dependency on the basis of age only being the ratio of the number of people aged 65 and over to the number of people of working age (15 or 20 to 64) (Sanderson and Scherbov 2010). Resulting calculations for the UK show that the ADDR remains constant at 0.10 between 2005–2010 and 2045–2050 whilst the OADR increases from 0.27 in 2005–2010 to 0.41 in 2045–2050. Though the ADDR brings important information on the disability status of the older population, and indeed of the younger population, thereby more accurately determining those dependent compared to those able to support them, the model assumes that DFLE/LE for a given age and sex (and country) remains constant over time. However, in the UK over the time

period 2001 to 2010, DFLE for men at birth more than kept pace with increases in LE but at age 65 and 85 this was not the case with gains in DFLE being much less than gains in LE (Jagger 2015). This assumption has been shown to be flawed by reference to results from a microsimulation model for Canada (Legare et al. 2014).

A similar method has been employed to estimate the prevalence of severe activity limitation from 2017 to 2047 across the EU based on Healthy Life Years (HLY), another DFLE (Scherbov and Weber 2017). Here a non-constant time trend for the ratio of years with severe activity limitation (sevHLY) to LE is formally assessed in the modelling but rejected on the basis that it relates to an increase in prevalence of <0.5 percentage points per year. The models suggest that the prevalence of severe activity limitations in adults aged 65 years and over is, and will remain, very similar across all EU countries. Thus increases in the numbers of older adults with severe activity limitation will result from ageing of the population rather than any real increase in the incidence of severe activity limitation.

Other researchers have relaxed the strong assumption of a constant ratio of HLY/LE over time across EU countries and explored the effect of different scenarios for HLY increases, and reductions in the gaps in HLY across countries to attain the European Innovation Partnership on Active and Healthy Ageing (EIPon-AHA) target of an increase of two HLY at birth in the EU27 between 2010 and 2020 (Jagger et al. 2013). Continuation of the previous trends (from 2005 to 2009) for each country resulted in nine countries meeting the EIPon-AHA target, predominantly those in Eastern Europe (Estonia, Hungary, Latvia, Lithuania), with the EU27 as a whole failing to reach the target and the HLY gap between countries increasing further to 18.3 years (men) and 19.5 years (women) at birth. The other scenarios explored focused on reduction of the HLY gap alone, then in combination with an increase of 2 HLY for each country, and finally together with no increase in unhealthy life years (LE minus HLY). All of these scenarios resulted in the majority of countries, and the EU27 as a whole, meeting the target, but in many cases the

required gain in HLY for a country was unlikely to be achievable, being much larger than that obtained under the assumption that previous trends were maintained.

Macrosimulation Models

Macrosimulation models project age groups rather than individuals (microsimulation) over time. Such models have been employed to project the future numbers of older people with disability and/or health and care use for Australia, Singapore, the Netherlands, the UK and the US (Ansah et al. 2015; Biddle and Crawford 2017; Jagger et al. 2009; Wouterse et al. 2015; Cao 2016). Only the US model reports forecasts of DFLE although the Dutch model tests the effect of three scenarios based on the relationship between mortality and health (compression of morbidity, expansion of morbidity and dynamic equilibrium).

The Australian model is the simplest in terms of taking no account of changing demographics of incoming cohorts, for instance levels of education (Biddle and Crawford 2017). The model aimed to estimate the future number of Australians aged 65 years and over who would be eligible for the National Disability Insurance Scheme (NDIS). Transition probabilities between the five disability states (none, mild, moderate, severe, profound) and death were estimated from an earlier study and applied to the base population in 2011 up to 2016. The NDIS eligible population in 2017 (when the scheme was implemented) were those aged 64 in 2016 with severe or profound disability and who survived to 2017. From this starting point the model then successively estimates the numbers eligible for NDIS through to 2026, comprising after 2016 of two components: the number of new entrants to the older population who survive the year and have severe or profound disability; and the number of existing NDIS eligible older people who remain in severe or profound disability states and survive the year. Results from the model suggest that between the inception of NDIS in 2017 and 2026 the numbers of older people eligible for NDIS will increase by 480%, from 18,200 to almost 105,700.

Many countries have experienced major improvements in levels of education of their older populations over the last decades, and these are set to continue for some time into the future. Education has a positive effect on health, resulting in lower incidence of disease and disability, and reduced mortality. Accounting for levels of education in forecasts is therefore key and the Singaporean model (Ansah et al. 2015) highlights this. Transition probabilities between the two disability states (active, disabled) and death were applied to the population aged 60 years and older by single year (to age 100) and sex. Transition probabilities were estimated from two multinomial regression models, one with age and sex as covariates only and the second also including education, so that the effect of education could be seen. Projected numbers of the young-old (aged 60–79 years) and old-old (aged 80+ years) with and without accounting for education from 2000 to 2040 are shown in Fig. 10.1. For the young-old improved levels of education result in lower incidence of disability and greater likelihood of recovery from disability which thus result in lower numbers of young-old with disability by 2040 if education levels are accounted for than if they are ignored. However higher levels of education in the young-old also result in lower mortality which, in turn, means greater numbers of old-old where disability incidence is higher. This outweighs the lower incidence of disability and greater recovery from better education in the old-old age group, especially since recovery is rare at very old ages (Kingston et al. 2014).

Rather than a single health indicator, the Dutch model included seven observed health indicators from the Longitudinal Ageing Study Amsterdam (LASA), including disability, self-perceived health and cognitive impairment, to represent the underlying latent health variable with three states: good health, moderate health, poor health (Wouterse et al. 2015). Transitions between the health states and death are modelled as a Markov process and the resulting age- and sex-specific transition probabilities are then applied to the Dutch older population aged 65 to 95 in 2010. New cohorts of 65 year olds are

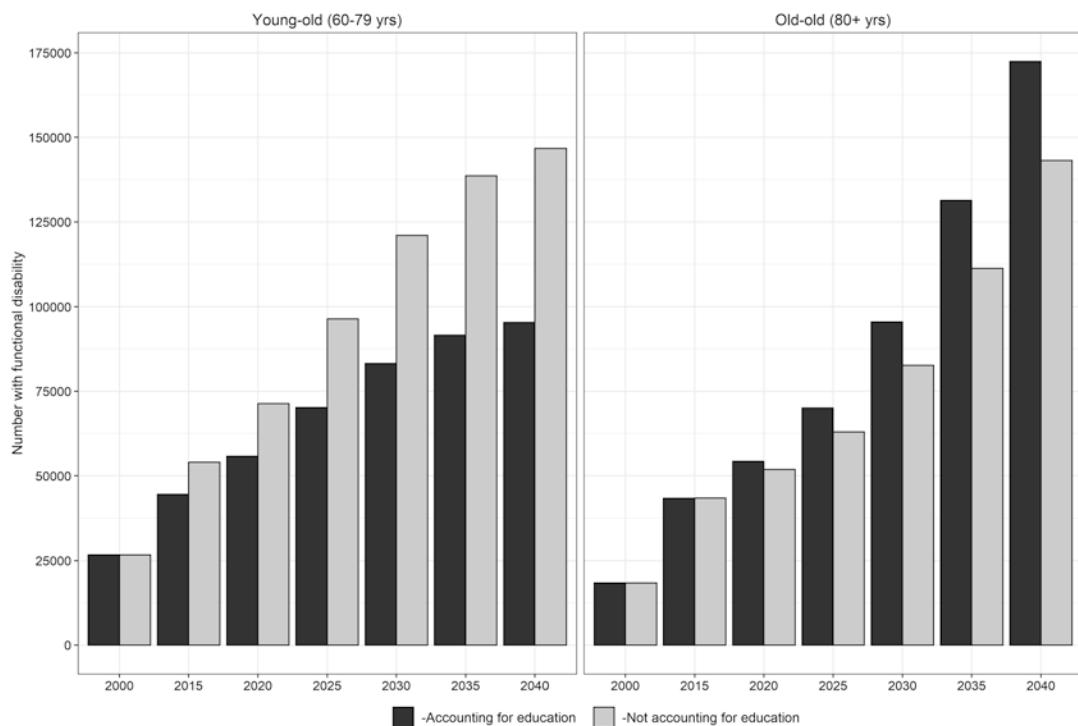


Fig. 10.1 Projections of numbers of young-old (60–79 years) and old-old (80+ years) with functional disability accounting and not accounting for educational levels, 2000 to 2040. (Source: adapted from Ansah et al. 2015)

entered each year with the assumption that they have the same health profile, or are healthier. Costs of three different types of health service (hospital, home care, long-term care) are estimated for the three health states through linkage of LASA to registry data on health service use. Two important findings emanated from this research. The first concerns the effect of improved health for incoming cohorts to the older population in that gains in life expectancy due to better health before age 65 led to less growth in expenditure than did gains in life expectancy due to health improvements post age 65. The second is that the model showed the potential for containment of long term care (LTC) costs if disability is prevented, since LTC costs were lower in the dynamic equilibrium scenario than the expansion of morbidity one. The prediction of a decline in hospital use after 2040 but a continued rise in LTC use up to 2050 may not be generalizable but may be specific to the way health services are accessed and delivered in the Netherlands.

Cognitive impairment and dementia have a profound effect on the ability to perform daily activities unaided, and therefore on disability. Linked with the higher levels of education in more recent cohorts of older people, and the improvement in vascular risk factors, both the prevalence and incidence of dementia have reduced over the last two decades in the UK and the US (Langa et al. 2016; Matthews et al. 2013; Matthews et al. 2016), along with a compression of cognitive impairment-free life expectancy in women (Jagger et al. 2016). The UK macrosimulation model SIMPOP (Jagger et al. 2009) was developed prior to the evidence of reducing dementia but specifically explored the effect of dementia trends and treatment on the future numbers of older people with disability. Although SIMPOP was similar to the models previously discussed in that transition probabilities were applied to age- and sex- specific cohorts, a greater number of variables were modelled to estimate the transition probabilities, these being socio-

demographic factors and ten chronic conditions, including cognitive impairment, arthritis, diabetes and coronary heart disease. Essentially SIMPOP included three parameters for each chronic condition that could be varied for different scenarios: the prevalence of the condition, its disabling effect and the probability of death given the condition. Thus, these parameters afforded scenarios of better prevention through risk factor reduction, improved treatment of the disabling consequences of the condition, and greater survival with the condition. All but one of the scenarios considered (improved survival with dementia) resulted in a reduction in the numbers of older people with disability compared to the base-case of ageing of the population alone. However, the greatest reduction came from the combined scenario of reduced dementia incidence and disabling effects and increased survival, although this amounted to only 15,000 people by 2026, which is small compared to the estimated 1.6 million disabled older people by 2026 with ageing of the population alone.

Though none of the macrosimulation models reviewed reported forecasts of health expectancies in comparison to life expectancies, all had the potential to do so, and therefore to address the question of whether compression or expansion of morbidity or disability were likely. However previously unpublished forecasts of DFLE are available for SIMPOP under three scenarios: ageing of the population alone, continuation of current trends, and improved population health (Table 10.1). SIMPOP demonstrated that if the levels of health prevailing in 2006 continued to 2026, over half of the 2 years of life expectancy at age 65 gained would be years with disability. If population health improved, with a focus on reducing risk factors, particularly smoking and obesity, thereby reducing the prevalence of stroke, CHD, arthritis and dementia by 2% per 2 years, together with treatments or technologies that alleviate or postpone the disabling consequences of disease, this would translate into most of the increases in life expectancy being years free of disability.

Whilst SIMPOP inferred the impact of risk factors for disease, such as smoking and obesity,

from the published literature, the US model directly estimates the effect of their opposing trends – declining prevalence of smoking whilst increasing prevalence of obesity – from 2010 through to 2040 (Cao 2016). Over the decades preceding the model the US had experienced considerable gains in LE and DFLE suggestive of a compression of disability at least at older ages (Crimmins et al. 2016). The forecasts suggest a continued gain in both LE and DFLE and a reduction in years with disability (DLE) for both men and women between 55 and 85 years, with gains for men being larger than those for women though reductions in LE are similar. Differential smoking history between men and women and the greater disabling effect of obesity in women go some way to explaining these findings, though important limitations are the restricted age range (55 to 85 years) and exclusion of the institutionalized population.

Microsimulation Models

In contrast to macrosimulation models, microsimulation models age individuals through time by applying transition probabilities of the relevant characteristics. A benefit of microsimulation models is that they can incorporate more characteristics that drive disability and they can therefore better simulate health policy interventions. Microsimulation models for disability and related health outcomes have been developed for the United States, Japan, Canada, New Zealand, and England (Chen et al. 2016; Goldman et al. 2005; Guzman-Castillo et al. 2017; Kingston et al. 2018a; Lay-Yee et al. 2017; Manuel et al. 2016). All these microsimulation models have been reviewed in Chap. 9, so here we will focus on the two English models that are the only ones to forecast health expectancies.

The IMPACT-Better Ageing Model (IMPACT-BAM), based on the English Longitudinal Study of Ageing (ELSA) simulates the health, disability and mortality of individuals aged 35–100 years in England and Wales from 2006 to 2025. Individual characteristics modelled are cardiovascular disease, cognitive impairment and moderate-to-

Table 10.1 Simulated life expectancy (LE), disability-free life expectancy (DFLE), life expectancy with disability (DLE) and proportion of life spent disability-free (DFLE/LE) at age 65 for population ageing alone, improved population health and continuation of current trends

| | 2006 | 2016 | 2026 | Change 2006 to 2026 |
|---|------|------|------|---------------------|
| Ageing of the population^a | | | | |
| LE (years) | 18.1 | 19.5 | 20.7 | 2.6 |
| DFLE (years) | 16.4 | 17.2 | 17.9 | 1.5 |
| DLE (years) | 1.8 | 2.3 | 2.9 | 1.1 |
| DFLE/LE (%) | 90.3 | 88.1 | 86.1 | -4.2 |
| Improved population health^b | | | | |
| LE (years) | 18.1 | 19.8 | 21.5 | 3.4 |
| DFLE (years) | 16.4 | 17.5 | 18.7 | 2.3 |
| DLE (years) | 1.8 | 2.3 | 2.8 | 1.0 |
| DFLE/LE (%) | 90.3 | 88.4 | 86.8 | -3.5 |
| Continuation of current trends^c | | | | |
| LE (years) | 18.1 | 19.3 | 20.2 | 2.1 |
| DFLE (years) | 16.4 | 17.0 | 17.2 | 0.8 |
| DLE (years) | 1.8 | 2.4 | 3.0 | 1.2 |
| DFLE/LE (%) | 90.3 | 87.8 | 85.4 | -4.9 |

^ano change in age-specific prevalence of disease, incidence and recovery rates to disability, and mortality rates continuing to decline at levels commensurate with GAD principal projections

^breduction in the prevalence of arthritis, stroke, CHD and mild dementia by 2% every 2 years from 2012 and for moderate/severe dementia of every 2 years from 2016, a 10% decrease in disabling consequences of arthritis, stroke, CHD and mild dementia from 2012 and a further 5% reduction (in addition to the adjustments as per GAD) in the mortality from stroke, CHD and mild dementia from 2016

^cincrease in the prevalence of arthritis, stroke, CHD and mild dementia by 2% every 2 years from 2012 and for moderate/severe dementia of every 2 years from 2016, a 10% increase in disabling consequences of arthritis, stroke and CHD from 2012 and a further 5% reduction (in addition to the adjustments as per GAD) in the mortality from stroke, CHD and mild dementia from 2016

severe disability based on activities of daily living. Mortality rates are estimated from ELSA and two death states are defined, those from cardiovascular disease and non-cardiovascular disease deaths. The model assumes that past declines in cardiovascular disease mortality and in dementia incidence will remain through to 2025. The resulting forecast for life expectancy (LE) and DFLE at age 65 showed a relative compression of disability for men between 2015 and 2025 with increases of 2.7 years in life expectancy and 1.6 in DFLE (Fig. 10.2) and a small increase of 2.6% in the proportion of life free of disability. For women increases in LE, DFLE and years with disability (DLE) were much smaller and 95% uncertainty intervals contained zero (no difference between 2015 and 2025). The authors concluded that the greater increases in LE for men were possibly due to the assumed declines in cardiovascular mortality influencing men more than women.

The second microsimulation model for England is the Population Ageing and Care Simulation (PACSim), a dynamic microsimulation model which simulates the characteristics (sociodemographic factors, health behaviours, and 12 chronic disease and geriatric conditions) (Kingston et al. 2018a; Kingston et al. 2018b). PACSim has generated forecasts for two health expectancies: years with multi-morbidity; and dependency-free life expectancy based on the interval of need measure (Isaacs and Neville 1976). Importantly PACSim includes baseline health and risk profiles for individuals aged 35 years and over, therefore not having to make assumptions about the health status of new entrants to the older population as the majority of microsimulation models. This is particularly important given the higher prevalence of obesity and diabetes in younger age groups, since both obesity and diabetes, and their combination, are more disabling than fatal at older ages (AI Snih

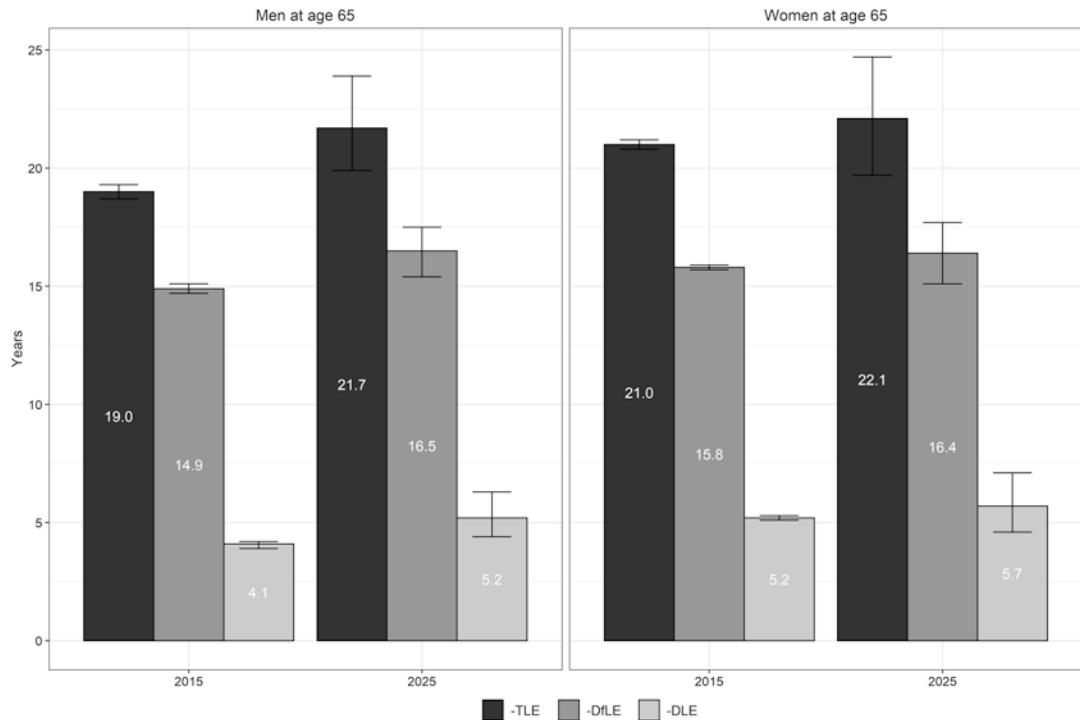


Fig. 10.2 Forecasts of life expectancy (LE), disability-free life expectancy (DFLE) and life expectancy with disability (DLE) at age 65 with 95% uncertainty intervals for

2015 and 2025, by gender. (Source: adapted from Guzman-Castillo et al. 2017)

et al. 2007; Gregg et al. 2018; Laditka and Laditka 2015; Reynolds et al. 2005). Indeed from PACSim, the gain in life expectancy at age 65 between 2015 and 2025 (3.6 years for men and 2.9 years for women) is mostly years with four or more diseases, termed complex multi-morbidity, and the gain in years with two or more diseases exceeds the gain in LE resulting in an expansion of morbidity (Table 10.2).

Compared to men, women's longer life expectancy at age 65 from PACSim appears to be distributed between all the disease states, with the result that the forecasts of years with dependency between 2015 and 2035 are rather different for men and women (Kingston et al. 2018a). For men, the years independent at age 65 that are gained between 2015 and 2035 exceed the gain in life expectancy whilst for women the greatest gain is in years with low dependency with time spent with low dependency constituting over half of women's life expectancy (Fig. 10.3).

Future Research

Our literature review and Chap. 9 have shown that the majority of models do not forecast health expectancy, preferring instead to focus on outcomes for resource planning such as the future numbers with disability or healthcare needs. Nevertheless, most of the microsimulation models found have the ability to produce forecasts of health expectancies and these would provide an opportunity to assess the impact of health interventions at a national level.

Apart from PACSim and, to a lesser degree, the Canadian Population Health Model (POHEM) (Manuel et al. 2016), models are limited in the diseases and risk factors they include. Future models should be more comprehensive for two reasons. Firstly risk factors are shared by a number of diseases and therefore, especially if the model is to be used for assessing the effect of interventions, changing the prevalence of a risk

Table 10.2 Forecasted life expectancy (LE) and years with varying levels of multi-morbidity at age 65 for men and women in 2015, 2025 and 2035

| | 2015 | 2025 | 2035 | Change 2015 to 2035 |
|-------------------------------|------|------|------|---------------------|
| Men age 65 | | | | |
| LE (years) | 18.6 | 20.7 | 22.2 | 3.6 |
| No disease (years) | 2.7 | 1.9 | 1.7 | -1.0 |
| One disease (years) | 5.1 | 4.6 | 4.5 | -0.6 |
| Two diseases (years) | 4.7 | 5.3 | 5.7 | 1.0 |
| Three diseases (years) | 3.3 | 4.2 | 4.7 | 1.4 |
| Four or more diseases (years) | 2.8 | 4.7 | 5.6 | 2.8 |
| Women age 65 | | | | |
| LE (years) | 21.2 | 22.5 | 24.1 | 2.9 |
| No disease (years) | 2.6 | 1.8 | 1.6 | -1.0 |
| One disease (years) | 5.4 | 4.8 | 4.7 | -0.7 |
| Two diseases (years) | 5.6 | 6.0 | 6.4 | 0.7 |
| Three diseases (years) | 4.0 | 4.8 | 5.2 | 1.2 |
| Four or more diseases (years) | 3.4 | 5.1 | 6.1 | 2.7 |

Source: adapted from Kingston et al. (2018b)

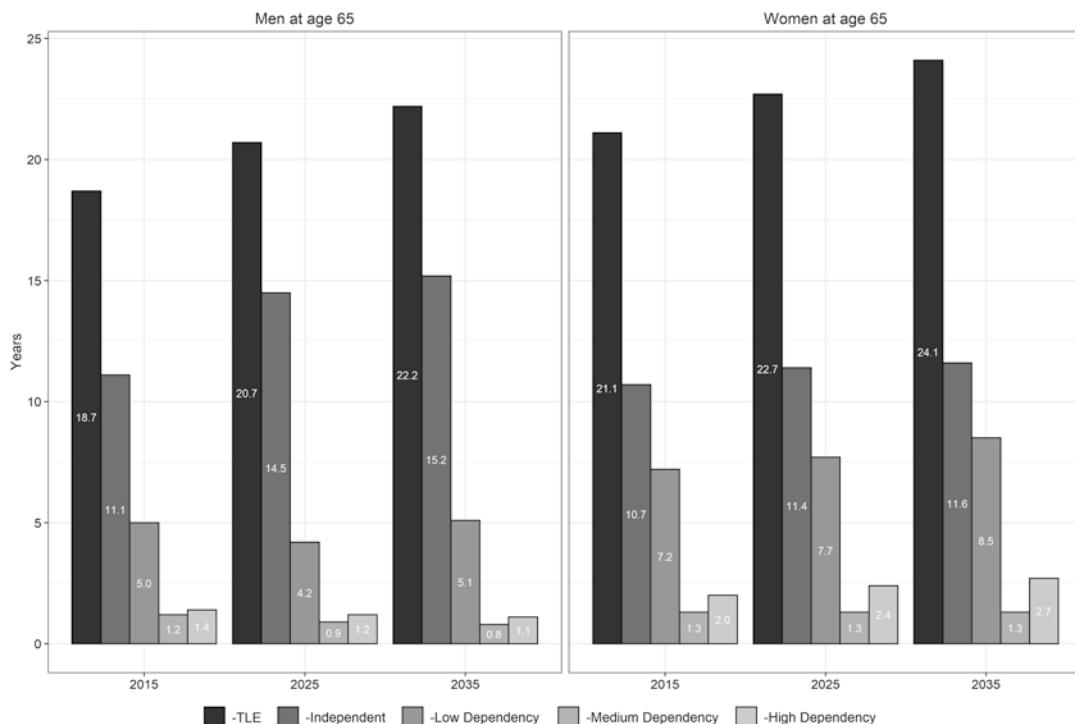


Fig. 10.3 Forecasts of life expectancy (LE), and years spent with low, medium and high dependency at age 65 for 2015, 2025 and 2035, by gender. (Source: adapted from Kingston et al. 2018a)

factor may have a knock-on effect for more than a single disease, or diseases which cluster, for example cardiovascular disease and dementia. Indeed obesity is a risk factor for arthritis, diabetes, cardiovascular disease and dementia. Secondly we have observed substantial increases in the prevalence of certain risk factors/characteristics (for instance level of education and obesity) and reductions in others (for example smoking) over the last decades, and omission of these may seriously under- or over- estimate health outcomes.

Finally the majority of the models produced forecasts at a national level. In many countries regional estimates would be useful but these need to be able to reasonably reflect differences in population structure and health between regions which might feed through to varying patterns of LE and DFLE. Again such models would provide a vehicle for testing whether public health interventions increased or decreased inequalities between regions.

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Part III

Quantity and Quality of Life: Synergy and/or Trade-Off



Gender Differences in Healthy and Unhealthy Life Expectancy

11

Vanessa Di Lego, Paola Di Giulio, and Marc Luy

Introduction

That women live longer than men has been known at least since the middle of the eighteenth century when Kersseboom (1737, 1740) mentioned his observation that the mortality experiences of males and females differ sufficiently to make it worthwhile to use separate tables for calculating annuities. The first gender-differentiating life tables by Struyck (1740) and Deparcieux (1746) added empirical evidence a few years later. The finding of male excess mortality was confirmed with the introduction of official population statistics in all Western societies and has been documented in Sweden from 1751 onwards (Tabutin 1978). Until recently, a higher life expectancy for men was known only for some countries in Africa and Asia, mainly due to excessive female mortality among infants and in early childhood (Aden et al. 1997). A few years ago, Barford (2006) announced in a British Medical Journal editorial entitled “Life expectancy: women now on top everywhere” that women now outlive men even in the poorest countries of the world. Men have higher mortality than women not only in terms of overall measures like life

expectancy at birth but also – at least in all industrialized societies – at all ages and for all leading causes of death. Male excess mortality is caused by a very complex network of biological factors (factors largely beyond human control which are also called ‘inherited risks’) and non-biological factors (behavioural, cultural and environmental factors, i.e. factors directly or indirectly influenced by human action which are also called ‘acquired risks’). Several authors have attempted to determine the relative contributions of these two cause categories and concluded that the acquired risks are mainly responsible for the differences in life expectancy between women and men (see e.g.; Luy 2003, 2016; Waldron 1983b; Wingard 1984).

In light of the universal observable male excess mortality it is surprising that studies on gender differences in morbidity report that women are in worse health than men (among many others, Deeg and Bath 2003; Spiers et al. 2003) and that women spend a higher proportion of their total life in poor health (Robine et al. 2001; Crimmins et al. 2002; Luy and Minagawa 2014). Women routinely show higher morbidity from acute conditions and nonfatal chronic diseases and also more short-term disability. Even when reproductive conditions are excluded, a sizable gender difference still remains in acute conditions and short-term disability (Verbrugge 1985; Green and Pope 1999). Further, women show a greater rate of decline in physical

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functioning and they are less likely to recover from disability (Beckett et al. 1996). Moreover, women are reported to have a higher utilization of health care services (Green and Pope 1999; Redondo-Sendino et al. 2006) and they generally use more prescription and non-prescription drugs than men (Roe et al. 2002). Last but not least, measurements of physical power reveal that men are stronger at all ages (Frederiksen et al. 2006). These obvious contradictions to the mortality differences between the genders have led to numerous publications describing this phenomenon with expressions like “gender and health paradox” (Rieker and Bird 2005), “morbidity paradox” (Gorman and Read 2006), “morbidity-mortality paradox” (Kulminski et al. 2008), or “male-female health-survival paradox” (Oksuzyan et al. 2009).

However, several studies have more recently shown that the paradox is not as constant and universal as the term suggests. For instance, gender differences in health can vary strongly by age, health measure, time and social context (Deeg and Bath 2003; Kulminski et al. 2008). Furthermore, research has shown that the paradox is usually based on studies that focus on major health traits, but that results are considerably diverse when analysing minor health deficits throughout the life cycle, indicating less pronounced paradoxes for particular gender-specific health issues (Kulminski et al. 2008). Nevertheless, despite recent questioning and evaluation of the gender paradox, the idea of a paradoxical relationship between health and mortality among women and men persists until today, and despite the efforts of many demographers, epidemiologists, socio-medical scientists and others, very little is understood about the reasons for the paradox or its mechanisms (Grundy 2006; Oksuzyan et al. 2018).

Perhaps the most consistent finding in the literature is the existence of differences in the types and severity of conditions experienced by women and men, suggesting that “one gender is sicker in the short run, and the other in the long run” (Verbrugge and Wingard 1987: 125). Prior research has shown that women suffer from a greater number of conditions than men, but

female disabilities tend to be less lethal. In contrast, men suffer from conditions leading to earlier death (e.g. Case and Paxson 2005; Spiers et al. 2003). Hence, the overall reversal in gender morbidity and mortality differentials occurs because conditions that figure importantly in morbidity are not very important in mortality, and vice versa. In addition, women have a higher life expectancy than men which translates directly into health inequalities. Previous work has found that women’s longer lives are in fact accompanied by increases in morbidity and concluded that women’s longevity advantage itself is an important contributor to their health disadvantage (Crimmins et al. 2002; Van Oyen et al. 2013; Luy and Minagawa 2014).

A second frequently cited explanation for apparently higher rates of morbidity among women are that they are more sensitive than men to bodily discomforts, and more willing to report symptoms of distress and illness (e.g. Dowd and Todd 2011). Yet the evidence, though limited, is conflicting. Some studies have found that when one controls for specific conditions, there are either no gender differences in pain or symptom reporting or men are more likely to complain (Macintyre 1993). With regard to the widely accepted belief that women use health services more than men, one can also find contradictory evidence in the literature (Arber and Cooper 1999). Other studies failed to detect any gender differences in the reporting of health problems and health service contacts or in the readiness to mention symptoms (Galdas et al. 2005). Oksuzyan et al. (2009) found that hospitalized women and women taking medication are somewhat more likely to participate in a health survey than comparable men, but the contribution of such a selection bias is only minor. Some other arguments regarding the different health behaviours of women and men are based solely on theoretical considerations or intuitive assessment, and thus many counterarguments could be found against these explanations (see Verbrugge 1982).

All this complexity leads to high variations in the extent—and in some cases even in the direction—of gender differences in health. The aim of

this chapter is therefore to highlight these variations of the male-female health differentials across countries and ages by focusing primarily on the impact of using different definitions of health. In addition, we will analyse the effect of gender differences in the reporting of health conditions. We approach the first effect through an overview of health expectancies computed using three different health domains (activity limitation, chronic morbidity and self-perceived health), according to the European Health Expectancy Monitoring Unit Information System (EHEMU), for the year 2015. For the second effect, we use the recently implemented survey tool of “vignettes”, short stories describing the characteristics of hypothetical individuals. For our purposes we are interested in vignettes that illustrate individuals with different degrees of severity in various health conditions. Respondents are asked to read the vignettes and evaluate the severity of the described health condition according to a given scale. In this way we can analyse whether the health reporting of women and men differs across European countries (King et al. 2004).

In this chapter we neither discuss in detail the main explanations provided so far for the paradox, nor do we estimate the specific contributions of gender differences in morbidity and in mortality which cause this phenomenon. Our focus is to provide an overview of the extent to which the paradox can vary when different health indicators are considered. Hence, the empirical illustrations are based on the health expectancy indicator rather than on prevalence or incidence data (for detailed work on the contribution of health and mortality to gender differences in health expectancy see Nusselder and Looman 2004).

In the next section we demonstrate the variation of the gender gap in health expectancy by the health measure. The subsequent section illustrates the extent and variability of gender differences in health reporting through the vignette approach. In both we focus on European countries because of the availability of harmonized data for a high number of populations. The final section summarizes the most impor-

tant messages of this chapter and discusses how the demonstrated effects of health definition, age and reporting should alter our understanding and analysis of the “gender paradox” phenomenon.

Variation of the Gender Gap in Health Expectancy by Health Indicator

For this section we use age- and gender-specific estimates for life expectancy (LE) and health expectancy (HE) from the European Health Expectancy Monitoring Unit Information System, for the year 2015 (<http://www.ehemu.eu>). The estimates for HE were obtained by the method developed by Sullivan (1971). The Sullivan method integrates age-specific disability prevalence into the conventional life table (Jagger et al. 2014; Sullivan 1971). In this way, HEs have a similar interpretation to total LE: they indicate the average number of person-years lived in a certain health state given that he or she survived to a given age. Thus, HEs are summary measures of population health which combine information on the quantity and quality of life, making them suitable for quantifying and monitoring population health, and also for comparing countries (Mathers 2002; Robine 2006; Berger et al. 2016). However, such comparisons are only effective if the data used are equivalent, which considerably limits global analysis in health differences. Nonetheless, since 2005, three harmonized HE indicators based on different definitions of health—to which we refer as “health domains”—have been annually monitored in the European Union: life expectancy without (with) activity limitation, life expectancy in bad (fair/good) self-rated health, and life expectancy without (with) chronic morbidity. Each indicator is based on global survey questions covering these rather broad definitions of health. The three questions form the so-called “Minimum European Health Module” (MEHM) (Jagger et al. 2014; Berger et al. 2016) and they are included in the European statistics on income and living condi-

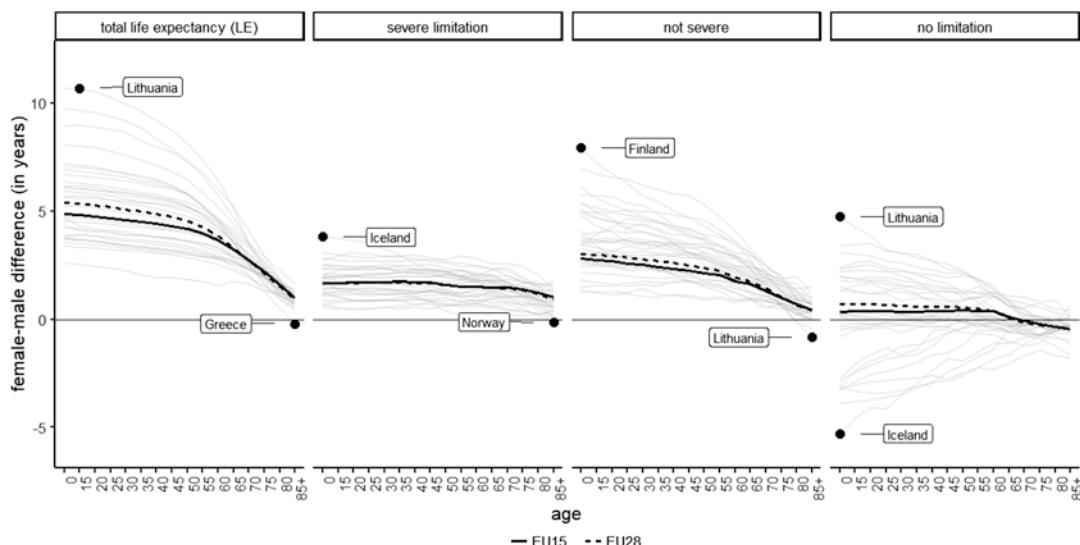


Fig. 11.1 Female-male difference (in absolute number of years) in Total Life and Health Expectancy by activity limitation status. Selected Europeans countries, 2015. (Source: Own calculations using data from Statistics on

income and living conditions (EU-SILC); European Health Expectancy Monitoring Unit Information System (EHLEIS))

tions survey (EU-SILC).¹ The validity and reliability of these questions have been widely documented and the SILC survey was specifically designed to enhance the comparability between countries (Jagger et al. 2014; Nusselder et al. 2010).²

Activity Limitation

This HE indicator is estimated based on the SILC survey question: “For at least the last 6 months have you been limited in activities people usually do, because of a health problem?”, also called the “Global Activity Limitation Indicator” (GALI). The answer allows for no limitation, severe limitation and not severe limitation. It was developed by the Euro-REVES group for the European Union (EU) and serves currently as the EU’s offi-

cial structural indicator to track levels and trends in population health labelled “Healthy Life Years” (HLY).

Figure 11.1 shows the absolute difference between women and men in the number of life years spent in each activity limitation state, together with the total LE at each age. The background light grey lines of the graph reflect the single European countries, and the black solid and dashed lines are for combined EU-15 and EU-28 countries, respectively.³ In addition, the labelled single countries represent the maximum and minimum values found, in order to highlight the variance of each indicator. If women and men experienced the same number of years in each activity limitation state and if there were no differences in total LE, then all values would be

¹For a full description of the survey please refer to <https://ec.europa.eu/eurostat/web/microdata/european-union-statistics-on-income-and-living-conditions>

²Nonetheless, one must account for the fact that issues with harmonization still persist and that the survey excludes the institutionalized population.

³Member states of EU15 are Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and United Kingdom, Austria, Finland and Sweden. By July 2013 the number of states increased to 28, with the inclusion of several eastern European countries (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia, Bulgaria, Romania, and Croatia) to form the EU28.

equal to zero (represented here by the straight horizontal black line). When considering EU-28 and EU-15 countries combined, it is clear that not only women live longer than men at all ages, but they also spend more years in practically all states of activity limitation. Gender differences in LE are largest at younger ages and then reduce at older ages, but with women always presenting higher life expectancies. Among the remaining life years by state of activity limitation, the highest differentials are found for not severe limitation. The gender differentials for life years with no limitation are smaller, with the level for combined European countries pivoting around zero. It is only from age 65 and over that men expect to spend more absolute years without activity limitation compared to women. Despite this overall pattern for combined European countries, the range of different values across countries is not trivial. In the year 2015, the highest gender gap across all countries, health indicators, and age groups was prevalent for LE at age 15 in Lithuania, with Lithuanian women living on average more than 10 years longer than men. Conversely, the highest gender differential in favour of men was found for limitation-free life years at birth in Iceland, with a difference of over 5 years compared to women. However, these figures for HEs are not taking into account the total number of life years or the proportion of the total life span spent in each condition. Since women live longer, they are also more exposed to spending more years in each health condition.

Therefore, Fig. 11.2 shows the gender ratios (M/F) of the proportions of LE in each state of activity limitation. The grey lines in the background represent each European country, while the solid black and dashed lines represent the combined EU-15 and EU-28 countries, respectively. Values above one indicate that men spent a larger proportion of their remaining LE in a certain health state, whereas values below one represent for a larger proportion among women. When accounting for the proportion of total life years that is spent in each one of those states, women stand out as spending a higher portion of their life span in poorer health (both with not severe and

severe limitation), since all ratios lie below one. Men, on the other hand, spend a higher proportion of their lives with no activity limitation (values above one), confirming the basic idea of the gender and health paradox.

Figure 11.2 additionally shows that the variation between countries increases with age. This reflects to a large extent the higher susceptibility of the proportions to the health prevalence values with decreasing number of overall life years. Austria stands out as the country in 2015 with the highest male excess in the proportion of total LE with no limitation at ages 85 and above. The greatest gender gap with female excess can be found at the same age in Iceland, referring to LE spent with not severe limitation. When considering EU-15 and EU-28 countries, however, the female-male figures almost overlap, suggesting no significant differentials in terms of the number of years expected to live in each health condition by gender and age in those combined countries.

Figure 11.3 shows the same proportions described in terms of ratios in Fig. 11.2, but now separately for each gender. The pattern is very similar for men and women, with the proportion of LE with no limitation decreasing with age, while the proportions of LE with severe and not severe limitation increase. However, women and men differ regarding the level of life years spent in different levels of limitation, women experiencing lower proportions of limitation-free life years and higher proportions of life years spent with severe and not severe limitation across all ages. In addition, the countries with extreme values vary by age for women and men, especially when considering the highest values: the highest proportion of LE at birth with no limitation can be found in Sweden among men and in Malta among women, with the corresponding lower values also for those same set of countries and health indicators at birth. However, when considering age 85, men in Lithuania are the ones who experience the highest proportions of LE with no severe limitation and Greek men exhibit the highest proportions of LE with severe limitation, while for women these same figures refer to the Netherlands and Slovakia.

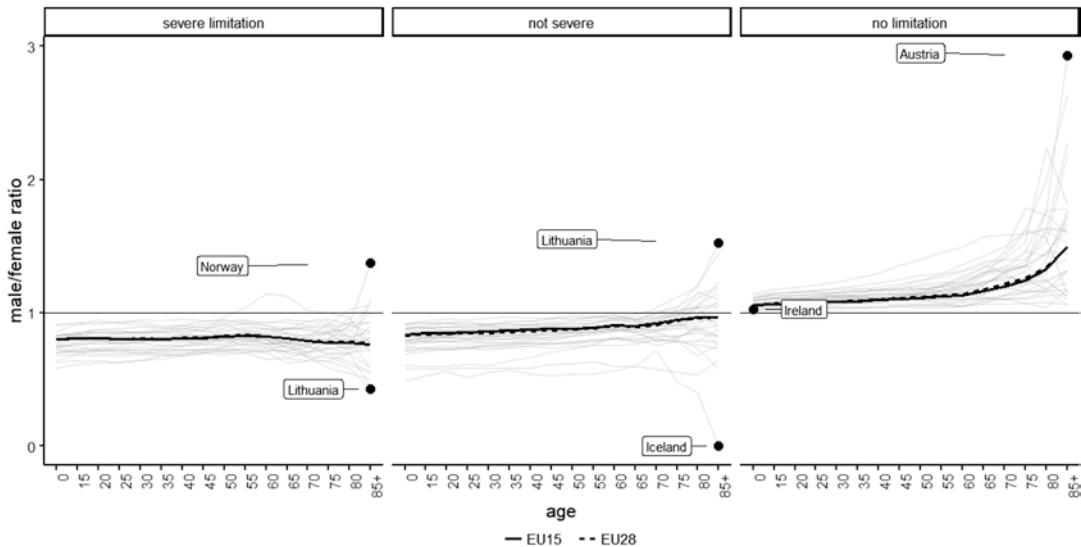


Fig. 11.2 Male/female ratios of the proportion (%) of Total Life Expectancy by limitation status, selected European countries, 2015. (Source: Own calculations

using data from Statistics on income and living conditions (EU-SILC); European Health Expectancy Monitoring Unit Information System (EHLEIS))

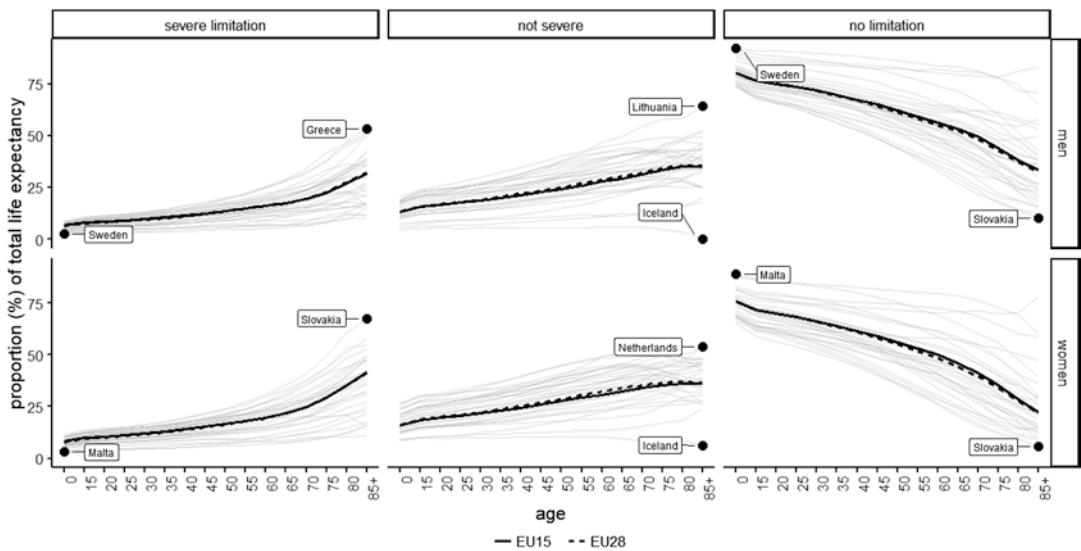


Fig. 11.3 Proportion (%) of Total Life Expectancy by limitation status, age and gender, selected European countries, 2015. (Source: Own calculations using data from

Statistics on income and living conditions (EU-SILC); European Health Expectancy Monitoring Unit Information System (EHLEIS))

Nonetheless, both men and women with no limitation in Slovakia and without severe limitation in Iceland at ages 85+ experience the lowest values, despite a difference in levels. In addition, differentials for EU-15 and EU-28 countries seem somewhat more evident compared to the

graph for the total populations (Fig. 11.2), with EU-15 countries showing a slightly higher proportion of total life expectancy free from activity limitation starting at age 35, and the gap widening with age until age 85. EU-28 countries seem to experience higher proportions of total life

expectancy spent with not severe limitation, especially among women, but overall differences between EU-15 and EU-28 are relatively small.

Chronic Morbidity

This HE indicator is estimated based on the SILC survey question: “Do you have any long-standing illness, disability or infirmity? By long-standing I mean anything that has troubled you over a period of time or that is likely to affect you over a period of time?”. The answer allows for the two options “yes” or “no”. Figure 11.4 shows the absolute difference between women and men in the number of life years spent in the two chronic morbidity states, together with the total LE at each age.

Like with activity limitation, the light grey lines in the background represent the single European countries, and the solid and dashed black lines are the combined EU-15 and EU-28 countries, respectively. Compared to the corresponding graph for activity limitation in Fig. 11.1, gender differences in life years spent with chronic morbidity are much closer to the gender gap in total LE. The highest differentials are still for total LE, but the gender gap in LE with chronic

morbidity is remarkably high, favouring men. In addition, Fig. 11.4 suggests that differentials among EU-15 and EU-28 countries are higher for this health indicator, compared to the other health dimensions, with EU-28 countries showing higher female-male gaps in absolute number of years expected to live with chronic morbidity at all ages, converging only after age 70. This means that the female surplus in LE is spent almost exclusively with chronic morbidity and at all ages. As with the figures based on the GALI indicator, the gender differences in LE free from chronic morbidity are lower at all ages, with women exhibiting lower levels than men only at age 85. Also, for this indicator, Iceland and Lithuania are outliers among European countries, with the highest differentials at ages 0 and 15, respectively.

When analysing these gender differences in terms of proportions of total LE we find another confirmation of the gender paradox. Women spend a higher proportion of their total LE in presence of chronic morbidity at all ages, despite living longer, while men expect to live a higher proportion of their remaining life time free from these conditions (see Fig. 11.5). The maximum extent of the gender gap again can be found for Lithuania, with the male-female ratio in LE free

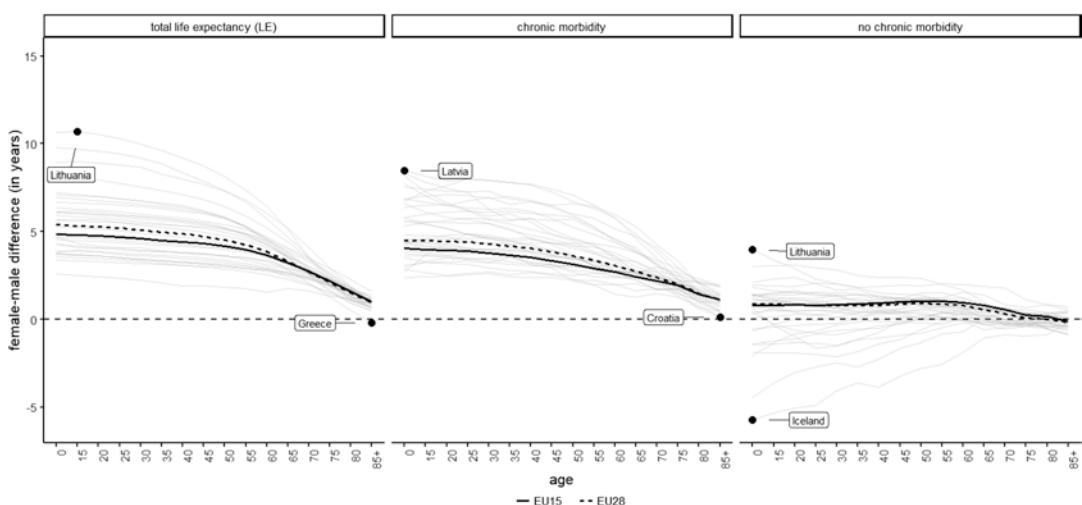


Fig. 11.4 Female-male difference (in absolute years) in Total Life and Healthy Expectancy by chronic morbidity status. Selected European countries, 2015. (Source: Own

calculations using data from Statistics on income and living conditions (EU-SILC); European Health Expectancy Monitoring Unit Information System (EHLEIS))

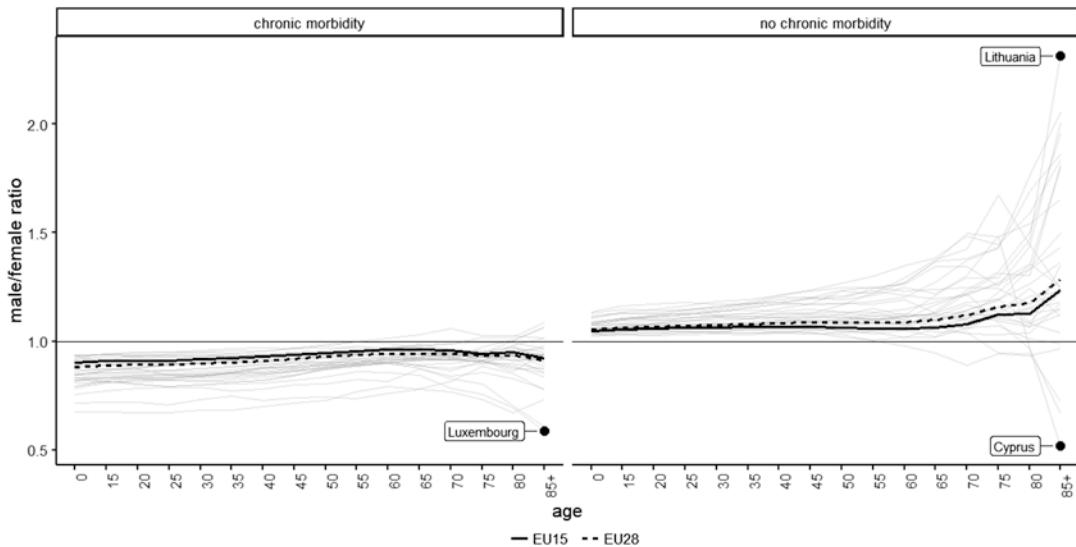


Fig. 11.5 Male/Female ratios of the proportion (%) of total life expectancy by chronic morbidity, selected European countries, 2015. (Source: Own calculations

using data from Statistics on income and living conditions (EU-SILC); European Health Expectancy Monitoring Unit Information System (EHLEIS))

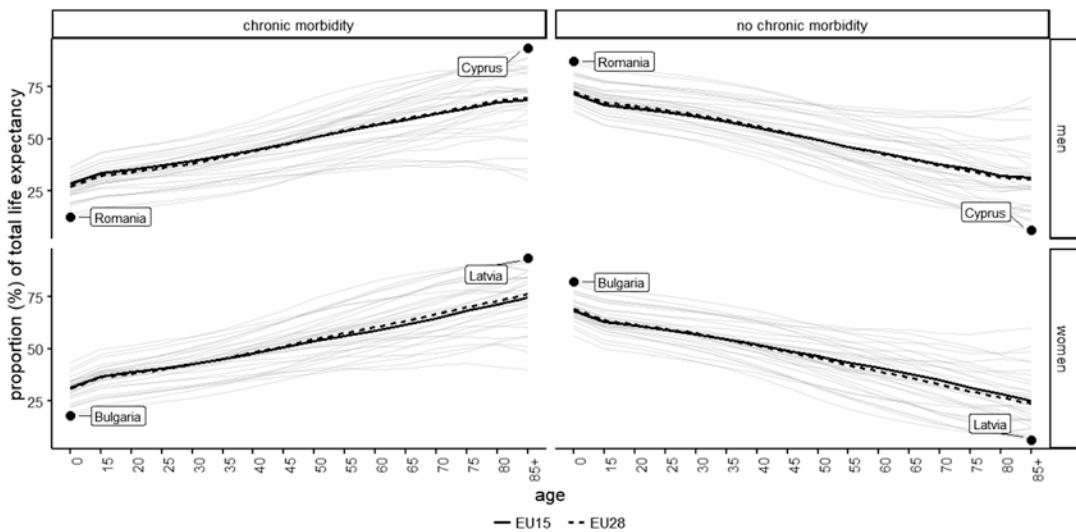


Fig. 11.6 Proportion (%) of total life expectancy by chronic morbidity status, age and gender, selected European countries, 2015. (Source: Own calculations

using data from Statistics on income and living conditions (EU-SILC); European Health Expectancy Monitoring Unit Information System (EHLEIS))

from chronic morbidity being more than 2.5 times in favour of men at age 85. Strikingly, however, Cyprus shows a reversed pattern at this age, with women living longer than men but also expecting to live these years with a lower proportion of chronic morbidity.

Figure 11.6 shows the same proportions, but now separately for each gender. The patterns for men and women are very similar, with the proportion of total LE without chronic morbidity decreasing with age, while the proportions of LE with chronic morbidity increase. The main differ-

ences appear with regard to the levels of limitation status. Women are always experiencing lower proportions of chronic morbidity-free LE and higher proportions of life years spent with chronic morbidity.

Again, the countries with extreme values differ for women and men. Across all the European countries in 2015, men in Romania have the highest proportion of LE at birth spent free of chronic morbidity. For women, the highest values are found for Bulgaria. Regarding LE with chronic morbidity, the highest values can be found in Latvia for women and in Cyprus for men, both at age 85. Thus, the extremely high male/female ratio for Cyprus shown in Fig. 11.5 is associated with a high proportion of male LE at age 85 spent with chronic morbidity. Since this indicator is binary, the lowest values mirror the highest ones for both genders at all ages.

Self-Perceived General Health

The third HE indicator presented in this chapter is estimated based on the SILC survey question:

“How is your health in general? Is it...”. Five answer categories are proposed in the survey question: very good/good/fair/bad/very bad. The European Health and Life Expectancy Information System (EHLEIS) merges the two top categories “very good” and “good” into one single category “good” and the two bottom categories “very bad” and “bad” into the single category “bad”, while “fair” retains its initial characteristics when estimating HEs. Since we use the EHLEIS estimates, the results presented here refer to these three answer categories. The corresponding gender differentials in HE can be found in Fig. 11.7. Not surprisingly, women expect to live more years in bad or fair general health. The gender gap for LE in good overall health condition is almost null, favouring men from ages 65 and over. The largest difference with female excess can be found for bad general health in Portugal at age 30, and the largest difference with male excess for good general health in Iceland at age 15. We present the results starting from age 15 since self-perceived HEs are estimated from ages 15 on by the EHLEIS.

When we analyse the M/F ratios in proportions of LE spent in the different states of gen-

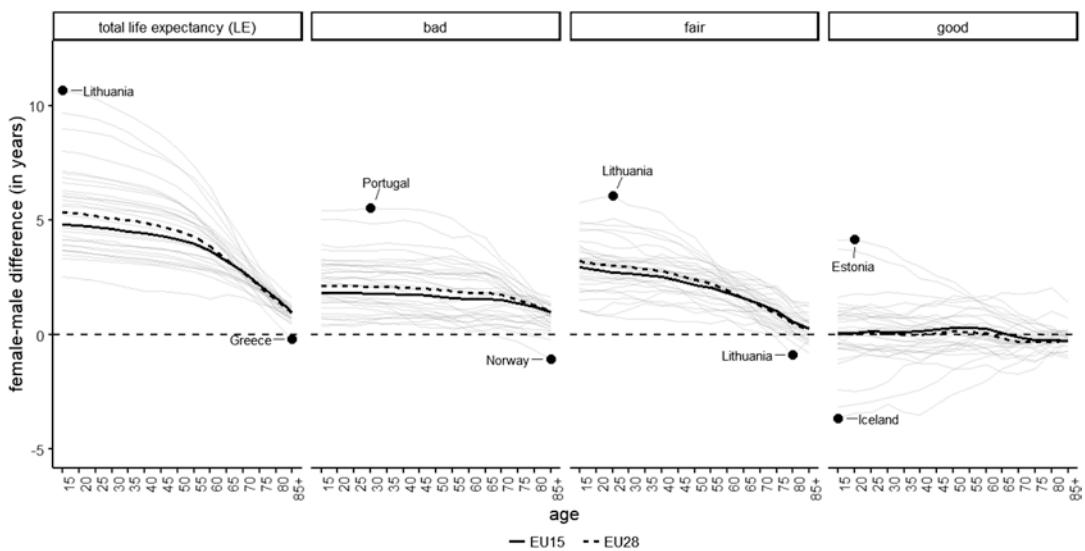


Fig. 11.7 Female-Male difference (in absolute number of years) in total Life and Healthy Expectancy, by self-perceived general health. Selected European countries, 2015. (Source: Own calculations using data from Statistics

on income and living conditions (EU-SILC); European Health Expectancy Monitoring Unit Information System (EHLEIS))

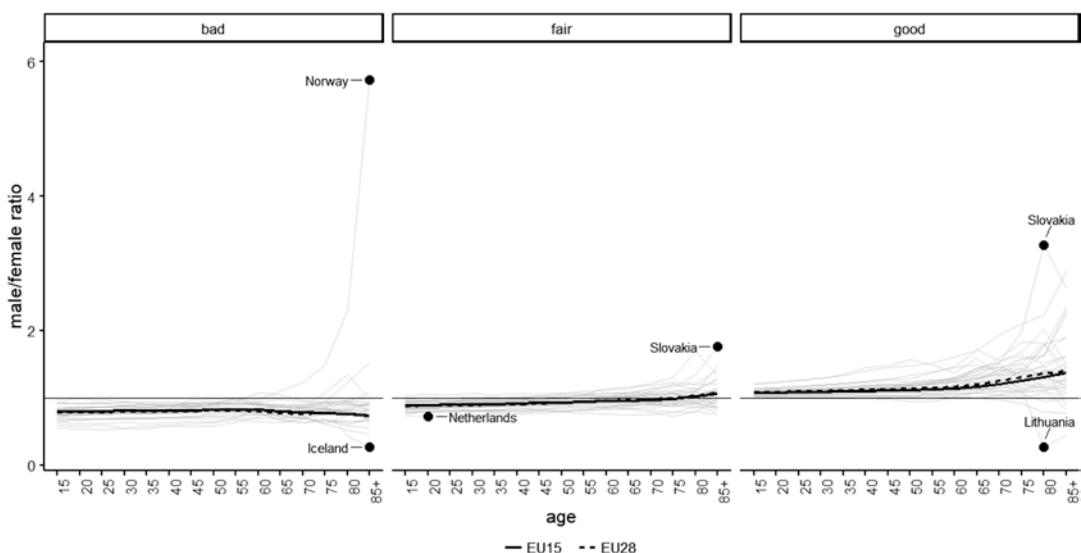


Fig. 11.8 Male/Female ratios of the proportion (%) of total life expectancy by self-perceived general health, selected European countries, 2015. (Source: Own calcula-

tions using data from Statistics on income and living conditions (EU-SILC); European Health Expectancy Monitoring Unit Information System (EHLEIS))

eral health, we find that women spend a higher proportion of their total lives with bad health at all ages, while men spend a higher proportion in good general health at all ages, on average, for both the combined EU-15 and EU-28 countries (see Fig. 11.8). The differentials increase with age for both fair and good health, and remain relatively constant with slight decrease at age 85 and over for bad self-perceived health. According to the data, an exceptionally high ratio for the proportion of LE spent in bad health can be found for the oldest age group in Norway. The lowest value is prevailing in Iceland for the same age group. For fair self-rated health, the highest ratio is found for Slovakia at age 85 and lowest for the Netherlands at age 20. Slovakia also rates in the maximum for good self-rated health, but for age 80, while the minimum is Lithuania at the same age.

The proportions of LE spent in each state of self-perceived general health separately for women and men are shown in Fig. 11.9. Women consistently spend a higher proportion of their lives with bad general health compared to men. Lithuania stands out as the country in which men at aged 85 can expect to spend the highest pro-

portion of their lives in bad health, while the corresponding scenario for women can be found in Slovakia. Additionally, both men and women from Malta present the highest proportion of LE spent in fair overall health at age 70, while 15-year olds from both genders in Ireland present the highest proportion of LE in good general health. Conversely, Swedish men experience the lowest proportions of LE in bad health at age 15, while the same is true for men of the same age in Greece as regards fair health. Lithuanian men at age 80 experience the lowest values for good self-perceived health. For women, on the other hand, Ireland is the country with the lowest proportion of total LE spent in fair health at age 15. At age 85, the lowest proportion of total LE spent in bad and good health among women is in Norway and Slovakia, respectively.

Variations in the Gender Gap in Healthy and Unhealthy Life Expectancy

The previous sections have illustrated that despite having a similar overall pattern, the

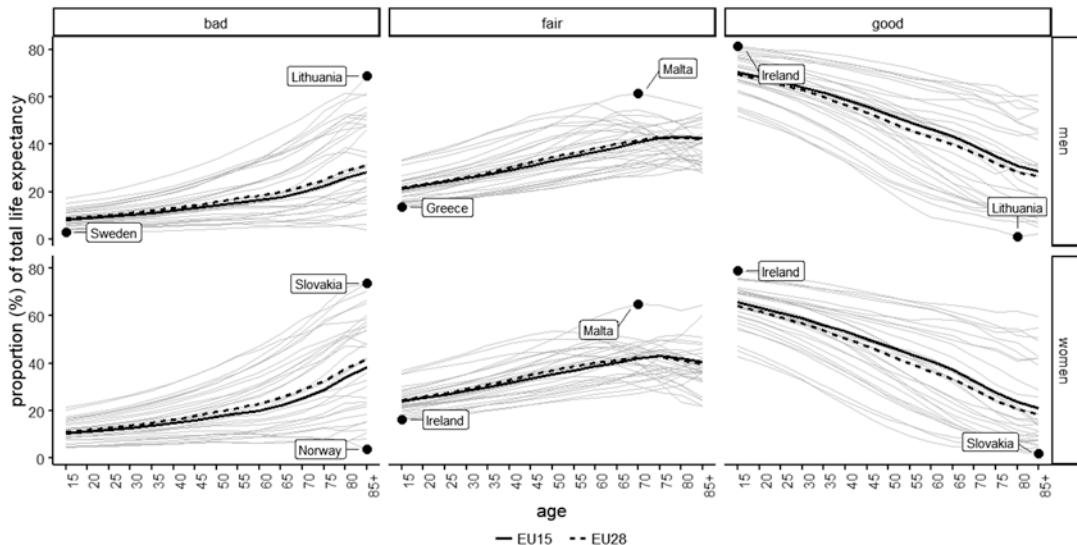


Fig. 11.9 Proportion (%) of total life expectancy by self-perceived general health, age and gender. Selected European countries, 2015. (Source: Own calculations

using data from Statistics on income and living conditions (EU-SILC); European Health Expectancy Monitoring Unit Information System (EHLEIS))

extent of the gender gap varies by indicator, severity level, age and the health domain used. In this section we demonstrate that age is also important for gender differences in healthy life expectancy (HLE) and unhealthy life expectancy (ULE). Figure 11.10 shows the rankings of European countries from the most equal to the most unequal in terms of total gender gap in HLE and ULE for the three health domains of the MEHM at ages 15, 50 and 65.

The change in country rankings for gender gaps in both %HLE and %ULE at ages 15, 50 and 65 for the three health domains activity limitation, chronic morbidity and general health is remarkable. When we look at the health domain activity limitation in the top left part of Fig. 11.10 we see that Denmark ranks 25th at age 15, with one of the highest gender gaps, but it moves to the fourth place at age 50 and even to first place at age 65. Germany maintains the same ranking for ages 15 and 50, taking the first position as the country with the lowest gender gap in no activity limitation at both ages, but at age 65 it moves five positions down to sixth place. When considering the combined EU-15 and EU-28 countries, both show increasing differentials with age, but EU15

countries have lower gender differentials at all ages considered.

For LE free of chronic morbidity (top middle part of Fig. 11.10), Denmark maintains its pattern of a remarkable decrease in gender gap by age, despite the jump being less substantial when compared to the activity limitation indicator (ranking changes from 18th place to third). Cyprus has an increasing gender gap with age, moving from the fifth position at age 15 to 12th place at age 65. Germany is an interesting case of a decrease in gender gap between ages 15 and 50, followed by an increase between ages 50 and 65. EU15 countries maintain a stable position between ages 15 and 50 and then decrease slightly in their gender gap between ages 50 and 65, while EU28 countries first experience a decrease in their gender gap, followed by a stability between ages 50 and 65.

As regards good self-perceived health, some important differences appear. Firstly, for both LE free from limitation and from chronic morbidity, Sweden presents a decreasing gender gap with age, but the opposite can be observed for good overall health. Cyprus maintains the same pattern as in the other health domains, now dropping

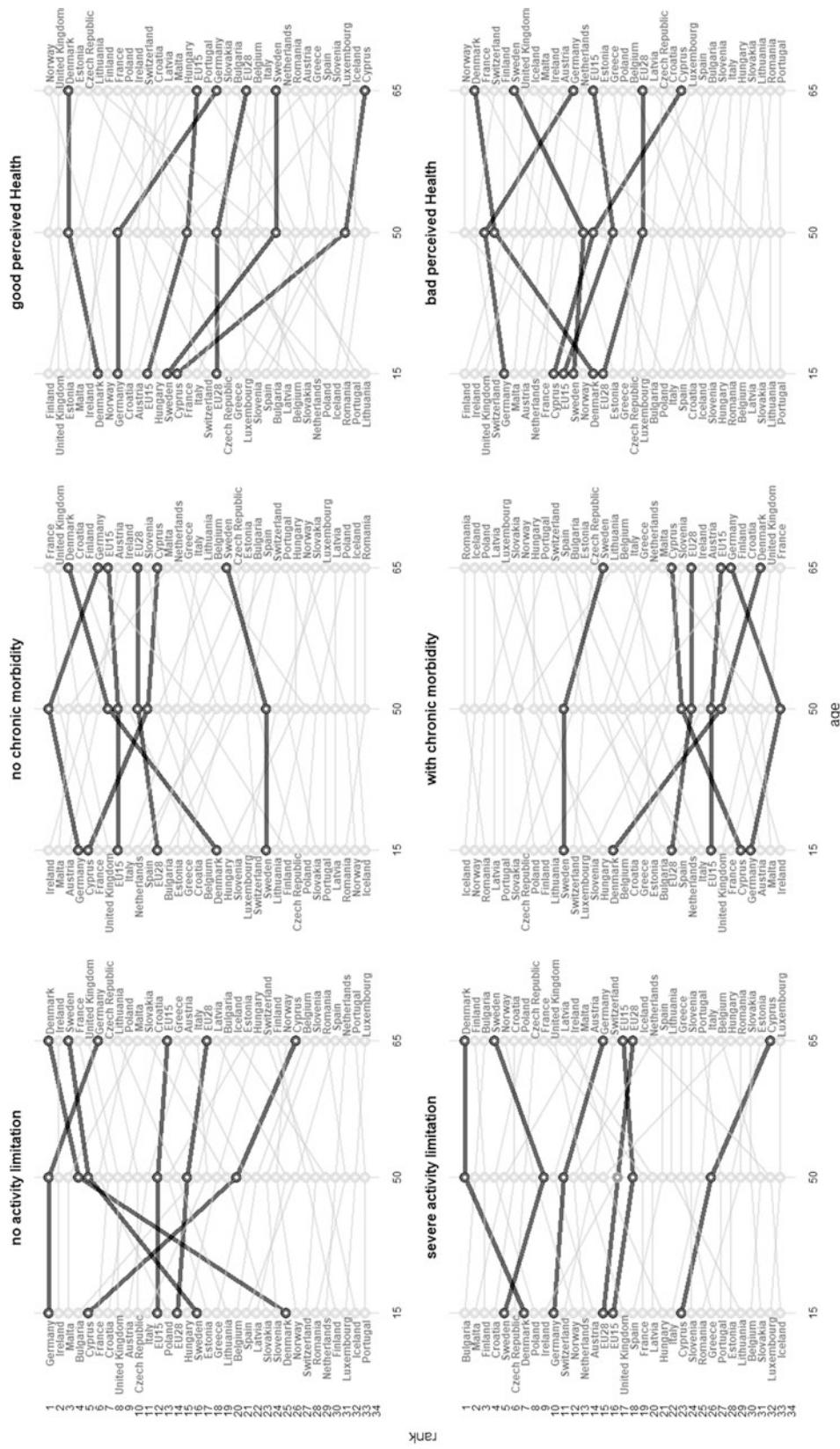


Fig. 11.10 Rankings of European countries in healthy and unhealthy life expectancy at different ages for the health domains activity limitation, chronic morbidity and self-perceived general health, 2015. (Source: Own calculations using data from Statistics on income and living conditions (EU-SILC); European Health Expectancy Monitoring Unit Information System (EHEIS))

from 14th position to the last place. Germany also shows a steeper increase in gender differentials, with Denmark experiencing a lower decrease in the gender gap with age. EU15 and EU28 countries also show a similar age pattern compared to the other health indicators. However, the distance between them is much higher at each age: while for the other indicators their difference in ranking is never more than four positions, now their biggest difference is seven positions, with EU15 countries always having the lowest gender gap at each age and health domain.

The bottom part of Fig. 11.10 shows the corresponding rankings for ULE. For chronic morbidity (middle top and bottom part of Fig. 11.10) the figures are again not critically different because they mirror each other. For severe limitation we can see that Denmark starts at a higher ranking at age 15 compared to the figures for HLE, but again at age 65 is first with the lowest gender gap. In addition, since the ULE reflect overall poorer health, now the relationship between EU15 and EU28 countries invert, and the ranking of EU28 is always higher. Interestingly, as regards severe limitation, there is a crossover at age 65: the gender gap in ULE lived with severe limitation is higher for EU28 countries at ages 15 and 50, but lower than EU15 at age 65.

In sum, all three HE indicators based on the health domains of the MEHM corroborate the literature in that women live longer than men in virtually all countries, but spend a higher proportion of their lives in poorer health, with only a few exceptions (for instance Cyprus for chronic morbidity). However, the magnitude of the gender paradox varies considerably across European countries, and it also depends on whether one focuses on the proportion of LE spent in good health or in poor health. It is important to note, however, that the MEHM indicators are very broad measures of health. Consequently, one can expect that the picture is even more diverse when looking at more specific health conditions, such as single illnesses or conditions (see for example Yokota et al. 2019) who focus on this aspect; other examples can also be found in the subsequent section).

Gender Differences in Health Reporting

As mentioned in the Introductory section, gender differences in health reporting, also called “different item functioning” (DIF), have frequently been stated as one of the explanations for the gender paradox in health and mortality. This assertion is based on the idea that women report an objectively identical health condition worse than men. The recently more frequently implemented survey tool of “vignettes”—that is, the description of hypothetical individuals whose condition is illustrated in short stories—enables researchers to test this assumption (King et al. 2004). In this survey design, respondents are asked to assess the health of these vignettes covering different health domains. The level of impairments is experimentally varied across the vignettes so that the impact of these levels on respondents’ assessments can be estimated (Auspurg and Hinz 2015). In this section, we use information from vignettes to describe the health reporting of women and men. The main purpose of vignettes, to adjust estimates of health disparities between (sub-) populations on the basis of self-reported survey data for DIF-effects, exceeds the scope of this chapter. Examples for such approaches can be found elsewhere (Auspurg and Hinz 2015).

For this section we use data from SHARE Wave 1 (Börsch-Supan 2018),⁴ (see Börsch-Supan et al. 2013 for details about the survey). In the first wave of the SHARE survey a subsample of respondents from selected countries received an additional self-administered questionnaire which started with seven questions about the extent of own problems with health. The questions covered the following health domains (1) bodily aches or pains; (2) difficulties with sleeping; (3) mobility problems; (4) difficulties with concentration; (5) problems because of shortness of breath; (6) feeling of sadness or depression; and (7) limitations in the kind or amount of work because of any impairment or health problem. These questions were followed by 27 vignettes,

⁴See Börsch-Supan and Jürges (2005) for methodological documentation about the survey.

three for each of the domains (1)–(6) and nine for domain (7) (three each for limitations because of pain, depression and problems with the circulatory system).⁵ The health conditions described in the three vignettes for each domain were constructed in a way to describe the different extent of health impairments, i.e. generally reflecting rather less, intermediate and more severe conditions.⁶ The respondents were asked to assume that the persons described in the vignettes have their own age and background.

We analysed the female and male respondents' assessments of both, their own health and those of the vignette characters. We dichotomized the assessments into one answer category including "severe" and "extreme", and another category including the three remaining answers "none", "mild" and "moderate". The few missing answers were excluded from the analysis. Figure 11.11 summarizes the results by means of so-called radar charts. The seven countries for which the data is available are arranged around the centre of the graphs. For each country, the proportions of assessed severe and extreme health problems (in percent) are plotted on axes which range from zero in the centre of the charts to 100 percent close to the labels for the countries. These points are further connected to octagons (in dashed line for women and solid line for men), which would be equilateral if the proportions were identical in all countries. The figure consists of seven sections for the seven health domains. Each of the domains (1)–(6) comprises four graphs which

⁵See full list of SHARE vignettes in <http://www.share-project.org/data-documentation/questionnaires/questionnaire-wave-1.html>

⁶The subsample of the SHARE respondents was further subdivided into two groups which received different questionnaire versions A and B. The questions of these survey variants differ only in the gender of the vignette characters, whereas the described health conditions are identical. For instance, the vignette story "Paul has a headache once a month that is relieved after taking a pill. During the headache he can carry on with his day-to-day affairs" from survey version A appears in version B for the vignette character Karen. We refrained from analyzing the vignettes assessments by gender of the vignette characters and separated the answers of female and male survey respondents only by domain and severity of the health condition.

show the respondents' assessment of their own (always the first graph on the left) and of the vignettes' health, the latter separated by three severity degrees less, intermediate and more severe. Domain (7) comprises 10 graphs, one for the respondent's assessment of their own activity limitation and nine for the assessments of the corresponding three vignette subdomains.⁷

The graphs of the respondents' own health confirm the generally higher frequency of health problems among women across all seven health domains, consistent with what has been shown in the previous Section for the MEHM domains. There are only few country-specific exceptions with higher male frequencies among some health domains. The gender differences in the assessment of the vignettes' health are much smaller but nonetheless present. However, they do not homogeneously point in the direction of female over-reporting of health problems. There are several cases in which more men than women interpret the vignettes' health condition as severe or extreme. Figure 11.11 also shows also that variations between countries are larger than those between the genders. For example, the proportion of respondents who assess rather less serious health conditions as severe or extreme is distinctly higher in Sweden than in the other European populations. This holds equivalently for both women and men. The larger extent of variations across countries is most likely to result from the translation of the vignettes into different languages, which seems to violate the intended vignette equivalence across national populations (Grol-Prokopczyk et al. 2015).

Figure 11.12 illustrates the gender differences in health reporting by female/male ratios of the proportions of survey respondents who assessed the vignette characters' health problems as severe or extreme. The ratios are separated by health domain (the same as reported in Fig. 11.11), extent of vignette character's health problem

⁷The distribution of the vignettes in less severe, intermediate and more severe health conditions presents some exceptions. For the health domain "sleeping difficulties" and for the limitations in the amount and kind of work "because of pain" two vignettes present conditions that are classified in-between intermediate and more severe.

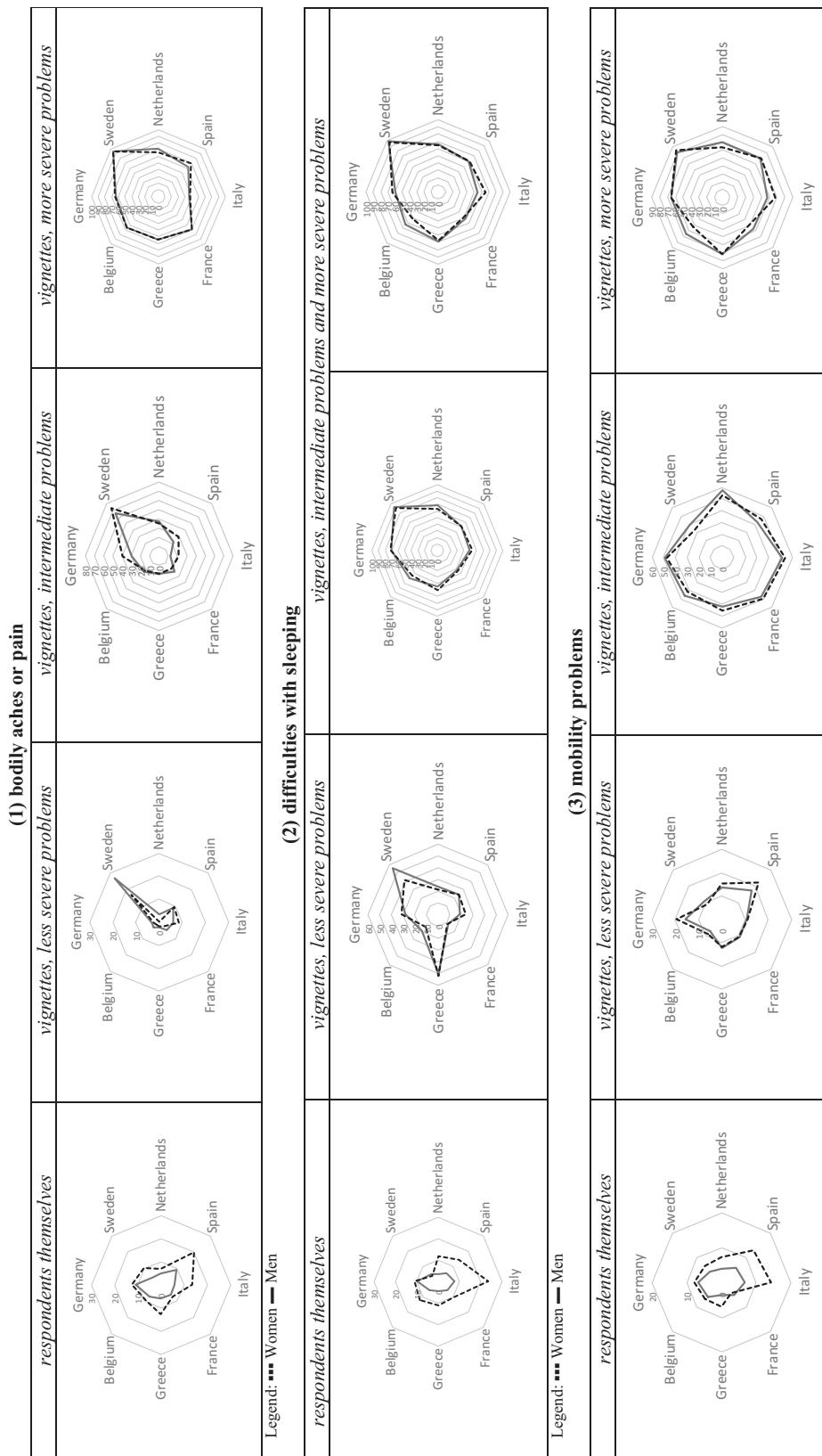
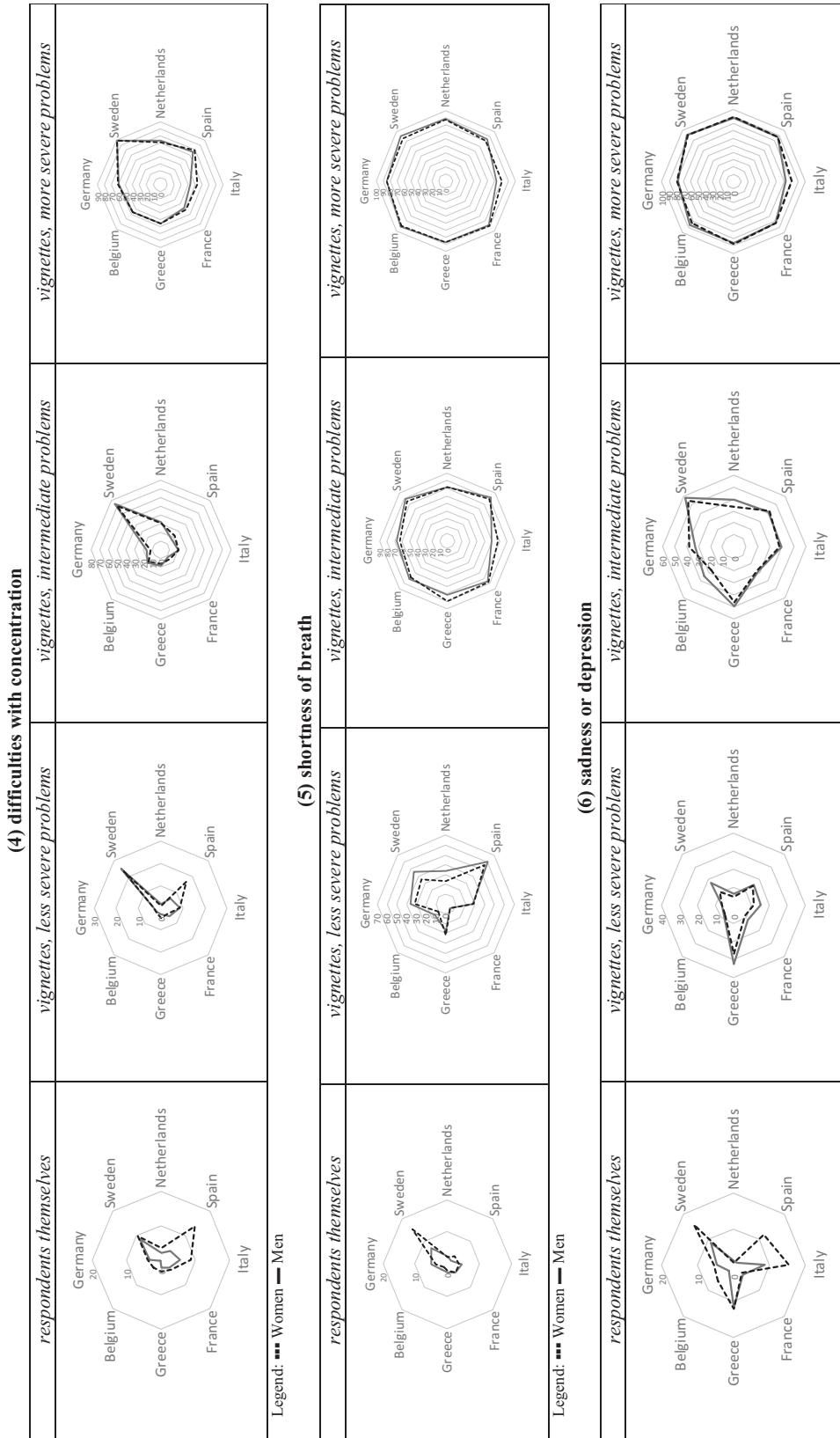
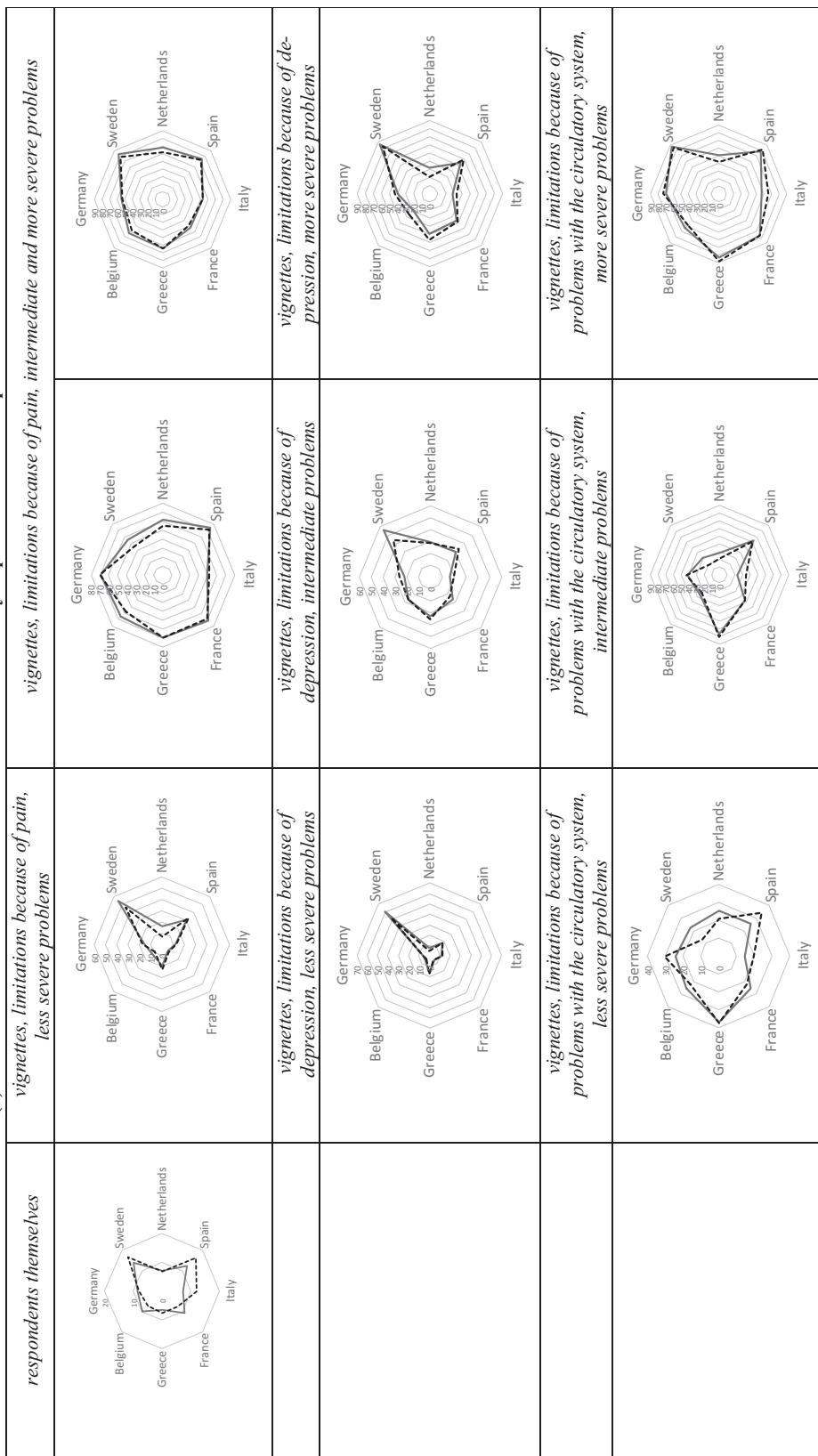


Fig. 11.11 Percentage of respondents aged 50+ reporting severe or extreme health problems for themselves and for vignette characters by gender, country, health domain, and extent of the vignettes' health problem. (Source: own calculations with SHARE data (wave 1))

**Fig. 11.11** (continued)

(7) limitations in the kind or amount of work because of any impairment or health problem**Fig. 11.11** (continued)

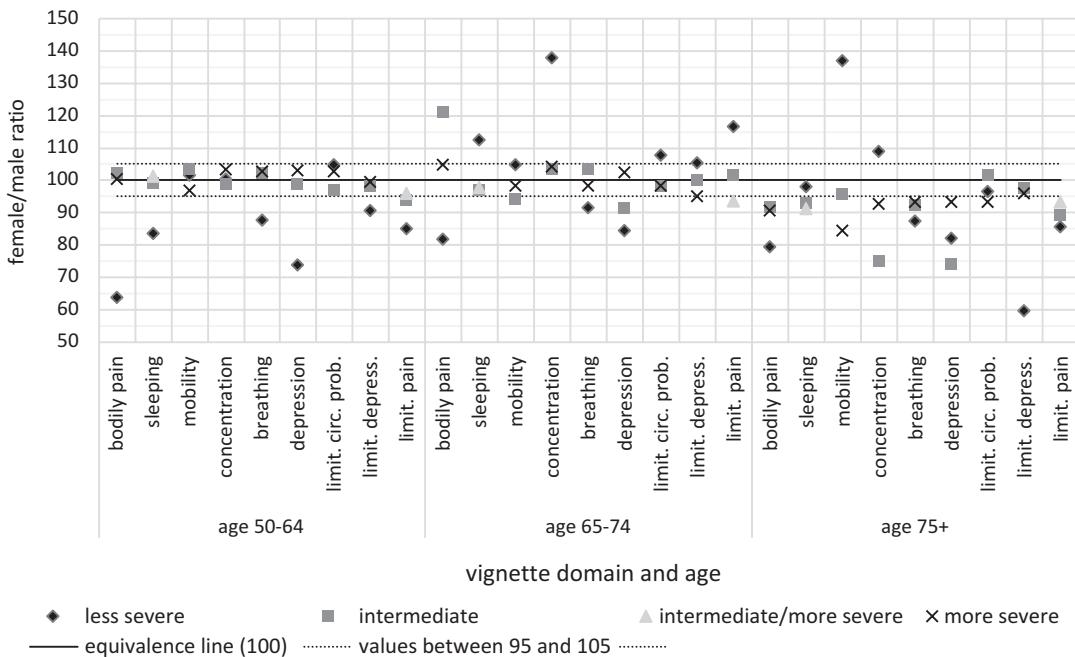


Fig. 11.12 Female/Male ratios of the proportions of survey respondents reporting severe or extreme health problems for vignette characters by health domain, extent of the health problem and age of respondents, all countries together. Source: own calculations with SHARE data (wave 1), data for all countries together

Note: Values above the equivalence line reflect excess female reporting of severe or extreme conditions, whereas values below the equivalence line reflect excess male assessment of serious health problems

(that ranges between less severe and more severe) and age of respondents (50–64, 65–74, older than 75). In this analysis, all countries are pooled together. Values higher than 100 reflect a higher female reporting of severe or extreme conditions, whereas values below 100 reflect excess male assessment of serious health problems. As shown already in Fig. 11.11, there is no general female over-reporting of health problems. In contrast, across all 81 values represented in Fig. 11.12, we find 53 cases with higher male proportions of assessed severe and extreme health problems for the vignettes, but only 28 cases with higher proportions among female respondents. About half of the values in Fig. 11.12 indicate only a slight difference between male and female answers (with values between 95 and 105).

The answers of men and women are more differentiated in the oldest age group, less so in the other age groups. At the oldest ages the answers reveal that men judged the vignettes' health sta-

tus more severely compared to the women, the only exception being less severe conditions in mobility problems and concentration difficulties. Moreover, in general, differences between genders are more noteworthy for less severe conditions. Across the less severe vignette conditions, men report more frequently severe or extreme conditions than women for several health problems, and especially for pains, sleeping difficulties, breathing difficulties, depression among the younger respondents; women report more difficulties in concentration and in limitations due to pain in the intermediate ages.

In sum, the vignette data of the SHARE survey suggests that differences in health reporting between women and men exist and have in fact the potential to bias gender differences in self-reported health, especially at older ages. However, the extent and direction of the bias vary considerably and depend on country, age of respondents and health domain(s) covered by the survey

(Molina 2016). Unexpectedly, across all health domains, the extent of health problems and age of respondents, we find more cases with excess male assessment of serious health problems.

Summary and Concluding Remarks

Beginning already in the 1920s, a common wisdom about differences between men and women in health and mortality emerged which is summarized in the saying “women get sicker, but men die quicker” (Lorber and Moore 2002:13). Intensive research during the last decades made it clear that the extent and the trends in mortality differences between women and men are caused by a complex combination of biological factors and acquired risks. Several authors have attempted to determine the relative contributions of these two causes and concluded that the acquired risks are mainly responsible for the differences in LE between women and men (e.g. Luy 2003, 2016; Waldron 1983a; Wingard 1982). In contrast to the situation regarding mortality differences, there is still no conclusive understanding about the reasons for the contradictory picture of higher female morbidity rates. This might be caused by the fact that, despite the efforts of many demographers, epidemiologists, socio-medical scientists and others still very little is understood about the reasons for the paradox or its mechanisms.

The literature about the “gender paradox” is dominated by two explanations. The first states that—because of a combination of biological and social factors—women and men differ in the kinds and severity of diseases. Consequently, this hypothesis argues that women suffer from a greater number of conditions than men, but female disabilities tend to be less lethal. Moreover, the additional life years of women make them exposed directly to a higher number of life years spent in both health states, those in good and in poor condition. Given that the additional life years of women are gained to a large fraction at the end of life and that the risk of poor health increases with age, the additional life years are spent primarily in poor health. Both these

lead to the result that the disadvantage of women varies with the specific health domain chosen for defining the health states, with the extent of the disadvantage depending also on the risk of dying of the particular health domains. The second explanation sees the reason for excess female morbidity derived from survey data being the different reporting behaviour of women and men, the so-called “different item functioning”. According to this hypothesis, health differences between women and men appear biased in surveys and are not reflecting the objective differences between the genders.

In this chapter we compiled empirical evidence for these two explanations with focus on European populations. In the first part we showed that the extent of the female disadvantage in health expectancy depends in fact on the definition of health. For demonstration purposes we used the three health domains of the Minimum European Health Module (MEHM). In line with the expectation, the female disadvantage in HE was largest for chronic diseases which have the lowest risk of dying among the three MEHM domains. We have shown also that there is a large variation in the extent of the gender gap by country, age, and whether we focus on life years spent with good or poor health. The extreme country outliers for some particular ages and health domains suggest further the importance of data quality issues. All this calls for a more careful interpretation of the “gender paradox” phenomenon because it is less clear than its name suggests, albeit the female disadvantage itself appeared in fact in almost all scenarios we looked at. Note, however, that the domains of the MEHM reflect very broad definitions of health. As stated in the introduction, several studies based on smaller and more specific health domains have found even cases with reversed scenarios, i.e. a male disadvantage in health.

In the second part of the chapter we have shown that differences in health reporting between women and men do also exist and have the potential to add further bias to the analysis of gender differences in HE. However, the extent of the difference in health reporting is much smaller than the extent of the actually reported differences

in health. Consequently, health reporting can contribute to the extent of the gender gap, but is unlikely to be the major explanation. The differences in health reporting appear in particular among less severe health conditions, whereas women and men are rather similar in their assessments of intermediate and more severe health problems. Interestingly, these reporting differences do not lead homogeneously into the direction of a female over-reporting of health problems. We demonstrated that there are at least as many cases with male over-reporting. However, older respondents (age group 75+) show predominantly a male over-reporting of the judgment of severe or extreme conditions, and women aged 65–74 show a more severe judgment of some light conditions. Moreover, the data suggests not only high variations across the age of respondents, but also—again—across countries and the kind of health domain considered.

To conclude, gender differences in health are extremely complex and one should be careful to describe them with a general label like the “gender paradox”. First, such a label might be misleading as it easily masks the high variability of the extent—and in some cases even the direction—of gender differences in health. Moreover, the different disease patterns of women and men and the association between health and mortality have the potential to explain a large fraction of the gender differences in health, which might make them at the end less paradoxical than they seem at first. As Luy and Minagawa (2014) put it, “women suffer from worse health than men do not in spite of living longer, but because they live longer.” Gender differences in health reporting also exist and possibly explain a further fraction of the gender paradox. However, the extent and direction of this effect is more heterogeneous and can affect the health gap between women men very differently. More specific research is necessary to put all these pieces together to complete the overall picture. While doing this it is important to keep in mind—as we have shown in this chapter—that this picture can look very differently depending on the health domain analysed, the population, and the age group.

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Self-Rated Health: When and How to Use It in Studies Among Older People?

12

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Introduction

Self-rated health (SRH) is a simple and pragmatic tool that researchers often use to measure overall health status. SRH reflects an individual's own concise evaluation of his or her health status and is closely related to well-being and quality of life (Fayers and Sprangers 2002). This health measure appears in different versions, but most often consists of only one question with pre-set responses on a 5-point scale (e.g., '*How is your health in general? very good, good, fair, poor, very poor*'). As a cheap and simple measure, SRH has been included in sociological and epidemiological studies since the 1950s, but gained inter-

est in particular after it was identified as a predictor of mortality (Mossey and Shapiro 1982). The World Health Organisation (WHO) includes SRH in the World Health Survey, for monitoring the health of populations and outcomes associated with the investment in health systems. SRH has also been recommended as an indicator for healthy life expectancy (i.e. the number of years a person is expected to live in good health, Robine and Jagger 2003) and has been described as a useful concept in prevention and clinical medicine (Fayers and Sprangers 2002).

Among older people, there is a large variation in the percentages rating their health as *good* across studies, but it typically ranges from

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40–70%. About two thirds of older adults do not adjust their health rating over several years (Galenkamp et al. 2012a). This observation suggests that SRH is insensitive to diseases and functional limitations that usually accompany ageing, illustrating the on-going debate as to the appropriateness of using SRH as a measure of overall health status (Lang and Delpierre 2009; Dowd 2012). Specific recommendations regarding the use of SRH in population health research are lacking, in particular for longitudinal and trend studies. This chapter discusses the discrepancies

between overall health status and SRH in different designs of studies among older people, and proposes practical recommendations for using SRH in future studies on ageing.

Why SRH May Deviate from More Objective Health Measures

Jylhä (2009) proposed a model for SRH (Fig. 12.1) which illustrates why SRH and changes in SRH deviate from health as measured

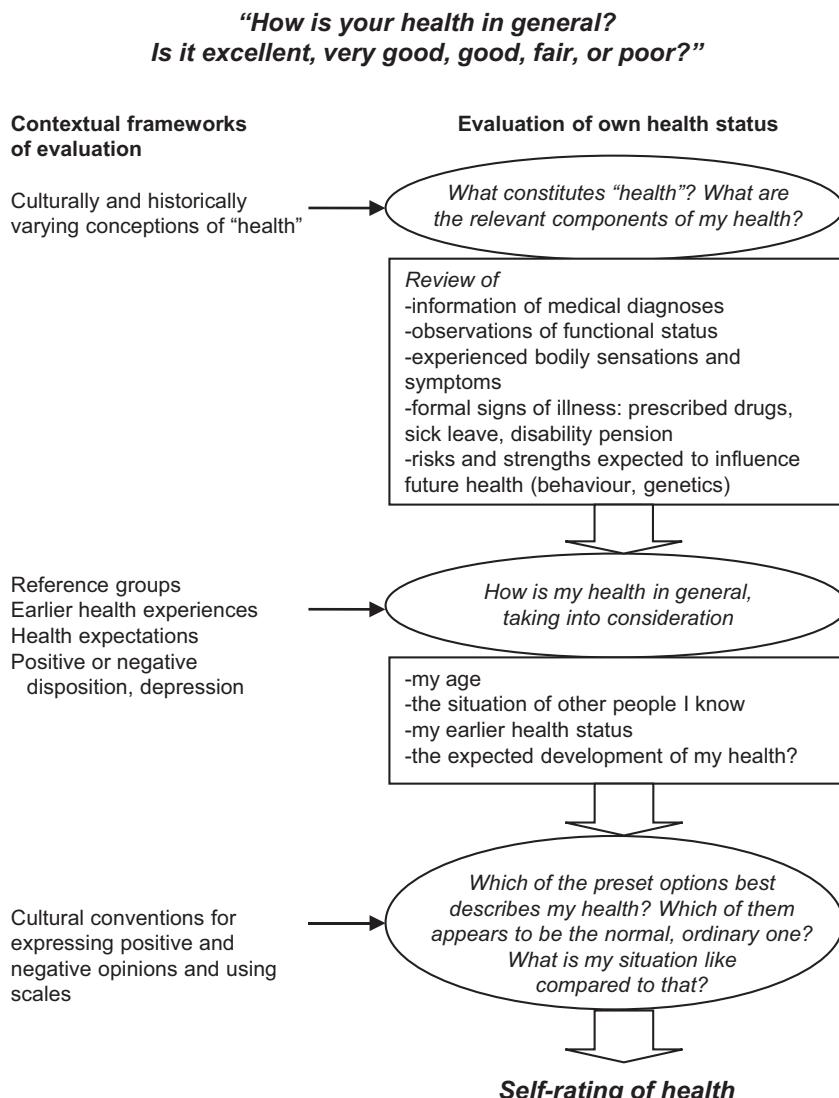


Fig. 12.1 The process of individual health evaluation (Jylhä 2009)

by other health indicators. The model distinguishes three stages in the process of self-assessment. When asked to rate their health, respondents (1) select relevant health aspects, (2) use a frame of reference to value these aspects, and (3) select one of the pre-set response options. These three steps are influenced by, amongst other factors, historical and cultural conceptions of health or conventions in expressing positive or negative opinions at a population level, and earlier health experiences at the individual level. As a result, a health state that is good from a medical point of view (e.g., free from disease and functional limitations) may be regarded as poor by an older man because of his recent fatigue. Vice versa, an older woman diagnosed with arthritis may rate her health as very good, just because she compares herself with her neighbour who is bedridden. What this implies for the use of SRH in research is discussed in the remainder of this chapter.

The Use of SRH as a Proxy Measure of Objective Health Status

Discriminating Between Poor and Good Health at One Point in Time

To examine the extent to which SRH reflects the health status of older people, an often applied approach is to study SRH in relation to the ultimate health-related outcome, mortality. Mossey and Shapiro (1982) for the first time showed that SRH was a predictor of survival several years later. Many studies replicated this finding, even when mortality-relevant indicators such as gender, socio-economic status and more objective measures of health were taken into account (Bamia et al. 2017). In addition to mortality, SRH also predicts other negative health outcomes, such as hospitalisation, disability and the onset of chronic diseases (Menec and Chipperfield 2001). An extensive review on the mechanism underlying the predictive value of SRH for negative health outcomes is given by Jylhä (2009).

The ability of SRH to reflect underlying disease and functioning has also been assessed.

Johnson and Wolinsky (1993), among other scholars, showed that chronic diseases have a negative impact on self-perceived health, partly via their negative effect on functioning. Other studies have confirmed these associations since (Hays et al. 1996). In addition to disease and disability, mental and physical symptoms may influence SRH, although the amount of research focusing on mental health, as opposed to physical health, is limited. A recent trend is to measure mental health using a one-item health measure, the so-called self-rated mental health (SRMH), which is increasingly being used in health research (Ahmad et al. 2014). SRH was shown to be associated with SRMH but both have distinct characteristics. The non-specific wording of SRH implies that it captures a wide range of health aspects, including physical and mental health.

More recently, research has focused on the relationship between biomarkers and SRH, showing that SRH may, to some extent, reflect physiological health states (Jylhä et al. 2006). Although the link between symptoms, diagnosed conditions and poor functioning on the one hand, and SRH on the other hand has been shown to weaken with age (Schnittker 2005), in our own research we found that even among nonagenarians, an age group with a high morbidity level, changes in SRH reflected increases in diseases, functional limitations, and depressive symptoms (Galenkamp et al. 2013a).

These findings, and in particular the consistent association of SRH with mortality, provide evidence for the ability of SRH to reflect more objective physical and mental health states. Comparisons of SRH across population groups, however, should be made with caution. Recently, efforts have been made to estimate the magnitude of reporting differences, for example across socioeconomic groups. These researchers either used anchoring vignettes, asking the respondents to rate the health of a hypothetical person with a certain health state (Grol-Prokopczyk et al. 2011), or compared SRH to specific indicators of morbidity, like cardiovascular risk factors or biomarkers (Dowd and Zajacova 2010). Both approaches revealed socioeconomic differences in the association between SRH and more objec-

tive health measures, implying that in a given objective health state, perceptions of health differ between socioeconomic groups. The extent to which differences in health perceptions influence the size of the socioeconomic inequalities in health remains uncertain (Hu et al. 2016; Garbarski et al. 2017).

Repeated Measures and Response Shift in SRH

Changes in SRH may be predicted by changes in underlying health status (Leinonen et al. 2002), but many studies indicate that SRH changes do not fully reflect declines in underlying health status, such as in physical functioning (Galenkamp et al. 2013a; Rodin and McAvay 1992). As opposed to self-assessed change in health, i.e. self-reports of declined, improved or stable health, and changes in disease status and functioning, comparison of two SRH responses in the same individual over time shows a rather strong stability (Rodin and McAvay 1992; Leinonen et al. 1998).

There is evidence that the strength of the association between physical health problems and SRH decreases, whereas the association between depressive symptoms and SRH increases with age (Schnittker 2005), which suggests that the relevance of specific health problems for SRH change with age. Remarkably enough, qualitative studies show that older people and those in worse health increasingly mention physical health problems as important aspects of health (Simon et al. 2005). This seeming contradiction probably reflects that physical health problems come to older people's mind more readily when they are asked to rate their health, but that they do not value physical health problems more than they do other aspects of health, such as being able to do the things they want to do (Benyamin et al. 2003). While many studies suggest that older people rate their health differently from younger people, few have specifically addressed the mechanisms responsible for the stability of SRH in older adults who experience health declines.

In the field of medical psychology, changes over time in how people rate their health or well-being have been termed response shift (Sprangers and Schwartz 1999), defined as "a change in the meaning of one's self-evaluation of a target construct as a result of a change in internal standards (recalibration), a change in values or priorities (reprioritisation), or a change in the definition (reconceptualisation) of that target construct". The three types of response shift partly overlap with changes in the first two steps in Jylhä's model (Fig. 12.1).

We have investigated reprioritisation and reconceptualization response shift by comparing predictors of SRH at two successive points in time (Galenkamp et al. 2012b) and examined recalibration response shift with a so-called 'then-test', which asks respondents to retrospectively rate their health which can then be compared with their actual ratings at the time. Our study indicated that the stability in SRH that is often found is probably accounted for by a lowering of health standards after health decline. I.e., people adapt to a worse health status by giving it the same rating as they did their former, objectively better, health status (Schwartz and Sprangers 2010). We did not find evidence for changes in the conceptualisation or prioritisation of health and its aspects, as has previously been hypothesised (Peck 1968). Given that in our study SRH was compared to other self-reported measures and that the then-test has its limitations as well (e.g., recall bias may influence its results), future studies are needed to investigate the value and interpretation of SRH changes in longitudinal studies.

SRH and Clinical Trials

Response shift has been identified as a measurement problem in clinical studies in particular (Barclay-Goddard et al. 2009). If patients' SRH or quality of life do not improve after having undergone a certain treatment intervention, this does not imply that the treatment was not effective. Indeed, evidence exists that people value health states differently throughout the course of

illness or treatment interventions (Ahmed et al. 2004). As a consequence, before- and after measurements of SRH may not show true change in health status. There needs to be an examination of whether using a then-test adds value in clinical trials to reveal potential response shifts.

Using SRH in Trend Studies

Similar to the within-person changes in the way health is rated, it might be that over time, people take different health aspects into account when rating their health, or use a different standard to evaluate their health (see also Fig. 12.1). Previous studies on trends in SRH were mixed (Zack et al. 2004; Doblhammer and Kytir 2001), which may partly be attributed to cross-national differences in health trends or to variations in methodology or time periods between studies. However, even within countries concurrent trends in chronic diseases and disability are also not always reflected in SRH trends (Parker and Thorslund 2007), indicating that the influence of these health indicators on SRH may change over time. Indeed, we found in our own research that the level of SRH did not reflect increases in the prevalence of chronic diseases and disability (Galenkamp et al. 2013b). When rating their health, older people in 2009 focused more on poor functioning than 17 years earlier, but less on their chronic diseases. As an explanation, we suggest that improvements in medical treatments of chronic diseases enable patients to lead the life they were used to before contracting the disease. In addition, poor functioning limits active ageing, which was emerging as a new standard for ageing in the 2000s (WHO 2002).

As SRH is influenced by many factors, opposing trends in these factors over time may result in a net unchanged perception of health. In addition, social comparison, which plays an important role in people's health ratings (Idler et al. 2004), may cause relatively stable trends in SRH, despite underlying changes in health and health care. It might also be that across generations, recalibration or reconceptualization has occurred in the predictors of SRH, i.e. diseases and disability,

which are usually self-reported. However, measuring diseases and disability is usually undertaken with specific indicators, making them less prone to such response shifts (Parker and Thorslund 2007). Finally, upward, downward or stable trends in SRH may result from recent generations having a changed concept or standard of health compared with previous ones. For example, the presentation of certain conditions, the diagnostic process (e.g., earlier detection of diabetes), or treatment possibilities of certain conditions (e.g., lower mortality after myocardial infarctions) may change over time, which might result in changing associations with SRH.

Using SRH in Cross-National Studies

When it is the aim of a study to compare health across countries, differences in accessibility of health care and in cultural background may accompany differences in standards for good health. In an early study comparing self-rated health across five countries located from North to South Europe, we found not only different national levels of fair to poor self-rated health, but also different associations of major correlates with self-rated health. Most notably, level of education and heart disease showed substantial cross-country differences in their association with self-rated health (Bardage et al. 2005). Although survey characteristics such as response rate, survey mode, and nature of questions preceding the self-rated health question have been shown to contribute to differences in levels of self-rated health (Croezen et al. 2016, Garbarski et al. 2015), it is not clear that they would also account for differences in associations (Jürges et al. 2008). The findings suggest that a different conceptualisation of health across cultures may play a role.

Variations in Measuring and Analysing SRH

SRH can be measured and analysed in empirical studies in several ways. A 5-point scale is

employed most often, but 3-, 4- and 7-point scales are also in use. Some studies have asked respondents explicitly to make a comparison between their health and the health of age peers or of their own health at a younger age, but most commonly the non-comparative question with five response options is used. Distributions of response categories may not be directly comparable across studies, for example when comparing the European/WHO response version ('very good' to 'very bad') with the US version ('excellent' to 'poor'), but associations with other health factors proved to be similar, regardless of the version used (Jürges et al. 2008).

SRH responses may be influenced by questions on specific health problems that are asked before SRH in the interview or questionnaire (Bowling and Windsor 2008). The direction of this effect, i.e., whether health is rated better or worse when questions on specific health problems are being asked in advance, differs across studies, but one should consider the possibility that changes in the question order across the waves of a longitudinal study may affect observed changes or trends in SRH. To minimise the influence of other health questions, it is recommended that the SRH question is asked at the beginning of health questionnaires.

With regard to statistical analysis, studies with SRH as the outcome measure most often applied ordinal regression models, as the full information from all response categories is then used. Other studies, in particular trend studies, focused on the prevalence of poor health (most often defined as all categories less than 'good') and used logistic regression models. Using generalised ordered regression analysis, in our own research we found evidence that, in the case of dichotomizing SRH, the split between response options good and less than good may be the most sensitive to underlying health problems (Galenkamp et al. 2011). Few studies compared results when different models are used, but one study showed that similar conclusions could be drawn from logistic regression and ordinal regression models concerning the relationship between socioeconomic position and SRH (Manor et al. 2000).

Conclusions and Recommendations

Figure 12.2 summarises the recommendations regarding specific research goals and study designs. Below we briefly highlight our conclusions about the current use of SRH in the litera-

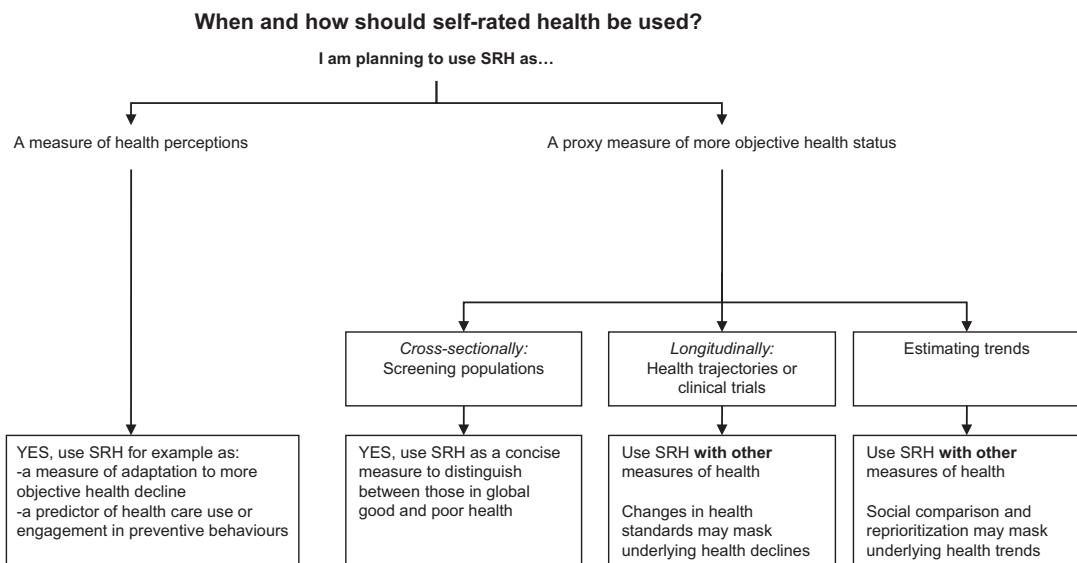


Fig. 12.2 Summary of recommendations for the use of SRH in the older population

ture and provide some recommendations for further, more appropriate uses.

Using SRH as a Measure of Health Perceptions

Most researchers seem to use SRH as a proxy measure of more objective or “true” health, ignoring that SRH reflects a perception (Gabarski 2016). However, SRH in its own right, as a measure of health perceptions, may actually be the most comprehensive health measure from a holistic point of view (Huisman and Deeg 2010; Picard et al. 2013). SRH is influenced by many factors other than physical health, and also indicates people’s ability to adapt to physical, social and emotional challenges. This latter characteristic corresponds to the WHO definition of health (WHO 1948), as discussed in Chap. 1. An additional reason for using SRH as a measure of health perceptions is that it reflects judgments that may guide people’s behaviours, for example seeking medical care or engaging in prevention programs (Bath 1999).

Using SRH as a Proxy Measure of More Objective Health Status

Cross-Sectional Studies: Screening Populations

Jylhä (2009) stated that ‘SRH can hardly replace more specific assessment tools, but it does yield information that cannot be reached by any specific tool’. This characteristic may be particularly useful for screening populations and deciding which subgroups have the highest risks for mortality, institutionalisation or other consequences of poor global health status. With respect to its use for estimating health inequalities across population groups, such as according to socioeconomic position, SRH may be measured jointly with more specific measures of health and functioning, or if these measures are not available, it may have a “thermometer function”, giving directions for further research rather than

providing definite conclusions about the magnitude of health inequalities.

Longitudinal Studies: Measuring Health Trajectories or Outcomes of Clinical Trials

Measuring trajectories of SRH, alongside changes in other measures of health, can provide valuable information. For example, stable good SRH is no guarantee of preserved good physical health, but rather indicates an individual’s ability to adapt to health declines. A declining SRH trajectory, on the other hand, may warrant further attention, given the predictive value of poorer SRH for health care use and mortality. However, if one’s interest is in health trajectories as such, other health indicators should always be measured. These indicators should be more specific, depending on the research question at hand. Preferably, they should also be objective measures, since other subjective health measures may be prone to changes in reporting as well. Due to response shifts, which are likely to occur during the course or treatment of a specific disease, researchers should avoid using SRH as the only outcome to measure effects of treatment or interventions.

Estimating Trends in Health Over Time and Across Countries

Finally, studies aimed at estimating trends in health should simultaneously use a variety of indicators, such as disability or morbidity, which are more specific or more objective measures of health. The same is true for comparative studies of health across countries. In addition, SRH may be used to monitor trends in health perceptions, for example reflecting how inclined older people are to use health care.

Conclusion

Returning to the question of ‘when and how’ SRH should be used, the distinctive characteristics of SRH should be kept in mind: SRH measures people’s own perception of their health, it is cheap and easy to assess and it is a very inclusive

and non-specific measure. The particular added value of SRH lies in its holistic nature and its potential to reflect global health status, in cases where other health indicators can or were not measured, or if other indicators capture only some aspects of health. These characteristics of SRH may have certain advantages for researchers depending on the research question at hand.

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Health Expectancy in Policy: The Use and Uptake of the Healthy Life Years Indicator and the Global Activity Limitation Indicator by the European Commission and Member States

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Healthy Life Years as an Indicator of Progress with the Lisbon Strategy: The Early Days

The 2000 Lisbon Strategy aimed to make the European Union (EU) “the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion” by 2010. In 2004, the European Council selected Healthy Life Years (HLY) as one of the European Structural Indicators to be used, among other things, to monitor progress in achieving the Strategy (Lagiewka 2012). The

justification for its inclusion was “not only because better health is a desirable objective in its own right, but also because it is an important determinant of economic growth and competitiveness” (Suhrcke et al. 2005). It also reflected a growing awareness of the limitations of more traditional indicators of population health, such as life expectancy or other summary measures based on mortality rates. Moreover, surveys such as the European Union Statistics on Income and Living Conditions (EU-SILC) composed of measures of disability, thereby capture conditions that cause significant limitations over many years before death, such as common mental illnesses and musculoskeletal conditions (Arora et al. 2015). HLYs had the additional benefit of bringing forward the data necessary to answer a key question facing European societies. Where ageing populations live the additional years in good health, these populations lead more fulfilling lives, contribute more to society, and reduce their demands on the economy but also reduce their demands on health systems. The measure of disability used in the EU measure is the GALI, derived from the answers to a single item survey question asking “For at least the past six months, to what extent have you been limited because of a health problem in activities people usually do?” (Van Oyen et al. 2018).

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In 2006, a review was conducted of the uptake of the HLY indicator in the work of the European Commission (EC) and Member States (MSs) (Oortwijn et al. 2006). It asked to what extent the HLY indicator had been taken up by Commission Services and by national and regional authorities since its adoption as an indicator of progress towards the Lisbon Strategy in 2005. It also sought examples of its use beyond the health sector. The evaluation was limited as it only considered its use since being adopted as a Lisbon Structural Indicator in the previous year. Identification of situations in which it had been used at national level was a two-step process. First, government policies on ageing were identified. They were inspected for evidence that the HLY indicator was being used to monitor progress in these policies and how it was being used.

This review allocated policies to one of three categories, according to the concept of ageing they adopted:

1. healthy ageing: with focus on health and quality of life for older people. Examples included Denmark, Hungary and Spain;
2. active ageing: with focus on increasing or extending the participation of senior citizen in social and economic life. Some of these policies touched upon other policy areas such as employment. Examples included Belgium, Finland, France, Estonia, Germany, The Netherlands, Latvia, Czech Republic and Portugal;
3. general health: no particular focus on ageing.

Only one of these policies did, however, include an actual measure of healthy ageing. This was the United Kingdom, which incorporated a measure of “healthy life expectancy” (HLE) in its national statistics. HLE is conceptually similar to the HLY, except that it used national data to capture disability rather than the EU-SILC. The British government included it in its national assessment of social progress, stating that “HLE is currently used to monitor progress towards achieving targets in a wide range of policies including:

- The Department of Health’s National Service Framework for older people includes targets to increase HLE for older people;
- The Treasury’s work on long term fiscal sustainability sees future HLE as an important demand driver; and
- The Department for Work and Pensions’ strategy for tackling poverty and social exclusion uses HLE as an indicator.”(Oortwijn et al. 2006)

Based on these findings, the authors of the study concluded that monitoring healthy ageing policies on the basis of the HLY indicator did not (yet) occur, or at least not on a widespread basis, and a number of reasons were offered. The authors found a widespread lack of awareness of the indicator, or even the concept. Among those familiar with the concept, several pointed to how authorities were already measuring something similar, and in most cases, conceptually identical (e.g. “année de vie en bonne santé” in France, “Healthy Life Expectancy” in the UK and “Healthy Life Years” in Sweden). The authors did, however, identify evidence of increasing interest in its use, especially as a means of capturing progress in healthy ageing, seen as a growing priority for policy makers working on labour markets and pensions. They also pointed to a series of obstacles hampering its more widespread use that need to be overcome.

Contemporary Uptake of the HLY Indicator

We are unaware of any assessment of the uptake of the GALI and HLY in the EU since the 2006 report until a further review in 2018 (Bogaert et al. 2018). A questionnaire was sent to individuals engaged in the European Health and Life Expectancy Information System (EHLEIS) project and others working in the same field in the 28 MSs and in the Commission (Robine et al. 2013). The survey findings were complemented with data available from the EHLEIS network and the literature.

The questionnaire consisted of six open-ended questions and addressed four topics. It inquired (1) whether the GALI and HLY were

being used to inform or monitor public policy goals; (2) whether the GALI was included in national surveys since 2005; (3) how the distribution of GALI responses and HLY were presented, discussed, and disseminated at national or regional level; and (4) the extent of the national capacity to calculate, analyses and follow-up on the GALI and HLY.

Twenty-two MSs and the EC responded, resulting in a 79% response rate from MSs. Responses were not obtained from Croatia, Ireland, Luxembourg, Malta, Poland, or Portugal. Not all questions were, however, answered completely although only 3 of 132 possible responses were completely blank.

HLY Use in Health and Other Policy Domains

Most countries reported that the HLY indicator is used in relation to health policy, being monitored and used to set targets in national health strategies or plans. The amount of policy interest varied, but in Italy it was reported that trends were monitored by a high-level committee and presented annually to the Italian parliament. Some respondents described how results from its use had influenced health policies, for example when it was seen that progress was poorer than expected, as in Estonia, where disappointing results stimulated new plans by the Ministry of Social Affairs. The 2013 report on progress towards implementing the National Health Plan noted how, although HLY among men increased by 0.7 years in that year, among women it fell by 0.3 years. A Lithuanian respondent reported how HLY had replaced life expectancy as the headline measure of policy progress. Only a few respondents cited examples of HLY being used at sub-national level.

The GALI and HLY are also used in policies on disabilities and healthy ageing, both by MSs and the EC (European Commisison 2012; Social Protection Committee 2016), but according to the respondents, more frequently in the context of sustainability and forecasting which is closely linked to budgetary and pension policy.

Respondents from Belgium, Czech Republic, Estonia, Hungary, Italy, Lithuania and Latvia cited examples of HLY being incorporated in policies on sustainable development, reflecting how HLY is a headline indicator in the EU Sustainable Development Strategy (Eurostat 2016). An Estonian respondent described how the government had explicitly set a goal of increasing HLY and thus the number of years that people are economically active, thereby offering the possibility of increasing the retirement age and ensuring sustainability of the pension system. HLY has featured in the policy discourse on pension age in the Netherlands, but ultimately it focused on life expectancy. In the UK, disability-free life expectancy at age 65 has been used to inform an independent review into the state pension age, although HLE was used in an exploration of the implications for fairness of pension changes.

Within the Commission, HLY and the GALI are used in various contexts by a range of Directorate Generals (DG), including DG Communication, DG Connect, DG Employment, DG Eurostat and DG Health and Food Safety (Table 13.1). HLY is also incorporated in the European Innovation Partnership on Active and Healthy Ageing and the European Pillar of Social Rights, adopted by the EU in 2017. HLY at age 65 was included as a headline indicator on the Social Scoreboard. DG Eurostat collects the GALI question in various surveys and HLY is included in the Sustainable Development Indicators (SDI) as a measure of quality of life (Eurostat 2019a). The GALI is used to inform the European Disability Strategy 2010–2020 by DG Employment (European Commission 2017), to monitor the situation of disabled people, thereby supporting the EU's implementation of the UN Convention on the Rights of Persons with Disabilities (UNCRPD) (Leonardi 2010; European Commission 2017), as well as by the Academic Network of European Disability Experts (ANED) to produce estimates for the Europe 2020 indicators on employment and education among people with disabilities. HLY are included in the Active Ageing Index by the United Nations Economic Commission for

Table 13.1 Overview of the use of Healthy Life Years in the European Commission (2005–2017)

| Directorate General | Use of Healthy Life Years | Measurement |
|--|---|---|
| DG Communication | Eurobarometer. Prevalence of activity limitation through survey instrument: GALI question. | Self-reported limitations in daily activities by age, sex and income level (SI-C11) |
| DG Eurostat | Metadata sheet Healthy Life Years | Healthy Life Years at birth, at 50, at 65 and by sex |
| | Sustainable Development Indicator | Healthy Life Years and life expectancy at birth, by sex |
| | Quality of Life indicators on health | Healthy Life Years at birth, at 65, by sex |
| DG Connect and wider European Commission | European Innovation Partnership on Active and Healthy Ageing: target 2020 | Healthy Life Years at birth, by sex |
| DG Employment | Social Protection & Social Inclusion | Healthy Life Years at birth, at 65, by sex (SI-C4a) Self-reported limitations in daily activities by age, sex and income level (SI-C11) |
| | European Pillar of Social Rights on Social Scoreboard | Healthy Life Years at the age of 65, by sex |
| | Joint Assessment Framework (JAF on health) | Healthy Life Years at birth, at 65, by sex (H-2) |
| | European Disability Strategy (2010–2020). Prevalence of activity limitation through survey instrument: GALI question. | Self-reported limitations in daily activities by age, sex and income level |
| | Health at a Glance: Europe report, Country health profiles | European Core Health Indicators on long-term activity limitations by sex, age and educational level (ECHI 35) European Core Health Indicators on health expectancy: Healthy Life Years at birth, at 65, by sex (ECHI 40) |

Europe and the EC (Zaidi and Unt 2017). Finally, the European Core Health Indicator on Health Expectancy is also based on HLY and is one of the main quantitative indicators used in the Health at a Glance: Europe and country health profiles by DG Health and Food Safety and DG Employment's Joint Assessment Framework Health.

Finally, there has been a growth in research papers where HLYs are used to quantify the health gain, such as a modelling exercise highlighting the contribution of changes in lifestyle-related factors, to estimate the burden of disease attributable to exposure to different risk factors, or to predict the consequences of population ageing (Eriksson et al. 2017; Lagergren et al. 2017; Füsseniich et al. 2019).

As this overview shows, from the very limited beginnings described in the 2006 report (Oortwijn et al. 2006), the GALI and HLY have become

used widely as means to monitor progress in a range of policy domains. There are now examples of how their use has contributed to changes in policy, as in Estonia, while they are discussed in high level political settings in countries such as France and Italy. The adoption of HLY as a headline indicator in the European Pillar of Social Rights has given them greater prominence. GALI and HLY are most often used in the health sector but, as health is increasingly accepted as a contributor to economic growth, the use of HLY has spread into other policy areas too. HLY and the GALI are used in at least 5 different DGs, and are incorporated within the European Semester. Compared with the situation described by Oortwijn et al. (2006), awareness of the HLY concept is now widespread and it is central to many discussions on sustainability (Bogaert et al. 2018), especially in relation to retirement age and pensions.

The GALI in Surveys

We now turn to the use of the GALI, the measure underlying the HLY, in surveys around Europe. The GALI was developed in the framework of work on a coherent set of indicators to monitor health across Europe (Robine et al. 2003), and is one of three questions of the Minimal European Health Module (MEHM), created for use in EU social surveys such as EU-SILC and Eurobarometer, organised by Eurostat (Robine et al. 2003). The GALI is included in the versions of the European Health Interview Survey (EHIS) used in most countries, though Austria is a rare exception, having removed it. Eight countries reported including the GALI question in other national or regional surveys. It is also used in the Survey of Health, Ageing and Retirement in Europe (SHARE), now conducted in 16 MSs. Other surveys mentioned by participants were censuses ($N=2$), the National Health Examination Survey ($N = 2$), and a variety of other surveys on specific issues related to aspects of social policy. However, some survey organisers use their own adaptation of the question, leading to inconsistencies and limiting comparability (Cambois et al. 2016). It is included in a few surveys that are disease-specific, such as one on Lyme disease in Belgium. A question on health problems limiting daily activities has been included in the Labour Force Survey of 2020 under the *ad hoc* module on accidents at work and other work related to health problems (European Commission 2018). The 2017 SILC module on children also included a disability perspective (the GALI question adapted for children), thereby expanding the scope of this concept.

A caveat is, however, necessary. While the GALI does correlate with three of the main measures of functional ability, activities of daily living, instrumental activity of daily living, and functional limitations in European countries, the relationship with each of them does vary, highlighting the need to monitor emerging findings from comparative analyses (Berger et al. 2015).

In conclusion, the GALI has now been incorporated in many of the main health surveys in the EU, in part because of its inclusion in the MEHM,

and including, among others, the EU-SILC, the SHARE and the EHIS. This reflects a decision by Eurostat to include a health benchmark in all their major surveys, especially those without a primary focus on health. Eurostat and EHLEIS have provided support to countries to promote harmonisation but this requires those conducting surveys to recognise the importance of consistency. Looking ahead, there will be less capacity to promote these indicators, following the termination of the Task Force on GALI and the completion of the EHLEIS project, giving rise to an inevitable degree of uncertainty about future progress.

Presentation and Dissemination of HLY

HLY now feature in numerous reports on the health of populations in Europe, including the annual country reports that were produced by EHLEIS until 2018 (The EHLEIS Team 2014). In the most recent reports, MSs could add a one-page summary of relevant research within their country. This was completed, on average, by 12 of the 28 MSs between 2014 and 2016. The country reports also contained annual updates of a bibliography of reports and scientific papers using the GALI and HLY published within the country. Eight countries reported examples appearing on websites. In France, HLY are included in the Report on New Indicators of Wealth (Service d'information du Gouvernement 2018). At least 11 MSs report data on HLY on national statistics websites. However, the prominence they are given varies. In the Czech Republic, the Institute of Health Information and Statistics dedicates a special page to HLY (Institute of Health Information and Statistics of the Czech Republic 2019). The UK publishes data on inequalities in healthy life expectancies (HLE), disability-free life expectancies (DFLE) and life expectancy. Eurostat publishes metadata on HLY and links to HLY in other websites and in reports (Eurostat 2019b). HLY data are reported on the website of the Belgian Health Interview Survey, which also includes regional data from Belgium (Drieskens et al. 2019). Finally, several EU

research groups are working on HLY estimation, using it in research on health inequality and to inform health priority setting.

In conclusion, data on HLY are now reported widely in the EU and responses have been positive, with the country reports that were produced by EHLEIS being well received and helping to promote the uptake of HLY at national level, as they are also published on some national websites. This process of dissemination is important to spread understanding of the concept of HLY.

Capacity to Use GALI and HLY

One of the main tasks of the EHLEIS project was to increase capacity to analyse HLY within the EU, delivering training workshops and developing guidance on estimation and interpretation of HLY (Oortwijn et al. 2006). The EHLEIS project established a network of researchers working on health expectancies that has continued after the conclusion of the project in 2014. Most countries have at least 3–4 people working on the GALI and HLY, while some, such as Belgium, France, and the United Kingdom have larger teams. In France, for instance, the HLY is now directly computed by the statistical office of the Ministry of health and released well in advance of Eurostat (Moisy 2018). The new figures are examined each year by the Section of social affairs of the Conseil économique, social et environnemental (CESE) (Conseil économique social et environnemental 2018). In 2017, the CESE made some recommendations in its annual report on the state of France (Duval and Lafont 2017). Eventually, trends and results are published every year in the annual report on wealth (Service d'information du Gouvernement 2018). Expertise can be found in national public health institutes, statistics authorities, and universities. Many of those in the network are engaged actively in generating other indicators from the EU-SILC and EHIS. The Réseau Espérance de Vie en Santé (REVES) directory is another source of data on those working in this field, with research groups listed in 13 EU countries (Institut National D'étude démographiques 2017). Within the EU

system responsibility lies with Eurostat, but it has relatively limited capacity, with a reduction from what existed when these measures were being developed, reflecting the view that less capacity is needed now that they have been mainstreamed.

Concluding Remarks

In the space of 10 years, there has been an evolution in the use of the GALI and HLY, which are now used widely by MSs and within the Commission, with both becoming incorporated into routine monitoring. There is growing evidence that the results from monitoring are feeding into policy making and impact assessment. Additionally, findings from analyses of HLY are increasingly being used to shape policies and programmes, not only in the health sector but also in areas such as pensions policy and sustainable development. The GALI is now a core feature of major health surveys, supporting a growing volume of long term trend analyses. Finally, although there are important national differences, there is a basic capacity in all MSs to analyse and interpret the data that are being produced.

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Policy Relevance of Health Expectancy in Health Promotion

14

Toshiyuki Ojima

Introduction

As the concept of health expectancies can influence politicians and the general public, health expectancies are useful to stimulate health promotion policy. The concept of health promotion was developed in the 1970s and the first health promotion plan, Healthy People in US, was published in 1979. This period overlapped with the time when Sullivan developed the new calculation method for health expectancy. Health expectancy use is not limited to health promotion and health care fields but has included more comprehensive policy including economic development strategies. In this chapter, the history and current situation of policy development including health promotion and other policy fields will be reviewed and the contribution of health expectancy will be discussed.

Health Promotion Movement and the World Health Organization (WHO)

The declaration of Alma-Ata, the outcome of the International Conference on Primary Health Care, was announced in 1978 (WHO 1978), with the objective to protect and promote the health of all the people of the world. The key phrase “Health for All” as well as the importance of quality of life were mentioned in the declaration. In the next stage, the Ottawa Charter for Health Promotion, the outcome of the First International Conference on Health Promotion, was created (WHO 1986), the charter providing the fundamental framework of health promotion policy to date.

Between these two conferences, a scientific conference on the epidemiology of ageing was held in 1983 (WHO 1984). The report of this meeting discussed the extension of the concept of the life-table to morbidity and disability, and it suggested the use of “the expectation of autonomous or disability-free life”, as well as “the number of years expected to be lived disease-free”. Within the WHO strategic vision to develop health targets, WHO Regional Office for Europe published the first version of “Targets for health for all” (HFA Targets) (WHO Regional Office for Europe 1985). Target 4 stated, without formulating a baseline, that “By the year 2000, the aver-

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age number of years that people live free from major disease and disability should be increased by at least 10%”.

Healthy People in the United States (US)

Health expectancy was first used in a US health promotion policy of “Healthy People”. Healthy People is a comprehensive set of national 10-year health objectives and a framework for public health priorities and actions. In 1979, the Surgeon General issued a report entitled *Healthy People: The Surgeon General’s Report on Health Promotion and Disease Prevention* (DHEW 1979). While this was a notable report that clarified key health promotion policy, the death rate was used as the main health indicator.

In *Healthy People 2000* (CDC 1990), published in 1990, Goal 1 was cited as increasing the span of healthy life for Americans. Baseline values for health expectancy (described as years of healthy life) were shown, and targets were set based on these baselines. The baseline value for 1980 was a life expectancy of 73.7 years, comprising a healthy life of 62 years and an unhealthy

life of 11.7 years. The dysfunction included either chronic or acute limitation provided through the National Health Interview Survey. The target established was for a healthy life of at least 65 years by 2000. Baseline values for 1980 and targets for 2000 were set for African Americans, Hispanic Americans, and older individuals aged 65 years or older. The baseline values were calculated using the National Vital Statistics System and the National Health Interview Survey. Various efforts were subsequently made to promote health. The *Healthy People 2000 Final Review*, published in 2001, estimated expected years of healthy life in 1998 to be 65.2 years overall (CDC 2001). The *Healthy People 2010 Summary Measures of Population Health* (CDC 2003) showed the results for various health expectancy estimates, including being in good or better health, not needing help in activities of daily living (ADLs), not having any activity limitations, being able to perform major activities, and not having chronic heart disease.

Figure 14.1 shows the evolution of the overarching goals from *Healthy People 1990* to *Healthy People 2020* in US (CDC 2012). The subsequently released *Healthy People 2010* and

| Target Year | 1990 | 2000 | 2010 | 2020 |
|------------------------------|--|---|--|--|
| Overarching Goals | Decrease mortality: infants–adults Increase independence among older adults | Increase span of healthy life Reduce health disparities Achieve access to preventive services for all | Increase quality and years of healthy life Eliminate health disparities | Attain high-quality, longer lives free of preventable disease Achieve health equity and eliminate disparities Create social and physical environments that promote good health Promote quality of life, healthy development, healthy behaviors across life stages |
| Number of Topic Areas | 15 | 22 | 28 | 42 |
| Number of Objectives | 226 | 312 | 969 | Approximately 1,200 |

SOURCE: *Healthy People 2010 Final Review*.

Fig. 14.1 Evolution of the overarching goals between the *Healthy People 1990* to the *Healthy People 2020*, US (Source: *Healthy People 2010 Final Review*)

Healthy People 2020 also described health expectancy as a key indicator.

Utilisation of Health Expectancy in Europe

Public health in Europe is promoted by the EU Health Programme, a funding instrument to support cooperation among EU countries, and underpin and develop EU health activities (EC 2018). In its first phase, the EU Health Programme 2003–2007, funding was provided to the European Health Expectancy Monitoring Unit. In the EU Health Programme 2008–2013, its second phase, major increases in funding compared with the first phase were implemented in order to increase healthy life years and promote healthy ageing.

One of the most significant instances of the utilisation of health expectancy in European policy is its inclusion in the Lisbon Strategy. The Lisbon Strategy was an action and development plan devised in 2000 to improve the economy of the European Union from 2000 through 2010. Achieving full employment by 2010 is seen as one of the main means of meeting the Lisbon expectations. In March 2001, the European Council added a new target, specifying that the employment rate for older workers should reach 50% by 2010. In this context, the Council invited the Commission to draw up an annual report providing an objective assessment of the progress made in achieving the Lisbon objectives. This assessment is made on the basis of the European Structural Indicators related to employment, innovation, economic reform, and social cohesion. It was developed for this purpose by the Commission to evaluate annual progress. Consequently, Healthy Life Years (HLY) was selected in 2004 to be one of the structural indicators to be examined every year during the European Spring Council for assessing the Lisbon Strategy (EC 2005a). HLY is a Disability Free Life Expectancy. The Global Activity Limitation Indicator (GALI), which measures participation restriction, constitutes the underlying health measure of the HLY. Eurostat has cal-

culated Healthy Life Years for each country in the EU annually from 2004 to the present (EC 2005b). HLY is also a key indicator to measure the progress in the European 2020 Strategy on Active and Healthy Aging (Lagiewka 2012). Further details on the history and current status of HLY in Europe is provided in Chap. 13.

Health Promotion in Japan

Health Promotion Policies in Japan at National Level

Health promotion policies in Japan started with the “First National Health Promotion Policy” in 1978, formulated on international discussion in the preparation of the Declaration of Alma-Ata by WHO. At that time policies for enhancing health surveys, establishing municipal health centres, and securing public health nurse and nutritionist work force were determined and promoted. In 1988, the policy was upgraded to the “Second National Health Promotion Policy.” The increase in the number of older individuals was a key policy issue at this time, and the policy was given the subtitle “Active 80 Health Plan.” The policy focused on making exercise habits more widespread, including the formulation of exercise guidelines and the promotion of facilities to increase health.

In 2000, Health Japan 21 was formulated as the third national health promotion policy, using the US Healthy People as a reference, and analysing current values and setting target values in each field. While it also contained an introduction to the concept of health expectancy, as disability free life expectancy (DFLE), and the significance of this idea, specific calculations were not included.

Health Japan 21 (the 2nd term), the fourth national health promotion policy, implemented from 2012 through 2022, was formulated by a planning committee with Ichiro Tsuji as the chairperson (MHLW Japan 2012). In this policy, health expectancy was set as the most important target, and current values were also described. With respect to healthy life expectancy, the target

was to extend healthy life expectancy by more than the increase in life expectancy. In terms of reducing health disparities, reducing gaps amongst prefectures was set as the target. For these targets healthy life expectancy was defined as the “average period of time spent without limitations in daily activities”, calculated based on data from the Comprehensive Survey of Living Conditions. The “average period of time individuals consider themselves as healthy”, was also calculated based on the same survey as a reference. The Comprehensive Survey of Living Conditions, a survey of approximately 300,000 households and household members in regions randomly selected throughout Japan, is conducted by the Ministry of Health, Labour, and Welfare (MHLW) using health questionnaires once every 3 years.

Figure 14.2 shows annual shifts in mean life expectancy and health expectancy in Japan to 2016 (MHLW Japan 2018). Interim evaluations based on these data has shown that targets for the extension of healthy life expectancy are being successfully achieved. Figure 14.3 shows shifts in health expectancy by prefecture from 2010 to 2016. Based on targets related to reducing the

gap amongst prefectures, the gaps for males appear to be decreasing significantly.

Health expectancy is also used in policies for fields other than health. In the 2014 revision of the Japan Revitalization Strategy, published by the Cabinet of Japan with the aim of activating the Japanese economy, the primary target is extending national healthy longevity. The key performance indicator (KPI) used is extending national health expectancy by at least 1 year by 2020. This strategy aims to create new industries to revitalize regional economies while extending health expectancies. The Health and Medical Care Strategy, formulated in 2013 and approved by the Cabinet in 2014, promotes policies for cutting-edge research and development in the fields of health and medicine, in addition to encouraging education regarding the creation of new industries and securing human resources. It cites the same targets for health expectancy extension as the Japan Revitalization Strategy. The Lancet also published a report by Prime Minister Shinzo Abe on Japan’s strategy for global health diplomacy, formulated in 2013. In the report Prime Minister Abe stated that public and private efforts to achieve a greater increase in

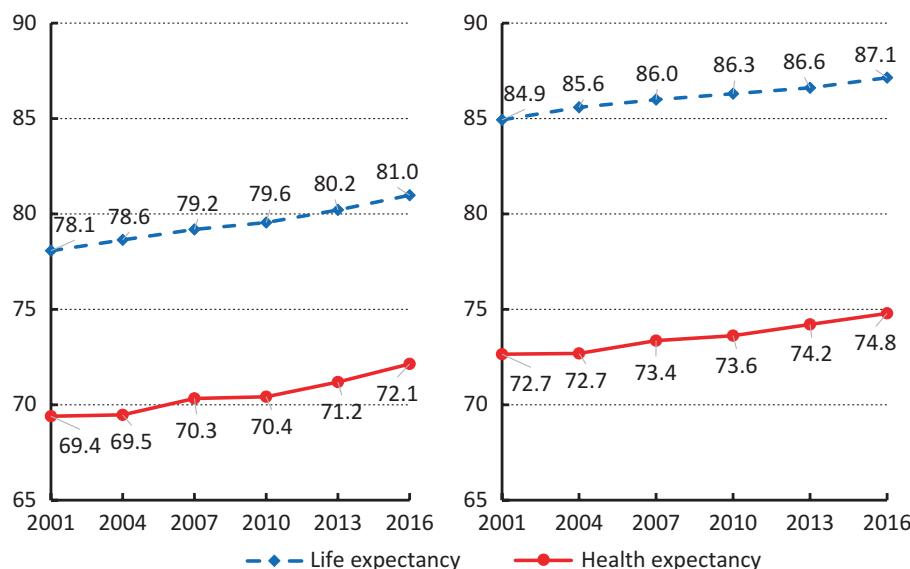


Fig. 14.2 Annual shifts in life expectancy and health expectancy in Japan

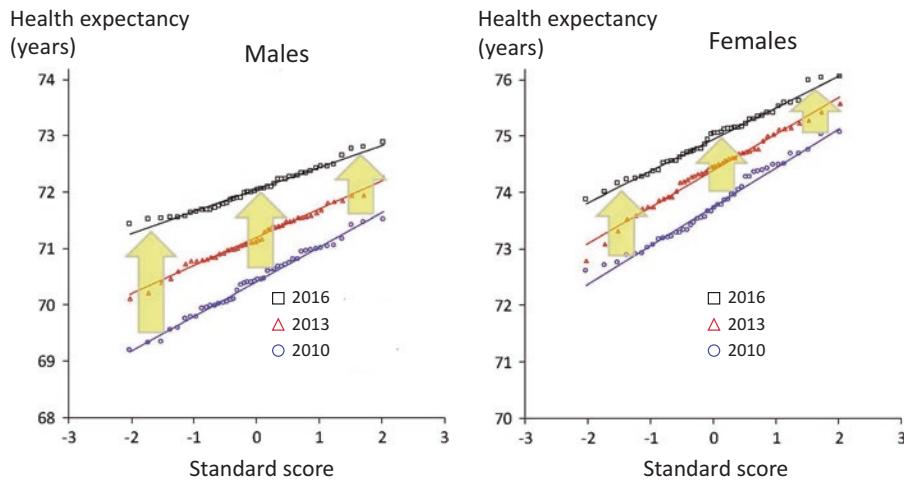


Fig. 14.3 Shifts in health expectancy by prefecture from 2010 to 2016

Note: SD: Standard deviation for prefectures (large SD indicates large inequality). SDs were 0.58, 0.47, 0.37 for

2010, 2013, 2016 among males respectively, while they were 0.65, 0.61, 0.53 among females
Inequality has reduced (males: $p = 0.001$, females: $p = 0.083$)

healthy life expectancy will lead to the successful handling of a test case of the most rapidly ageing society in the world (Abe 2013). In the Ministry of Health, Labour and Welfare, Japan, “Social Security and Way of Working Reform Headquarter looking to 2040” was established in 2018. As one of the missions of the headquarter is to prolong health expectancy, the Expert Study Group on Health Expectancy was called up and the final report was published (MHLW Japan 2019). It suggested setting a national target to extend health expectancy by more than 3 years from 2016 to 2040.

In terms of academic research in support of these policy-setting trends, the “average period of time spent independent in daily activities” from 65 years of age onward of each prefecture was calculated (Hashimoto et al. 1999) directly before Health Japan 21 was formulated. The results had much media coverage, including newspapers. The researchers calculated health expectancy not requiring long-term care at the age of 65 years based on the number of persons at home requiring long-term care according to the 1995 Comprehensive Survey of Living Conditions, the Survey of Rehabilitation

Facilities for the Elderly, the Survey of Social Welfare Institutions, and other surveys. The long-term care insurance system was introduced in 2000, thereby establishing a framework for the periodic reporting of the number of individuals requiring long-term care by region throughout Japan. In 2007, the MHLW published the Prefectural Health Promotion Planning Guidelines, in which health expectancy of the “average period of time spent independent in daily activities” defined by the research team should be the standard. The Healthy Life Expectancy Calculation Guidelines (Hashimoto et al. 2008) were published to enable each local government to calculate health expectancy. Then, in 2012, when Health Japan 21 (the 2nd term) was released, the Healthy Life Expectancy Calculation Guidelines for calculating health expectancy by local governments based on data such as the “average period of time spent without limitation in daily activities” were released, together with a Microsoft Excel calculation sheet.

In terms of international comparisons of health expectancy, a survey has been conducted of regions in Japan using both the Japanese questionnaire regarding activity limitations and a

Fig. 14.4 Health expectancies without activity limitation in 2010

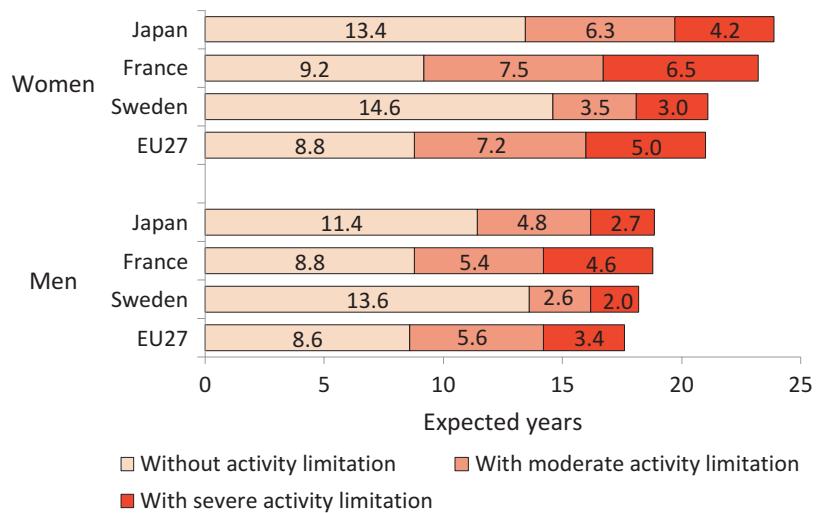
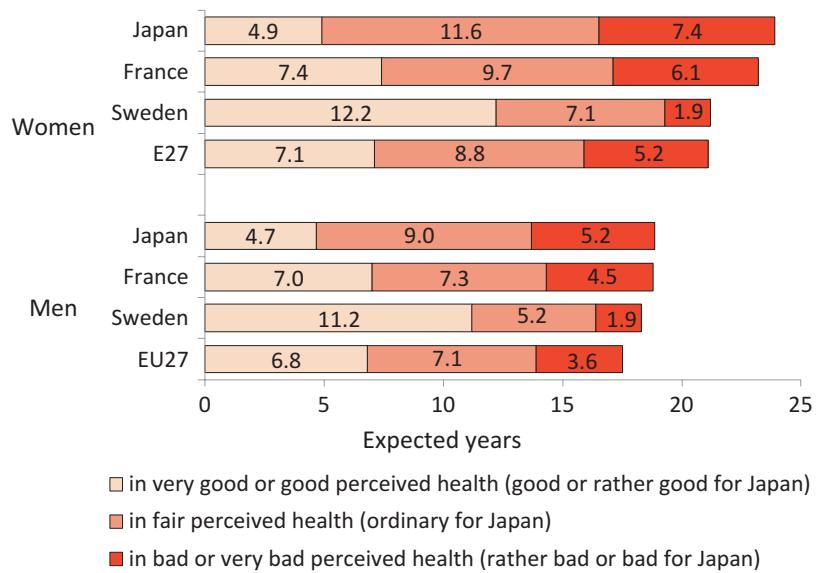


Fig. 14.5 Health expectancies by self-perceived health at age 65



Japanese translation of the EU questionnaire (Ojima et al. 2013). A conversion table was prepared for the two questionnaires to compare health expectancy between Japan and the EU. Figure 14.4 shows health expectancies without activity limitations using the global activity limitation indicator (GALI) at age 65 in 2010. According to this figure, health expectancy without activity limitation in Japan is shorter than that

of Sweden but longer than other countries in the EU. Figure 14.5 shows health expectancies by self-perceived health at age 65 in 2010. Expected years in good health in Japan was shorter than in EU countries. Such international comparisons appear to be useful for considering the health promotion policies of various countries in the light of an international context.

Health Promotion Policies at Local Level in Japan Including Public and Private Initiatives

Japanese local governments comprise 47 prefectures and over 1700 municipalities. The Health Promotion Act made it mandatory for the central government, as well as prefectural governments, to formulate health promotion plans, but municipalities are also required to make efforts to formulate such plans. Health Japan 21 (the 2nd term), formulated by the central government in 2012, cited health expectancy as the most important index, and this has also been adopted as the target indicator for the health promotion plans of many local governments. Like the central government, many prefectures and major cities use the concept of health expectancy as calculated based on Comprehensive Survey of Living Conditions data using the “average period of time spent without limitations in daily activities” proposed by a MHLW-funded research team. Meanwhile, many small to medium sized municipalities use the “average period of time spent independent in daily activities” calculated using data from the long-term care insurance system, as issues related to sample size make it impossible for such municipalities to determine the status of their own region according to Comprehensive Survey of Living Conditions data.

The results of a national survey conducted in 2017 on health expectancy in each municipality were presented during the 29th REVES meeting (*Réseau espérance de vie en santé*) (Ojima et al. 2017). Overall, 62% of municipalities responded that they were calculating health expectancy. The most common response, accounting for 35% of all municipalities, indicated that figures were calculated by prefectural governments, followed by municipalities, and the National Health Insurance Association, the latter accounting for 15% of responses. Thus health expectancy has become an important index for evaluating the progress of health promotion plans for local governments in Japan.

In 2012, the MHLW started the Smart Life Project to extend health expectancy. The Smart Life Project focuses on the three themes (ade-

quate exercise, appropriate diet, not smoking), and offers awards to local municipalities, organisations, and corporations that implement excellent awareness-raising activities and initiatives contributing to promoting health and preventing lifestyle-related diseases. First prize for the first round of awards went to the Shizuoka prefectural government, which is proactively engaging in health promotion activities based on nutrition, physical activity, and social participation, as well as analysing big data on resident health and calculating health expectancy for municipalities within the prefecture. An award of excellence was also presented to a company in which employees themselves autonomously deployed health promotion activities to improve lifestyle-related diseases under the slogan “Change Lifestyle and Improve Health Expectancy.”

Health management is garnering attention as health promotion is being implemented by private sector companies in Japan. Health management refers to an understanding of the supervision of employees’ health as a management issue and the strategic implementation of countermeasures. The effects of employee health promotion are thought to include improving company productivity, enhancing employee creativity, and boosting corporate image, as well as company risk management. In 2006, the Specified Non-profit Corporation Workshop for the Management of Health on Company and Employee was established, leading to increased utilisation of health management, and, around 2009, some major corporations started engaging in the practice. In cooperation with the Tokyo Stock Exchange, the Ministry of Economy, Trade, and Industry began highlighting companies who had implemented health management since 2014. The purpose of this initiative is to encourage investors to become aware of companies that actively engage in health management to promote attempts to extend national health expectancy in accordance with the National Revitalization Strategy. Robert H. Rosen, author of *The Healthy Company*, first proposed the term health management in 1992, and the Corporate Health Achievement Award activities began in the US in 1996.

Recently, descriptions such as “contributing to extending health expectancy” are becoming common in advertisements by companies in health-related industries such as the food, health equipment, and health and medical care-related industries. As of September 2018, a Google search of health expectancy (referred to in Japanese as “*kenkou jyumyou*”) amongst co.jp domain websites that are mainly held by private sector companies resulted in 155,000 hits. In addition, a search of go.jp websites operated by central government-related bodies resulted in 42,000 hits, while a search of all websites resulted in 2.38 million hits. Companies that came high on the list for the search included a pharmaceutical company manufacturing osteoporosis medication, a consulting firm handling retirement benefit schemes, a manufacturer of health foods, a company supporting corporate industrial health-related activities, and a company developing a health point business utilising pedometers. The Japanese government is also making efforts to support the development of such industries related to the extension of health expectancy.

Health Expectancy Knowledge and Interest Within the General Population in Japan

We investigated the term “health expectancy” (referred to in Japanese as “*kenkou jyumyou*”) with a G Search database service to determine the

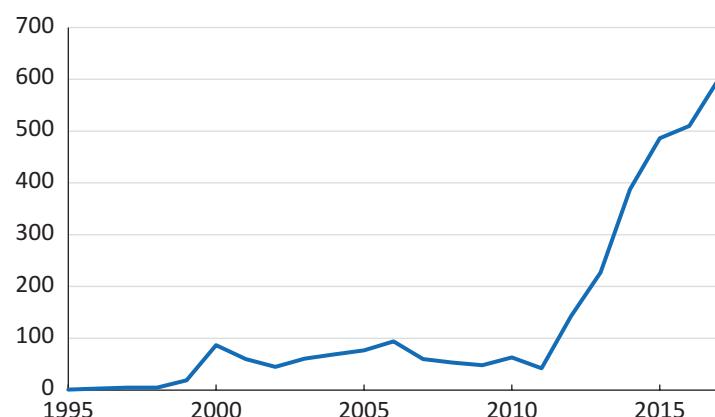
number of related articles in 44 newspapers in Japan. Figure 14.6 shows the annual shifts in the number of articles related to health expectancy. The first such article appeared in 1993 when a professor at The University of Tokyo gave a lecture on ideal health promotion going forward, including the state of health expectancy. Since Health Japan 21 was announced in 2000, over 100 such articles have appeared each year. Since Health Japan 21 (the 2nd term) was announced in 2012, the number of articles has increased each year, with close to 3000 hits for such articles in 2017.

A nationwide telephone survey of Japan, using random digit dialling, by a research team for promoting Health Japan 21, funded by the MHLW, examined recognition of health expectancy amongst the general population; i.e., the proportion of people who understood the meaning of the term or had heard of it before (Sugiyama 2016; Tsuji 2016). Figure 14.7 shows annual shifts in the proportion of Japanese people who recognise the term health expectancy. It is apparent that recognition of health expectancy has improved dramatically each year since Health Japan 21 (the 2nd term) was announced in 2012.

Conclusion

As health expectancy is a combined index of good health status and long life, the concept of health expectancy is relevant to health promo-

Fig. 14.6 Annual shifts in the number of articles related to health expectancy in Japanese newspapers



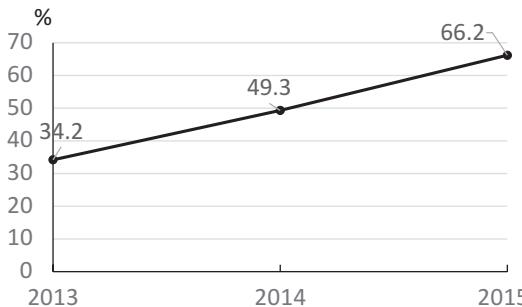


Fig. 14.7 Proportion of people who know about health expectancy, Japan 2013–2015

tion. Moreover, health is one of the most important concerns among the general public in an ageing society. Therefore, health expectancy has been used for health promotion policy as well as comprehensive policy of nations in many countries. One of the challenges to utilize health expectancy for policy is that a substantial extension of health expectancy requires many years. Another challenge is that the link between public health efforts and any change in health expectancy is not simple. Many studies, however, are now revealing the relationship between various factors or interventions and health expectancy. The concept of health expectancy, which refers to healthy, as opposed to simple longevity, is an attractive idea for members of the general population. The Japanese government is responding to greater interest amongst the general population regarding health expectancy while it enhances its health promotion policies, and engages in related activities. Collaborative development of health promotion policy for, and research on, health expectancy will contribute to extending the health expectancy of people.

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Utility of Health Expectancy When Evaluating Health Care Systems

15

Matthew C. Stiefel

Contribution of Health Care to Health Outcomes in Determinants of Health Framework

Health care's world is expanding. From the simple (and wrong) caricature by Evans and Stoddart (1990) in Fig. 15.1....

...to their more expansive, complex and more accurate depiction (Fig. 15.2).

This expanded framework from nearly 30 years ago presages the expanding field of view of health care, upstream to the behavioural, social, environmental and genetic factors and downstream to the health, functional, well-being and prosperity outcomes about which people care.

There is no standard definition of the term "health care system". For this discussion, health care systems are broadly defined to include those organizations responsible for financing and/or delivering health care to a defined population, both public and private. Socio-ecological models of the determinants of population health indicate a limited contribution of health care to population health, compared to behaviours, social and environmental circumstances and genetics (McGinnis

et al. 2002). However, this limited contribution of health care to health is historically empirical, not normative. Health care can have a greater impact on population health outcomes by broadening its lens upstream and downstream, and there is evidence of that trend worldwide. Health care organizations are increasingly recognizing the importance of proximal behavioural, and, somewhat more distal, social determinants of health in their work. For example, UK governments are moving toward "joining up" of health care and social services budgets (Bate 2017). Similarly, the US government is promoting "accountable health communities" and providing more flexibility in Medicare funding for potential coverage of social services (Centres for Medicare and Medicaid Services 2018a). While there is general recognition that health care organizations do not have the resources to address many basic needs, there is growing recognition of the importance of understanding these needs in providing health care services and collaboration with social services and public health organizations to address these needs. Although there is some evidence of the potential value of addressing social determinants in reducing health care costs, health care organizations worldwide face intense pressure to reduce costs in the short term through traditional expense reduction.

Health care systems also are expanding their lens downstream in the determinants of health framework, with greater focus on health and

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well-being outcomes as experienced by patients (Stiefel et al. 2019). For many health care organizations, such as independent hospital and physician groups in the US, it is difficult to define the population served, which makes it more difficult to measure and interpret health outcomes like health expectancies (Stiefel et al. 2010). However, growth of Accountable Care Organizations in the US and the increasing importance of outcome measurement increases the potential relevance of health expectancies (Centres for Medicare and Medicaid Services 2018b). Health care is moving toward expanded measurement of health outcomes in addition to traditional measures of clinical conditions, cost, utilization and service. Health expectancies are well-suited to this expanded measurement of

outcomes. Even with the historically narrow health care frame on process and intermediate outcomes, the mission statements of health care organizations typically include some reference to the aim of improving population health. The absence of an all-encompassing health outcome measure, however, limits our ability to make informed judgments about value for our health care investment (Stiefel et al. 2010). As Kindig et al. (2008) noted, “Without careful attention to the outcomes, attention to determinants and policies could proceed without reference to the ultimate goals and become ends instead of means to an end.” The US case is illustrative of this misalignment. In 2016 in the US, 17.9% of GDP was spent on health care (Hartman et al. 2017), and in 2017, US health spending per capita was 2.5 times greater than the average for the countries in the Organization for Economic Cooperation and Development (Organization for Economic Co-operation and Development 2017). However, according to the World Health Organization (WHO 2018), in 2016 the US ranked only 40th in the world in healthy life expectancy at birth. A greater focus on health outcome measures could help reallocate spending on health care to the broader social and environmental determinants of health, which are more influential determinants of population health than health care is.

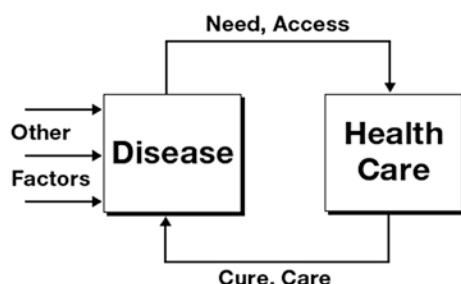
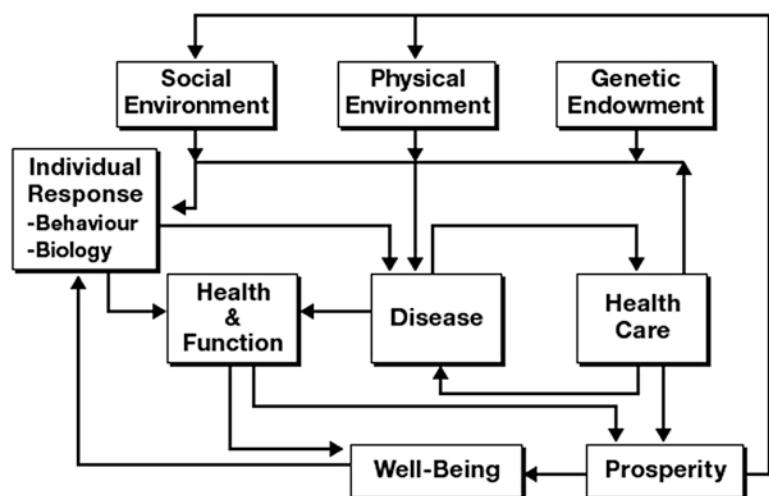


Fig. 15.1 Relationship between health care and health outcomes – simplified view. (Reproduced with permission from Elsevier and Stoddart 1990)

Fig. 15.2 Relationship between health care and health outcomes – expanded view. (Reproduced with permission from Elsevier and Stoddart 1990)



Current Uses of Health Expectancies by Health Care Systems

Health care applications of health expectancy are limited but growing, falling into the broad categories of research/planning, clinical/operational and mission/strategy/policy. There are important differences in the type and appropriateness of health expectancy applications depending on the health care uses. There currently are no standard approaches to health expectancy calculations, in general or specifically, as used by health care systems. The most common applications of health expectancies in health care utilize quality-adjusted life-years (QALYs) and disability-adjusted life-years (DALYs), discussed below.

QALYs (discussed further in Chap. 1) have been used by health care organizations and the pharmaceutical industry for many years for evaluation of clinical- and cost-effectiveness of health care interventions. The QALY is the established benchmark for capturing benefits for patients through lengthening life and/or improving the quality of life, and it is the standard used by academics, manufacturers, patient groups and governments around the world. As noted by the Institute for Clinical and Economic Review (2018), “The primary measure by which the incremental cost-effectiveness of different care options will be compared will remain the cost per quality-adjusted life year.”

However, there is not a standard measure of quality of life used for QALYs. The quality of life measures for QALYs are typically based on individual subjective reports of health and functional status, which are then converted to utility scores. One QALY is 1 year in perfect health, and death corresponds to zero QALYs (Neumann and Cohen 2018). These may be applied directly or indirectly in the assessment of the value of individual dimensions of multi-attribute systems like the Health Utilities Index (Torrance et al. 1996) or the EuroQol (Dolan 1997).

In the UK, the National Institute for Health and Care Excellence, which advises on the use of health technologies within the National Health Service, uses “£ per QALY” to evaluate their utility. However, in the US, the Affordable

Care Act prohibits the Patient-Centered Outcomes Research Institute from using cost-per-QALY benchmarks, based in part on concerns that they might be used by insurers to ration care and might be perceived as de-humanizing (Neumann and Cohen 2018). Recently, QALYs have received increased interest in the US from the work of the Institute for Clinical and Economic Review (ICER), a private, non-profit organization that evaluates pharmaceuticals and other technologies and uses QALYs in its cost-effectiveness assessments (Neumann and Cohen 2018).

The use of the QALY as a health outcome measure for groups of patients is clear for payers, managed care and governmental organizations, which seek to make decisions that maximize the value of health-care spending in terms of health outcomes given limited resources. Nevertheless, the importance and need to bring QALYs into the wider decision-making process of clinicians and patients is more controversial. Although these data are typically applied in the economic evaluation of new health technologies, they also may be used in other non-economic applications, for example, in monitoring health status in individual patients or in measuring population health or the impact of therapies in clinical studies (Kind et al. 2009). The application and relevance of QALY measures to clinicians is expanding, and it is possible to find examples that report the use of QALYs in a range of conditions such as heart failure (Sullivan et al. 2007), diabetes (Glasziou et al. 2007) and oncology (Halyard and Ferrans 2008; Protière et al. 2000). The use of cost-effectiveness analyses that incorporate QALY outcomes to supplement formulary decisions also is increasing in managed care pharmacy (Aspinall et al. 2005; de Haes and Koedoot 2003; Kaplan 1999; Parameswaran et al. 2008; Schackman et al. 2008; Watkins et al. 2006). One reported application demonstrated the use of QALYs in the evaluation of quality improvement in diabetes management (Schmittiel et al. 2007). A patient-level QALY metric, simulated from risk factor and case-mix variables in a Markov model, was used to examine performance across medical centers in terms of delivering improved

outcomes to patients with diabetes by adopting appropriate monitoring and treating strategies for those patients.

Another study utilizing health expectancy at the health care provider group level investigated the feasibility of monitoring the health of elderly people with and without diabetes using a measure of “active life expectancy” with routinely collected primary care data in a general practice in England (Jagger et al. 2003). The study found that among the elderly, those with diabetes had a lower life expectancy and were active for a smaller percentage of their remaining life compared to those without diabetes. It concluded that such methods could be used by the Strategic Health Authority, Primary Care Trust and general practice levels to monitor health needs, highlight health inequalities and evaluate intervention strategies.

Health care organizations are beginning to use health expectancies in support of their planning and strategy. HealthPartners, an integrated health care financing and delivery system in the US, has recently established a framework of summary measures of population health and well-being to guide their strategy. The summary measures comprise three components: current health, sustainability of health and well-being. The measure of current health is disability-adjusted life years (DALYs), calculated from health care claims and death records. The sustainability of health measure includes two components: member reporting of six behaviours associated with health plus a clinical preventive services index that indicates adherence to evidence-based preventive care guidelines. Life satisfaction represents the summary measure of subjective well-being (Kottke et al. 2016a). For the mortality component of the DALY calculation, years of life lost, they use a combination of state death records and administrative data. For the morbidity component, years of life with disability (YLD), they use their own administrative data from their electronic medical record. The Global Burden of Disease method for calculating YLD is not used by HealthPartners and other US health plans. Therefore, HealthPartners created a crosswalk between the weights for the YLD conditions defined by the

Global Burden of Disease project and the Johns Hopkins Adjusted Clinical Groups (ACG) system (Johns Hopkins University 2018). HealthPartners uses the summary measures to identify and address conditions and factors that have the greatest impact on the health and well-being of its patients, members and community. For example, from their initial analysis of member claims, they found that three broad classes of conditions (i.e., musculoskeletal, psychosocial and neurologic) are responsible for 44% of the loss in DALYs. Within these broad categories, the leading conditions were lower back pain and cervical spine pain; anxiety and depression; and headache, migraine and head injury (Kottke et al. 2019).

Kaiser Permanente, a large integrated health plan and care delivery system in the US serving more than 12 million members, also is evaluating the use of health expectancy as part of their strategy. The organization has articulated a vision to increase healthy years for their members and communities and is currently evaluating alternative data sources, including clinical and self-reported, to measure performance (personal communication).

The Blue Cross Blue Shield Association (BCBS) is a federation of 36 separate US health insurance organizations and companies, providing health insurance to more than 106 million people. They recently created the Blue Cross Blue Shield Health Index, which provides a type of health expectancy for the commercially insured population under age 65 in the US at the county level (Blue Cross Blue Shield 2020). The health index is based on weights assigned to over 200 health condition categories, based in part on the DALY methodology. The BCBS Health Index assigns defined populations a health index score between 0 and 1, where 1 represents optimal health and anything less than 1 represents the adverse impact of illness or disease on longevity and quality of life. For example, a health index score of 0.9 for a population indicates that the population could gain up to 10% in healthy lifespan by addressing the top health conditions impacting their area. Nationally, the conditions that have the greatest impact on the health index

include hypertension, major depression, high cholesterol, coronary artery disease, diabetes, alcohol and substance abuse disorder, COPD, psychotic disorder and ulcerative colitis.

The American Heart Association (AHA) recently set the decade-long 2030 Strategic Impact Goal, which will guide organizational strategies and be used to measure success through the year 2030 (personal communication). The core metric selected for this goal is health-adjusted life expectancy from the Global Burden of Disease (Institute for Health Metrics and Evaluation 2019). Since enhancing the well-being of all Americans also is an AHA priority, the organization will develop and implement focused efforts and has chosen the Gallup-Sharecare Well-Being Index (Gallup Sharecare Well-Being Index n.d.) as a major data source for monitoring and evaluation. At the time of goal setting, no national surveillance data included a metric that represents both the current state of health and subjective well-being in the US. Therefore, the AHA plans to collaborate with several key leaders in this area to develop such a measure.

Potential Applications of Health Expectancies as Outcome Measures for Health Care Systems

Although there are some examples of health care applications of health expectancies, their full value in health care settings has yet to be exploited. This section explores potential applications, in the domains mentioned above: research/planning, clinical/operational and mission/strategy/policy. Uses of health expectancies in health care systems include assessing health status, comparing data with normative reference data and measuring change over time, at the individual patient level, patient group level and population level. Patients and individual providers are potentially interested in all three applications at the individual patient level, while individual providers, provider groups and purchasers also are interested in these data at the patient group level, and provider groups and purchasers are inter-

ested in data at the population level (Kind et al. 2009).

Research and Planning Applications

As noted, health expectancies are useful summary outcome measures of “effectiveness” for cost-effectiveness analysis. They are clear, consistent and important population health outcome measures that can inform judgments about value for health care investment (Stiefel et al. 2010). QALYs are well-established as outcome measures for pharmaceutical trials and health services research. Health expectancies also can be an important outcome measure to guide and evaluate resource allocation and improvement initiatives for both health care systems and public health agencies. According to the World Health Organization (Murray et al. 2000), potential applications include: (1) comparing the health of one population with another (for example, across health care systems); (2) monitoring changes in the health of populations over time for evaluating health care system performance; (3) identifying and quantifying health inequalities within populations; (4) providing appropriate and balanced attention to the effects of non-fatal health outcomes on overall population health; (5) informing debates on priorities for health service delivery and planning based on the contributions of different causes of disease and injury or risk factors to the total; (6) informing debates on priorities for research and development in the health sector; (7) improving professional training curricula in public health; and (8) analyzing the benefits of health interventions for use in cost-effectiveness analyses.

Clinical and Operational Applications

Health expectancy measures have had the least uptake to date in clinical and operational applications, although there is plenty of opportunity for value-added applications. In informing decisions about individual patients or patient groups, it is relevant to consider patient-specific data and

preferences on quality and quantity of life rather than health expectancies based on aggregated data that incorporate a societal perspective on the value of any health benefits (Kind et al. 2009).

Stine et al. (2013) recently have proposed a novel method for patient- and population-level application of health expectancy in a health care setting with proposed person-level measures of mortality and morbidity. As opposed to the typical population-level methods of calculating life expectancy, they propose using a person-level prediction of life expectancy based on a mathematical model that incorporates an individual's specific risk profile. Electronic Medical Records (EMRs) and clinical data warehouses offer a rich and growing repository of data to run advanced modelling analytics such as this. Mathematical models validated to predict individualized risk-related outcomes based on the demographic, biometric and risk behaviour data are increasingly common and more sophisticated (Hobbs and Fowler 2014; Lim et al. 2015; Lumpkin 2007; Project Big Life n.d.; Stevens et al. 2019; Taksler et al. 2013). As these tools demonstrate sufficient evidence of clinical predictive validity, patient-reported data can be integrated with historical and biometric data from the EMR and run through the model to calculate a specific individual's estimated life expectancy at each clinical encounter.

For individual morbidity measurement, Stine et al. (2013) propose using one of the standard instruments for measuring health-related quality of life (HRQL), such as the EuroQol EQ-5D (Euro-Qol Group 2009). Such instruments can identify important individual and group differences to guide treatment approaches. For example, the EQ-5D was used in a study of gender and educational differences in the association between smoking and HRQL in Belgium (Charafeddine et al. 2017). Smoking was not significantly associated with HRQL among men; however, it was associated with lower HRQL scores among women with lower education. The authors concluded that smoking cessation interventions should be tailored to the needs of women with lower education. Such data can be collected from the patient at the same time as the mortality risk-related data during a pre-visit phone call, via

tablet/kiosk in the waiting area, or by a medical assistant during intake. The mechanics for collecting patient-based HRQL assessments have been presaged in the UK National Health Service with the requirement from 2009 for pre- and post-surgery measurement of health status in selected procedures (Kind et al. 2009). In the US, the Medicare "Comprehensive Care for Joint Replacement Model," with 465 participating hospitals, incentivizes collection of both generic and condition-specific patient-reported outcome data (Centres for Medicare and Medicaid Services 2018c). The utility of the individual results can be enhanced by comparison to population benchmarks of HRQL.

The calculation of health expectancies for individuals would be the same as that for populations, by multiplying the predicted life expectancy by the 0–1 utility score from the HRQL measure. This adapts the standard population methods of calculating health expectancy to the individual in the clinical setting in real time. The calculated health expectancy score for an individual could be further adjusted by comparing it to an optimal health expectancy based on modifiable risk factors for that individual, given their sociodemographic data and comorbidities, such as the score Eddy et al. (2012) proposed in the Global Outcomes Score framework. The issue of uncertainty of estimates, and patient understanding of this uncertainty, will be critically important to address for operational implementation.

For patients, a point-of-care health expectancy metric allows for placing a broad, and often confusing, list of health care interventions in the context of a clear, understandable goal: living a longer, healthier life. Patient communication can be personalized in this healthy life context to create a tangible framework for valuing medical interventions and healthy behaviours. For clinicians, a point-of-care health expectancy metric could help organize patient preferences and an ever-expanding medical literature by prioritizing a lengthy list of recommended actions by the proportional impact of specific interventions on the health of the patient in front of them. At the health care system population-level, a summary health expectancy metric could enable placing often

diverse system-level efforts into a coherent framework by aggregating data to illuminate which diseases and risk factors are the greatest drivers of poor health in a population. When major contributors to lost health expectancies are less amenable to clinical interventions, these data could identify priority areas for developing capacity or building bridges with community-based programs in behavioural health, social work, care coordination, or public health.

This proposed method for calculating health expectancy based on predicted mortality for use in health care systems was recently tested in Kaiser Permanente, Southern California using member data from the electronic medical record (Stevens et al. 2018). For mortality, a microsimulation model predicting 5-year mortality based on clinical and administrative data was developed and validated. For the health measure, the standard single, self-reported health item (“In general, how would you rate your health”, on a 5-point scale from excellent to poor) was used in a member-level health risk assessment. The mortality model showed good validity compared to data from the EMR. Measures of current life expectancy and health expectancy were calculated and compared to an age- and gender-matched cohort based on US population data. Potential gains in health expectancy were calculated using decomposition methods, estimating the impact of eliminating risk factors such as physical inactivity, unhealthy diet, smoking, uncontrolled diabetes and high cholesterol.

Mission/Strategy/Policy Applications

An important question for health policy and health care practice in many countries is the extent to which the improvement of quality of life is keeping pace with the increase in life expectancy, since as noted by the WHO (1998), “increased longevity without quality of life is an empty prize.” Health care organizations are experiencing the burden of increased health care needs of an aging population. The change in the ratio of health expectancy to life expectancy over time is a measure of the compression or expansion

of morbidity or functional health status in a population, or the extent to which an increase in life expectancy is accompanied by an increase or decrease in the burden of ill health (see Chap. 2 for further discussion on compression and expansion of morbidity). Traditional studies on the impact and prevention of disease and disability tend to look at mortality and morbidity separately and thus ignore differences in the time spent in ill health. Interventions that add life years may have differential effects on the amount and percentage of time spent in ill health. Strategies delaying both death and functional loss may still increase the relative and absolute amount of time spent with functional loss (Nusselder and Peeters 2006). The extent to which increases in life expectancy are accompanied by increases (expansion) or decreases (compression) of the percentage of that time in ill health has substantial implications for the demand for and cost of health care. For example, although women live longer than men, their higher prevalence of disability reduces their advantage in health expectancy (Van Oyen et al. 2013). In a study of the contribution of chronic conditions to gender disparities in health expectancies in Belgium, not only higher life expectancy (LE) and disability-free life expectancy (DFLE) but also life expectancy with disability (LED) were observed for women compared with men (Yokota et al. 2018), consistent with other studies (Freedman et al. 2016). The gender gap in LE and DFLE has been decreasing over time but increasing for LED. Higher LED in women was attributed to lower cancer and heart disease mortality but higher musculoskeletal disability, suggesting a focus on those conditions for women to reduce the LED gap (Yokota et al. 2018).

Empirical estimates vary on the extent to which expansion or compression of morbidity is occurring in various countries in the world, depending in part on the measures of morbidity used (see Chap. 2 for a further discussion of current trends worldwide). The US has substantially lower life expectancy and health expectancy than many other developed countries, and the causes include behaviours, social conditions and policies (Crimmins et al. 2011). The US has recently

experienced slight expansion of morbidity, in part because the age of onset of most health problems has not increased markedly, and people are living longer with those conditions. Younger cohorts appear to be reaching old age with increasing levels of frailty and disability, and trends in health risk factors, such as obesity and smoking, show worrisome signs of further expansion of morbidity (Beltrán-Sánchez et al. 2015; Crimmins 2015). In Canada, although both life expectancy and health expectancy have been increasing in recent years, the ratio has remained relatively stable based on some measures of morbidity but increasing for women based on other estimates (Bushnik et al. 2018; Mandich and Margolis 2014; Steensma et al. 2017). In England, one study reports that over the past two decades there has been an absolute compression of years spent with cognitive impairment, a relative compression of years spent in poor self-perceived health, and dynamic equilibrium of years of life with disability (Jagger et al. 2015). However, another study reports a small expansion of years spent in poor self-reported health (Public Health England 2017). Over the next 20 years, one study predicts an expansion of morbidity, particularly from years with complex multi-morbidity (4+ diseases; Kingston et al. 2018).

These findings raise important implications for health care and long-term care, especially near the end of life when trade-offs between quantity and quality of life become stark, compounded by the growing shortage of geriatricians. Decomposition of health expectancy into the specific conditions that lead to mortality and morbidity illustrates the utility of the composite measure by providing important insights into how to improve overall health expectancy, including the impact on the compression or expansion of morbidity (see Chaps. 6 and 7 for further discussion). Recommendations to compress morbidity include addressing mobility problems and pain (Bushnik et al. 2018), improving lifestyle and behaviors (Hubert et al. 2002), and improving care management for stroke, cognitive impairment, arthritis, visual impairment and complex multi-morbidity (Jagger et al. 2007; Kingston et al. 2018).

The US Burden of Disease Collaborators recently published a comprehensive study that provides estimates of DALYs and health-adjusted life expectancy for US States with significant implications for health care (US Burden of Disease Collaborators 2018). The study reveals that there has been far greater progress in reducing the burden of some major causes of mortality, such as IHD and lung cancer but no progress in addressing some of the leading causes of morbidity such as mental health disorders and musculoskeletal disorders. While the top two causes of DALYs in the US, ischemic heart disease and lung cancer, were unchanged from 1990 to 2016, the third leading cause changed from low back pain to COPD during that period, and opioid use disorders moved from the 11th leading cause of DALYs in 1990 to the seventh leading cause in 2016. Further, they note wide differences in the burden of disease at the state level. When modelling the impact of risk factors on DALYs, they note that many of the risk factors that contribute to the disparities in burden are amenable to medical treatment within the context of supportive behavioural and lifestyle changes, the broader frame for health care as noted above. For example, in 2016, each of the following six risks individually accounted for more than 5% of risk-attributable DALYs: tobacco consumption, high body mass index (BMI), poor diet, alcohol and drug use, high fasting plasma glucose and high blood pressure. They recommend that these findings should be used to examine the causes of health variations, and to plan, develop and implement programs and policies to improve health overall and eliminate disparities in the US, and that many of the risk factors that contribute to the disparities in burden are amenable to medical treatment within the context of supportive behavioural and lifestyle changes.

Recently, a framework for “compression of functional decline” has been proposed to compress morbidity (without necessarily impacting life span) through measuring and slowing the progression of functional decline from the stages of protection against decline, reactivation, compensatory technology and personal support (Gore et al. 2018).

As healthcare organizations move downstream from process to outcomes measurement to measure performance against their mission and strategy, health expectancies provide a particularly useful summary measure combining quality and quantity of life, both individually and potentially collectively, for population health. The Institute of Medicine (IOM; now National Academy of Medicine), in a 2011 report on the role of measurement in action and accountability, stated that, “Because a summary measure of population health . . . would serve as a marker of the progress of the nation and its communities in improving health, it is important that it be implemented in data collection and public communication efforts at the federal, state, and local levels” (Institute of Medicine 2012). As noted by HealthPartners, if individual health plans were to collect and report a uniform set of summary measures of health and well-being, they would make a significant contribution to implementing these IOM recommendations. When aggregated across health plans, the measures would be applicable regionally and nationally, because nearly 90% of Americans are now registered with a health plan (Kottke et al. 2016a).

Equity also is an increasingly important strategic priority for health care systems, and again, health expectancies are valuable summary measure of equity outcomes. The UK reports health expectancies and level of deprivation for over 7,000 neighbourhood “middle-layer super output areas,” with population size ranging from 5,000–15,000 people (White and Butt 2015). The level of inequality in healthy life expectancy between those living in the most and least deprived parts of England was over 16 years, over double the inequality in life expectancy. They also are able to measure disparities in health expectancies within local authorities and report a positive association between level of health expectancy and level of disparity across local authorities.

With the expanded field of view of health care described above, public policy related to health care is increasingly relevant, especially in areas with government-run health care systems. Scenario modelling and evaluation of public policy can provide valuable insights and implications

for health care. For example, DYNAMO-HIA is a generic, public domain modelling tool that was developed to quantify the health impact of policies influencing health determinants (National Institute for Public Health and the Environment n.d.). It was used to compare the results of seven different population health models estimating the impact of salt reduction on morbidity and mortality in western populations (Hendriksen et al. 2017). The authors found major differences in outcome related to the size and shape of the dose-response relation between salt and blood pressure and blood pressure and disease, concluding that clearly defined assumptions and transparent reporting for different models is crucial. Another example using the model is a study evaluating the impact of alternative tobacco control interventions on health expectancies in Belgium (Otavova et al. 2018).

Bogaert et al. (2018; Chap. 13) recently surveyed the European Commission and 28 Member EU states on their use of health expectancies for policy purposes. The authors found that health expectancy, specifically the Healthy Life Years measure, was frequently used for target setting and strategy development. Examples include use in development of national health plans, overall health targets, pension and retirement age and sustainable development.

Barriers to Using Health Expectancies as Outcome Measures for Health Care Systems and Opportunities to Overcome the Barriers

Actionability: Health Care Systems and Clinicians May Not Know How to Impact Health Expectancies, and Health Expectancies May Be Slow to Respond to Clinical Interventions

Since health expectancies are broad outcome measures of quantity and quality of life, the impact of specific clinical interventions may be hard to detect and take long to unfold for both individuals and populations. Clinicians may be

uncertain of the clinical meaning and interpretation of subjective outcomes and may find it difficult to know how to act on issues raised in these assessments (Lavallee et al. 2016; Valderas et al. 2008). The relevance of such considerations in patient-centred decision-making is more common in therapeutic areas such as oncology and end of life care where trade-offs between life expectancy and the quality of the time that remains are particularly salient but less relevant where such trade-offs are not present as, for example, in many orthopaedic procedures (Kind et al. 2009). In addition, health care interventions alone may have limited impact on health expectancies (Chang 2007).

Two characteristics of health expectancies are particularly challenging for individual clinical use. First, they are generic measures that means that for some clinicians, they will be seen as lacking the specificity that is required in daily practice. Second, when the health component of the measure is calculated as a utility score, the weighting system used to compute the quantity and quality product is most often calibrated in terms of social preferences—not those of the patient. Hence, the criticism that the value attached to quality of life may be determined by wholly disinterested and ill-informed third parties (Kind et al. 2009). Techniques for patient-level elicitation of trade-offs, as described above, address this concern.

The broad challenge of limited influence of health care interventions on population health outcomes is a major source of motivation for health care systems moving upstream to address behavioural, social, economic and environmental factors, and join in multistakeholder collaborations to improve population health (Kottke et al. 2016b). For individual clinicians, the individual-level, point-of-care health expectancy metric proposed by Stine et al. (2013) may have significant utility. A point-of-care health expectancy metric could help organize patient preferences and an ever-expanding medical literature by prioritizing a lengthy list of recommended actions by the proportional impact of specific interventions on the health of the patient in front of them. Patient-reported outcome and experience measures

(PROMs and PREMs) are growing in importance and use. These measures complement clinical outcomes and enable a better understanding of the patient perspective on health and quality of care. Their use at the point of care can improve alignment of the clinician's and the patient's views of health and the care experience, connecting the patient perspective of health status with clinical findings and tailoring treatment plans to patient preferences.

Limited Data Availability and Currency: Limiting Frequency of Reporting and/or Minimum Population Size

Challenges associated with availability and currency of the data required to calculate health expectancies are the biggest obstacle to their adoption by health care systems, as discussed elsewhere (Stiefel et al. 2010). Mortality data and morbidity/health data each present unique challenges. Population mortality data are publicly available but usually with a few years latency and for relatively large geographic areas. Health care systems have an advantage in calculating health expectancies by supplementing this mortality information with data from their own records when available. Because deaths are relatively rare events, minimum population size for stable mortality data is an issue, with 5,000 lives commonly recommended as a minimum population size (Scherbov and Ediev 2011). In the US, there is growing recognition of the need for life expectancy estimation at small geographic areas, in part due to profound place-based disparities. In the UK, life and health expectancies are regularly reported for local authorities, generally with a minimum gender-specific population size of 5,000 and aggregated over 3 years (Butt 2017). In the US, life expectancy has been reported at the county level, with minimum population size of 10,000, using small area estimation techniques. The US Centres for Disease Control and Prevention and the Council of State and Territorial Epidemiologists recently initiated a multiphase project, the Sub-County Assessment of Life

Expectancy, to explore the feasibility of scaling efforts to produce sub-county life expectancy data (Boothe et al. 2018). Phase I results suggest that most state and local health departments will be able to calculate actionable sub-county life expectancy estimates despite varying resources, expertise and population sizes, densities and geographies.

Morbidity/health measurements present different data availability challenges for health care systems. There are two broad categories of morbidity/health data, depending on whether the data are based on individual clinical and administrative data from the medical record or patient registries or based on self-report directly from individuals. The primary health expectancy method using clinical information is the Global Burden of Disease calculation of “disability-adjusted life-years” (DALYs) and “health-adjusted life expectancy” (Institute for Health Metrics and Evaluation 2019). This health expectancy method utilizes data on clinical conditions along with disability weights provided by population surveys to estimate morbidity burden, or “years of life with disability” (YLD). Self-reported data on morbidity or health and well-being used in health expectancies are typically provided through population surveys and cover a broad range of health states, from self-reported disability to happiness, as discussed in Chap. 5.

There are advantages and disadvantages of the clinical and self-report methods for health care system use in calculating health expectancies. Health care systems are uniquely positioned to provide the morbidity/health data from clinical/administrative records, which are available for all users of the health care system. The resulting health expectancy calculations may have more relevance and meaning to clinicians who are used to working with that information. A potential disadvantage of this method is the complexity of the required calculations to produce health expectancies. Since the disability weights are derived from population surveys, the measures do not reflect individual preferences or utilities, although there are trade-offs between the two perspectives depending on the application (Kind et al. 2009). Also, although health care systems are the source

of clinical data, organizations that do not care for a defined population, which is often the case in the US, do not have access to clinical data from non-users of their facilities or providers (Stiefel et al. 2010). With clinical data, as well as self-reported data, there also are important issues of data harmonization across different systems or different measurement instruments that need to be worked out.

Use of self-reported data typically requires additional survey costs plus data collection and respondent burden, and the resulting data from sampling is not as complete as data from the medical record (Chang 2007; Lavallee et al. 2016; Nelson et al. 2015; Valderas et al. 2008). Health care systems could take advantage of such information collected in national or regional surveys if the sample size is large enough to calculate health expectancies at the level of the service area of the health care system. For example, in the UK, estimates of self-rated health for health expectancies come from the Annual Population Survey, which is fielded continuously and reported annually for three-year periods (Office for National Statistics 2017). In the US, the Behavioural Risk Factor Surveillance System (BRFSS) also is an ongoing national population survey, which completes more than 400,000 interviews each year (Centers for Disease Control and Prevention n.d.). Although the BRFSS was designed to enable state-level estimates, the need for more local prevalence estimates has led to calculation of estimates for over 200 selected metropolitan city and county areas. The Canadian Community Health Survey (CCHS) collects population-level information on health determinants, health status and health system utilization (Government of Canada 2018). The CCHS is comprised of two types of surveys: a survey on general health and a focused survey on specific health topics. The general health survey is ongoing, with a sample size of 65,000 per year, and the focused surveys are conducted every 3 years with a sample size of 35,000. The annual survey provides reliable estimates down to the provincial health region level, and the focused survey provides reliable estimates down to the overall provincial level.

Health care systems also can gather their own self-reported health information either at the point of care or through surveys. Potential advantages of self-reported data include the ability to include positive measures of health and well-being which are increasingly important outcome measures for health care systems (Kottke et al. 2016b), reflect individual preferences and utilities for different states of health, and provide information on non-users of the health care system.

The UK and Canada have been producing sub-national health expectancy estimates for many years. In the UK, disability-free life expectancy and health state life expectancy are reported annually for a three-year period for over 200 local areas (Butt 2017; Office for National Statistics 2017). Canada reports health expectancy by province (Statistics Canada 2012). Small-area calculations of health expectancy were done for the 42 public health units in Ontario, based on a large health survey administered in the province (Manuel et al. 2000). An experimental technique for small-area estimation of health expectancy was developed by researchers in the Netherlands using a Bayesian random-effects modelling approach (Jonker et al. 2013). The approach allows for calculation of health expectancy for areas as small as 2000 person-years at risk.

Discussion

As the world of health care expands to include upstream determinants and downstream outcomes, health expectancies are increasingly well suited to shed light on this expanded field of view. Health expectancies provide an intuitive and meaningful summary outcome measure combining the length and quality of life that can enable informed health care decisions at both the individual and population levels. There is growing interest among health care systems in using health expectancies in a variety of applications, including research/clinical, planning/operations and mission/strategy/policy. Barriers to full adoption of health expectancies among health care

systems remain, including issues related to actionability and data availability. Recent developments, together with existing structural advantages of health care systems, address these barriers and provide promise for greater health care system adoption of health expectancies. Population mortality measurement for small areas has improved with small area estimation techniques. Governments and health care systems are investing more in survey methods to gather information on self-rated health and well-being. Health care systems are uniquely positioned to provide the clinical and administrative data for health expectancies that utilize diagnosis information to calculate disability weights and potentially test new measures of health status that combine clinical and self-report measures.

Novel techniques for calculating health expectancies at the individual level open new doors for health care system applications, as an alternative or supplement to traditional health expectancy calculation methods. Models have been developed to predict mortality for individuals based on risk factors. Health status is being assessed at the point of care. Together, these measures can be combined to calculate health expectancies for individuals. These calculations, in combination with models estimating the impact on health expectancy of alternative interventions, have applicability in a variety of health care functions supporting individual patient and provider clinical interactions, research, resource allocation and planning and strategy development.

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Part IV

Assessing New Dimensions



Pain and Disablement

16

Zachary Zimmer and Sara Rubin

Introduction

Common conceptualizations of disablement used across the health expectancy literature define disability as the end result of a sequence of linked events wherein diagnosable medical conditions (pathology) cause bodily dysfunctions (impairments), which act to restrict physical movements (functional limitations) and subsequently the ability to perform tasks necessary for daily survival (disabilities) (Verbrugge and Jette 1994; Nagi 1979). A common characteristic of the impairment part of this process is that it frequently involves pain. In fact, pain often plays a critical function in disablement. However, there are challenges in situating pain within the disablement process. For one, pain is hard to characterize; the definition of pain has been much debated (Anand and Craig 1996). Because of a great deal of subjectivity in reporting pain, the way in which it influences functionality may be

idiosyncratic. Pain is notoriously complicated to measure and therefore to monitor, and a glance through many population level studies indicates that there is no standard for evaluating pain in survey research. Moreover, the interplay between pain and other conditions, impairments and functional restrictions is complex. An individual with rheumatoid arthritis for instance can experience joint tenderness, deformity and inflammation, which might impact upon pain as well as restrict movement, the latter of which has feedback effects on pain (Escalante et al. 2005).

In this chapter, we consider pain as fundamental to the disablement process. Advancements in the management of pain, including development of analgesic drugs and expansion of cognitive and psychological approaches, could be critical for explaining past and predicting future trends in disability. Moreover, the prevalence of pain is itself a reason to pay attention to its role in the disablement process. Pain is the most frequent reason for doctor visits and the most highly reported health symptom among older persons (Brody and Kleban 1983; Mäntyselkä et al. 2001; Wolfe 1999). Actual estimates of pain prevalence vary widely across studies and populations, but the prevalence is high. A report of a broad based study of those 65 and older in the United States put the prevalence at a little over 50% (Patel et al. 2013). This number corresponds fairly well with several other well-cited prevalence studies around the world (Elliott et al. 1999; Gibson and

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Lussier 2012; Rottenberg et al. 2015). Clearly, pain is a predominant characteristic of the human condition; most people will experience pain at some time in their lives to varying degrees. Likely, more than one-half of older people at any point in time are experiencing pain. Despite this ubiquity, pain remains one of the least understood constituents of disablement.

The remainder of this chapter places pain within the context of disablement. The next section examines how pain is commonly perceived (or misperceived) and measured. Next, we present a review of literature that links pain and disability. Following is a descriptive analysis that demonstrates the associations that exist between pain, functional limitation and disability using two commonly employed datasets in the health expectancy literature, the Health and Retirement Survey (HRS) and the Survey of Health, Ageing and Retirement in Europe (SHARE). The last section draws a conclusion to the discussion.

Measurement and Conceptualization of Pain

Pain is difficult to conceptualize. The result is that there is a certain amount of ambiguity in pain measurement. Medical research has more or less settled on a 1994 definition provided by the International Association for the Study of Pain, where pain is defined as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (Merskey and Bogduk 1994). The definition goes on to express that pain is a personal feeling since each individual learns the application of it through their own idiosyncratic past experiences. Since the definition includes sensory, emotional and subjective experiences, it would seem that the existence and severity of pain is highly personal and therefore its intensity can only be reported by those capable of communicating their thoughts. Yet we know from clinical studies that pain is experienced by those incapable of verbalization (Porter et al. 1996; Smith 2005). Further, the personal aspects of pain suggest it is highly contextual, embedded

within cultural and social frameworks. It is unclear whether pain is conceptualized similarly, for instance, across age, sex and race. The expression of pain itself as a sensation can be difficult to pinpoint. Common descriptors are broad and abundant but often vague, including words such as burning, stabbing, shooting, aching or stinging, and pain can be described as being anything from uncomfortable to excruciating.

There have been many attempts to develop scales and indices to accurately depict the existence of pain and its severity. A few frequently used scales are the Brief Pain Inventory, the McGill Pain Questionnaire, and the Oswestry Disability Index and Critical-Care Pain Observation Tool (Katz and Melzack 1999). Techniques involved in these measures vary from survey questions to visual indicators. These scales are not easy to use in population level research for a variety of reasons, including the complexity and time it takes to administer. Moreover, pain is often specific to sites on the body. Some standard measures examine specific sites, like back pain, while other sites may be ignored.

While not all data collection instruments used for studying health expectancy include measures of pain, there have been attempts to monitor pain on a population level using brief summary measures. These are generally not consistent across sources and sometimes change over time, making comparisons across time and space difficult. The Health and Retirement Survey (HRS) has for many years been asking individuals: “Are you frequently bothered by pain?” If the answer is ‘yes’ respondents are asked whether the pain is ‘mild, moderate or severe’ and if it hampers their ability to conduct regular daily activities. The National Health and Nutrition Examination Survey (NHANES) has been collecting pain indicators less regularly but has asked ‘during the past month have you had a problem with pain that lasted more than 24 hours?’. NHANES has also asked about site-specific pain experienced in the ‘past 3 months.... that lasted a whole day or more’ (e.g., joint, neck, low back, knee, headaches or migraines). The most recent version of the National Health Interview Survey asks individuals to report ‘in the past six months, how

often did you have pain?’ as well as whether this pain limited work activities. It then asks whether an individual has suffered from neck, low back, facial or headache pain ‘experienced in the past three months.’ The Survey of Health, Aging and Retirement in Europe (SHARE) has only in recent waves been measuring pain in a way that compares to the HRS. The World Health Organization’s Survey of the Aged inquires “Overall in the last 30 days how much of bodily aches and pains did you have?” As can be seen, questions about pain in these surveys are inconsistent in terms of time reference and specific ways of reporting. Comparisons of pain incidence and prevalence are therefore either not possible or not reliable.

Regardless of pain instruments used, and the aspects they express, the contextualized nature of pain poses serious challenges. Across disciplines, social scientists have examined how the interpretation of pain varies over time, across social and demographic groups and cultures (Baszanger 1998; Mellor and Shilling 2014; Cohen 2015). Studies have shown that the burden of pain falls more heavily upon those in structurally disadvantaged positions, particularly those who face multiple, intersecting forms of oppression (Fuentes et al. 2007; Canizares et al. 2008; Boyd et al. 2016). The association between age and pain measurement has been particularly puzzling and will be discussed in more detail in the next section. Unfortunately, while the study of many medical conditions can be triangulated with data collected through various formats, including biomarkers, there is no clear biomarker when it comes to pain. Even imaging technologies are suspect in their ability to produce reliable and comprehensive representations of pain (Davis et al. 2012). Moreover, there are far-reaching implications for thinking about the experience of pain as cultural. Studies have exposed racial discrepancies in the way in which physicians diagnose and treat pain, at times resulting in inequities in care (Hoffman et al. 2016; Freeman and Payne 2000; Anderson et al. 2009).

In conclusion, structural aspects of pain, such as those related to socioeconomic status and access to care, can only be quantified if large-

scale population health surveys include appropriate questions. While recent years have witnessed some increase in population surveys that ask about pain, it is unclear whether the information being collected is nuanced and accurate enough to gauge pain prevalence and trends at a population level. Clinicians have long recognized the biopsychosocial aspects of pain and the importance of acknowledging how psychological and social factors can influence brain processes related to the experience of pain (Turk and Monarch 1996). Demographers and others that focus on health expectancy research lag behind when conceptualizing pain with measures that treat it as a purely biological phenomenon.

Linking Pain to Disability

Pain is often divided into three main types: transient, acute and chronic (Loeser and Melzack 1999). Transient pain acts as a warning function, like exposure to intense heat. Acute pain is caused by a precipitating event, such as injury or trauma, and is subject to repair in a relatively short period of time. Chronic pain is similar to acute but persists beyond the immediate precipitating event. While transient and acute pain may be temporarily disabling, it is chronic pain that is enduring and subsequently most likely to lead to a record of disability. The diagnosable conditions that lead to chronic pain are many and an adequate discussion of the aetiology is beyond the scope of this review. Croft et al. (2010) provide several good up-to-date discussions. Briefly, the most prevalent cause of pain is arthritis (particularly osteoarthritis), while other common causes include headaches, fibromyalgia, diabetes, neuropathy, shingles, cancer and various autoimmune disorders such as lupus. Regardless of the condition, by far the majority of pain is musculoskeletal in origin, and for older persons it is musculoskeletal brought about by arthritis (Bergman et al. 2001). Yet, ultimately, the underlying root of chronic pain can be difficult to pinpoint; it can be experienced without an obvious detected disease and it can be a function of multiple conditions. As such, the link between pathology and

pain in the disablement process can be ambiguous.

Extant literature contains a fair number of studies that test the magnitude of the association between pain and physical functioning disorders. It is no surprise that the link exists. On the pain side, the majority of studies focus on specific types of site-specific pain (e.g., back, foot, and headache) and concentrate on older persons, the population that is typically thought and expected to be more at risk of pain. On the functioning side, studies consider varying definitions of functional disorder. Disability, as it is commonly conceptualized in the disablement process, using Activities of Daily Living (ADLs) and Instrumental Activities of Daily Living (IADLs), is not often the focus.

Despite extant literature, the overwhelming view is that the association between pain and physical functioning is not well understood for several reasons (Leveille et al. 2001; Weiner et al. 2003). Not everyone who suffers from chronic pain reports functional disorders. Clearly factors mediate the association, and these have not been sufficiently studied. Little attention has been devoted to how associations between pain and disability change over the life course, especially at increasingly older ages. Similarly, most studies are cross-sectional making it difficult to examine the impact of pain on the disablement process (Williamson and Schulz 1992; Scudds and Østbye 2001; Ettinger et al. 1994). Most rely on small and specific clinical samples, while population level studies that might provide for more robust estimates of an association are infrequent (Reid et al. 2002; Scudds and Robertson 1998; Shega et al. 2010; Weiner et al. 2003). Varying measurement strategies for both pain and functionality make it difficult to compare studies. In many studies disabilities and functional limitation are broadly defined or combined, or pain is considered simultaneously with other related problems, such as stiffness in joints or chronic disorders (Scudds and Østbye 2001; Leveille et al. 2001; Edmond and Felson 2003; Puts et al. 2008).

It is not surprising then that the magnitude of associations represented by coefficients varies

widely across studies, in some cases being robust and in other cases quite weak. For instance, Scudds and Robertson (1998) studied a sample of about 900 people aged 65 and older living in London, Ontario, Canada. They report those with musculoskeletal pain to be seven times more likely to have difficulty performing three or more functional activities based on an inventory of 20 from the Stanford Health Assessment Questionnaire. In contrast, Jakobsson et al. (2003) considered a sample of about 4000 Swedish elders 75 and older and found that while pain was associated with decreased mobility, measured using a question about walking and another about general mobility, there was no statistically significant association between pain and IADLs or ADLs; each of which was measured using a single item related to needing help.

Literature on longer-term effects is comparatively absent. Only two published studies could be found that have examined ‘pain-free life expectancy,’ both of which highlighted sex differences. Schön et al. (2011) used 2000–2002 data to show that Swedish women aged 65 had a pain-free life expectancy of 10.6 years and a life expected with pain of 10.0 years, while for men it was 11.7 versus 5.5 years. These authors indicated that proportions of life lived free of pain were lower in 2000–2002 than they were a decade earlier. Zimmer and Rubin (2016) calculated life expectancy with any and severe pain in the United States and found it to be higher among women than men. Further, while those with severe pain at one point in time live about the same total years as those without pain, they can expect to live a much larger proportion of remaining life with pain, suggesting that pain itself influences quality but not quantity of life.

Studies that have considered any type of follow-up data are noteworthy since, first, the implications of pain on disability incidence are relatively unknown and second, these studies are better able to affirm causality. Soldato et al. (2007) examined disability incidence of elderly in home care situations across 11 European countries. Defining pain as “any type of pain or discomfort in any part of the body every day in the last seven days,” they found the hazard ratio of

reporting a disability, defined as one or more ADL as described by Katz (1963) was 1.35 for those with pain relative to those without. Dividing pain into severity levels however, there was no association with ADL disability for those with mild or single site pain, only more severe levels being statistically related. Reid, Williams and Gill (2005) conducted an 18-month follow-up of a small sample of community-dwelling people aged 70 and older in New Haven Connecticut. They found that the length of time with pain between baseline and follow-up was significantly associated with lower scores in timed physical performance measures like chair stands and foot taps.

There are virtually no studies of pain and disability across the entire life course. Covinsky et al. (2009) however examined associations from age 50 and over using the 2004 Health and Retirement Study. Those reporting pain had higher rates of functional limitation across domains of mobility, stair climbing, upper extremity tasks (extending arms above shoulders, pulling or pushing, lifting or carrying) and ADLs (bathing, dressing, transferring, toileting, eating). The influence of pain on domains of functional ability did not vary across age groups, with the implication that those with pain may develop functional limitations earlier in life than those without. Still, since this study is cross-sectional rather than longitudinal, the implication is hypothesized rather than confirmed.

The consistency of associations between pain and functionality across age groups in Covinsky et al. (2009) is important given varying findings on the overall association between age and pain. Some studies show a robust association between increasing age and pain prevalence (Johannes et al. 2010; Thomas et al. 2007; Elliott et al. 1999; Nahin 2015), whilst others show more moderate or little relationship (Patel et al. 2013; McCarthy et al. 2009). Whether and how the incidence and prevalence of pain increase at ever increasing old age is a controversial topic. While it is reasonable to assume that the likelihood of experiencing pain continues to increase with age some studies have reported that pain prevalence increases until approximately 65, after which

point it flattens out or even declines, resulting in a ‘plateau’ effect (Tsang et al. 2008; Blyth et al. 2001; Andersson et al. 1993; Helme and Gibson 1999). There are several possible reasons for this plateau. First, there are selection issues, since older persons with the most severe health problems and thus the most likely to be experiencing pain are also the most likely to be living in institutions and ineligible for many studies that consider community-living only. Related to this, it is difficult to obtain information about pain from those with dementia or those who for other reasons associated with age cannot respond to surveys, which results in omission of a critical portion of the population (Farrell et al. 1996; Smith 2005; Shega et al. 2004). Second, changes in the composition of the population could result in cohort effects if succeeding cohorts differentially report pain. Third, the elderly could be deemphasizing pain if they think about health comparatively to those their own age (Rubin and Zimmer 2015). Finally, there could be actual physical de-sensitivity associated with aging due to reduced function of the nervous system (Cole et al. 2010).

Empirical Evidence Using Two Datasets

This section demonstrates the empirical connection between pain and disability in three countries. Since the previous section indicated that there is uncertainty about how age associates with pain, and that we know little about the extent to which age is a distinguishing factor in the association between pain and disability, this section provides some focus on age variation.

Data

Data come from two studies commonly used in health and disability-free life expectancy research: The Study of Health Ageing and Retirement in Europe (SHARE) 2013 wave, and The Health and Retirement Study (HRS) 2014 wave. For heuristic purposes, SHARE data is

Table 16.1 Descriptive information for each country in the current analysis

| | Germany | Spain | U.S. |
|----------------------------|--------------------|--------------------|------------------|
| Study | SHARE ^a | SHARE ^a | HRS ^b |
| Year of data collection | 2013 | 2013 | 2014 |
| Valid N | 4160 | 4510 | 16,712 |
| Youngest age in sample | 55 | 55 | 55 |
| Oldest age in sample | 100 | 103 | 104 |
| Mean age (std dev) | 67.7 (9.1) | 70.7 (10.2) | 67.3 (9.5) |
| % of sample that is female | 52.6 | 55.1 | 53.9 |

^aStudy of Health Ageing and Retirement in Europe

^bHealth and Retirement Study

limited to two countries that make for an interesting comparison – Germany and Spain. These two represent among the most populous in Europe, but they are in different regions (Western versus Southern Europe) and, while being culturally diverse, are characterized by different cultural, political and economic backgrounds. HRS data are from the United States. Samples include those aged 55 and older and are limited to those without missing data for age and sex. Descriptive information about each country's sample is provided in Table 16.1. SHARE and HRS data make for a good comparison because they provide a closer match on measures used in this section than any other population level surveys frequently used for health expectancy studies. Even the measures of pain are similar. HRS and SHARE questions when translated, both generally ask 'are you frequently bothered/troubled by pain?' and if the answer is yes respondents are asked if the pain they experience is mild, moderate or severe.

Prevalence

This analysis considers two measures of pain: any and severe. Figure 16.1 displays the prevalence across countries by age and sex, with age divided into five-year categories from 55 to 79 and then a category for those 80 and older. The percent reporting any pain is highest in Spain

(Spain: 56.1%; Germany: 39.1%; U.S.: 38.5%) as is the percent reporting severe pain (Spain: 16.0%; Germany: 13.1%; U.S.: 5.8%).

Any debate in the literature about the relationship between age and pain prevalence remains unresolved by these findings. For any pain and for severe pain, the relationship appears flat among men in Germany and among men and women in the U.S., but strongly positive among women in Germany and among men and women in Spain.

The Association Between Pain and Disablement

Using the process described by Verbrugge and Jette (1994) as a guide, we consider disablement measures of having a functional limitation and having a functional limitation *plus* disability. Disability is defined with ADL and IADL limitations. The specific items across countries are identical. Having a functional limitation is a response of any difficulty or being unable to do one or more of nine tasks (walking, sitting, rising from a chair, climbing stairs, crouching, reaching above one's head, pulling or pushing, lifting and grasping with fingers). An ADL disability considers difficulty or inability with six tasks (dressing, walking across a room, bathing, eating, getting out of bed and toileting) and an IADL disability with seven (using a map, preparing a meal, shopping, using a telephone, taking medications, doing household chores and managing money). The last column in Table 16.2 is the distributions across countries. The highest percentage reporting functional limitation is in the U.S. (U.S.: 60.4%; Spain: 52.0%; Germany: 49.9%). The percent reporting a functional problem plus disability (ADL, IADL or both) is also highest in the U.S. (U.S.: 31.6%; Spain: 29.0%; Germany: 18.4%). Of those with a functional limitation, the percent that also have a disability is highest in Spain (Spain: 55.8%; U.S.: 52.3%; Germany: 36.9%). On balance, Germany has the lowest proportion of functional limitation and disability.

The text that follows concentrates on functional limitation and functional limitation plus

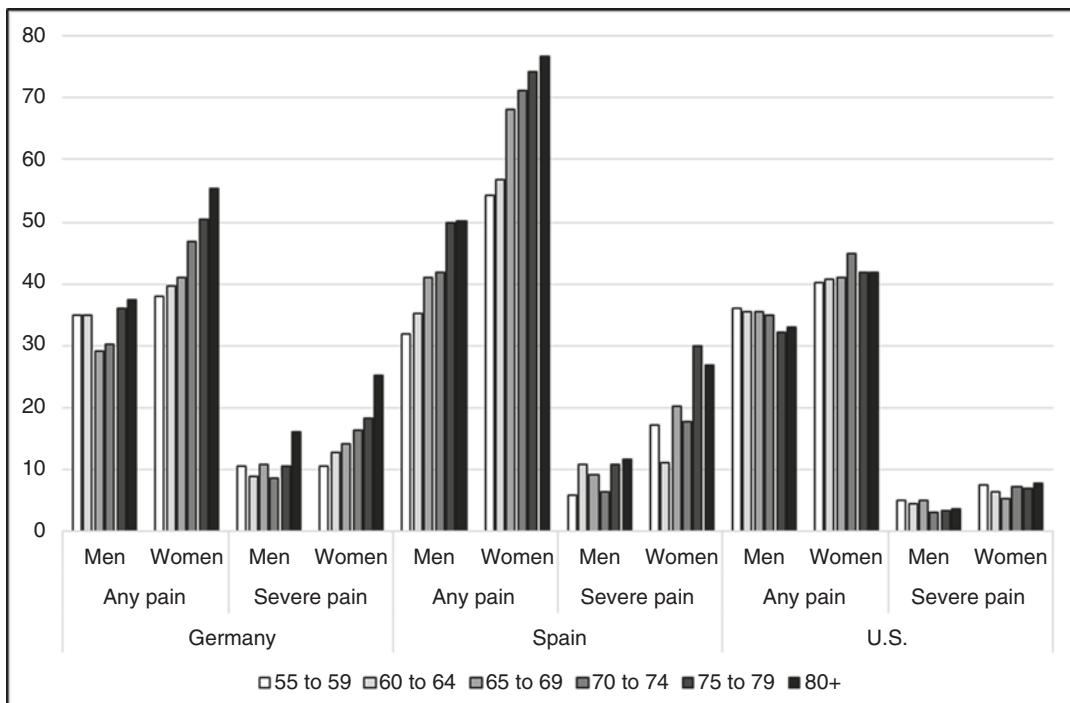


Fig. 16.1 Percent reporting any severe pain by age, sex and country

any disability, but for completeness tables show functional limitation plus ADL limitation and plus IADL limitation separately. Table 16.2 demonstrates that the link between pain and disablement is very strong and can be highlighted in several ways:

1. Across all three countries, those with pain and those with severe pain are extremely likely to have a functional limitation. The percent with pain that have a functional limitation is 77.9% in Germany, 71.7% in Spain and 85.2% in the U.S., while for severe pain the percentages are 88.6%, 91.4% and 95.2% respectively.
2. While not everyone with pain or severe pain has functional limitation plus disability, the percent with functional limitation and disability is much higher for those with pain than for those without. Taking the U.S. as an example, 18.4% of those without pain report both a functional limitation and disability compared to 52.7% of those with any pain and 79.8% of those with severe pain. Percentages are a little

lower in Spain and Germany, but the association is strong across all three countries.

3. The chance that someone with a functional limitation will also have a disability is much higher for those with pain than those without, suggesting that functional limitations develop into disabilities at a higher rate for those with pain compared to those without. In the U.S., fully 83.8% of the sample population with a functional limitation and severe pain report a disability, compared to only 41.1% of those with functional limitation but without pain. While the percentages are a little lower in Spain and Germany, the association is strong across all three countries. This suggests strongly that pain is a determining factor in whether or not a functional limitation turns subsequently into a disability.

Delving deeper into the association, Fig. 16.2 shows the percent with a functional limitation, and Fig. 16.3 the percent with functional limitation plus disability, by age and sex. These

Table 16.2 Disablement status by pain status and country

| | Pain status | | | | Total |
|---|-------------|----------|-------------|--|--------|
| | None | Any pain | Severe pain | | |
| Germany | | | | | |
| N | 2532 | 1628 | 545 | | 4160 |
| % with... | | | | | |
| Functional limitation | 31.9 | 77.9 | 88.6 | | 49.9 |
| + any disability ^a | 8.4 | 34.1 | 49.5 | | 18.4 |
| + ADL disability | 5.3 | 22.7 | 36.5 | | 12.1 |
| + IADL disability | 6.8 | 28.2 | 40.7 | | 15.2 |
| % of those with functional limitation that have any disability ^a | 26.3 | 43.8 | 55.9 | | 36.9 |
| Spain | | | | | |
| N | 1983 | 2532 | 721 | | 4510 |
| % with... | | | | | |
| Functional limitation | 26.8 | 71.7 | 91.4 | | 52.0 |
| + any disability ^a | 11.0 | 43.1 | 62.2 | | 29.0 |
| + ADL disability | 5.5 | 26.1 | 42.3 | | 17.5 |
| + IADL disability | 10.4 | 39.6 | 58.2 | | 26.7 |
| % of those with functional limitation that have any disability ^a | 41.0 | 60.1 | 68.1 | | 55.8 |
| U.S. | | | | | |
| N | 10,282 | 6432 | 969 | | 16,712 |
| % with... | | | | | |
| Functional limitation | 44.8 | 85.2 | 95.2 | | 60.4 |
| + any disability ^a | 18.4 | 52.7 | 79.8 | | 31.6 |
| + ADL disability | 7.2 | 31.2 | 61.5 | | 16.4 |
| + IADL disability | 16.6 | 46.4 | 70.9 | | 28.1 |
| % of those with functional limitation that have any disability | 41.1 | 61.9 | 83.8 | | 52.3 |

^aAny disability refers to either ADL or IADL limitation or both

percentages are ‘estimated’ in that they are based on predicted probabilities from logistic regression models with functional limitation and functional limitation plus disability as dependent variables and pain status, age, sex, and interactions between pain and age as independent variables, for each country.

Looking at Fig. 16.2 it is apparent that age and functional limitation are highly associated among those without pain but not for those with severe pain. The best example of this is the U.S. where the chance of functional limitation for women without pain increases steadily from a little over 30% to a little less than 80% as age rises from 55 to 59 to 80 and older. In contrast, among those with severe pain, the estimated chance of a functional limitation is over 90% regardless of age.

The story in Fig. 16.3 is different. The association between age and functional limitation plus a disability is strongly positive in Germany and Spain across all levels of pain. Taking men in Germany as an example, there is virtually no chance that a man 55 to 59 years-old who has no pain will have functional limitation plus disability. The percent increases steadily to almost 30% by 80 and older. For those with any pain, the association remains positive, increasing from about 20% for the youngest two age groups to over 60% for the oldest. A positive association is also apparent for those with severe pain. In contrast, in the U.S., the association between age and functional limitation plus disability resembles that seen in Fig. 16.2 in that there is a strong positive trend for those without pain and a flatter

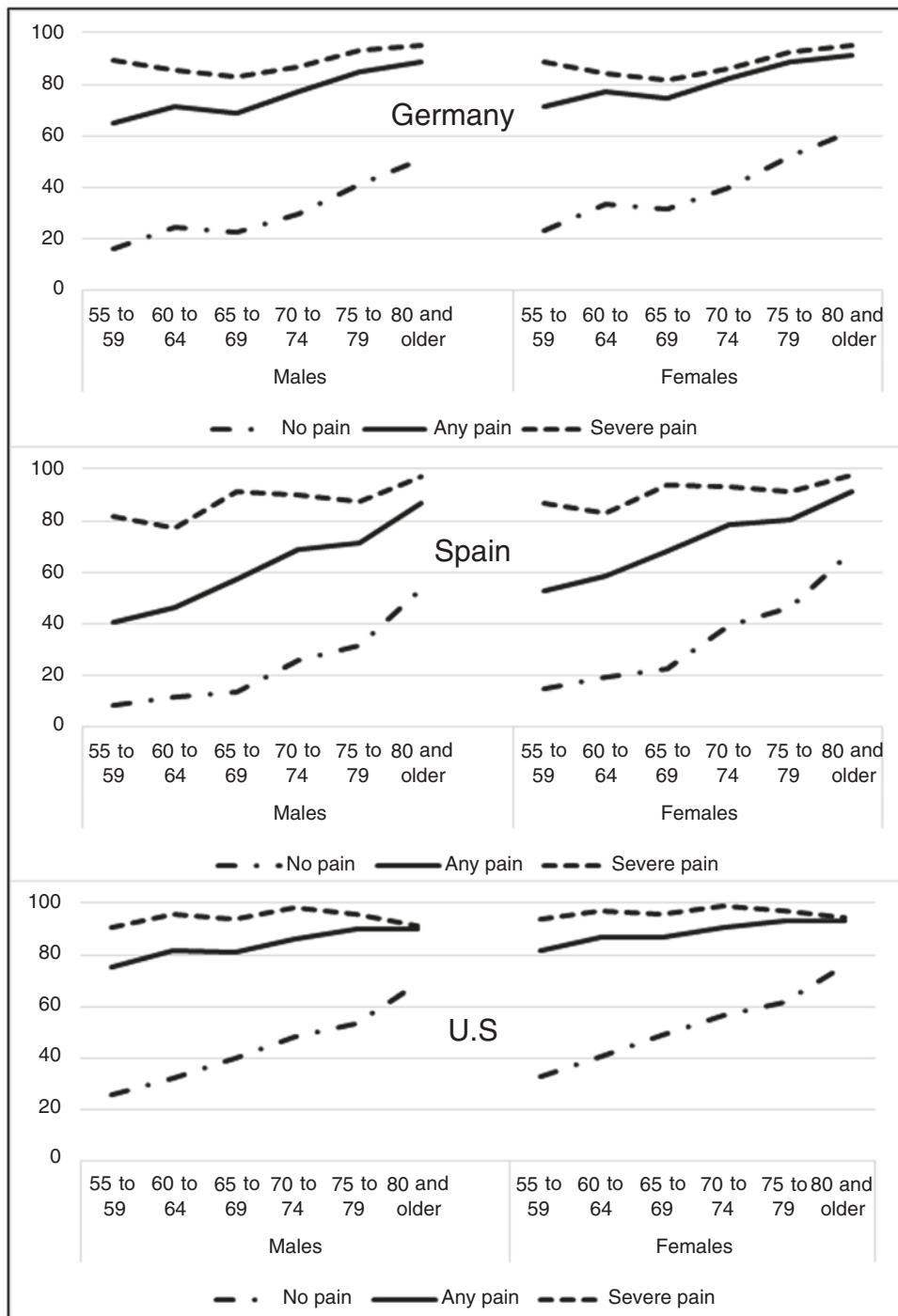


Fig. 16.2 Estimated percent chance of a functional limitation by pain status, age, sex and country

association for those with severe pain. Taking women in the U.S. as an example, there is about a 10% estimated chance that a woman without

pain aged 55 to 59 has a functional limitation plus disability. This chance rises to about 50% by age 80 and older. For those with severe pain, the

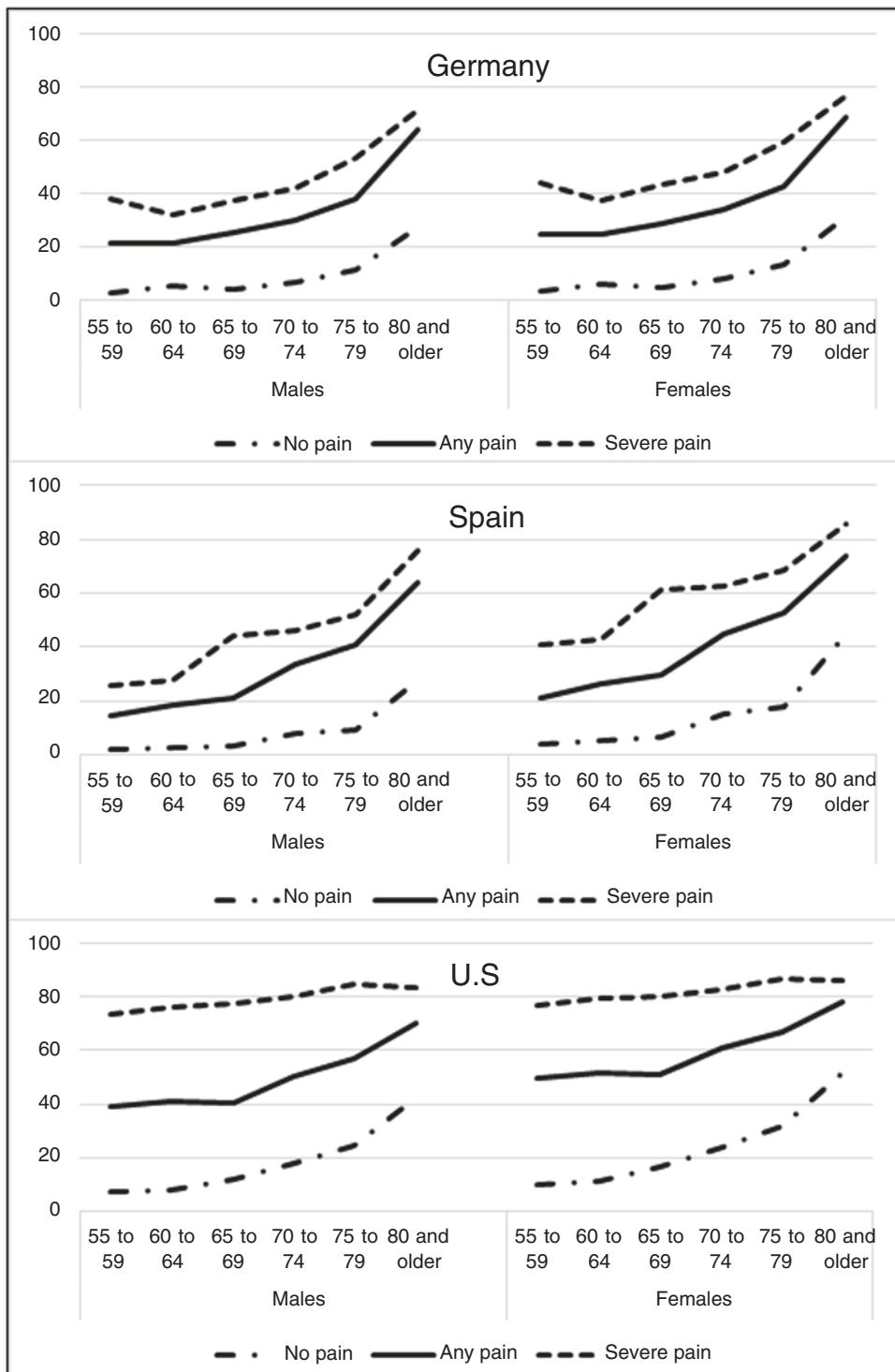


Fig. 16.3 Estimated percent chance of a functional limitation + any disability by pain status, age, sex, and country

percent chance starts at about 80% for those 55 to 59 and barely changes to the oldest age group.

Summary and Discussion

Cross-national comparisons of pain and disability should be conducted with caution given that responses to these types of self-reported health conditions can vary by differential tendencies to report health problems in different countries. Despite potential differences in the tendency to report pain and disability, we have demonstrated empirically robust and consistent links between any and severe pain on one hand and functional limitation and functional limitation plus disability on the other, in three countries. Since such a high percentage of people with pain also have a functional limitation in all countries, and given the nature of the disablement process described at the start of this chapter, it can be presumed that a great majority of those with pain will develop functional limitation, as will nearly everyone with severe pain. It is not inconceivable to hypothesize, in fact, that the process of developing pain and functional limitation is simultaneous. Moreover, while not everyone with pain has advanced to the state of having disability, the association is extremely robust, suggesting that pain and disability are inextricably linked.

Two other conclusions are pertinent. The first is in regards to the connection between age and pain. Correlations in extant literature at times indicate a plateau effect where things are similar for people once hitting the age of 65 or so (Helme and Gibson 1999). Findings in this section suggest that if one looked at the U.S. only, this conclusion is accurate. However, prevalence of pain increases with increasing age in Germany and Spain. This leads to the second conclusion. There are quite clearly complex contextual factors involved in the pain and disablement connection. This is apparent since, although associations are strong across three countries, differences are transparent. For instance, the highest percentage report pain in Spain, while a greater percentage report functional limitation and disability in the U.S. Subsequent associations between pain and

disablement, and especially when considering age, differ across the three countries and across sexes. Even very large discrepancies in the prevalence of severe pain (much lower in the U.S. than the other two countries) intimate that there could be differences in the way in which pain is experienced physically and psychologically across countries. Variation in the reporting of pain and disability across countries is not a new finding. Kapteyn et al. (2007) analysed health vignettes across the U.S. and Netherlands, showing that the reporting of disability for those with and without pain differs substantially by country. In an analysis of 10 European countries, including Spain and Germany, Jürges (2007) used SHARE data to demonstrate that differences in the reporting of a series of self-rated health measures were due to cross-cultural differences in the reporting styles. The Verbrugge and Jette (1994) disablement model refer to extra- (e.g., built environment) and intra- (e.g., psychosocial attributes) individual factors that can influence the pathway from pathology to disability. It is possible that these factors are influencing associations across geographic boundaries.

Conclusion

An enormous amount has been written about pain within the medical literature where it has long been recognized as an important quality of life determinant. Several highly impactful journals are devoted solely to pain, such as *Pain* and *The Journal of Pain*. Pain is the most common reason for visiting a doctor, and direct and indirect costs of pain have been estimated to be enormous (Mäntyselkä et al. 2002; Gaskin and Richard 2012). Within the disablement literature however, research on pain has been scattered and unfocused. Yet, it unmistakably has a critical role to play in the process of disablement. Given the degree to which people report chronic pain, particularly in older age, it is likely the single most prevalent physical impairment, the single most prevailing cause of functional limitation and a chief determinant of disability. In the data we analysed, almost everyone with severe pain

reported a functional limitation, and the chance that an individual with a functional limitation had a disability was much greater for those with than those without pain. Quite likely, the probability that a functional limitation develops into a disability is higher for those with pain. More so, many pathological disorders as well as other impairments result in pain. Our overall conclusion is that pain may not only be a leading cause of disability but, within the disablement process, may be an intervening mechanism between impairment and functional limitation.

There are virtually no studies of the impact of pain on disability across the life course and over time, yet such studies could lead to important insights into the source of disablement. Besides a better understanding of how pain and age interact, we need to know more about how pain functions as a determinant of disability at different points in life. Pain not only precedes but also is a predictor of disability. In turn, early life pain may foreshadow later life disability. Understanding how this process unfolds could be critical for intervention. Generally, good demographic research on pain, its life-course trajectory, its variation across demographic groups, and its implication for length and quality of life is absent.

We also note that the importance of pain in the disablement process has far-reaching implications for the development of pain policy in the U.S. and likely beyond. In the U.S., pain medicine is undergoing a rapid transformation in the wake of a prescription drug crisis. Since the 1990s, opiates have been the gold standard for treating chronic pain. More recently, in light of the devastations of the opioid-related overdose epidemic, new guidelines have emerged that limit the prescribing of opiates for chronic pain (Centers for Disease Control and Prevention 2016). Physicians and researchers alike are searching for new therapies, and are reflecting on broader conceptualizations of pain and its treatment. Increasingly, it seems evident that physicians will be moving towards a pain management approach that is more closely tied to functional ability, rather than a quantified pain scale. Demographic research that ties pain to disability

is necessary if this new approach is to succeed. Further, linking the experience of pain to functional limitation and disability has political ramifications in the realm of entitlements. Disability benefits for chronic pain sufferers has long been a site of debate in U.S. polities (Wailoo 2014). Evidence as to how pain interacts with disability may help to arbitrate some of the concerns over whose pain is seen as legitimate and worthy of support.

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Cognitive and Mental Health Expectancies

17

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Introduction

This chapter provides an overview of research on cognitive and mental health expectancies including findings from cross-sectional studies, longitudinal studies and studies of conditions that moderate these health expectancies. We provide an update of how the literature has progressed since the earlier work by Ritchie and Polge (2003), and focus on studies that include population-based samples or large-scale samples that are considered representative. Specific challenges for measurement and analysis of cognitive and mental health are identified as well as research and knowledge gaps. The reduction in disability free life expectancies associated with cognitive impairment is highly comparable to the

impact of diabetes (Jagger et al. 2007). Dementia reduces total life expectancy (TLE) (Brodaty et al. 2012), whilst late-onset depression does not appear to reduce life expectancy (Peres et al. 2008) and data regarding life expectancy are sparse for severe but less prevalent mental disorders.

Over the past decade, studies reporting cognitive health expectancies and mental health expectancies have been increasing although there is still less information on these topics than health expectancies relating to physical function and disability. Most research on cognitive and mental health expectancies has been from high income countries with established longitudinal ageing studies and similar cultural heritage such as the United Kingdom (UK), the United States (US) and Australia (Ashby-Mitchell et al. 2014; Matthews et al. 2009; Suthers et al. 2003). There are some isolated reports from low and middle-income countries that extend knowledge in this field (Ashby-Mitchell et al. 2015; Muangpaisan et al. 2011; Andrade et al. 2016).

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Dementia and Cognitive Impairment

Cognitive impairment refers to difficulties with memory, thinking and problem solving that impact on instrumental activities of daily living. Clinically, severe cognitive impairment may

meet criteria for a dementia, such as Alzheimer's disease or vascular dementia, depending on symptoms, and aetiology. Research in this field includes estimates of both dementia-free life expectancy (DemFLE) and cognitive impairment free life expectancy (CIFLE) with the latter being a more inclusive category.

Measurement of Dementia and Cognitive Impairment in Population-Based Studies

A challenge for synthesising the literature on CIFLE is the diversity of methods and measures used to define outcomes. Outcomes broadly fall into three categories: (a) clinical diagnosis of dementia; (b) clinical diagnosis of mild cognitive impairment that is not dementia and (c) cognitive impairment defined according to a screening instrument.

Studies vary in terms of the available outcome data and comparability of studies between countries is often limited by the use of different instruments. Obtaining population-based estimates of cognitive impairment is costly where a clinical diagnosis is used, as this typically requires a neurological assessment, brain imaging and possibly other biometrics. Clinical diagnoses typically use widely accepted criteria such as the Diagnostic and Statistical Manual of the American Psychiatric Association (DSM) or the International Classification of Diseases (ICD). For clinical diagnosis of mild cognitive impairment, consensus diagnosis criteria are widely used such as the Winblad criteria (Winblad et al. 2004). Cognitive impairment and dementia cause attrition from cohort studies (Matthews et al. 2004) and hence the true estimate of the association between cognitive impairment and healthy life expectancy is likely to be underestimated.

The most common screening measures used in population-based studies include the Mini-Mental State Examination (MMSE) (Folstein et al. 1975) and the Telephone Interview for Cognitive Status (TICS) (Knopman et al. 2010) although some studies used different measures or derive their own classifications based on assess-

ments and proxy reports. These measures are typically administered by trained interviewers and a cut-point is used to classify cognitive impairment. These measures have been validated against clinical diagnoses but are often less reliable in specific groups such as those with high levels of education (Fratiglioni et al. 1993).

Dementia Findings

Studies of DemFLE were conducted in the 1990s with few recent publications. These studies typically used the Sullivan method to combine national life expectancy data with estimates of age and sex specific dementia prevalence from cohort studies. Results typically differ for males and females and show different trends over time. Some studies reported data from nationally representative samples but most report data derived from cohorts and hence the within country variation is unknown. Despite this, there is general consistency in the pattern of results for DemFLE. Tables 17.1 and 17.2 summarise findings for DemFLE for eight countries (Australia, Belgium, Canada, France, Hong Kong, Ireland, the Netherlands, UK) for males and females respectively. Both TLE and life expectancy with dementia (DemLE) were longest in Canada for males and longest in Hong Kong for females although this may be conditional on year of data collection as LE varies between countries over time. At age 70, years spent with dementia ranged from 1.0 to 1.9 for males and 1.5 to 3.5 for females. It appears that the proportion of TLE lived without dementia declines with age.

The ERDA study (Epidemiological Research on Dementia in Antwerp) reported that at age 65 adults could expect 1.1 years of dementia (combining males and females) (Roelands et al. 1994). Results from Australia were similar, reporting an average of one year spent with dementia (Ritchie et al. 1994a). Likewise, results from France estimated 0.9 years of life spent with dementia (Ritchie et al. 1994b). This early French study showed that women had greater DemFLE than men, but they also had greater time spent with dementia so that increased life expectancy of women was divided into time spent with and

Table 17.1 TLE, DemLE, DemFLE for males by age and country from cross-sectional studies

| | | Australia ¹ | Belgium ² | Canada ³ | France ⁴ | Hong Kong ⁵ | Ireland ⁶ | Netherlands ⁷ | UK ⁸ |
|------------------|-----------------------------|-----------------------------|----------------------|---------------------|---------------------|------------------------|----------------------|--------------------------|-----------------|
| Males aged 65 | TLE | NR | 14.0 | 16.4 | 15.4 | 20.0 | 13.5 | 14.5 | 14.4 |
| | DemLE | 0.9 | 1.2 | 0.6 | 1.8 | 0.5 | 0.5 | 0.5 | 0.7 |
| | DemFLE | 13.4 | 15.1 | 14.8 | 18.2 | 13.0 | 14.0 | 13.0 | 13.7 |
| | % DemFLE/TLE | 95.7 | 92.4 | 96.4 | 91.1 | 96.5 | 96.4 | 96.4 | 94.6 |
| Males aged 70 | TLE | 12.0 | 10.9 | 12.5 | NR | 16.2 | NR | NR | NR |
| | DemLE | 1.0 | 1.0 | 1.3 | | 1.9 | | | |
| | DemFLE | 11.0 | 10.2 | 11.2 | | 14.3 | | | |
| | % DemFLE/TLE | 91.9 | 93.6 | 89.5 | | 88.5 | | | |
| Males aged 80 | TLE | 6.8 | 6.1 | 7.4 | 6.9* | 8.6 | NR | NR | NR |
| | DemLE | 0.9 | 1.1 | 1.6 | 0.6* | 2.0 | | | |
| | DemFLE | 5.9 | 5.3 | 5.8 | 6.3* | 6.6 | | | |
| | % DemFLE/TLE | 86.6 | 86.9 | 78.8 | 91.0* | 76.5 | | | |
| Year of baseline | 1990-1991 | 1991 | 1991 | 1988-1990 | 2013 | 1993 | 1993 | 1994 | |
| Diagnostic tool | DSM-III-R & ICD-10 criteria | CAMDEX & DSM-III-R criteria | DSM-III-R criteria | DSM-IV criteria | AGECAT | CAMDEX & DSM-III-R | GMS & CAMCOG | | |

Note. *Denotes estimated average of reported data for ages 77 and 83, NR denotes not reported

¹Ritchie et al. (1994a), ²Roelands et al. (1994) ERDA study, ³Dubois and Hebert (2006) CHSA Study, ⁴Ritchie et al. (1994a) Persons Aged Quid (PAQUID) Study, ⁵Cheung et al. (2015), ⁶Jagger et al. (1998), ⁷Jagger et al. (1998) Rotterdam Elderly Study, ⁸MRC-CFAS

Table 17.2 TLE, DemLE, DemFLE for females by age and country from cross-sectional studies

| | | Australia ¹ | Belgium ² | Canada ³ | France ⁴ | Hong Kong ⁵ | Ireland ⁶ | Netherlands ⁷ | UK ⁸ |
|------------------|--------------------------------|--------------------------------|-----------------------|-----------------------|---------------------|--------------------------------|----------------------|--------------------------|-----------------|
| Females aged 65 | TLE | NR | 18.3 | 19.1 | 19.7 | 24.1 | 18.9 | 19.0 | 19.7 |
| | DemLE | 2.2 | 2.2 | 0.9 | 3.6 | 1.2 | 1.3 | 1.9 | |
| | DemFLE | 16.7 | 16.9 | 18.8 | 20.5 | 15.7 | 17.7 | 17.8 | |
| | %DemFLE/ TLE | 91.3 | 88.6 | 95.4 | 85.0 | 93.1 | 93.2 | 89.9 | |
| Females aged 70 | TLE | 15.1 | 14.4 | 15.3 | NR | 19.8 | NR | NR | NR |
| | DemLE | 1.5 | 2.3 | 2.3 | 3.5 | 3.5 | | | |
| | DemFLE | 13.7 | 12.7 | 13.0 | 16.3 | 16.3 | | | |
| | %DemFLE/ TLE | 90.3 | 88.2 | 85.1 | 81.9 | | | | |
| Females aged 80 | TLE | 8.6 | 7.9 | 8.9 | 8.7* | 11.3 | NR | NR | NR |
| | DemLE | 1.6 | 2.3 | 2.6 | 0.9* | 3.6 | | | |
| | DemFLE | 7.0 | 6.3 | 6.4 | 7.8* | 7.7 | | | |
| | %DemFLE/ TLE | 81.2 | 79.7 | 71.4 | 88.9* | 68.6 | | | |
| Year of baseline | 1990–1 | 1991 | 1991 | 1988–1990 | 2013 | 1993 | 1993 | 1994 | |
| Diagnostic tool | DSM-III-R & ICD-10 criteria | CAMDEX & DSM-III-R criteria | DSM-III-R criteria | DSM-III-R criteria | AGECAT | CAMDEX & DSM-III-R criteria | GMS & CAMCOG | | |

Note. *Denotes estimated average of reported data for ages 77 and 83; NR denotes not reported.
¹Ritchie et al. (1994a), ²Roelands et al. (1994) ERDA study, ³Dubois and Hebert (2006) CHSA Study, ⁴Ritchie et al. (1994a) Persons Ageés Quid (PAQUID) Study, ⁵Cheung et al. (2015), ⁶Jagger et al. (1998), ⁷Jagger et al. (1998) Rotterdam Elderly Study, ⁸MRCC-CFAS

without cognitive disability. More recently the French PAQUID study has been able to report increases of 2.2 years in DemFLE at age 65 compared with LE increases of 2.5 years (Grasset et al. 2019).

Results from the Netherlands showed that at age 65 women could expect to spend more time living with dementia than men (0.5 years vs 1.3 years) (Perenboom et al. 1996). This study found that the absolute number of years lived with dementia did not vary with age and that the average Dutch male would spend 0.1 year and female would spend 0.3 years in a nursing home with dementia.

The Canadian estimates are based on the Canadian Study of Health and Ageing (CSHA) that included 9008 adults living in the community and 1255 residents living in institutions, whereas previous studies had only sampled community dwelling older adults. This difference in sampling is likely to account for the longer estimate of life lived with dementia reported for Canada (Dubois and Hebert 2006). At age 65 males could expect 1.24 years of dementia and females 2.18 years. Results from Japan also replicated the gender differences observed in other countries whereby women live longer than men but spent more time with life expectancy with cognitive impairment (CILE), in addition to longer CIFLE (Sauvaget et al. 1997).

In a US study that drew from the Kaiser Permanente Medical Care Program of North California, an increase in life expectancy was associated with an increase in DemLE for males, but decrease in DemFLE for females (Sauvaget et al. 1999). Recent studies have demonstrated a reduction in dementia prevalence in some countries (Langa et al. 2016; Peres et al. 2016), and once data are available it will be of interest to see if there are associated changes in DemFLE.

Cognitive Impairment Findings

It could be argued that studies using dementia do not fully estimate ‘cognitive impairment free’ life expectancies because there is disability associated with the preclinical stages of dementia (Chang et al. 2011), as well as mild cognitive dis-

orders that do not progress to dementia (Landau et al. 2010).

Early estimates of CIFLE using cognitive screening tests rather than dementia diagnoses were reported for the US based on the Assets and Health Dynamics of the Oldest Old (AHEAD) study (Suthers et al. 2003) that included adults living in institutions. The cognitive measure was constructed from items administered by telephone based on a modification of the TICS and was augmented by informant reports where participant data were unavailable. This methodology is not comparable to other published studies that used the MMSE. At age 70, the authors report that males could expect 1.1 years of cognitive impairment (11.1 years of CIFLE) and females could expect 1.7 years of cognitive impairment (13.5 years CIFLE).

Repeated cross-sectional studies that have estimated CIFLE have been equivocal on the relationship between increases in life expectancy increases and the time spent with and without CILE. For example, in Hong Kong, a woman aged 70 in 1998 could expect to live another 16.8 years, of which 2.7 years would be spent with CILE, but in 2013, she could expect to live another 19.8 years, of which 3.5 years would be spent with CILE (Cheung et al. 2015). In contrast, repeated cross-sectional studies in the UK, US and the Netherlands have all shown a reduction in CILE, at least for women (Crimmins et al. 2016; Deeg et al. 2018; Jagger et al. 2016).

Using the Survey on Health, Ageing and Wellbeing in Latin American countries (SABE) dataset, Ashby-Mitchell and colleagues report estimates for Argentina, Barbados, Brazil, Chile, Cuba, Mexico, and Uruguay (Ashby-Mitchell et al. 2015) using a modified version of the MMSE scale in combination with the Pfeffer scale for persons scoring less than 12 on the MMSE (Pfeffer et al. 1982). The advantage of SABE is that it used the same survey instrument for multiple countries and provides for the first report of CIFLE from Latin American countries. Results demonstrated the pattern of long life expectancies and longer time lived with cognitive impairment for females reported in studies from Australia, the UK, and Canada (Tables 17.3 and 17.4) was repeated for all countries

Table 17.3 TLE, CILE, CIFLE for males by age and country from cross-sectional studies

| | | Australia ¹ | Canada ² | UK ³ | US ⁴ | Latin American and Caribbean countries ⁵ | | | | | | | |
|------------------------------|-----------------------|--------------------------------|-----------------------|--|-----------------|---|----------|--------|-------|------|--------|---------|-----------------------|
| Males | TLE | 23.5 | NR | NR | NR | Argentina | Barbados | Brazil | Chile | Cuba | Mexico | Uruguay | Thailand ⁶ |
| aged 60 | CILE | 2.4 | | | | 17.7 | 19.4 | 17.6 | 19.1 | 19.7 | 19.3 | 17.6 | 19.7 |
| | CIFLE | 21.1 | | | | 0.8 | 1.1 | 0.9 | 0.8 | 0.7 | 1.0 | 0.8 | 2.0 |
| | %CIFLE/ TLE | 89.8 | | | | 16.9 | 18.3 | 16.7 | 18.3 | 19.0 | 18.3 | 17.0 | 17.7 |
| | | | | | | 95.2 | 94.5 | 95.0 | 95.8 | 96.6 | 94.8 | 97.0 | 89.8 |
| Males | TLE | 19.4 | 16.4 | 17.5 | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| aged 65 | CILE | 2.2 | 1.3 | 3.8 | | | | | | | | | 2.2 |
| | CIFLE | 17.2 | 13.8 | 13.6 | | | | | | | | | 14.1 |
| | %CIFLE/ TLE | 88.7 | 84.1 | 78.2 | | | | | | | | | 86.5 |
| Males | TLE | 15.4 | 12.5 | NR | 12.2 | NR | NR | NR | NR | NR | NR | NR | 16.3 |
| aged 70 | CILE | 1.8 | 1.3 | 1.1 | 1.1 | | | | | | | | 2.4 |
| | CIFLE | 13.6 | 9.9 | 11.1 | | | | | | | | | 10.8 |
| | %CIFLE/ TLE | 88.3 | 79.4 | 88.6 | | | | | | | | | 81.8 |
| Males | TLE | 8.9 | 7.4 | NR | 7.1 | 6.3 | 6.0 | 6.8 | 6.8 | 7.2 | 6.5 | 9.6 | |
| aged 80 | CILE | 1.8 | 1.3 | | 1.1 | 0.1 | 1.2 | 0.8 | 0.5 | 1.0 | 0.3 | 0.5 | 2.1 |
| | CIFLE | 10.1 | 4.5 | | 6.0 | 6.2 | 4.8 | 6.2 | 6.6 | 6.3 | 6.9 | 6.0 | 7.5 |
| | %CIFLE/ TLE | 84.9 | 61.7 | | 79.4 | 98.4 | 80.2 | 91.3 | 97.0 | 93.2 | 95.0 | 92.9 | 78.1 |
| Year of data collection | 2011–2012 | 1991, 1996 | 2011 | 1993 | | 1999–2000 | | | | | | | 2005–2009 |
| Cognitive impairment measure | MMSE, $\leq 23/30$ | Modified MMSE, $<78/100$ | MMSE, $\leq 25/30$ | Self-respondent summary measure, $\leq 8/35$ | MMSE, $<12/30$ | MMSE, $<18/30$ | | | | | | | |

Note. NR not reported

¹Ashby-Mitchell et al. (2014) Australia Diabetes Obesity and Lifestyle Study (AusDiab), ²Dubois and Hebert (2006) CHSA, ³Jagger et al. (2016) MRC-CFAS, ⁴Suthers et al. (2003) AHEAD, ⁵Ashby-Mitchell et al. (2015) SABE, ⁶Mutangpaian et al. (2011) Bangkok Longitudinal Study by Siriraj Hospital for the Older Men and Women (BLOSSOM)

Table 17.4 TLE, CILE, CIFLE for females by age and country from cross-sectional studies

| | | Australia ¹ | | | | | | Canada ² | | | | | | UK ³ | | | | | | US ⁴ | | | | | | Latin American and Caribbean countries ⁵ | | | | | |
|------------------------------|----------------|------------------------|------------------------------|-----------------|--|-----------------|----------------|---------------------|------|------|------|------|------|-----------------|------|------|------|------|------|-----------------|-----|----|--|--|--|---|------|------|-----|--|--|
| Females aged 60 | TLE | 26.8 | NR | | | | | NR | | | | | | 22.5 | 22.0 | 20.2 | 22.8 | 22.5 | 21.4 | 22.5 | | | | | | Thailand ⁶ | | | | | |
| | CILE | 1.5 | | | | | | | | | | | | 2.5 | 1.3 | 1.8 | 3.1 | 2.1 | 2.1 | 2.0 | 2.0 | | | | | | 21.4 | | | | |
| | CIFLE | 25.3 | | | | | | | | | | | | 20.0 | 20.7 | 18.4 | 20.1 | 20.0 | 18.8 | 20.1 | | | | | | 7.8 | | | | | |
| | %CIFLE/ TLE | 94.4 | | | | | | | | | | | | 88.8 | 94.1 | 91.2 | 88.5 | 89.0 | 87.9 | 89.1 | | | | | | 13.6 | | | | | |
| Females aged 65 | TLE | 22.4 | 19.1 | 20.3 | NR | | | NR | | | | | | NR | NR | NR | NR | NR | NR | NR | NR | | | | | | 63.6 | | | | |
| | CILE | 1.4 | 1.5 | 5.9 | | | | | | | | | | | | | | | | | | | | | | | 21.4 | | | | |
| | CIFLE | 21.0 | 15.5 | 14.5 | | | | | | | | | | | | | | | | | | | | | | | 14.1 | | | | |
| | %CIFLE/ TLE | 93.4 | 80.9 | 71.2 | | | | | | | | | | | | | | | | | | | | | | | 79.7 | | | | |
| Females aged 70 | TLE | 18.2 | 15.3 | NR | 15.3 | NR | | NR | | | | | | NR | NR | NR | NR | NR | NR | NR | NR | NR | | | | | 17.7 | | | | |
| | CILE | 1.2 | 1.5 | 1.7 | | | | | | | | | | | | | | | | | | | | | | | 3.6 | | | | |
| | CIFLE | 17.0 | 11.5 | 13.5 | | | | | | | | | | | | | | | | | | | | | | | 14.1 | | | | |
| | %CIFLE/ TLE | 93.4 | 75.6 | 91.2 | | | | | | | | | | | | | | | | | | | | | | | 79.7 | | | | |
| Females aged 80 | TLE | 10.6 | 8.9 | NR | 8.9 | NR | | 8.9 | 7.8 | 7.5 | 7.2 | 8.2 | 8.2 | 7.8 | 7.9 | 9.6 | | | | | | | | | | | 10.5 | | | | |
| | CILE | 0.4 | 1.4 | | | | | 1.8 | 0.7 | 1.2 | 1.2 | 1.5 | 1.5 | 0.7 | 1.0 | 2.6 | | | | | | | | | | | | 73.9 | | | |
| | CIFLE | 1.2 | 5.0 | | | | | 7.1 | 6.4 | 6.7 | 6.0 | 6.7 | 7.1 | 6.9 | 7.0 | | | | | | | | | | | | | | 9.6 | | |
| | %CIFLE/ TLE | 96.2 | 56.3 | | | | | 84.2 | 82.4 | 89.4 | 82.8 | 82.1 | 81.2 | 91.3 | 87.0 | 72.9 | | | | | | | | | | | | | 7.0 | | |
| Year of data collection | | 2011–2012 | 1991, 1996 | 2011 | 1993 | | | | | | | | | 1999–2000 | | | | | | | | | | | | | | | | | |
| Cognitive impairment measure | | MMSE, ≤23/30 | Modified MMSE, <78/100 | MMSE, ≤25/30 | Self-respondent summary measure, ≤8/35 | MMSE, ≤12/30 | MMSE, ≤8/35 | | | | | | | | | | | | | | | | | | | | | | | | |

Note. NR not reported

¹Ashby-Mitchell et al. (2014) Australia Diabetes Obesity and Lifestyle Study (AusDiab), ²Dubois and Hebert (2006) CHSA, ³Jagger et al. (2016) MRC-CFAS, ⁴Suthers et al. (2003) AHEAD, ⁵Ashby-Mitchell et al. (2015) SABE, ⁶Mutangpaisan et al. (2011) Bangkok Longitudinal Study by Siriraj Hospital for the Older Men and Women (BLOSSOM)

except Mexico (Ashby-Mitchell et al. 2015). CIFLE was highest in Cuba and lowest in Brazil. Overall results for Latin American countries are lower than for Canada, Australia and the UK (Tables 17.3 and 17.4). This study also reported that CILE increased with age and that country differences were not explained by education. One study of CIFLE from Thailand used the Thai Mental State Examination (TMSE) to estimate cognitive impairment (Muangpaisan et al. 2011). Similar to studies from other countries, women had longer life expectancy than men, and shorter CIFLE.

Demographic and Risk Factor Differentials in Cognitive Impairment Free Health Expectancies

Several studies have now shown that education has a major impact on CIFLE, in addition to gender. For example, analysis of the UK Medical Research Council Cognitive Function and Ageing (MRC-CFAS) study showed that although adults with low education spent almost twice as long with cognitive impairment as adults with high education (Matthews et al. 2009). However, this study also showed that if the MMSE cut points were adjusted for education level, the difference between high and low education groups in CIFLE was attenuated. The role of education was also evaluated in the US Health and Retirement (HRS) that used the TICS to assess cognitive impairment and multistate models to estimate CIFLE (Reuser et al. 2011). This study found that highly educated women lived for 1.9 years with cognitive impairment, whereas low education women lived for 3.8 years with cognitive impairment. Reuser et al. (2011) also examined a range of risk factors such as smoking, gender, education, body mass index (BMI) and race, but concluded that education was the only factor that was associated with both an increase in life expectancy and reduction in CILE (in women). Similar results of more years with cognitive impairment in lower educated groups have also been reported in China and Brazil (Andrade et al. 2019; Hou et al. 2018). Moreover, men and women with less than high

school education in the US had smaller increases in years with good cognition at age 65 between 2000 and 2010 (men: 0.66 years; women: 0.27 years) compared to those with college education or above (men: 1.51 years; women: 1.79 years) (Crimmins et al. 2018).

Large disparities in TLE and CIFLE associated with race were also reported in the HRS that found Hispanics had the highest cumulative probability of CILE followed by Blacks and Whites. It is difficult to interpret these results without more contextual data as it is possible results are confounded by socio-economic status.

Smoking has been shown to reduce TLE and years lived with cognitive impairment in two studies (Anstey et al. 2014; Reuser et al. 2011). This may be due to competing risks of mortality experienced by smokers i.e. smokers die from other diseases before they develop dementia or cognitive impairment. BMI has complex associations with cognitive impairment. Low BMI is associated with shorter LE and higher CILE (Reuser et al. 2011). Obesity is associated with small reductions in life expectancy (Anstey et al. 2014). Sedentary males and females had shorter life expectancy in Australian data (Anstey et al. 2014) and shorter CIFLE for males but not females.

Mental Health

A number of studies have consistently demonstrated that common mental disorders and elevated levels of psychological distress are associated with disproportionate reductions in disability free life expectancies compared to total life expectancies (Peres et al. 2008; Chiao et al. 2013; Steensma et al. 2016). Yet there has been less of a focus on estimating expected years lived with and without mental ill-health. After a small number of early reports provided European estimates of mental ill-health and depression free life expectancies in the mid-to-late 1990s (Jagger et al. 1998; Ritchie and Polge 2003), publications in this field have accumulated at a slow rate.

Mental health refers to the psychological wellbeing of individuals and is often (but not always) defined in contrast to the experience of emotional and psychological distress affecting how an individual thinks, feels, and behaves. Mental health expectancies are generally taken to refer to this latter aspect of mental ill-health and provide an estimate of years lived free from mental illness. Common mental disorders typically include psychiatric conditions such as depression and generalised anxiety disorders. A key feature of common mental disorders is that they are primarily episodic in occurrence, and properly capturing the duration and flow between incidence and recovery poses methodological challenges. Common mental disorders also follow a different age-trend compared to physical disability and many other chronic diseases, and it is therefore important to take into account the lifespan when investigating mental health expectancies.

Substance use disorders and less frequent but more severe psychiatric disorders, such as schizophrenia and bipolar disorders, are associated with considerably shorter life expectancies (from 10 to 20 years (Chesney et al. 2014)) compared to the general population. However, to our knowledge these conditions have primarily been investigated in relation to adjusted life expectancies within the context of the global burden of disease project (Whiteford et al. 2015) rather than health expectancies and so will not be covered in this review. Nor does this chapter consider wellbeing or happiness related life expectancies that are covered elsewhere in this handbook (see Chap. 18).

Measurement of Common Mental Disorders and Mental Health in Epidemiological Surveys

Diagnosis of common mental disorders are made according to a standardised classification criteria such as the ICD or DSM via either a consensus based clinical interview (as a gold standard) or a fully structured diagnostic interview (an imperfect gold standard) such as the Composite International Diagnostic Interview (CIDI) or the

Structured Clinical Interview for DSM (SCID). Similar to the difficulties in diagnosing dementia in large omnibus population-based surveys, proper diagnosis of psychiatric conditions is time consuming and often unable to be implemented for pragmatic reasons.

It is more common for brief self-reported rating scales to be used to identify persons with elevated levels of psychological distress or symptomatology. Self-rated screening instruments capture a broader experience of mental ill-health, including pro-dromal and sub-threshold levels of psychological distress that may not meet clinical criteria. They also tend to be sensitive to the presence of other psychiatric disorders that preclude a diagnosis of common mental disorders such as generalised anxiety or major depression. Cut-points used to identify possible cases should ideally be validated against a gold standard diagnosis, but this is not always done. Scales can either be fixed on symptoms of a specific disorder, or reflect a more general measure of mental ill-health. They may require responses on a Likert scale or comprise symptom count with dichotomous responses, and can vary with respect to their reference period and target population. For instance, the Centre for Epidemiological Studies Depression scale (CESD) (Radloff 1977) is a 20 item scale of depressive symptomatology experienced over the past week, whereas the five item Mental Health Inventory (MHI-5) includes items that assess the occurrence of both depression and anxiety over the past 4-weeks (Ware et al. 2000). Both the CESD and MHI-5 were designed for use in the general population. In contrast, the Geriatric Depression Scale (GDS) (Sheikh and Yesavage 1986) is a count of depression related symptoms experienced within no specified time frame and is specifically designed to screen for depression among older adults.

Summary of Findings on Mental Ill-Health Free Life Expectancies

To date, all studies of mental health expectancies have employed the Sullivan method of analysis for cross-sectional data and focused on

cross-national comparisons, gender differences, or birth-cohort differences. One recent study has used fully structured diagnostic interviews to make diagnoses according to standard classification criteria, but most studies have relied on a range of validated screening instruments.

Table 17.5 provides a summary of studies of mental health and depression free life expectancies based on rating scales. These include earlier European studies (Jagger et al. 1998; Gispert et al. 1998), and more recent findings from Thailand (Muangpaisan et al. 2011) and Brazil (Andrade et al. 2016). No study is nationally representative, but all randomly sampled participants from the general community. Aside from a clear consistent pattern in gender differences and age trends, it is difficult to make direct comparisons across the different studies due inconsistencies in the measurement of mental ill-health, the period and birth cohort, and representativeness of each sample. In all studies, women were estimated to live for longer with mental ill-health both in absolute (years) and relative (percentage of TLE) terms (Table 17.6). A key finding of analysis from the Danish and Spanish data was that despite variation in the prevalence of mental ill-health with age, the proportion TLE lived with poor mental health was relatively stable across ages (contrast this with other health expectancies, for example DemLE comprise a greater proportion of TLE with increasing age). This was also evident in the Brazilian data, but over a smaller age-range.

Findings from the SABE study (Andrade et al. 2016) are interesting as they allow comparison of cohort differences over one-decade within São Paulo Brazil. Importantly, the authors reported that depression free life expectancies increased between 2000 and 2010 for men and women, while years lived with depression were more stable, indicating some relative compression of morbidity in relation to depressive symptomatology. This was during a period where Brazil experienced strong economic growth with an accompanying reduction in income and social inequalities, pointing to the importance of the broader social and economic context in underpinning good mental health at a population level.

Table 17.6 presents data comparing mental health expectancies for major depression, dysthymia, and generalised anxiety disorder across six European countries as part of the European Study of the Epidemiology of Mental Disorders (ESEMeD) (Brugha et al. 2013). Interested readers would benefit from referring to the original article to make more reliable comparisons based on confidence intervals, which we have not reported here. All ESEMeD studies were nationally representative and diagnoses were made according to the fully structured CIDI 3.0, with organic exclusions applied (e.g. those identified with substance use disorders are not classified with generalised anxiety or major depression). When compared to earlier studies, it is clear that mental health expectancies derived from a fully structured diagnostic interview are noticeably smaller in magnitude than those estimated from self-report scales. This is consistent with the point that self-report scales measure a broader component of mental ill-health than specific diagnoses. However, there are also many similarities in the pattern of results in the ESEMeD with studies that assessed mental health using rating scales. The relative period of life lived with a common mental disorder was generally stable across all ages. Women are again shown to live for longer with mental illness, and were estimated to live two to three times more years with a common mental disorder than men.

A strength of the ESEMeD is the capacity to make cross-national comparisons, and there are a number of notable differences between countries. Gender differences in years lived with a common mental disorder were greatly reduced for Belgium men and women at age 25. Young Italian men were estimated to have both longer life expectancies and fewer years lived with a common mental disorder than men from other countries. Overall, the Netherlands, Germany, and Spain appear to have fewer years lived with a common mental disorder compared to Italy, France, and Belgium. This difference can be largely attributed to the longer life expectancies with generalised anxiety disorder in Italy, France and Belgium, particularly for women. One of the striking findings from these data is the relative dominance of

Table 17.5 Characteristics and key findings of studies reporting mental health expectancies using self-report rating scales

| Author | Study | Region and country, date | Sample size | Age range | Method | Outcome and measurement scale | Estimated years lived with poor mental health/depression and proportion of TLE |
|-------------------------------------|---------------------------------|-----------------------------|-------------|-----------|-------------------|----------------------------------|--|
| Andrade et al. (2016) | SABE | Sao Paulo Brazil, 2000 | 2143 | 60+ | Sullivan weighted | Depression GDS-15 > 5 | Women age 65: 4.5 years (24.5%); men age 65: 2.3 years (16.3%) |
| Andrade et al. (2016) | SABE | Sao Paulo Brazil, 2010 | 1345 | 60+ | Sullivan weighted | Depression GDS-15 > 5 | Women age 65: 4.7 years (23.8%); men age 65: 2.2 years (13.5%) |
| Muangpaisan et al. (2011) | BLOSSOM | Bangkok Thailand, 2005-2006 | 5936 | 50+ | Sullivan | Psychological health WHOQOL-BREF | Women age 65: 2.3 years (12.9%); men age 65: 1.5 years (9.2%) |
| Jagger et al. (1998) | DICE | Denmark, 1994 | 4084 | 16+ | Sullivan | Mental health MHI-5 ≤ 52 | Women age 66: 2.1 years (12.4%); men age 66: 0.7 years (5.2%) |
| Gispert et al. (1998) | Catalan Health Interview Survey | Catalonia Spain, 1994 | 12,2000 | 15+ | Sullivan | Mental health GHQ-12 & PSE | Women age ≥ 65: 4.0 years (19.5%); men age ≥ 65: 2.3 years (14.0%) |
| Deeg et al. (1994) ^a | LASA | Netherlands | 3107 | 55-85 | Sullivan | Depression CESD >16 | Women age 55: 5.5 years (19.6%); Men age 55: 3.2 years (14.3%) |
| Mutafova et al. (1999) ^b | | Bulgaria | | | Sullivan | Mental health GHQ | Women age 65: 11 years (71.9%); Men age 65: 7.6 years (59.8%) |

^aCited in Jagger et al. (1998), Ritchie and Polge (2003)^bCited in Ritchie and Polge (2003)

Table 17.6 Estimated years lived with a CIDI diagnosed common mental disorder and proportion of TLE for men and women at age 55 and age 25 in the year 2002, from the ESEMeD (Brugha et al. 2013) (n = 21,425)

| Gender | Condition | Belgium | France | Germany | Italy | Netherlands | Spain |
|------------------------------|---------------|----------------|---------------|---------------|---------------|---------------|---------------|
| Men at age 55 | | | | | | | |
| Generalised anxiety disorder | 0.6 (2.5%) | 0.5 (2.0%) | 0.5 (2.1%) | 0.6 (2.4%) | 0.4 (1.7%) | 0.5 (1.7%) | 0.5 (2.0%) |
| Major depression | 0.3 (1.3%) | 0.2 (0.8%) | 0.1 (0.4%) | 0.4 (0.4%) | 0.1 (1.6%) | 0.1 (0.4%) | 0.3 (1.2%) |
| Dysthymia | 0.1 (0.4%) | 0.1 (0.4%) | 0.1 (0.4%) | 0.3 (1.2%) | 0.1 (0.4%) | 0.2 (0.4%) | 0.2 (0.8%) |
| Any common mental disorder | 0.7 (3.0%) | 0.7 (2.8%) | 0.6 (2.5%) | 0.9 (3.6%) | 0.5 (2.1%) | 0.7 (2.1%) | 0.7 (2.8%) |
| Women at age 55 | | | | | | | |
| Generalised anxiety disorder | 2.0 (1.8%) | 3.3 (1.0%) | 1.1 (1.4%) | 2.2 (3.9%) | 2.2 (3.0%) | 1.0 (0.5%) | 1.4 (4.7%) |
| Major depression | 0.5 (1.1%) | 0.3 (1.7%) | 0.4 (0.4%) | 0.9 (0.4%) | 0.9 (1.3%) | 0.5 (0.4%) | 0.9 (3.0%) |
| Dysthymia | 0.3 (8.1%) | 0.5 (12.6%) | 0.1 (5.3%) | 0.4 (5.3%) | 0.1 (9.4%) | 0.1 (5.4%) | 0.4 (1.3%) |
| Any common mental disorder | 2.3 (4.5%) | 3.8 (4.5%) | 1.5 (3.7%) | 2.8 (3.5%) | 1.5 (2.1%) | 1.5 (3.5%) | 2.0 (6.7%) |
| Men at age 25 | | | | | | | |
| Generalised anxiety disorder | 2.4 (1.8%) | 1.8 (1.0%) | 1.8 (0.6%) | 0.8 (0.4%) | 1.5 (0.8%) | 1.5 (0.4%) | 0.9 (0.8%) |
| Major depression | 0.9 (0.2%) | 0.5 (0.4%) | 0.3 (0.4%) | 0.4 (0.4%) | 0.4 (0.4%) | 0.4 (0.4%) | 0.4 (0.8%) |
| Dysthymia | 0.1 (6.3%) | 0.2 (4.5%) | 0.2 (4.5%) | 0.2 (3.7%) | 0.2 (2.1%) | 0.2 (1.8%) | 0.1 (0.2%) |
| Any common mental disorder | 3.2 (4.5%) | 2.3 (4.5%) | 1.9 (3.7%) | 1.1 (3.5%) | 1.1 (2.1%) | 1.8 (1.5%) | 1.2 (2.3%) |
| Women at age 25 | | | | | | | |
| Generalised anxiety disorder | 3.4 (2.1%) | 7.1 (1.2%) | 3.7 (1.4%) | 4.0 (1.4%) | 4.3 (2.0%) | 4.3 (2.5%) | 3.1 (5.3%) |
| Major depression | 1.2 (0.9%) | 0.7 (0.9%) | 0.8 (0.2%) | 1.2 (0.5%) | 1.4 (0.6%) | 1.4 (1.1%) | 1.5 (1.5%) |
| Dysthymia | 0.5 (7.6%) | 7.9 (13.5%) | 0.1 (4.2%) | 0.5 (4.7%) | 0.6 (8.0%) | 0.6 (5.1%) | 0.9 (4.2%) |
| Any common mental disorder | 4.3 (7.6%) | 7.9 (13.5%) | 4.2 (7.4%) | 4.7 (7.4%) | 5.1 (8.0%) | 5.1 (9.0%) | 4.2 (7.2%) |

One-month diagnoses based on assessment using the CIDI 3.0

generalised anxiety. Although studies using self-rating screens have tended to focus on depressive symptomatology (even general mental health scales like the General Health Questionnaire (GHQ-12) and MHI-5 are more heavily weighted towards mood and affect), mental health expectancies are actually longer for anxiety than they are for mood related disorders.

At younger ages, the longer life expectancies for women (compared to men) almost entirely consisted of years lived with a common mental disorder. In contrast, at older ages this gender difference in TLE was accounted for in equal parts by women's longer years lived with and without a common mental disorder. Mental health expectancies are therefore argued to be important particularly for describing the health and healthy life expectancies of younger segments of the population, among those who are less likely to be experiencing physical limitations or cognitive impairments. The authors point out that a larger proportion of activity limitations can be attributed to mental illness for younger adults than older adults and this warrants greater recognition in health policy (Brugha et al. 2013).

Limitations and Future Research

In 2003 Ritchie and Polge (Ritchie and Polge 2003) identified three avenues for future research on mental health expectancies. These included the use of standardized instruments to aid comparisons, investigation of how cognitive impairment and mental illness contribute to disability free life expectancies, and use of multi-state methods to address recovery and episodic nature of mental illness. It is pleasing to note that in the intervening years, all three areas have been addressed for cognitive impairment, but the latter two aims have not been explored for mental illness. Despite an increase in the number of studies reporting health expectancies for cognitive function and mental health, significant gaps remain in the evidence base. Data are limited by the omission of countries and still relatively few longitudinal comparisons to enable change in health

expectancies over time. The variation in measurement instruments between studies limits cross-national and inter-study comparisons.

For the key domains of health expectancies, such as disability, dementia, and chronic disease, there are typically low rates of recovery and so it is intuitive to conceptualise these types of health expectancies as periods towards the end of life that generally follow continuous uninterrupted years of relatively good health. In contrast, a different approach is required for accurate interpretation of mental health life expectancies due to the episodic nature of most mental illness. Years lived with good mental health may be interspersed with numerous shorter periods of mental ill-health that together are accumulated to give a total number of years lived with common mental disorders. This dynamic nature of mental health is not sufficiently captured by cross-sectional data. Future research should use multistate methods with longitudinal data to reflect better the episodic nature of mental illness. It would be valuable to compare differences between groups who experience cumulative years comprising a series of shorter episodes, from those who experience a long continual spell of chronic mental illness.

Consideration of the full life course, and not just older age, is an area for future research, particularly in relation to mental health expectancies. There are some critical periods in the life course where mental illness is likely to occur first, usually during later adolescence and early adulthood. By mid-life most of the cumulative lifetime prevalence of mental illness has already occurred. However, older adulthood is also a period where new incidence of mental illness can often present, as in the case of late life depression. It is often unclear to what extent the measurement of mental illness reflects lifelong chronic mental health problems or more recent onset relating to changes to health, work, and family that are associated with older age. Finally, a key lack in the literature is an estimate of the impact of co-morbid cognitive impairment or dementia, with depression, on healthy life expectancy.

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Combining Working Life and Health Expectancies

18

Elke Loichinger and Daniela Weber

Introduction

People around the world are living longer while fertility has been declining in the great majority of countries. These developments result in changes in population age-structures, with initially increases in the proportion of people of working age, accompanied by a decline in the proportion of younger persons. Over time, the proportion of older adults in the population begins to increase noticeably, as large numbers of the working-age population reaches older ages. In general, continuously increasing life expectancy and increasing numbers of older persons is a major and positive achievement. However, in order to support larger numbers of older people (both in relative as well as absolute terms), certain adjustments to social support systems are necessary. Depending on the specification of social security systems, the effects of changes in

the age-composition on public finances are felt more or less immediately and severely. Even in contexts where family support is still the main source of income in old age, as it is the case in many Asian countries, governments are striving to build up and/or adjust pension systems for their aging populations.

Increasing the length of working lives is a commonly sought remedy to deal, at least in part, with the financial consequences of longer lives. In countries with well-established pension systems, this is mostly done by extending official retirement ages and restricting other paths into retirement – like disability retirement Schemes. A crucial question is whether people are physically and mentally capable of work until continuously higher ages, i.e. whether the planned or already implemented increases in official retirement ages will be faced by persons of good health. Hence, it is crucial not only to look at the development of working lives and focus on lengthening them but, at the same time, to take a close look at developments of the health status of people around retirement ages. In order to do so, detailed information on the health status – particularly dimensions of health that are necessary for continued economic activity – of people before, at and beyond current retirement ages has to be collected and analysed.

An existing indicator that can be used to monitor developments of working life for people at any age is working life expectancy (WLE). It is a

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summary measure that is calculated analogously to healthy life expectancy (HLE), the difference being that, instead of providing information about the number of years that someone can expect to live in good health, it describes the number of years someone can expect to be working. Recently, this indicator has been used in the context of population aging and the argument about the need to increase the length of working lives, but it has been a common measure for a long time in the actuarial sciences where work-loss compensations are calculated based on expected and lost life time earnings (Alter and Becker 1985).

After defining the concept of WLE in the next section, in the third section we will give selected examples of working life expectancy measures across the world and trends in Europe's working life expectancy. A substantial amount of research has been done on health developments, elsewhere and in Europe, and in the penultimate section we cast light on the relationship between WLE and HLE. The final section summarizes and gives an outlook of potential future research avenues in the context of WLE and health.

The Concept of Working Life Expectancy

Some of the earliest calculations of working life expectancy go back to Durand (1948) and Wolfbein (1949) for the US. They recognized the potential this indicator offered to summarize the working experiences of real or synthetic cohorts. Since then, others have calculated WLEs for a range of countries and various time periods (for details, see the next section). Several names have been used to refer to the same concept, i.e. to summarize the number of years individuals at a certain age are expected to remain working. "Working" is interpreted and defined differently by different authors (Leinonen et al. 2015), depending on whether work is understood as strictly referring to people in employment or in the labour force (which includes both, those employed and unemployed). Also, several names

that in principle refer to the same concept are in use (Loichinger and Weber 2016).

The two most often used methods to calculate the average length of working lives are based on prevalence rates of economic activity or transition rates between states of economic activity, respectively. Prevalence rates are either employment or labour force participation rates, depending on the specific definition of WLE, and combining them with life-tables results in worklife tables (Nurminen and Nurminen 2005). This approach is analogous to the one described in Sullivan (1971) and has been widely used to calculate healthy life years (HLY) (Salomon et al. 2012); see Hytti and Nio (2004) for a detailed description of how to calculate worklife tables. This approach has some shortcomings, mostly due to the fact that, data based on period-observations that refer to many birth cohorts is applied to make life-course statements (Nurminen and Nurminen 2005). It is however possible to use cohort prevalence to calculate WLE, given the necessary time-series data are available. Leinonen et al. (2015) compare period and cohort calculations and demonstrate for Finland that results based on period prevalence are overly optimistic estimates of worklife expectancies of 50-year old Finns. As well as approaches based on Sullivan (1971), another prominent method is based on multi-state transition probabilities that enter a multistate worklife table (Hoem 1971; Nurminen and Nurminen 2005; Willekens 1980). This is more intensive in terms of data requirements and methods, but can deliver more refined calculations of WLE, allowing for much more complex analyses with more covariates especially when combined with hazard or econometric models (Hayward and Grady 1990; Millimet et al. 2010).

Irrespective of the methods used, estimates of WLE can be stratified by age, sex and further characteristics, for example education level or occupation. More detailed analyses are usually single-country studies (Cambois et al. 2011; Hayward and Grady 1990; Leinonen et al. 2015; e.g. Smith 1986) whereas comparative studies often have fewer dimensions of analysis (Loichinger and Weber 2016).

Measures of Working Life Expectancy Across the World and Trends in Europe

Calculations of WLE are by no means restricted to highly developed economies but have been applied to populations in various contexts all along. Depending on the country-specific circumstances, the objectives for calculating the length of working lives or the exact definition of it vary, as do the characteristics of work e.g. with regard to distributions of formal and informal employment. Looking at countries outside of Europe and North America first, we cite a few selected studies to show the range of applications. Projections of WLE for India were performed with the goal to estimate whether projected increases in life-expectancy will be accompanied by increases in WLE (Dhillon and Ladusingh 2013). In the case of Sri Lanka, the goal was to evaluate past developments in unemployment-free working life (Krishnan 1986). Palamuleni (2007) tellingly demonstrates the destructive effect of HIV/AIDS on WLE of South African men and women between 1996 and 2001. Tareque et al. (2015) calculate what they call “work-loss free life expectancy”, for 2004 and 2007, for ever married male workers aged 30 to 54 in Bangladesh. This definition differs slightly from the normal way WLE is conceptualized, but is, nonetheless, insightful into the distribution of work-loss days by age, cause and over time, and is a good example of how, depending on a country’s development stage, specific definitions of WLE might be more useful. In the case of Bangladesh, current interest is less on extending working life towards higher ages but more about health-related losses of working days among middle-aged workers.

Several studies have looked at developments of WLE, overall or for specific subgroups, in the US. Smith (1986) shows results of worklife expectancies by race and education for the US. More detailed analyses of the retirement process in the US showed that older men and their labour market exit behaviour is anything but homogeneous and that WLE at age 55 differs greatly across men with different characteristics,

for example between men with different occupations and highest levels of educational attainment (Hayward and Grady 1990). Eggleston and Fuchs (2012) compile life table and labour force information in the US for over 100 years and calculate what they call “Expected Labor Force Participation (XLFP)”. While XLFP increased from 30.0 years in 1900 to 41.3 years in 1950 and remained around that level until 2007 for men, it showed a stark continuous increase from 6.4 years in 1900 to 34.4 years in 2000 for women. Krueger and Slesnick (2014) show for that when working life expectancy is not based on market work alone but also includes non-market work (taking care of family, housework), the observed difference between men and women for WLE based on labour force participation disappears.

Finland is the European country which has most results of WLE over time, and stratified by various factors (Hytti et al. 2004; Leinonen et al. 2015; Nurminen 2012; Nurminen et al. 2005; Nurminen and Nurminen 2005). Results from these analyses clearly show the range of outcomes of WLE when stratifying WLE by individual characteristics and the variation over time in age- and gender-specific WLE. Leinonen et al. (2015), for example, calculate the life expectancy spent working for selected occupational social classes between 1989 and 2012. Results for upper non-manual and manual male and female workers at age 50 reveal a generally increasing trend in the years spent working in all four sub-groups. However, differences between occupational social classes persist: in 2012, upper non-manual male workers had a working life expectancy of 11.6 years, compared to 8.0 years for manual workers. The respective numbers for women are 11.7 and 8.1 years.

From analyses comparing several European countries, it becomes clear that observed developments of WLE are the results of differing development over time and by gender across countries. In general, life expectancy in Europe increased since the early 1980s with men showing a stronger increase than women who have on average longer life expectancies. Nevertheless, disparities between countries remain for both

men and women. At the same time, developments of labour force participation rates (LFP) of 50 to 74 year-olds show a diverse pattern. Men's and women's LFP increased after 2000 with women starting from a lower level, and with some convergence between the genders. The time before 2000 is restricted to a few countries only, where men's LFP declined until the mid-1990s and women's increased (Loichinger and Weber 2016).

Consequently, for men at age 50 the number of years remaining economically active decreased slightly until 1990 followed by a subsequent increase whereas it increased continuously during three decades for women. This resulted in a reduction in the gender difference, which even became slightly negative in Estonia, Finland, and Latvia (Loichinger and Weber 2016). However, large differences across countries remained as highlighted in Fig. 18.1 and Fig. 18.2. In 2013, WLE at age 50 spanned a range for men from 8.6 years in Hungary to 16.5 years in Iceland (Fig. 18.1), and for women from 5.6 years in Luxembourg to 13.6 years in Iceland (Fig. 18.2).

To better judge what these developments mean in the context of aging populations, it is also important to examine the WLE/LE ratio, the share of economic active years among the remaining life years. In almost all investigated European

countries men aged 50 years spend about one third of their remaining life economically active in 2000, whereas this is more of an exception when it comes to women where the share spent economically active is generally lower (Table 18.1). The magnitude of the difference in the WLE/LE ratio across gender declined over the years, but levels still vary substantially across countries as well as by gender. Some countries showed an increase in the share for both sexes, others a decrease for men, in particular, and a few countries showed a stable profile for both sexes (Loichinger and Weber 2016). Differences in the WLE/LE ratio between men and women are still noticeable in 2017 (Table 18.1).

Differences in working life expectancies might, in part, be attributed to diverse educational distributions across countries. In general, LE varies by education, for Central and Eastern European men in particular, but also labour force participation rates at higher ages vary by educational attainment especially for women (Loichinger 2015). Comparing WLE at age 50 by highest educational attainment within countries, tertiary educated men and women showed most remaining years in economic activity, followed by upper secondary and post-secondary, and by lower secondary subsequently (Fig. 18.3).

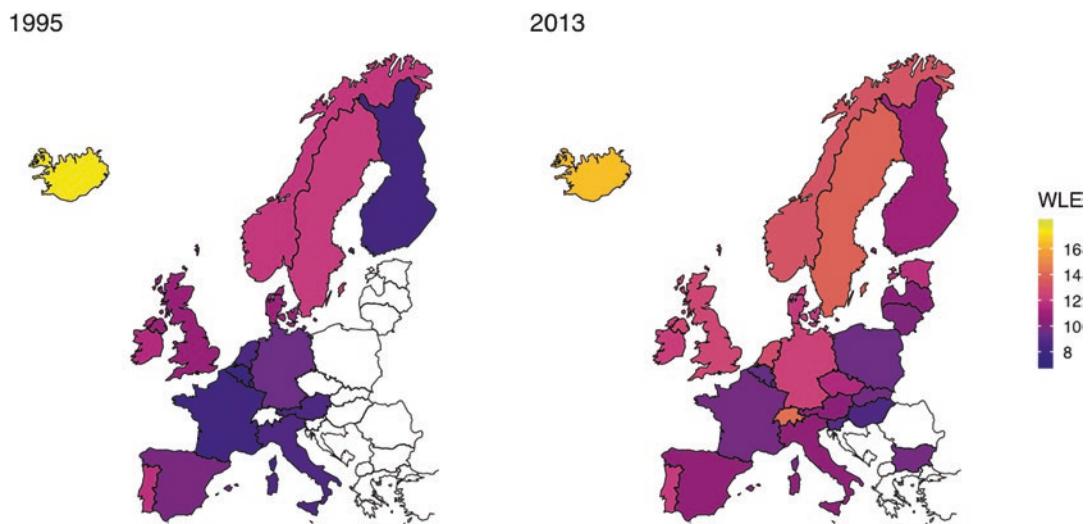


Fig. 18.1 Men's working life expectancy (WLE) in years at age 50 in 1995 (left) and 2013 (right) across Europe. (Based on Loichinger and Weber 2016)

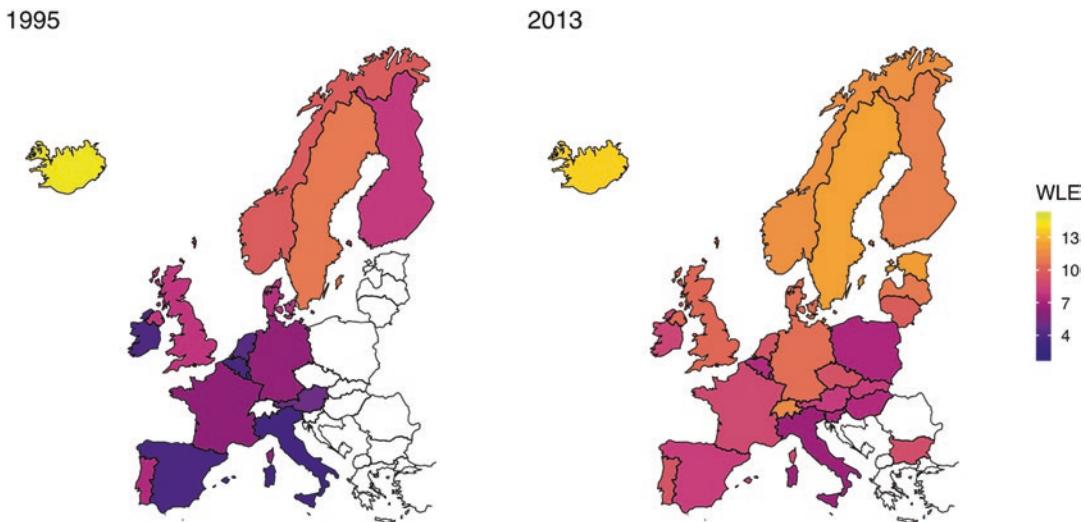


Fig. 18.2 Women's working life expectancy (WLE) in years at age 50 in 1995 (left) and 2013 (right) across Europe. (Based on Loichinger and Weber 2016)

However, the level as well as the magnitude of the gap in remaining active years by education varied across countries and gender with larger differences among women than men. Nordic countries such as Denmark and Finland exhibit the smallest educational differences for men as well as women in WLE whereas higher educated Estonian men remain about eight more years active in comparison to their less educated counterparts (Loichinger and Weber 2016). Gender differences within a country did not diminish when comparing education specific subgroups. Moreover, gender differences are much smaller for tertiary educated than for lower secondary educated in some countries such as Sweden, whereas the opposite is true for other countries. Investigating education specific remaining years in economic activity as share of education specific remaining life years showed that disparities across education persisted.

There is also some limitation when interpreting the results for WLE in the context of retirement decisions and leaving the labour force. The indicator working life delivers insights into remaining economic activity, but in fact people could be receiving retirement benefits and still count as economically active. This is very much dependent on the retirement system of an indi-

vidual country, some do not allow working while receiving pensions or this is made unattractive. Further, results are normally not adjusted for differences in working hours among those who are working, which disguises large differences in working age and gender.

Researchers face limitations while investigating trends in WLE. For instance, the availability of long time series of labour force participation data is limited. Women's contribution to the labour market increased particularly from the mid-1990s, so gender specific labour force participation rates from the early 1990s would capture this trend. However, in the case of European research, Eurostat provides gender specific labour force participation rates from 1983 for selected countries whilst the OECD provides them by 5-year age groups since 2000. The availability of participation rates by highest level of educational attainment is even more limited. Education specific data are available from Eurostat since 1998 for selected countries only, although education specific data, in particular, could highlight the disparities at early adulthood and higher ages with higher educated working longer, but entering at a higher age. When it comes to education specific data there is also a lack of education specific life tables (starting

Table 18.1 Ratio of WLE and LE for 31 European countries at age 50 in 2000 and 2017 by sex. (Own calculations, based on data for economic activity and mortality from EUROSTAT)

| Country | 2000 | | 2017 | |
|----------------|-------|------|-------|------|
| | Women | Men | Women | Men |
| Austria | 0.16 | 0.31 | 0.25 | 0.36 |
| Belgium | 0.12 | 0.27 | 0.23 | 0.32 |
| Bulgaria | 0.18 | 0.33 | 0.33 | 0.44 |
| Croatia | n.a. | n.a. | 0.22 | 0.34 |
| Cyprus | 0.20 | 0.45 | 0.25 | 0.4 |
| Czech Republic | 0.22 | 0.39 | 0.32 | 0.44 |
| Denmark | 0.28 | 0.39 | 0.33 | 0.43 |
| Estonia | 0.30 | 0.42 | 0.40 | 0.48 |
| Finland | 0.26 | 0.33 | 0.33 | 0.39 |
| France | 0.18 | 0.27 | 0.26 | 0.32 |
| Germany | 0.22 | 0.35 | 0.33 | 0.43 |
| Greece | 0.15 | 0.37 | 0.20 | 0.35 |
| Hungary | 0.16 | 0.29 | 0.29 | 0.43 |
| Iceland | 0.42 | 0.59 | 0.41 | 0.53 |
| Ireland | 0.17 | 0.43 | 0.27 | 0.40 |
| Italy | 0.11 | 0.30 | 0.22 | 0.36 |
| Latvia | n.a. | n.a. | 0.38 | 0.46 |
| Lithuania | 0.27 | 0.41 | 0.37 | 0.47 |
| Luxembourg | 0.12 | 0.28 | 0.2 | 0.28 |
| Malta | 0.06 | 0.33 | 0.17 | 0.37 |
| Netherlands | 0.17 | 0.34 | 0.30 | 0.42 |
| Norway | 0.31 | 0.42 | 0.34 | 0.42 |
| Poland | 0.20 | 0.34 | 0.25 | 0.39 |
| Portugal | 0.27 | 0.46 | 0.28 | 0.42 |
| Romania | 0.38 | 0.51 | 0.26 | 0.42 |
| Slovakia | 0.16 | 0.34 | 0.30 | 0.39 |
| Slovenia | 0.15 | 0.31 | 0.24 | 0.33 |
| Spain | 0.13 | 0.36 | 0.24 | 0.35 |
| Sweden | 0.33 | 0.42 | 0.38 | 0.45 |
| Switzerland | 0.28 | 0.46 | 0.33 | 0.44 |
| United Kingdom | 0.25 | 0.39 | 0.31 | 0.41 |

from 2007) in addition to lacking labour force participation rates. Moreover, one could also investigate WLE separately by occupational profiles, but then again appropriate life tables would be required.

Working Life and Health Expectancies

Much research has been devoted to the analysis of the developments of healthy life years (HLY) (see Chap. 13). In Europe when based on the

GALI question in the EU-SILC survey, HLE represents the number of years a person at a specified age can expect to live without activity limitations when carrying out normal daily activities. Even though these calculations do not explicitly include information about labour market activity, they can still be a starting point for comparing the number of expected healthy years at age 50 to average or official retirement ages. Comparisons across 25 EU countries between the year 2005 and 2010 showed that inequalities in healthy life years at age 50 are large and increasing, and that in 2010 in eight of the 25 countries men could expect to experience activity limitations before age 65; for women, the respective number was six out of 25 countries (Fouweather et al. 2015). Hence, monitoring future developments of HLE are crucial in the context of increasing retirement ages. Fouweather et al. (2015) also point out that events like the current financial crisis, which meant increased material deprivation for people in several European countries, could lead to even larger inequalities in health expectancies in the future since material deprivation was identified as being negatively correlated with healthy life years.

However, average results for whole countries, even if obtained separately for men and women, can only serve as a basic indication when the goal is to gauge the advantage and feasibility for increasing the length of working lives. Country averages disguise much heterogeneity across socio-economic status, whether measured by income, education, or occupation. Cambois et al. (2011) found large inequalities in health expectancies after age 50 by occupational class in France, for men as well as women, when considering five dimensions of health that served as indicators of potential or actual restriction in social participation. Their findings of significant occupational gradients when it comes to life expectancies and healthy life expectancies are important because they reveal existing inequalities and question the uniform ability to lengthen working lives that is implicit in blanket increases in legal retirement ages. Similarly, large differences in disability-free life expectancy (DFLE) by sex and educational attainment found for 10

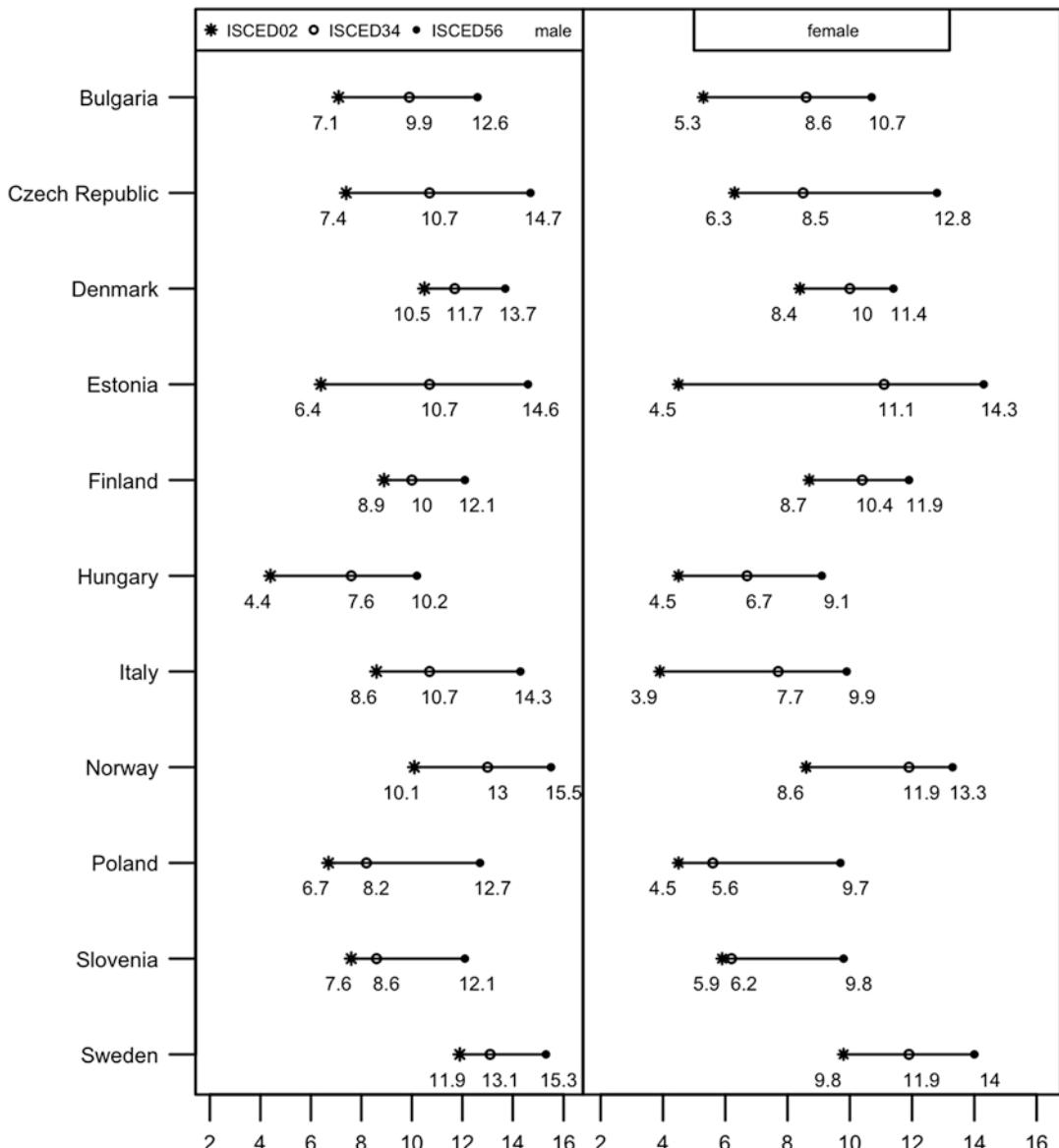


Fig. 18.3 Working life expectancy at age 50 for men (left) and women (right), by highest level of educational attainment, 2009. (Based on Loichinger and Weber 2016). Note: ISCED International Standard Classification of Education

Western European countries suggest that those with higher educational attainment enjoy a double advantage: they can expect to spend more years in good health as well as live longer overall, compared to persons with lower educational attainment (Majer et al. 2011). Again, this points towards severe issues with extending working lives universally across persons with different socio-economic status.

Wubulihasimu et al. (2015) investigate the effect that declines in disability incidence have on DFLE and WLE. Since they find that the effect of changes in disability incidence is much larger on life-expectancy and DFLE than on WLE, they conclude that it must be other factors besides health that are important in explaining differences in labour force participation between disabled and not disabled individuals. Consequently,

they argue that policies to decrease disability incidence will show effects on DFLE, but to a much lesser degree translate into increases in WLE. Focusing on the Dutch context, van der Noordt et al. (2019) analyse developments of WLE with disability in the Netherlands between 1992 and 2016 for respondents aged 55–65, using GALI as their main measure of disability. They find an overall increase in WLE with disability from 0.8 to 1.5 years but no statistically significant difference between neither male and female nor low- and highly-educated workers.

Lièvre et al. (2007) propose and calculate a new indicator that they call “Healthy Working Life Expectancies” (HWLE) for 12 European countries. Using longitudinal data and applying the multi-state life table approach, they combine survey information on health and employment status to estimate the number of years that an individual between ages 50 and 70 can expect to be at work in good health. Their results indicate that there is little correlation between HWLE and health status in the 12 countries in the analysis, supporting earlier research that found low explanatory power of health status for differences in employment levels across countries. This is a good example where results on the micro level, showing that health status plays an important role for retirement decisions, are not found on the macro level (Lièvre et al. 2007). Wind et al. (2018) also combine information on employment status and health in their study on changes in WLE in good and poor self-perceived health of Dutch workers with a chronic disease. Their results for different cohorts of workers provide important insights into the developments between economic activity and health status of workers with a chronic disease: an initial increase in WLE of this group was due to an increase in years in poor self-perceived health, while the increase later – i.e. among younger cohorts – was due to an increase in years in good self-perceived health.

Though not commonly performed, the concept of WLE can also be used to calculate differences in working lives for persons with specific diseases. Lacaille and Hogg (2001) analyse the effect of arthritis on work loss in the Canadian context. For their study population of men and

women between ages 15 and 64, they find that having arthritis or rheumatism is associated with a 4 year lower WLE for women and 3 years for men compared to the total population. Applications like this have to deal with the difficulties in obtaining life tables specifically for their study population and with issues related to self-reported health conditions, as well as the general problem that cross-sectional calculations across the whole adult age-range summarize the experiences of many birth cohorts. Nevertheless, particularly in rapidly aging societies, they can help to estimate the effect of diseases on lifetime losses of working time. Another application where the concept of WLE and information about health are linked is in the human capital approach taken to estimate the societal cost of cancer-related death before age 65 (Hanly et al. 2015). Here, data on cancer deaths, labour force participation and wages are combined to calculate lost productivity due to cancer-related mortality.

As stated earlier, HLE measures the remaining years in good health. When it comes to comparisons of remaining years in the labour market and remaining years with good health, HLE is only of limited use. Impairments in daily activity for a longer period such as half a year as addressed with the GALI question become relevant particularly for older adults, that is people aged at least 65 or 70 years, which is in fact after retirement for most high and upper-middle income countries. Hence, health indicators other than HLE are needed to investigate whether older adults are still fit enough to be part of the labour force. Cambois et al. (2011) performed analyses that involved five specific health indicators for France, and we will present some results for selected European countries, for three health indicators that cover abilities that are related to work performance and employability. Adequate muscle power is required for optimum productivity (Shephard 2000), whereas lower levels of muscle strength (e.g. measured by hand grip strength) are a predictor of physical limitations (Germain et al. 2016). Hand-grip strength peaks on average at ages 30–40 years and decreases at higher ages (Dodds et al. 2014; Steiber 2016). Next to muscle power, affective disorders (e.g. depression)

appear to play a major role in reducing productivity due to shorter working life, absenteeism and on-the-job performance, for example bad mental health has been shown to be the leading cause of sickness absence and incapacity in most high-income countries (Harvey et al. 2009). Furthermore, cognitive abilities are obviously beneficial labour skills, and studies have found that cognitive ability levels predict individual productivity better than any other observable individual characteristics and that they are increasingly relevant for labour market performance (Schmidt and Hunter 2004; Spitz-Oener 2006). A normal age-related cognitive decline is usually characterized by having difficulty recalling facts (Ritchie and Tuokko 2010), but may additionally affect processing speed (Salthouse 2010). Affective disorder (e.g. depression), the normal aging processes in muscle strength, and cognitive aging may negatively affect labour productivity particularly among the oldest workers.

To examine the relationship between WLE and remaining years with good cognitive, physical and mental health there is the need to first define the lower bounds for those health measures although different occupations might require different strengths in cognitive, physical, and affective functioning. Nevertheless, previous studies investigating this topic suggested thresholds for good episodic memory (Skirbekk et al. 2012), good hand grip strength (Bohannon et al. 2006; Massy-Westropp et al. 2011), and no/low risk of clinical depression (Dewey and Prince 2005).

On an aggregate level, we can compare WLE with years in good cognitive, mental, and physical health for selected European countries using the panel data surveys EU-SILC and SHARE. Relying on these two data sources restricts our analysis to 10 countries and 4 points in time (2003, 2007, 2011, 2013). In Europe, particularly, participation in the labour market after legal retirement ages is quite rare; therefore we investigate partial life expectancies between the ages 50 and 60 separately for men and women rather than complete life expectancies (Hickman and Estell 1969).

Women's life expectancy increased in Europe and so did WLE in recent decades, and the question is how these developments compare to developments in women's health at advanced ages? While the number of remaining active years for women aged between 50 and 60 years increased in the early 2000s, the number of remaining years in good physical health was maintained at a constant high level for most of the ten selected European countries and was at almost 10 out of 10 years for the Nordic countries (e.g. Denmark and Sweden) as well as Switzerland (Fig. 18.4). When it comes to life expectancy with good cognition, we can identify two different patterns. In Austria, Belgium, and France and the Southern European countries, women could expect an increasing number of remaining years with good cognitive functioning, whereas in other countries, such as the Nordic countries, the life expectancy with good cognitive function is already at a high level (Fig. 18.4). This trend difference between countries might be explained by the differences in women's educational attainment and the level of involvement of women within the labour market in some countries. For women's life years without risk of depression, the trajectories showed a diverse picture. While there was an overall decrease for remaining years without risk of depression in Belgium and Germany, we noticed an overall increase in Spain and Switzerland, and a relatively constant pattern across cohorts in Denmark (Fig. 18.4). Moreover, years in good mental health between age 50 and 60 was even lower than WLE in a few countries (e.g. France, Germany, and Sweden). In summary, the relationship between partial WLE and partial years with good cognitive function was strongest for women (correlation coefficient, based on 10 countries and 4 time points: 0.72), followed by WLE and years with good physical health (correlation coefficient: 0.46), and WLE and years with good mental health (correlation coefficient: 0.31) subsequently.

The relationship between WLE and years with good cognitive function was the only one significant for men (correlation coefficient: 0.50). The time trends shown in Fig. 18.5 provide more

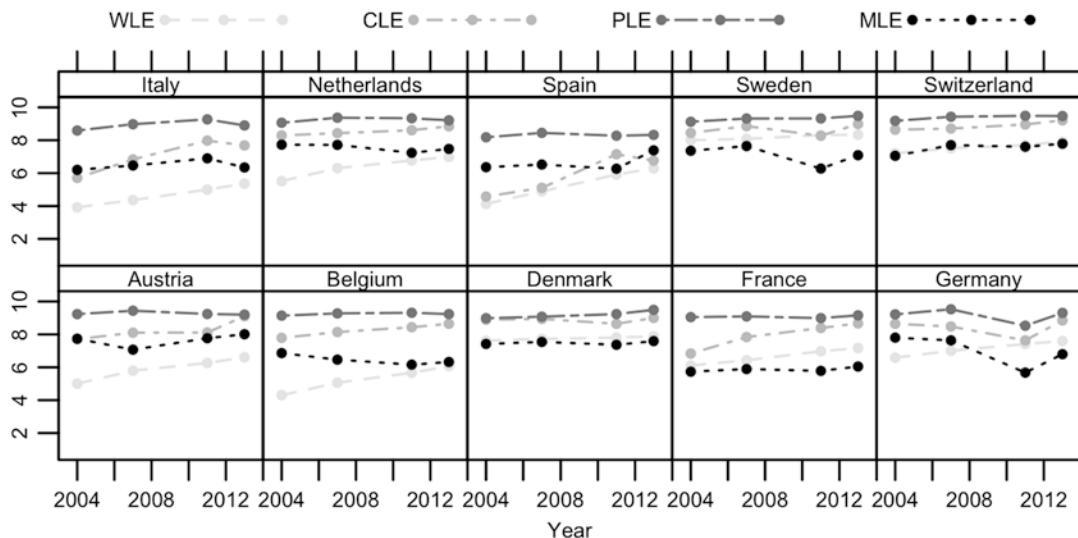


Fig. 18.4 Partial working (WLE), cognitive (CLE), physical (PLE), and mental (MLE) life expectancy between ages 50 and 60 for women in 10 selected

European countries. (Own calculations, based on data for economic activity from EUROSTAT, health information from EU-SILC and SHARE and mortality data from the Human Mortality Database, <https://www.mortality.org/>)

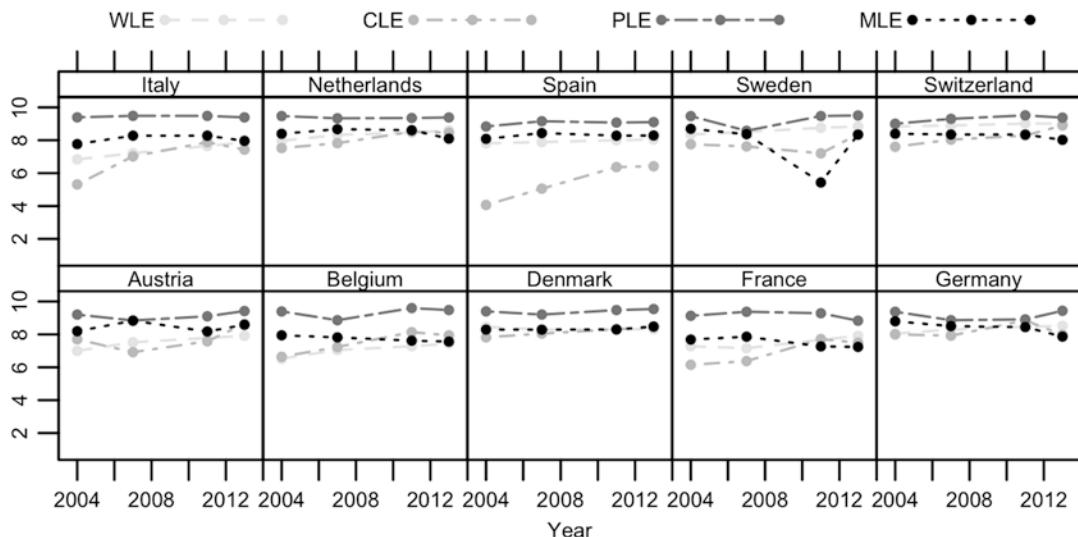


Fig. 18.5 Partial working (WLE), cognitive (CLE), physical (PLE), and mental (MLE) life expectancy between ages 50 and 60 for men in 10 selected European

countries. (Own calculations, based on data for economic activity from EUROSTAT, health information from EU-SILC and SHARE and mortality data from the Human Mortality Database, <https://www.mortality.org/>)

detail. For men all four measures showed very high levels in Denmark, Germany, the Netherlands, and Sweden. The remaining years with good cognitive health increase for men in all countries during the 10-year observation period similar to women, whereas the starting levels

varied significantly (Fig. 18.5). Moreover, in Spain men had many fewer remaining years in good cognitive health than the number in the labour force, in spite of significant increases in cognitive life expectancy between ages 50 and 60. Overall, a 50-year-old man in Europe can

expect to be in good physical health for at least 9 years before turning 60 in most of the analysed countries, while his mental health is expected to remain in a good state for about 8 years. Further, WLE is at a high level, as described previously, but not in all selected countries can a 50-year-old man expect to remain with good cognitive health during his time with good physical and mental health or during his labour market participation.

Summary and Outlook

WLE is a useful indicator for analysing economic activity across periods and cohorts, be it for the whole working career or for persons at specific ages. Depending on the purpose of the analysis, the exact definition and interpretation of WLE can differ, but the basic concepts underlying this measure do not change. The calculation and analysis of WLE has relevance in itself, but, as this chapter showed, it is the combination of WLE with analyses of health indicators that are gaining prominence, particularly in the context of ageing societies. Simultaneous consideration of both dimensions – economic activity and health – is useful for a range of reasons. It allows the detection of inequalities in the development of both indicators, for example for different subgroups of the population; it indicates where the limits of increasing WLE might lie, given current levels of population health; and, particularly, the analysis of trends in both indicators can point to possible issues in extending WLE further, or to do so universally for persons with very different socio-economic status.

This chapter focused on analyses of economic activity and health in the context of retirement and the extension of working life, hence the concentration on age groups at or around present retirement ages. Ideally, these calculations would be complemented with calculations starting at age 15, since it is well known that labour market activity and health outcomes above age 50 are to a large degree influenced by events earlier in the life-course (Boekelheide et al. 2012; Gertler et al. 2014; Taylor 2010; Weber et al. 2014). In addi-

tion, when analysing WLE for persons with different socio-economic status, it is crucial to consider that not only do they show different retirement behaviour but also they entered the labour market at varying ages, which can only be captured with calculations that cover the whole working career. The disadvantages that certain occupational groups like e.g. manual workers face when it comes to remaining life and health expectancies are the result of their whole working lives (Cambois et al. 2011).

WLE calculations stratified by more than gender can help in detecting incongruities in countries – i.e. that those with lower SES and with low WLE are having low LE as well, potentially spending larger shares of their lifetimes economically active. Of course, detecting incongruities is one thing, trying to fix them is another. Nevertheless, with ever-increasing life expectancies, having as much information as possible about how economic activity is distributed across the life-course, how it changes over time, and how it varies for persons with differing characteristics will be very useful when designing policies to react to these developments. Although it may be impossible to include such detail in pension policies, because of the complexity, there may be other policies that can indirectly support or even compensate those whose WLE as share of LE are disproportionately large. Along the same lines, it requires interventions around retirement ages as well as during an individual's whole life-course to support healthy aging and to ensure that longer lives are accompanied by more years in good health.

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Subjective Well-being: Long and Happy Lives

19

Aïda Solé-Auró

Introduction

Living a long, healthy and a happy life is a desire for most people. These three features of life interact with each other to different degrees over the life cycle. They can all be influenced by factors such as standard of living, lifestyle, occupation, place of residence, social environment, marital or civil status, and family status. To evolve in the understanding of the well-being of people is crucial to examine how these factors are linked to the well-being among different groups in different societies.

The rise of survival over the past century has been marked and population aging is one of the greatest social challenges facing the European Union and other high-income countries in the twenty-first century. Although longevity is important, focus should include not only long, but also healthy and happy lives. What can we learn from those that experience exceptional longevity (centenarians (aged ≥ 100 years) or supercentenarians (aged ≥ 110 years))? They might have the recipe for joining these three conditions: longevity, good health and happiness. Although centenarians and supercentenarians are relatively

rare, the increase in their numbers in recent decades has permitted investigation of their characteristics in multiple scientific areas including demography, genetics, epidemiology, and medicine. However, examination of very long-lived persons makes it clear that they do not necessarily share similar health conditions or similar environments, or evaluate their life in a common way. The life journey of these very old people does not show common characteristics aside from the fact that the majority are women, most enjoy relatively good health until advanced age, most smoked very little, and most were not obese (Maier et al. 2010). Overall, knowing longevity differences across developed countries is important in evaluating part of the quality of life puzzle, it is crucial to study the association between long longevity and the well-being of people in terms of experiencing good health and happiness.

Quality of life and standard of living incorporate multiple conditions of the “good life”: happiness, health and prosperity. Social researchers have worked to develop a comprehensive indicator of quality of life to measure the degree to which citizens live long and happy, an indicator that combines an objective measure (the length of life) with data on subjective appreciation of life (Veenhoven 2005; Veenhoven 1996; Veenhoven 1993). Unlike objective measures (such as socio-economic level, life expectancy or recorded state of health), subjective measures provide a per-

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sonal viewpoint and help us better understand people's general state of well-being, reflecting the extent to which their vital needs are being satisfied. Moreover, a growing number of publications on happiness and life satisfaction have documented characteristics of those who are happy and satisfied (Solé-Auró and Lozano 2019; Hamplová 2019; Solé-Auró et al. 2018; Easterlin 2010; Koopmans et al. 2010; Diener 2000; Kahneman 2000).

This chapter provides information on the determinants of happiness and the length of happy life across places, particularly among high-income countries, and across time. Our aim is to elucidate how individual, social and contextual characteristics might be linked to the well-being of people, their happiness, and the length of happy life.

Subjective Well-being

Measuring Subjective Well-being

Well-being is a multidimensional concept indicating quality of life. Concerns about quality of life, particularly in old age, have been investigated over recent decades by the social and behavioural sciences (Solé-Auró and Lozano 2019; George 2006). Healthy life expectancy has sometimes been defined using subjective measures of health, for instance self-reported health (see Chap. 12), one important dimension of well-being. While quantitative social scientists consider subjective indicators a good way to evaluate the well-being of society, subjective measures such as happiness, there are concerns around comparability, reliability and validity of measurement across populations. However, such concerns should disappear as most people's lives are centred on making a living, maintaining health and family life. Therefore, comparing happiness among comparable group of people (i.e. same social class) is possible due to the fact that the similarity of feelings gives credence to such comparison (Frey and Stutzer 2002; Easterlin 2001).

The field of subjective well-being uses affective evaluations of a person's life to differentiate

those that have a high level of subjective well-being from those with low levels (Diener et al. 2002). This can be measured by several components including satisfaction with life, happiness, or a positive or negative affect. These are not mutually exclusive dimensions and are commonly measured by self-reports. At present, there is some discussion of how happiness should be measured (George 2010) and the literature suggests some caution when using the concept of "happiness". For international comparisons, life satisfaction may be a better measure of subjective well-being than general happiness (Helliwell and Putnam 2004), even though, when both measures are available, analyses tend to show similar results (Myrskylä and Margolis 2014; Veenhoven 2005). Happiness not only indicates a good life, but also can be an important indicator of a person's evaluation of life as a whole. Since the 1970s, happiness has been a core variable in many quality-of-life surveys and is the basis of much of the work on quality of life.

Population differences in subjective well-being among different strata (i.e. age groups, socioeconomic status, gender or health status) and across countries have been investigated (Solé-Auró and Lozano 2019; Arrosa and Gandelman 2016; Pinquart and Sörensen 2001). Several European surveys provide estimates of the level of happiness. For instance, the 2016 wave of the European Social Survey (ESS), a cross-national survey representative of the European population and measures attitudes, beliefs and behaviours patterns in Europe, provides information on happiness. The questionnaire of the 2016 ESS asked respondents to evaluate their level of happiness by the following question: "Taking all things together, how happy would you say you are?" Responses were coded from 0 to 10, where 0 was extremely unhappy and 10 extremely happy. As no standard criteria on happiness is available on an international basis, we dichotomized the responses as follows: those who rated their happiness between eight and ten were coded as happy, and the rest as less happy or unhappy.

Figure 19.1 shows the proportion of high levels of happiness for men and women at age 30,

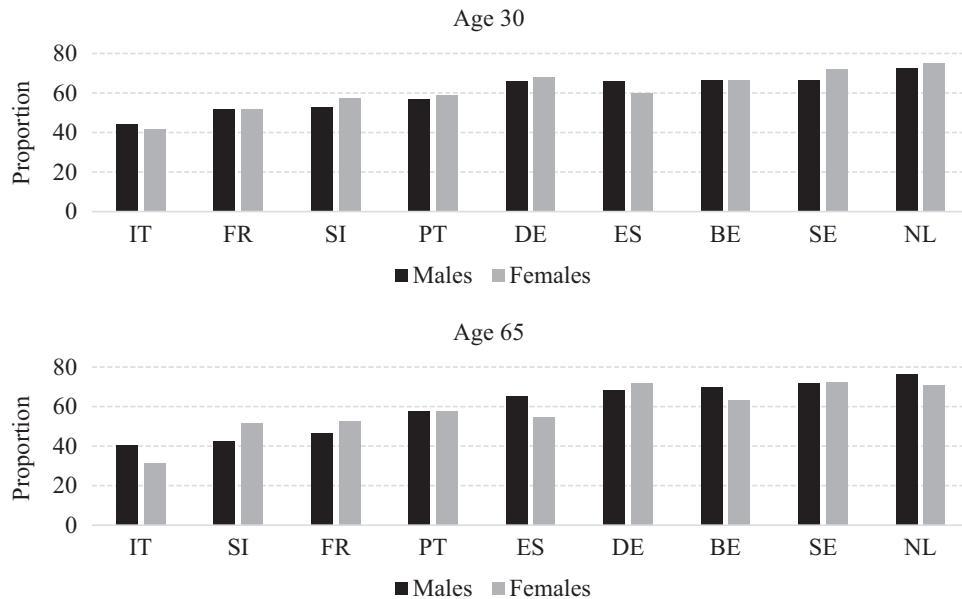


Fig. 19.1 Prevalence of high levels of happiness by gender in nine European countries. (Source: the 2016 wave of the European Social Survey)

Note: Those who rated their happiness in the scale between eight and ten were coded as happy, and the rest as less happy or unhappy

Note: The acronyms of the countries listed corresponds to: *IT* Italy, *SI* Slovenia, *FR* France, *PT* Portugal, *ES* Spain, *DE* Germany, *BE* Belgium, *SE* Sweden, *NL* The Netherlands

Note: Countries are ordered by males

and at a commonly used statutory age of retirement (65), for three central European countries (Belgium, France and Germany), three Southern European countries (Italy, Spain and Portugal), two Nordic European countries (Sweden and the Netherlands), and one from Eastern Europe (Slovenia) in 2016. There is a substantial variation on the prevalence of high levels of happiness across countries, proportions ranging from around 40% in Italy to around 75% in the Netherlands. However, similar patterns are seen for men and women. At age 30, except for Spain, gender differences across countries are minimal. Women report having worse levels of happiness at older ages compared to younger ages in most of these countries, while, in general, for men it appears to be the opposite. Even though not substantial differences by men and women appear in these countries, when we look at gender differences in happiness at both ages, results are not straightforward as half the countries show greater levels of high happiness for men while the

other half show greater levels for women. However, we found the largest gender differences in the prevalence of high levels of happiness at ages over 65 years and particularly for Southern European countries where women report lower levels of happiness.

Determinants of Happiness

Life circumstances, such as friendship, work, and employment status, affect happiness, although income, family and health conditions are the most often cited sources of happiness by people (Crimmins and Easterlin 2000). We will now describe briefly the association of these three dimensions (income, health and family and relatives) on happiness.

Easterlin's work over his academic life has documented the association between income and happiness; that those with higher income are, on average, happier (Easterlin 2001). It is important

to consider that overall happiness of individuals depends on aspirations and social comparisons at a point in time (Easterlin 2003). Additionally, the level of economic development and cultural beliefs together with material norms might shape happiness and therefore policy implications.

The relation between health and happiness is worthy of discussion as the initial impact of health on happiness, say an accident or a serious disease, is greater than its long-term impact. However, as health gets worse as people age people do not necessarily become unhappier. In general, though, greater health problems are linked to less happiness. For instance, those with fewer chronic conditions (Siahpush et al. 2008), lower levels of hypertension (Blanchflower and Oswald 2008), and people that are able to manage stress better has been associated to being happy (Papousek et al. 2010). Moreover, those with high life satisfaction tend to have a stronger social network (Solé-Auró and Cortina 2019). In addition, low levels of life satisfaction are associated with increased mortality and health problems (Mojon-Azzi and Sousa-Poza 2011; Koivumaa-Honkanen et al. 2000), poorer self-rated health, more physical disabilities, depressive symptoms, and other common health conditions (Strine et al. 2008).

Other life circumstances, such as work or environment, also affect happiness. Work is likely to affect people's health and quality of life, as well as their perceptions of well-being over the life cycle, with previous studies showing the link between work and personal satisfaction with life (Argyle 2001; Veenhoven 2003). In general, it has been found that working contributes significantly to happiness, though there might be substantial differences according to the type of occupation, and by gender and across countries. Argyle (2001) underlined social relationships, work and leisure activities as the main reasons for individuals' happiness. In addition, working has not only been found to increase social participation, but also to boost individual satisfaction because of the income earned, especially among men (Knabe and Rätzel 2010). In China Xiang et al. (2016) found that occupations with higher levels of prestige and power were strongly asso-

ciated with higher levels of happiness. In general, though, the higher the occupational status, the greater the reported happiness. Contextual environmental characteristics also correlate with happiness, with, for instance, individuals living near water and in green neighbourhoods perceiving their neighbourhood as safe and functional, attributes that are associated with high levels of happiness (Hart et al. 2018).

With respect to the family domain, the desire for a happy marriage is common as part of a good life. The protection factor of having a partner not only has beneficial effects on health (Gumà et al. 2019) but also improves life satisfaction at older ages much more than the protection provided by having children; so, lack of a partner has a strong negative relationship with life satisfaction (Solé-Auró and Cortina 2019). Partnerships and family ties, rather than economic circumstances, are thought to be explanations for the gender differences in happiness (Stasoval and Vilka 2018), with the effects of family circumstances changing over the life cycle and differing for men and women. It is possible that children have a very positive effect on happiness when they first arrive and this may change as they age to become teenagers (Blanchflower 2008; Dolan et al. 2008), possibly being this effect stronger for women than for men. In general, good relations with others (family, relatives and friends) contribute to human happiness but may differ in importance by gender (Azizi et al. 2017). When we look at the determinants of happiness, gender differences appear not to be affected by socioeconomic levels (Yang 2008).

Gender Differences in Happiness

Let us address now how men and women assess happiness or well-being. Some studies have found that women tend to be slightly happier than men, particularly in Western Europe (Arrosa and Gandelman 2016). Considering happiness across the lifespan in countries with high life expectancies, one would expect that the old would fare less well and have lower levels of happiness than their younger counterparts. However, when ana-

lysing gender differences in this pattern it seems that across the life span gender differences occur. Some studies have shown that men are happier or more satisfied with life than women across all ages with the gender gap widening with age (Pinquart and Sørensen 2001); while others have found that women at the beginning of life seem to be happier than men, but that this reverses and women become less happy later in life (Easterlin 2010). In middle adulthood women tend to report higher levels of stress than men, leading to lower levels of happiness (Jacobs and Gerson 2004; Mattingly and Sayer 2006). Work circumstances also differ between men and women in assessing happiness. For instance, in Spain, women tend to be less attached to the labour market than men (Sánchez-Mira 2016), and their working trajectories are less secure (i.e. more temporary jobs, career interruptions, unemployment, etc.) and more precarious (Lozano and Renteria 2019). Moreover, working mothers were also found to be less satisfied with life, and significantly more stressed than fathers (Musick et al. 2016).

Cross-Country Differences in Happiness

Comparative studies at the population level have generated inconsistent findings on the question of whether national populations reporting higher levels of happiness also have longer and healthier lives (Danner et al. 2001). Happiness is negatively associated with longevity at the national level across 15 European countries (Bjørnskov 2008), whilst there appears to be no clear association between life expectancy and life satisfaction as exemplified by countries like the Netherlands and Ireland both with high levels of life satisfaction but with high and low levels of life expectancy, respectively. Determinants of national levels of happiness are thought to include population health (commonly measured by computing healthy life expectancies), the strength of social networks, personal freedom, social trust (measured by the public's perception of corruption in government and business), and generosity (Helliwell et al. 2018).

We examine cross-country differences in happiness using data from the Gallup World Poll from 2015 to 2017. The Gallup World Poll is a set of nationally representative surveys undertaken in more than 160 countries worldwide. We select 17 European countries, Japan and the United States (Fig. 19.2). Life evaluation is used as a proxy for happiness and the respondents are asked about the “Cantril Ladder” with the following question: *“Please, imagine a ladder, with steps numbered from 0 at the bottom to 10 at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time?”*

Figure 19.2 shows the average answer to the Cantril ladder question for 19 countries in 2015–2017. Following Helliwell et al. (2018), we provide information on six determinants that measure mean life evaluations for each bar of the ladder level. These six determinants are: (1) GDP per capita in terms of Purchasing Power Parity (PPP) adjusted to constant 2011 international dollars, taken from the World Development Indicators (WDI); (2) Healthy life expectancy at birth for the year 2012 based on the data from the World Health Organization and WDI; (3) Social support is the national average of the binary responses to the Gallup World Poll (GWP) question “if you were in trouble, do you have relatives or friends you can count on to help you whenever you need them, or not?”; (4) Freedom to make life choices is the national average to the question “are you satisfied or dissatisfied with your freedom to choose what you do with your life?”; (5) Generosity relates to the question “Have you donated money to charity in the past month?”, (6) Perception of corruption are the average of binary answers to two GWP questions: “is corruption widespread throughout the government or not?” and “is corruption widespread within business or not?” (More details on the definition of these measures and its limitations can be found in <http://worldhappiness.report/ed/2018/>). Among the selected countries, three Nordic countries ranked first (Finland, Norway and Denmark) with no statistically

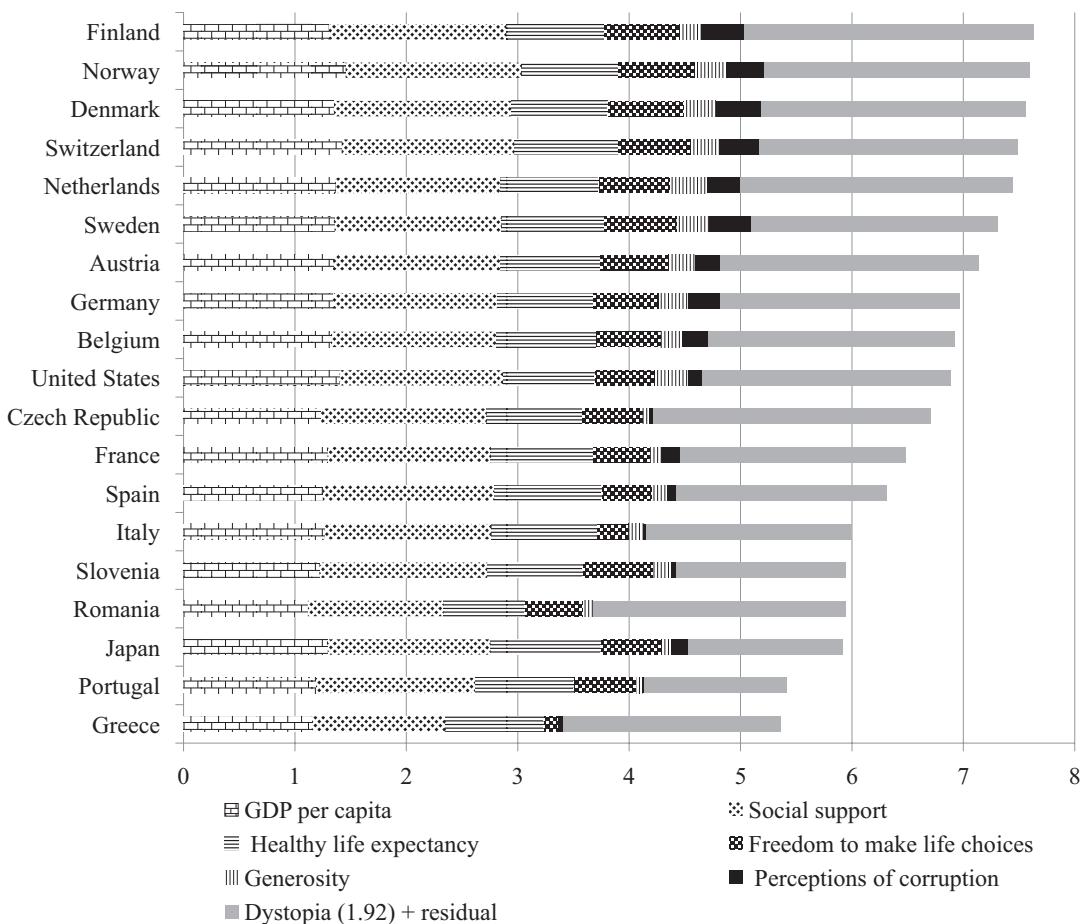


Fig. 19.2 Happiness score based on six determinants of life evaluations by country, 2015–2017. (Source: Gallup World Poll 2015–2017)

Note: The Cantril ladder question asks people to evaluate the quality of their current lives on a scale of 0 to 10

significant difference found between them, while Portugal and Greece ranked last. Thus, there remains a two-point gap between the three top-ranked and the two bottom-ranked countries. The United States ranks in the middle of this distribution ladder scale, and France, Spain and Italy below the overall country average. In all countries except Greece, GDP per capita, social support and healthy life expectancy explain over 50% of the average ladder scores. Corruption is also an important variable that explains almost 5% of the variation in the six top countries. The results for the Nordic countries are in line with previous findings that these are the happiest people in the world, and the various dimensions of social capital are some of the main factors

explaining why certain nations are happier than others (Bjørnskov 2003).

However, it is important to note that when comparing happiness across countries, there are many methodological questions regarding the responses to questions about happiness. The most common are whether the concept has the same meaning across cultures (Carlquist et al. 2017), how people present themselves and response styles (Oishi 2010), and whether differences in language hinder comparison (Delle Fave et al. 2011). Words like “happiness” or “satisfaction” may have different meanings in different tongues, though Veenhoven (1996) found no significant differences when comparing bi-lingual countries.

Happy Life Years

National Differences

In the last decades, an important question raised in public health is whether longer survival at ages would lead to more years of health deterioration and worsening of well-being. Happy life expectancy, or happy life years, is a way of measuring empirically the lifespan that people live with a subjective emotional feeling of well-being. It includes both how long, and happily, people live. Like healthy life expectancy, happy life expectancy is a summary measure of population well-being that combines data on the length of life (objective measure) and a measure of well-being (subjective measure) (Robine 2006). While there is a large body of literature on differences in survival, health and healthy life expectancy and well-being, the number of studies focusing on happy life expectancy and its variations by gender is increasing more slowly (Solé-Auró et al. 2018).

When comparing research on the levels of happy life expectancy in Europe, in the early 1990s, Eastern European countries, such as Bulgaria and Belarus, showed the shortest length of happy life compared to the longest in wealthy North-West European Union countries, such as Iceland, the Netherlands, Sweden and Switzerland (Veenhoven 1996). Nowadays, Nordic European countries are leading with a greater proportion of years with happy life, while Eastern European countries such as Hungary or Estonia ranked last (Solé-Auró et al. 2018). China is another important country for its recent unprecedented growth in GDP per capita, reflecting the improvement in material living conditions. In fact, the Chinese population has followed similar patterns of life satisfaction trajectory over time to European countries (central and eastern), this being an inverted U-shape with a no change or declining trend. This trend and U-shaped pattern are associated with a pronounced rise of the unemployment rates followed by a slight decline along with a growing inequality in, for example, income (Easterlin et al. 2012). Particularly for China, life satisfaction has declined in the lowest-income

and least-educated people, while increasing in the upper socioeconomic status stratum (Easterlin et al. 2012).

Using data from the World Database of Happiness (2005–2014: https://worlddatabaseofhappiness.eur.nl/hap_nat/findings/RankReport_HappyLifeYears.php), we show in Table 19.1 the average satisfaction with life on a scale from 0 to 10, life expectancy at birth and happy life years since birth in 18 countries. Countries in Table 19.1 are ordered by happy life years, and the ranking is almost the same as that in the value of satisfaction with life. Denmark, Switzerland, Finland, Luxemburg and the Netherlands are the leading countries in the number of years lived happily, with values at birth ranging from 61.7 to 66.4 years. However, these are not necessarily the countries with the highest

Table 19.1 Satisfaction with life, total years of life expectancy and happy life years at birth across countries

| Countries | Satisfaction with life (scale 0–10) | Life expectancy in years | Happy Life Years |
|----------------|-------------------------------------|--------------------------|------------------|
| Denmark | 8.4 | 79.4 | 66.4 |
| Switzerland | 8.0 | 82.6 | 66.0 |
| Finland | 7.9 | 80.5 | 64.0 |
| Luxembourg | 7.7 | 80.5 | 61.7 |
| Netherlands | 7.6 | 81.0 | 61.7 |
| Austria | 7.2 | 81.1 | 58.4 |
| Germany | 7.2 | 80.7 | 58.4 |
| Belgium | 7.2 | 80.5 | 58.2 |
| Spain | 7.0 | 82.1 | 57.8 |
| United Kingdom | 7.1 | 80.5 | 57.5 |
| United States | 7.3 | 78.9 | 57.5 |
| Italy | 6.6 | 82.4 | 54.5 |
| Japan | 6.4 | 83.6 | 53.7 |
| Greece | 6.5 | 80.8 | 52.7 |
| France | 6.4 | 81.8 | 52.4 |
| Czech Republic | 6.6 | 77.7 | 51.3 |
| Estonia | 6.2 | 74.4 | 45.8 |
| Lithuania | 5.8 | 72.1 | 42.1 |

Source: World Database of Happiness; Veenhoven, R. Happy Life Years in 158 nations 2005–2014. World Database of Happiness. Rank report Happy Life Years https://worlddatabaseofhappiness.eur.nl/hap_nat/findings/RankReport_HappyLifeYears.php

Note: Countries are ordered by happy life years

life expectancy. Spain and Italy are among the countries with the highest life expectancy at birth; however, in terms of length of happy life years they are in the middle of this distribution (57.8 years and 54.5 years, respectively). Japan, the country with the highest life expectancy at birth, ranks thirteenth in happy life years. However, the Eastern European countries, like the Czech Republic, Estonia or Lithuania, not only have the lowest life expectancy at birth, but also the lowest number of happy life years.

Gender Differences

When examining the magnitude and variation of the gender differences in happy life expectancy across countries, studies conducted in the United States have demonstrated that at all ages, women have longer happy and unhappy lives than men, but the proportion of life spent in a happy state is greater among men than among women (Yang 2008). Similar results are found in a recent study made by Solé-Auró et al. (2018) using European data that sheds additional light on how differently

men and women across different nations live these added years of life in terms of happiness at older ages. In general, European women have an advantage in happy life expectancy. Despite this advantage over men, a larger share of the remaining years of women's life is expected to be spent in an unhappy state (Solé-Auró et al. 2018). And again, results from Brazil (Lima et al. 2016) and from South Africa (Chirinda and Phaswana-Mafuya 2019) also found that men could expect to live a greater proportion of their lives happy compared to women.

Figure 19.3 illustrates the correlation between life expectancy and happy life expectancy at age 50 for men and women using data from the 2010–11 Survey of Health, Aging and Retirement in Europe (SHARE). SHARE participants were asked to evaluate their life satisfaction by responding their life satisfaction on a scale from 0 to 10. The responses were dichotomized in the same manner as presented when using the ESS earlier. Although Fig. 19.3 shows a general trend between life and happy life expectancy particularly for men across these European countries, countries with the highest life expectancy are not

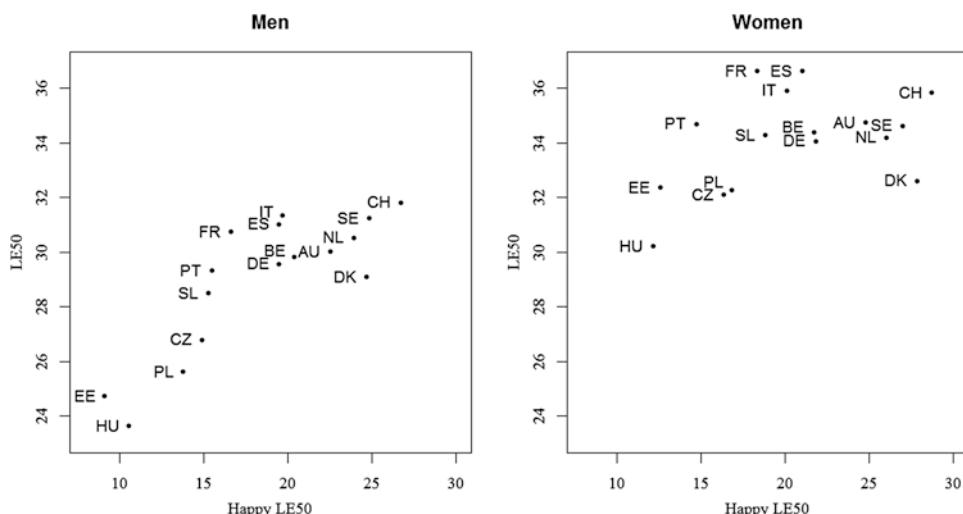


Fig. 19.3 Life expectancy and happy life expectancy at age 50 by gender in 16 European countries. Source: Own calculations based on SHARE 2010–2011; HMD 2010; Solé-Auró et al. (2018)

Note: LE50 – Life expectancy at age 50. Happy LE50 – Happy Life expectancy at age 50. Countries: AT Austria,

BE Belgium, CH Switzerland, CZ Czech Republic, DE Germany, DK Denmark, ES Spain, EE Estonia, FR France, HU Hungary, IT Italy, NT The Netherlands, PL Poland, PT Portugal, SE Sweden, SI Slovenia

necessarily the countries with the highest happy life expectancy. Additionally, the countries with the largest gender gaps in life expectancy are not the countries with the greatest gender differences in happy life expectancy. Therefore, there are substantial differences across countries for men and women. Even though women always had higher life expectancy than men, happy life expectancy at age 50 varied considerably across countries among both men (from 26.7 years in Switzerland to 9.1 years Estonia) and women (from 28.7 years in Switzerland to 12.1 years in Hungary).

Solé-Auró et al. (2018) also highlighted that in almost all of the European countries analysed, the contributions of mortality were positive and larger than the contribution of high levels of satisfaction with life when they looked at the total female-male gap in happy life years. These results reflect the longer life (lower mortality) among women than among men. Importantly, the effects of lower mortality among women are offset by the lower prevalence of happiness among women in all of the European countries studied. Interestingly, in some European countries, a gender reversal in the higher prevalence of happiness around retirement age was evident, suggesting that conditions after retirement may play a role in explaining differences between genders in the level of happiness.

Conclusion

This chapter addresses the importance and the value of analysing measures of subjective well-being, such as happiness, its variability and determinants across countries and sociodemographic groups in order to improve our quality of life. Happiness in individuals has been associated with longer lives, fewer health problems (less stress and depressive symptoms), more stable marriages, stronger social relations, better jobs and higher income. Patterns of happiness change throughout the life cycle, pointing at an upside-down U-shape with the highest levels observed in midlife (Easterlin 2010).

We found a substantial variability of happiness levels within different segments of populations and across countries. Richer countries tend to have higher average levels of happiness and within Europe, the Nordic European countries reported the highest levels, followed by central and finally Eastern Europeans. Across time, happiness levels have remained constant or improved and most importantly in countries that have experienced a sustained economic growth (Veenhoven 2018). Multiple characteristics of countries are thought to explain levels of happiness but it is important to distinguish between material living conditions (GDP per capita) and living circumstances (social support, healthy life expectancy, not living in poverty or not being disabled). On average, economic circumstances improve substantially up to the retirement ages, yet there is no corresponding advance in subjective well-being (Easterlin 2001). Therefore, understanding better the living circumstances of our society is crucial to improve well-being. For instance, there is a need to promote better quality jobs, which may, in turn, increase people's level of happiness in the labour market. This is especially important for the most vulnerable groups, such as manual workers and women, especially as women, even if working long hours, are still responsible for the majority of housework and childcare, these multiple responsibilities contributing to stress and conflict (Baxter and Tai 2016). As occupation, improvements to increase happiness have to happen in other dimensions of living circumstances.

Questions remain on the levels and the evolution of happy lives across countries and across demographic and socioeconomic groups. The value of measuring happy life expectancy, which summarizes information on quantity and quality of life into a single indicator of length of time with well-being, is essential for exploring new social research avenues on quality of life. Findings within Europe show that Nordic countries lead in the number of years with happy life, while Eastern European countries present the lowest values (Solé-Auró et al. 2018). Worldwide, the length of happy life years is longer in more advanced societies (i.e. European countries and

Canada); however, Costa Rica ranks first and most of the African regions rank last (Veenhoven 2018). Recent studies worldwide have found similar results in terms of gender differences in happy life expectancy, with women having an advantage in length of happy life expectancy, although, due to women's higher longevity, men are expected to live a greater proportion of their lives happily (Chirinda and Phaswana-Mafuya 2019; Solé-Auró et al. 2018; Lima et al. 2016).

There is a growing number of scientific publications addressing trends in happy life expectancy, but further research is needed across countries, time and segments of the population (i.e. by education level, gender, age groups, etc.) where an increasing longevity is offset by deterioration in the quality of life. Measurement has been a limiting factor in this research area. The lack of a clear level of happiness to differentiate among those who are considered to be happy or unhappy or the difficulty in choosing the right indicator (e.g. happiness or life satisfaction) have been factors that may have limited the expansion of this research field. However, it is very useful to study trends in happy life expectancy to identify environments or social groups where policy can improve well-being as well as life expectancy.

To conclude, improvement in health, home life, job security, strong networks of friends and relatives, should increase our positive life evaluation and improve our quality of life. Happiness aims to assess the drivers of future human well-being across and gives us a more complete picture on the quality of the years gained, beyond the increment in life expectancy. Life satisfaction is a meaningful indicator of people's life circumstances and well-being that has to be implemented to build future social policies across the globe. More surveys are needed to give reliable information for all of these dimensions of years of good life. National policies should view happiness as an important determinant of health and well-being at old age, especially among women.

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Revisiting the Disablement Process

20

Lois M. Verbrugge

Introduction

The Disablement Process is a scientific model designed to aid research and thinking on disability. It has been of high utility in recent decades, serving as architecture for many specific studies. This chapter builds on earlier work by the author but takes a fresh look at the disablement process model, placing it in the context of other options and considering its future value (Verbrugge 2015, 2016).

Types of Models

Models are ways of thinking about a topic that help in stating hypotheses, designing studies, and interpreting results. For disability, a good model should be relevant to persons of all ages, functional limitations of short or long duration, and changes in limitations, and capable of identifying both commonalities and distinctive differences in disability experiences. Types of models for disability research are visual image, taxonomy, scientific model, and formal theory. In this section, we discuss visual image, taxonomy, and formal theory for disability. Then we concentrate on scientific model, specifically the disablement process.

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Visual Image

Visual images summarize and suggest in compact, mostly nonverbal ways, and they can greatly stimulate new hypotheses and research designs. For disability, a good example of visual image is in a high-profile report on rehabilitation (Brandt and Pope 1997, Figure 3–4; reprinted here in Fig. 20.1). The trampoline image portrays a person with functional abilities in two environments, one with good support (many buffers, few barriers) and one with weak support (few buffers, more barriers). Disability is measured by how deeply the person stands in the trampoline—lightly in the first environment (so, easy to jump), and deep down in the second one (so, difficult to jump). This is a simple way to emphasize the importance of the environment for anyone in society, counterposing their own abilities with their own milieu.

Another well-used and admired visual image is the “daily activities” chart in the COOP/WONCA set of functional status charts (COOP: Dartmouth Primary Care Cooperative Research Network, WONCA: World Organization of National Colleges, Academies, and Academic Associations of General Practitioners/Family Physicians) (van Weel et al. 2012). The charts are used in clinical settings, where patients readily score their status on six dimensions: physical fitness, feelings, daily activities, social activities, change in health, overall health.

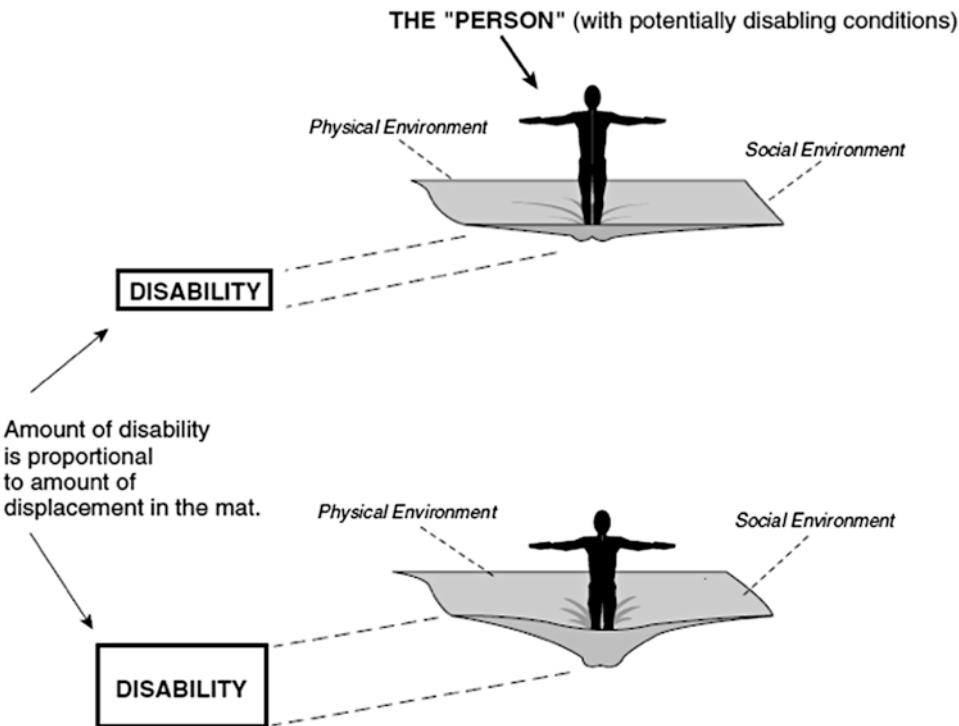


Fig. 20.1 Visual image. (Source: Figure 4 (p. 9) in Brandt, E. N., Jr., & Pope, A. M. (Eds.). (1997). Enabling America: Assessing the role of rehabilitation science and engineering. Washington, DC: National Academy Press)

Taxonomy

A taxonomy is a highly organized inventory with names for items, overarching categories, and often a numbering system. Some taxonomies have mutually exclusive elements (an element has just one name and sits in just one category), while others provide a multiple scoring system (an element has several features and all are recorded).

For disability, a good example of taxonomy is the International Classification of Functioning, Disability and Health (ICF) (World Health Organization 2001). Figure 20.2 shows two pages of the taxonomy. ICF is a comprehensive inventory of body functions and structures, activities and participation, and environmental factors relevant to disability which followed an initial approach called the International Classification of Impairments, Disabilities, and Handicaps (ICIDH) (World Health Organization 1980). As a scoring system, it is quite complex. Still, ICF has

high utility for organizing thinking about disability (Jette 2006, 2009; Spoorenberg et al. 2015; World Health Organization 2002), and it is now broadly adopted by national statistical agencies as a guide to designing surveys and coding data.

Formal Theory

Formal theories are models with big general hypotheses embedded within them. The hypotheses are used deductively for specific hypotheses in research studies. Some formal social science theories relevant for disability research are population ageing, life course, life-span development, role theory, exchange theory, and person-environment theory. All of these have excellent literatures that readers can easily find. Good places to start are noted (Alley et al. 2010; Baltes 1991; Baltes and Baltes 1990; Ferraro 2016; French et al. 1974; Higgins et al. 2014; Lawton 1982; Ram et al. 2010; Robine and

| <i>Activities and Participation</i> | <i>ICF</i> | <i>Activities and Participation</i> |
|--|---|---|
| d 6403 Using household appliances Using all kinds of household appliances, such as washing machines, dryers, irons, vacuum cleaners and dishwashers. | | d 6501 Maintaining dwelling and furnishings Repairing and taking care of dwelling, its exterior, interior and contents, such as by painting, repairing fixtures and furniture, and using required tools for repair work. |
| d 6404 Storing daily necessities Storing food, drinks, clothes and other household goods required for daily living; preparing food for conservation by canning, salting or refrigerating, keeping food fresh and out of the reach of animals. | | d 6502 Maintaining domestic appliances Repairing and taking care of all domestic appliances for cooking, cleaning and repairing, such as by oiling and repairing tools and maintaining the washing machine. |
| d 6405 Disposing of garbage Disposing of household garbage such as by collecting trash and rubbish around the house, preparing garbage for disposal, using garbage disposal appliances; burning garbage. | | d 6503 Maintaining vehicles Repairing and taking care of motorized and non-motorized vehicles for personal use, including bicycles, carts, automobiles and boats. |
| d 6408 Doing housework, other specified | d 6504 Maintaining assistive devices | d 6504 Maintaining assistive devices Repairing and taking care of assistive devices, such as prostheses, orthoses and specialized tools and aids for houseskeeping and personal care; maintaining and repairing aids for personal mobility such as canes, walkers, wheelchairs and scooters; and maintaining communication and recreational aids. |
| d 6409 Doing housework, unspecified | | |
| d 649 Household tasks, other specified and unspecified | | d 6505 Taking care of plants, indoors and outdoors Taking care of plants inside and outside the houses, such as by planting, watering and fertilizing plants; gardening and growing foods for personal use. |
| Caring for household objects and assisting others (d650-d669) | | d 6506 Taking care of animals Taking care of domestic animals and pets, such as by feeding, cleaning, grooming and exercising pets; watching over the health of animals or pets; planning for the care of animals or pets in one's absence. |
| d 650 Caring for household objects Maintaining and repairing household and other personal objects, including house and contents, clothes, vehicles and assistive devices, and caring for plants and animals, such as painting or wallpapering rooms, fixing furniture, repairing plumbing, ensuring the proper working order of vehicles, watering plants, grooming and feeding pets and domestic animals. | | d 6508 Caring for household objects, specified |
| <i>Inclusions: making and repairing clothes; maintaining dwelling, furnishings and domestic appliances; maintaining vehicles; maintaining assistive devices; taking care of plants (indoor and outdoor) and animals</i> | | d 660 Assisting others |
| <i>Exclusions: acquiring a place to live (d610); acquisition of goods and services (d620); doing housework (d640); caring for others (d660); remunerative employment (d850)</i> | | Assisting household members and others with their learning, communicating, self-care, movement, within the house or outside; being concerned about the well-being of household members and others. |
| | | <i>Inclusions: assisting others with self-care, movement, communication, interpersonal relations, nutrition and health maintenance</i> |
| | | <i>Exclusion: remunerative employment (d850)</i> |

Fig. 20.2 Taxonomy. (Source: World Health Organization. (2001). International classification of functioning, disability and health. Geneva, Switzerland: Author)

Michel 2004; van Vianen 2018; Wahl et al. 2006). Although it is an exciting prospect, fashioning integration between disability models and formal theory has not yet occurred.

Scientific Model: The Disablement Process

A scientific model proposes an architecture of how things are related to each other. Scientific models contain implicit hypotheses by showing

typical causal pathways, and they readily inspire specific testable hypotheses for research.

For disability, a good example of scientific model is the disablement process (Verbrugge and Jette 1994, Figure 2; reprinted here in Fig. 20.3). A simplified version is in Fig. 20.4 (words are trimmed). The model posits a main pathway of disablement, moving in time and causation from pathology to body system impairments, then to functional limitations, and then to disability. Each concept is distinct and defined. Factors that affect level and pace of disablement are stated,

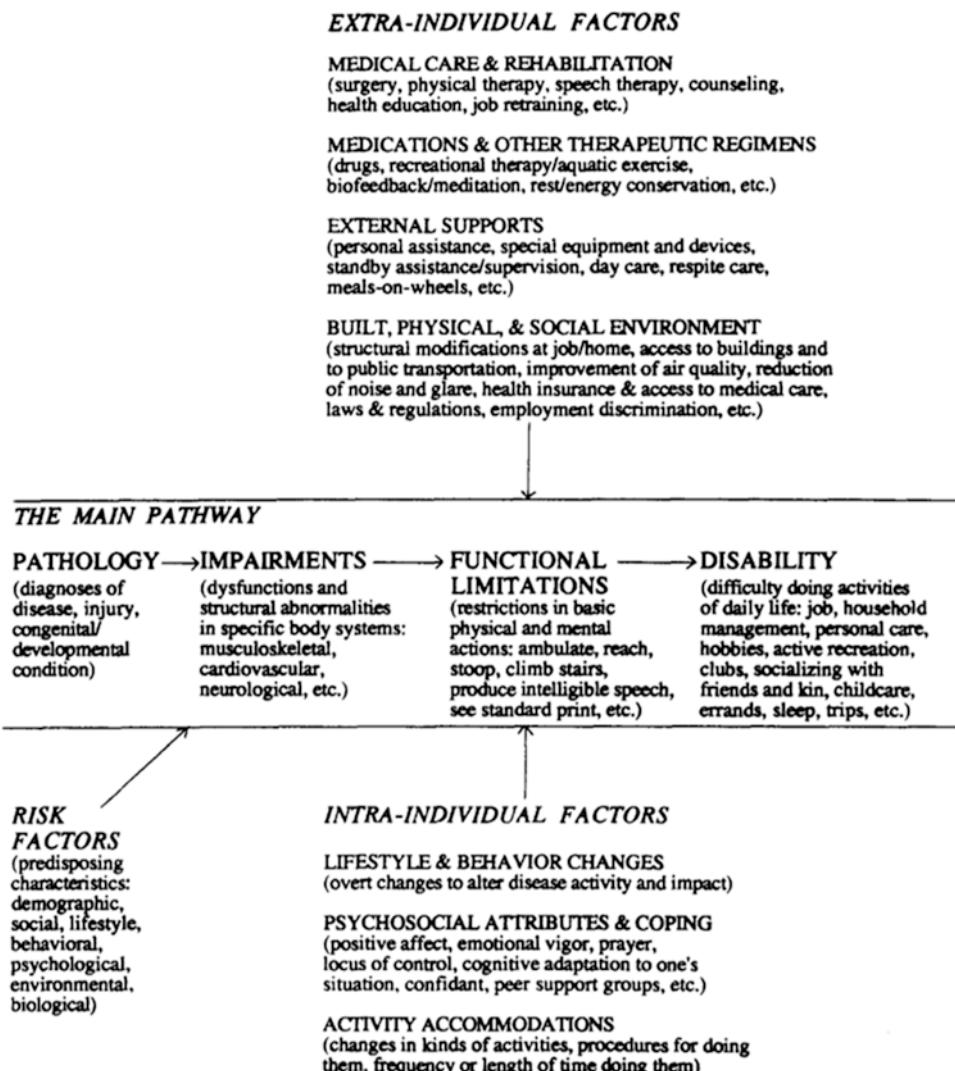
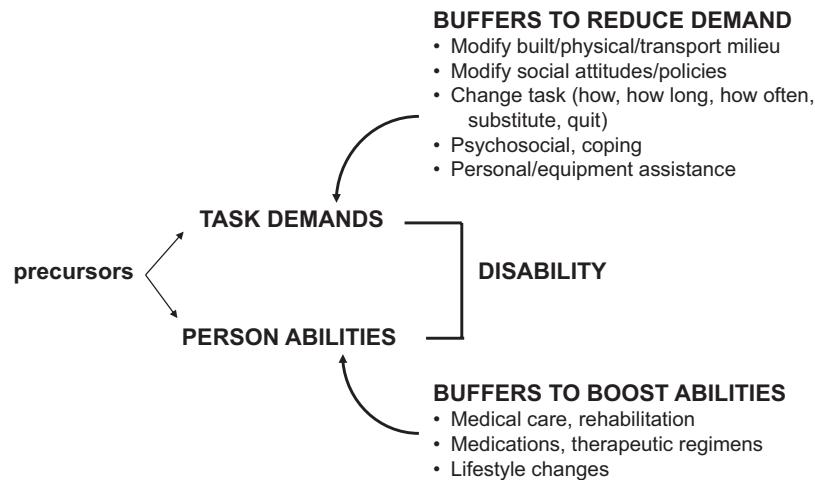


Fig. 20.3 Disablement process 1 (Person-Centered). (Source: Figure 2 in Verbrugge, L. M., & Jette, A. M. (1994). The disablement process. Social Science & Medicine, 38, 1–14)

Fig. 20.4 Simplified disablement process 1.
(Source: Modified from Figure 2 in Verbrugge, L. M., & Jette, A. M. (1994))



namely, risk factors, intra-individual factors (features within the person), and extra-individual factors (features outside the person). Think of the diagram as *Disablement Process 1*. It maintains a person-centered focus. The main pathway concerns people's functional situation over time.

Intellectually, the author prefers a model that gives equal attention to person and environment. The 1994 article includes a person-environment fit model (Verbrugge and Jette 1994, Figure 4; reprinted here in Fig. 20.5). A simplified version is in Fig. 20.6 (the term "buffers" is used, categories are revised, precursors are collapsed to highlight task demands versus person abilities). Think of it as *Disablement Process 2*. This model recommends, even compels, explicit measures of task demands, and the difference between task demands and person abilities. That is very difficult for social scientists to implement with their typical skills, measuring mostly features of people. It is even difficult for teams of social scientists and human factors professionals skilled in measuring task demands to accomplish together. But another approach exists that takes environment into account, which is more comfortable for social scientists and very suitable. This is represented in the "health and place" field of research. Environmental features at home or away-from-home are included as predictors of disability (Balfour and Kaplan 2002; Clarke and George 2005; Clarke et al. 2008, explicated in Verbrugge 2016:1129; Keysor et al. 2005; Mollenkopf

et al. 2004). Fine guides to designing predictors come from studies of attitudes about one's environment, and direct evaluations of environmental features (examples in Bendixen et al. 2005; Gray et al. 2008; Shumway-Cook et al. 2003; Spivock et al. 2007; Whiteneck et al. 2004). Thoughtful discussions of the role of environment in disability are noted (Fozard 1981; Keysor 2006).

In sum, Disablement Process 1 (person-based) is easier to implement than Disablement Process 2 (plus environment). But the second model should be a constant companion, cautioning scientists about person-based thinking and encouraging them to find ways to include environmental aspects overtly in empirical research. The more this occurs, the truer-to-life disability research results will be.

What preceded the disablement process model? Does it need revision? What is its future?

Empirical disability research started in the 1950s and 1960s, propelled by clinicians and gerontologists interested in long-term care and rehabilitation (Katz and Akpom 1976; Katz et al. 1963, 1970; Lawton and Brody 1969). Their focus on personal care (ADL; activities of daily living) and household management (IADL; instrumental activities of daily living) disabilities continued as social scientists entered the field. A leap forward for scientific research came with Nagi's development of a disability model (Nagi 1965, 1976, 1991; other references in Pope and Tarlov 1991), now called the "Nagi model".

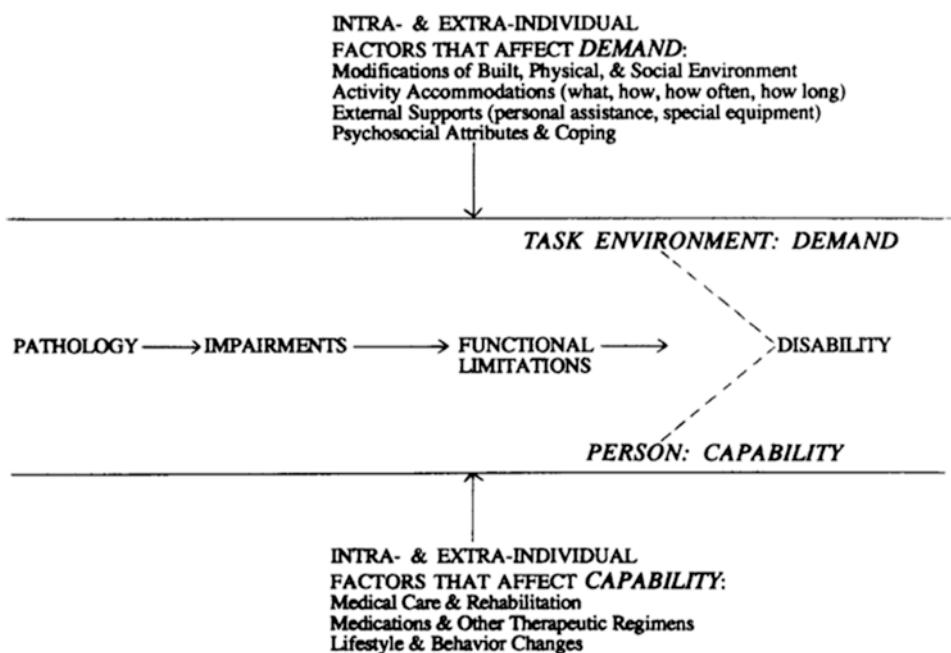


Fig. 20.5 Disablement process 2 (Person and Environment). (Source: Figure 4 in Verbrugge, L. M., & Jette, A. M. (1994). The disablement process. *Social Science & Medicine*, 38, 1–14)

Nagi's interest centered on work disability and rehabilitation, not exclusively, but it was a long-time focus in his career. For two decades, his writings were the sole source of conceptual thinking for researchers; they were broad-minded and well-written. In the mid-1980s, this chapter's author chose disability as her main research topic, and Nagi's work was influential in creation of the disablement process model. The disablement process model (Verbrugge and Jette 1994) appeared in the context of fast-rising interest in disability in the 1990s in the social sciences, public health, survey research, and social policy. Other thoughtful and influential discussions of disability models and measurement were prepared (chronological: Pope and Tarlov 1991; Brandt and Pope 1997; Field and Jette 2007; Freedman et al. 2014). The 1991 report's model (Figures 4 and Fig. 3-3) became known as the "IOM model"; it moved quickly into public discourse and has had continuing value. Several workshops were also important spurs for disability research (chronological: Levine et al. 1990;

Mathiowetz and Wunderlich 2000; Field et al. 2006). Disability advocacy researchers contributed models and instruments especially pertinent to long-term disability (Fougeyrollas 1995; Fougeyrollas et al. 1998; Gray et al. 2006; Whiteneck et al. 1992). ICIDH and its successor ICF were also a base for disability discussions. Good reviews of disability models are noted (Higgins et al. 2014; Masala and Petretto 2008; Robine et al. 1997).

Among these models, what is distinctive about the disablement process? It has a broad scholarly spirit and a strong research-oriented stance. Measurement options and their substantive implications team up in the discussion. Examples are supplied that "put meat on the [model's] bones". The article is, we think, easy to read and prompts reader thinking. It is flexible, nonprescriptive, and research-ready. For interested readers an interview about the writing of the paper, journal submissions, and first decade of use was conducted by Essential Science Indicators (Reuters 2006).

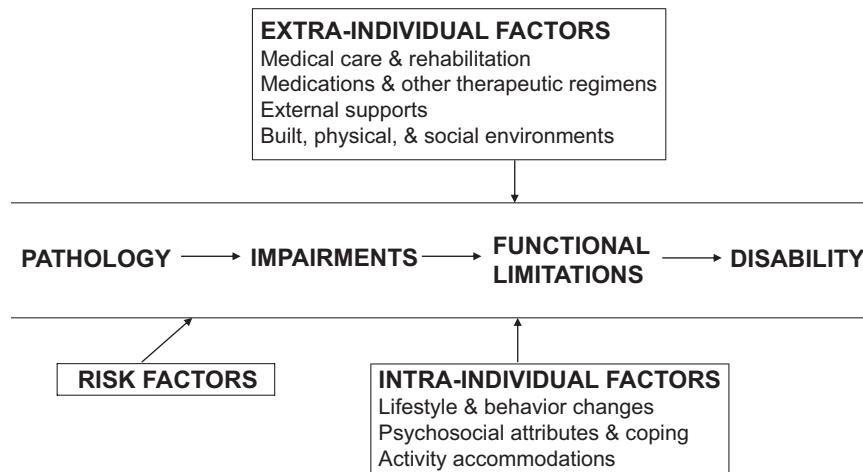


Fig. 20.6 Simplified disablement process 2. (Source: Modified from Figure 4 in Verbrugge, L. M., & Jette, A. M. (1994))

Does the disablement process need revision?

- (1) Should intra-individual and extra-individual factors affecting disablement be revamped and reorganized? Should the model's official emphasis be on how they act on task demand and personal ability? Although both person-centered and person-and-environment options are in the original article, the first is used more often.
- (2) Besides "difficulty" as the measure of disability, should the model explicitly include other aspects such as time, effort, fatigue doing tasks, changed procedures, frequency, and the like? This topic is addressed in Verbrugge 2016; see "More activities, answers, and aspects".
- (3) Does the model suit long-run disability experience as people's functional problems, valued activities, and personal goals change over their lifetime? Substantive questions and analysis techniques go hand-in-hand. A decade or so ago, it was difficult to study disability changes over many waves of a survey in parsimonious way. Methods were developed to identify trajectories, and longitudinal disability studies have benefited enormously.
- (4) Should reciprocal and non-additive effects for issues such as disability recovery, pace, and multiplicity, be overtly included in the diagram? We note the discussion in Wang et al. (2006).
- (5) Should a global outcome such as quality of life or overall wellbeing always be portrayed?

- (6) Should the model distinguish activity and participation as ICF does? All of these questions, except the last, are evident and stated in the original article, and offered to researchers to make their own choices in specific studies. Other publications by the chapter author bring up these issues (Verbrugge 1990a, b, 1994, 1995). Empirical analyses using the disablement model show specific scholarly choices and modifications (for example, Barberger-Gateau et al. 2002; Femia et al. 2001; Infurna and Wiest 2018; Kail and Carr 2016; Lawrence and Jette 1996; Mänty et al. 2014; Mendes de Leon and Rajan 2014; Peek et al. 2005; Peres et al. 2005). This kind of reshaping-to-suit will continue so long as the disablement process model fits research questions and hypotheses, public discourse on disability, and real-world disability experience.

Comparing Types of Models

The key distinction among models is what happens to conceptual domains: a taxonomy is about "what", a scientific model adds "how", and a formal theory adds "why". Visual images are a breed of their own, offering content with few words; good ones can succinctly convey "what", "how", and "why".

The four types of models vary greatly in their flexibility. Taxonomies are exactly as is, and a researcher cannot add, subtract, or revise elements. Scientific models can be reshaped and elaborated to suit specific analyses. Visual images, with verbal translation, can also foster specific analyses. Formal theories are very open and non-specific, and are well-suited to many (at their best, all) topics within the overarching one. Formal theories are not intrinsically better than taxonomies, scientific models, or visual images. Each type can serve its job well. Still, "why" is the ultimate goal of scientific research, so formal theories do have very shiny status. Disability research will benefit in coming decades by aligning with existing social science theories.

The disablement process model is a mid-level model, readily useful for contemporary research and broadly pensive about disability experience. As a scholarly product, it is more developed than visual image or taxonomy, and less so than formal theory.

Conclusion

The disablement process model's aim is to promote research thinking and design, offering a framework with causal implications, and options for measurement. It has apparently succeeded in that goal, having been used as a foundation for disability research since its publication. What will happen to the disablement model? If its value for science and discourse persists, and its ability to map real-life experience continues, then it will endure. If it falls short, some other model will replace it. The main criteria for continued longevity will be the model's aptness for disability experiences of diverse world cultures, all ages, and all durations and courses over time.

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Oral Health, Longevity and Quality of Life

21

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Introduction

As populations continue to age rapidly worldwide, a growing spotlight is thrown on the complex relationships between oral health and adverse health outcomes, especially in old age. These health outcomes may include malnutrition (De Marchi et al. 2008; Gil-Montoya et al. 2013), cardiovascular diseases (Kebschull et al. 2010; Li et al. 2014; Lockhart et al. 2012; Sfyroeras et al. 2012), respiratory diseases (Azarpazhooh and Leake 2006), diabetes (Leite et al. 2013; Luo et al. 2015), cognition (Avlund et al. 2004; Kimura et al. 2013), disability (Avlund et al. 2004; Holm-Pedersen et al. 2008; Kimura et al. 2013; Miura et al. 2005), and poor quality of life (Ingram et al. 2005; McMillan et al. 2005; Nasu and Saito 2006). In addition, studies have shown that poorer

oral health status, such as the presence of caries, periodontal disease, masticatory dysfunction, and edentulism, is associated with an increased rate of mortality among older persons (Awano et al. 2008; Holmlund et al. 2010; Watt et al. 2012). Not surprisingly then, the negative impact of poor oral health on the quality of life of older adults has become an increasingly important public health issue. Therefore, as rapid population aging occurring globally, planning and evaluating the effects of oral health care in the older population are becoming a priority and necessity for public health policy makers (Petersen and Yamamoto 2005). The chapter will first review the evidence of the relationship between oral health and morbidity and mortality separately. Then we will examine the association between oral health and health expectancy in two ways: firstly using oral health as a risk factor, thereby examining health expectancy by oral health status (Nasu and Saito 2006a); and secondly by using oral health status as an outcome and calculating oral health expectancy, that is computing years lived in different oral health statuses. To date, there are no published papers for this second method.

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Oral Health and Morbidity

Epidemiological studies have shown that periodontal disease is associated with systemic diseases, such as cardiovascular disease, stroke,

respiratory diseases, and diabetes (Kuo et al. 2008; Pihlstrom et al. 2005; Seymour et al. 2007). For example, patients with periodontal disease have elevated risk of developing CVD and stroke (Blaizot et al. 2009; Sfyroeras et al. 2012). Adults with diabetes have increased risk of periodontal disease compared to those without diabetes (Luo et al. 2015), and periodontal disease negatively associate with the metabolic control of diabetes (Mealey 2006). The associations between prognostic biomarkers of coronary heart disease and tooth loss, a marker of oral disease and periodontal disease have been confirmed (Vedin et al. 2017). There are two main explanation for the link between periodontal disease and systemic diseases. One is the common shared external factors, such as smoking (Blaizot et al. 2009; Gomes-Filho et al. 2010; Preshaw 2008). The other potential explanation is that bacteria from periodontal diseases can enter the bloodstream because of chewing or tooth brushing or dental flossing (Crasta et al. 2009; Murphy et al. 2007), and bacteria from periodontal diseases is associated with systemic infection and inflammation (Leite et al. 2013; Olsen 2015; Paju and Scannapieco 2007; Sfyroeras et al. 2012). However, there is still debate on this causal relationship (Olsen 2015; Pihlstrom et al. 2005). For example, no evidence supports that treatment of periodontal disease can lower the risks of atherosclerotic disease (Li et al. 2014; Lockhart et al. 2012).

Oral health is also related to the onset of disability among elders, although the relationship and pathways are nuanced (Holm-Pedersen et al. 2008). Tooth loss and decreased chewing ability are factors associated with an increased risk of disability among elders (Holm-Pedersen et al. 2008); however the association between oral health and disability are complex (Avlund et al. 2004; Kimura et al. 2013; Miura et al. 2005). Beyond physical disability, a study explored the link between late life depression (a significant public health problem for elders) and oral health, noting that oral hygiene and oral health issues are largely neglected among those elders with mental health conditions (Friedlander and Friedlander 2003). Be it a side effect of medication, physical impairment or neglect resulting from depression,

the inability to maintain oral hygiene and resultant poor oral health are important factors relating the transition from a healthy state to an inactive state among elders.

Health transitions, or the movement from one health state to another, herald the change in health status from and between different health states and mortality. Studies looking at oral health across time have shown that there may be interactions between oral health and the movement between health states; for example, among individuals who have transitioned from no physical/cognitive disability to physical/cognitive disability, those with fewer teeth have a higher incidence of physical/cognitive disability (Shimazaki et al. 2001). In a 2008 study, having fewer natural teeth was related to the onset of disability at the 5- and 10-year follow ups, and having no teeth was related to higher mortality at the 21-year follow up (Holm-Pedersen et al. 2008). While tooth loss has been shown to play a role in health transitions, chewing ability may be a better oral health indicator than number of teeth (Miura et al. 1997), since there was a close relationship between chewing ability and the activities of daily living (ADL) score, whereby better mastication scores were more strongly correlated with ADL scores than were number of missing teeth. While the exact interplay between oral health and health transitions may be unclear, it remains true that poor oral health (edentulousness or decreased chewing ability) is both a sign and a symptom of declining overall health and may put elders at risk for transitioning from a healthy to an inactive state (Nasu and Saito 2006a).

Oral Health and Mortality

Numerous studies have shown the association between oral health and mortality; the common thread being that having fewer teeth or decreased chewing ability is associated with an increased risk of mortality, independent of other factors including socioeconomic status, life style, and health factors (Ansai et al. 2007; Österberg et al. 2008; Shimazaki et al. 2001). The pathways between oral health and mortality have proven

to be varied. Studies have shown that poor oral health is related to the increasing mortality risk from acute infections such as pneumonia, as well as from chronic underlying systemic infections (Awano et al. 2008; Seymour et al. 2007). In terms of chronic diseases, multiple studies have found a connection between cardiovascular disease mortality and poor oral health (Holmlund et al. 2010; Watt et al. 2012). Other studies have pointed to a link between chewing ability, nutritional status, and an increased risk of mortality among elders (Nakanishi et al. 2004; Walls and Steele 2004). Edentulousness, and the subsequent problems in chewing, can inhibit the ability to attain adequate nutritional requirements, leading to a diminished health status, and subsequently increased mortality risk among elders (Awano et al. 2008; Walls and Steele 2004).

Oral Health and Health Expectancies and Quality of Life

Oral Health as a Risk Factor for Health Expectancy

Many papers have explored the association between oral health, morbidity, and mortality, though there is little research looking at the association between oral health and health expectancy. However, since health expectancy, as a summary measure of population health, is calculated using both morbidity and mortality (Pongilione et al. 2015), it is well worth considering that poor oral health will be reflected in lower health expectancy. A previous study underscores that oral impairment, oral functional limitations, and general functional limitations are interconnected and that oral health care and disability prevention is crucial to active aging (Avlund et al. 2004). Indeed, there are several Asian studies finding a statistically significant association between oral health and health expectancy. They all use disability (ADL and IADL combined) to define health of health expectancy, and examine the association between oral health (chewing ability or number teeth) and health expectancy.

Table 21.1 Estimates and standard errors (SE) of total life expectancy (TLE), healthy life expectancy (HLE), and unhealthy life expectancy (ULE) by chewing ability for Japanese at age 65

| Unable to chew hardest foods | | Able to chew hardest foods | |
|------------------------------|------|----------------------------|--------|
| Estimate | SE | Estimate | SE |
| Men | | | |
| TLE | 16.7 | 0.78 | 19.3 |
| HLE | 13.7 | 0.68 | * 16.8 |
| ULE | 3.1 | 0.42 | 2.4 |
| Women | | | |
| TLE | 21.1 | 0.71 | 23.2 |
| HLE | 16.3 | 0.54 | * 18.6 |
| ULE | 4.8 | 0.42 | 4.6 |

Note: Comparison between groups of different chewing ability within same sex, *indicates $p < 0.05$. From Table 5 of Nasu and Saito (2006a)

Nasu and Saito (2006a) used the Nihon University Japanese Longitudinal Study of Aging (NUJLSOA) from Japan and found a strong association between chewing ability and health expectancy, healthy being defined as being able to do without difficulty all of 7 ADLs and 7 IADLs. Older Japanese with the ability to chew the hardest group of food items live between two and three extra years healthy from age 65 ($p < 0.05$) compared to people without this ability (See Table 21.1).

A Singaporean study (Chiu et al. 2016) using similar health measures (6 ADL and 7 IADL items) and the list of food to define chewing ability found similar results. Older Singaporean who can chew the hardest food live significant more years than those who cannot, and the difference is about 6 years at age 60 ($p < 0.05$). Those with the ability to chew the hardest group of food items also have five more years in the active state ($p < 0.05$) compared to people without the ability to chew the hardest group of food items (Table 21.2).

Li et al. (2008) used the Taiwan Longitudinal Study on Aging with similar health measures (1 ADL and 5 IADL items) to examine the association between chewing ability and health expectancy. They define chewing ability as “Good” if self-rated chewing ability is very good or good, and “Bad” otherwise. Taiwanese aged 60 and over who have good chewing ability live 1.5–

Table 21.2 Estimates and 95% confidence intervals (95%CI) of total life expectancy (TLE), healthy life expectancy (HLE), and unhealthy life expectancy (ULE) by chewing ability for Singaporean at age 60

| | Unable to chew hardest foods | | Able to chew hardest foods | |
|--------------|------------------------------|---------------|----------------------------|--------------|
| | Estimate | 95% CI | Estimate | 95% CI |
| Men | | | | |
| TLE | 18.6 | (16.4, 20.9)* | 23.2 | (21.1, 25.2) |
| HLE | 15.8 | (13.9, 17.7)* | 20.3 | (18.7, 21.8) |
| ULE | 2.9 | (1.9, 3.8) | 2.9 | (1.8, 3.9) |
| Women | | | | |
| TLE | 21.7 | (19.3, 24.1)* | 28.7 | (25.5, 31.9) |
| HLE | 14.1 | (12.3, 15.8)* | 19.9 | (18.5, 21.4) |
| ULE | 7.6 | (5.9, 9.3) | 8.8 | (6.3, 11.3) |

Note: Comparison between groups of different chewing ability within same sex and life expectancy categories, where *indicates $p < 0.05$. Foods rated as the hardest (dry small fish or shredded dry squid) in the survey. From Chiu et al. (2016)

2.5 years more than those who do not, the difference in women being statistically significant ($p < 0.05$). For healthy life expectancy, both men and women with good chewing ability have significantly more years (men: 2.1 years, women 2.9 years) in the healthy state ($p < 0.05$) compared to those who do not (Table 21.3).

Nasu and Saito (2006b) and Chiu et al. (2016) found a statistically significant association between number of teeth and health expectancy for both sexes combined. People with 20 or more teeth have longer total and healthy life expectancy than do those with less than 20 teeth. However, the two studies did not find statistically significant differences by number of teeth for men and women separately.

Among elders, poor oral health conditions are negatively associated with quality of life, interacting with other health conditions, and increasing the risk of morbidity and mortality (Kandelman et al. 2008; Österberg et al. 2008). The confluence of these risks and relationships points to an association between health expectancy and oral health that warrants further exploration. Mortality and morbidity, in the form of

Table 21.3 Estimates and standard errors (SE) of total life expectancy (TLE) and healthy life expectancy (HLE) by chewing ability for Taiwanese at age 60

| | Bad chewing ability | | Good chewing ability | |
|--------------|---------------------|------|----------------------|------|
| | Estimate | SE | Estimate | SE |
| Men | | | | |
| TLE | 18.1 | 0.39 | 19.6 | 0.52 |
| HLE | 13.5 | 0.34 | * 15.6 | 0.40 |
| Women | | | | |
| TLE | 20.7 | 0.39 | * 23.2 | 0.69 |
| HLE | 11.5 | 0.35 | * 14.4 | 0.46 |

Note: Comparison between groups of different chewing ability within same sex, *indicates $p < 0.05$. “Good” indicates self-reported “very good” or “good” chewing ability. (From Li et al. 2008)

illness or disability, are major mitigating factors to an individual’s health expectancy. Furthermore, the transitions that individuals make between health states are of interest when exploring factors related to health expectancy among elders, because these transitions are important signposts by which to contextualize a person’s health.

Oral Health Expectancy

As stated earlier, the presence of poor oral health, as defined by inability to chew hard foods, poor self-reported chewing ability or reduced number of teeth, is associated with lower healthy life expectancy. It is then useful to explore oral health status as a health outcome, to see whether the difference in healthy life expectancy for different social groups, for instance by level of education, might be related to differences in the years spent with good oral health. To date the research literature has no examples of oral health expectancy.

Using data from the NUJLSOA, we compute years with good and poor chewing ability at age 65 by sex and level of education (Table 21.4). Good chewing ability is defined as having the ability to chew the hardest group of food items such as hard dried squid and pickled radish. There are differences between men and women as well as by level of education. Women live more years with good chewing ability, but as a proportion of their longer life expectancy they spend a lower proportion of expected years with

Table 21.4 Estimates and standard errors (SE) of total life expectancy (TLE), and years with good and poor chewing ability by sex and level of education for Japanese at age 65

| | | All | | Low education | | High education | |
|-------|---|----------|------|---------------|------|----------------|------|
| | | Estimate | SE | Estimate | SE | Estimate | SE |
| Men | TLE | 19.3 | 0.29 | 18.6 | 0.34 | 20.3 | 0.43 |
| | Good chewing ability years | 13.9 | 0.25 | 13.1 | 0.30 | 14.9 | 0.35 |
| | Poor chewing ability years | 5.4 | 0.19 | 5.5 | 0.22 | 5.4 | 0.26 |
| | Proportion of TLE spent with good chewing ability (%) | 72.0 | | 70.4 | | 73.4 | |
| Women | TLE | 23.0 | 0.33 | 22.5 | 0.35 | 24.3 | 0.52 |
| | Good chewing ability years | 15.0 | 0.26 | 14.3 | 0.30 | 16.3 | 0.38 |
| | Poor chewing ability years | 8.0 | 0.24 | 8.2 | 0.27 | 8.0 | 0.39 |
| | Proportion of TLE spent with good chewing ability (%) | 65.2 | | 63.6 | | 67.0 | |

Note: Good chewing ability defined as having the ability to chew the hardest group of food items such as hard dried squid and pickled radish. High education defined as above high school education. (Source: own calculation)

good chewing ability. Those with higher levels of education (above high school) live over 1 year more with good chewing ability and a similar time with poor chewing ability, thereby spending a greater proportion of expected years with good chewing ability. Thus the majority of the extra years of life enjoyed by those with high education compared to those with low education are years with good chewing ability.

Discussion

Previous studies have investigated the association between oral health, morbidity, and mortality. Yet, there is little research exploring the association between oral health and health expectancy. However, because health expectancy is calculated from transitions between different health states and mortality, it is important to show how oral health is associated with health expectancy.

There is evidence of a significant association between health expectancy and number of teeth, with having more teeth being associated with more years in a healthy state for older adults. Older people with 20 or more teeth spend more years disability-free than do individuals with less than 20 teeth, reflecting that the number of teeth is associated with the onset of disability in old

age, and that tooth loss may be an early indication of accelerated aging (Holm-Pedersen et al. 2008). Therefore, having more teeth is related to better physical functioning for older people (Akifusa et al. 2005). However, even though previous studies (Chiu et al. 2016; Nasu and Saito 2006a) show that older people with more teeth live longer than those with less teeth, the difference is not statistically significant for men and women separately. Reasons for this include the smaller sample sizes when stratifying by sex, or that number of teeth are not associated with ADLs but affect limitations earlier in the disablement process (Akifusa et al. 2005).

In agreement with previous findings in the literature demonstrating the association between chewing ability, nutritional status, health status, and mortality incidence among elders (Awano et al. 2008; Nakanishi et al. 2004; Walls and Steele 2004), studies show that having better chewing ability (being able to chew the hardest food items in our study) is significantly associated with higher HLE and longer lives on average (Chiu et al. 2016; Li et al. 2008; Nasu and Saito 2006a). Hence, having better chewing ability is associated with longer total and healthy life expectancy for Japanese and Singaporean elders.

Why is weaker chewing ability associated with lower total and healthy life expectancy? As chewing ability declines, people may have

increasing difficulty chewing foods and, thus, may tend to avoid foods that are difficult to chew (Walls and Steele 2004). As a consequence, people with weaker chewing ability or who experience difficulty chewing may suffer impaired intakes of important nutrients or have a higher chance of undernutrition compared to people with better chewing ability or who experience no difficulty chewing certain foods (Walls and Steele 2004). Undernutrition has been shown to be an independent risk factor for body cell mass, multiple organ failure, disability, life-threatening morbidity, length of hospital stay and costs, and even mortality for older people (Correia and Waitzberg 2003; Omran and Morley 2000; Zuliani et al. 2001). Therefore, better chewing ability is associated with food sufficiency, better nutritional status, higher levels of serum albumin, improved performance of ADLs/IADLs, better general health, lower mortality risk, higher ALE, and better quality of life (Ansai et al. 2007; Kimura et al. 2013; Moriya et al. 2010; Nasu and Saito 2006a; Walls and Steele 2004).

Chiu et al. (2016) shows that chewing ability, rather than number of teeth, is associated with health expectancy, which is consistent with previous research showing that chewing ability, not number of teeth, is associated with the ability to perform ADLs (Akifusa et al. 2005). This is because when tooth loss is present, especially edentulism, dental prosthetic use can help to maintain chewing ability, which is associated with nutritional status (Walls and Steele 2004).

However the current research on oral health and health expectancy is not without limitations. One limitation is that the oral health measures were self-reported, although previous studies have concluded that the self-assessment of number of teeth is valid and reliable, even in older people (Buhlin et al. 2002; Hung et al. 2005; Ueno et al. 2010). Nevertheless another limitation is that there was no assessment of the number of teeth that are functionally in occlusion. Finally, due to the constraints of the software used for calculating health expectancy, no other control variables or confounders were included (e.g., shortened dental arches (Armellini and Von

Fraunhofer 2004; Sarita et al. 2003)), and therefore results may be influenced by unobserved and possibly unknown confounders. Future studies have to consider potential confounders.

It is important to examine the association between health expectancy and different oral health measures, such as chewing ability and number of teeth. There is little previous research exploring the association between health expectancy and different oral health measures in a single study. This is of interest for public health policy to allow a clearer understanding of the importance of better oral health for improving healthy life expectancies, quality of life, and length of hospital stay and costs among elders (Correia and Waitzberg 2003; Omran and Morley 2000). For example, Japan's Long-Term Care Insurance (LTCI) system, launched in 2000 (Yong and Saito 2012), recognized the importance of preventive care (including oral health) for elderly Japanese, and in 2006, included oral health in an amendment introducing a large-scale program of preventive care. This amendment encouraged Japanese elders to participate in activities to improve their motor and oral functions and their nutrition status (Tsutsui and Muramatsu 2007).

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Conclusions and Future Directions

22

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This collection of research on health expectancy from the REVES network refreshes the knowledge gained since the first REVES book, *Determining Health Expectancies*, published in 2003. As well as presenting substantive findings on trends and inequalities in health expectancies from around the world, it includes chapters that also document the newer methodology that has developed, as well as the enormous increase in the use of health expectancies in public policy. Notable among the latter is Healthy Life Years (HLY), the first pan-European health indicator, instituted in 2004 based on questions developed by the Euro-REVES network, and, since that time, supported analytically by REVES members. That a number of other countries, including

Japan (see Chap. 14), Philippines, Singapore, Taiwan (Hsiao et al. 2019), Vietnam, and India (Kerala), have also used the GALI question that underlies HLY, is testament to the pursuit of global harmonisation of measures, one of the main pillars of REVES.

Previous chapters of this book have ended with sections on future directions for research, but predominantly on their specific topic area. In the rest of this chapter we bring these together under three key areas that we see will have growing importance in the next decade, these being: future trends in life and health expectancy; inequalities in health expectancy between population subgroups; and the inter-relationship between different health dimensions.

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Future Trends in Life and Health Expectancy

After reviewing the recent trends in life and health expectancy worldwide, mainly to ascertain the co-evolving trajectories in terms of compression or expansion of disability, or dynamic equilibrium, Chap. 2 raised the question of whether life expectancy would continue to increase in the future. There are strongly differing views in the profession about the future of life expectancy with some expecting it to continue to increase and others being more pessimistic about continuing increases. In fact, there have been periods when the life expectancy for particular countries has stalled, for example, Denmark between 1975 and 1995 for women, and, more recently, a number of European countries have seen life expectancy gains slowing down. Among these is the UK where life expectancy at birth and at age 65 officially stalled in the latest figures from the Office for National Statistics (Office for National Statistics 2019).

However, the question of whether life expectancy will continue to increase is usually raised in terms of countries that have the highest life expectancy at birth. This is the case of France (Le Bourg 2019). The UK has never held this position (Oeppen and Vaupel 2002) and thus the stagnation of its life expectancy does not provide evidence that we are close to the limits of life expectancy. Continuation of the Oeppen and Vaupel graph suggests that maximum life expectancy at birth is continuing to increase at the same rate, with new leaders from Asian countries, such as Hong Kong, Singapore and South Korea.

Why is it important to know what the future trends in life expectancy will be? Firstly, population projections depend on the assumptions about future mortality rates and hence future life expectancy. Such projections are of enormous importance for government departments and businesses to plan for the future numbers of older people. Secondly, future trends in life expectancy are necessary to view alongside trends in health expectancy, although evaluation of current trends in health expectancies are hampered by the binary approach. To appreciate

changes in health of populations fully, the health dimension of health expectancy needs to include a level of severity (see Chaps. 1 and 2). Perhaps the most startling change over the last decades has been the increase in cognitive impairment-free life expectancy (see Chaps. 2 and 17) but it is uncertain whether this is linked to more universal schooling during the last century or to early life health both of which are unlikely to produce similar gains in the future.

Nevertheless, there is little hard evidence that prevention or intervention strategies have reduced unhealthy life or changed the links between aspects of morbidity and mortality that might affect the link between total and healthy life expectancy. Mostly the evidence is from longitudinal observational studies or from microsimulation models demonstrating the effect of scenarios on life and health expectancies (see Chaps. 8, 9 and 10). Microsimulation models that can show the effects of scenarios to reduce risk factors or increase protective factors on future life and health expectancy are particularly useful and could be used more often. Providing evidence of the effect of a risk factor on health alone can be misleading. Most risk factors for ill-health are also implicated in mortality, and it is the delicate balance between the two that determines whether the reduction of a risk factor would indeed result in a compression of morbidity (if the effect on ill-health was greater than the effect on mortality) or in an expansion (if the risk factor had a greater effect on mortality than morbidity). Moreover, most lifestyle factors are risk factors for multiple conditions, therefore their reduction might have a greater overall effect on a global health expectancy such as disability-free life expectancy. Better knowledge of the disabling impact of diseases is also relevant here (see Chaps. 6 and 20) to target optimal treatment of disease to delay the disabling consequences.

It is perhaps relevant here to note that health expectancy, although a population health indicator, might be an appropriate means of highlighting the risks of poor lifestyle factors and health expectancy calculators are beginning to take off. In the future these may be a means of health promotion (see Chaps. 14 and 15).

Inequalities in Health Expectancies Between Population Subgroups

A number of countries appear to have growing inequalities between population subgroups. Inequality at the level of geography (region or countries) has been covered in Chap. 3, gaps in health expectancies between groups defined by various socioeconomic status (SES) measures (education, occupation, deprivation) in Chap. 4, and the well-known inequality in life and health expectancy between men and women in Chap. 11. Specific decomposition methods are also available to quantify the gaps (see Chap. 7). To be actionable for public policies (Chaps. 13 and 14), causal models, preferably using incidence data, can be used to identify the role of both diseases and/or lifestyle risk factors in the disability process (see Chap. 6).

Aggregate level measures of socioeconomic status, such as GDP or wealth, are strongly associated with higher life and health expectancies across countries, thus suggesting the solution would be to equalize the distribution within, and across, countries. However, as for prevention and intervention strategies mentioned earlier, it is not clear that the solution would increase life and health expectancies. Overall targets to increase health expectancies may increase inequalities, as evidenced by exploration of strategies to meet the European Innovation Partnership on Active and Healthy Ageing target of increasing HLY by 2 years between 2010 and 2020 (Jagger et al. 2013). With the greater availability of health expectancies over longer time periods in the European Union and indeed in individual countries, there is a need for developing better methods that can take account not only of potential drivers but that these drivers may themselves be changing, some such as economic crises relatively rapidly.

Although less optimal for assessing trends, longitudinal data does have the ability to unpick the underlying transitions (incidence of ill-health, recovery and state-specific mortality) and therefore can provide evidence of where inequalities are arising (see Chap. 3). However, when considering trends over time, ‘exposure’ levels may

change and the question arises as to whether the comparison is with absolute or relative levels. Education provides a good example as school leaving ages have been raised in a number of countries over time, thus changing the number of years of minimum education. Is it the absolute years of schooling that matters, or the minimum levels for a particular cohort?

There is also a continuing problem with harmonisation of subgroups of SES, with many countries using education (although life tables by education are unavailable in most countries), whilst the UK routinely reports health expectancy by area level deprivation. Certainly at an individual level and for older ages, education provides an exposure that is likely to be completed before the onset of ill-health or disability and therefore is less likely to be subject to reverse causation. Nevertheless, though low education is positively associated with subsequent lower levels of occupation and more disadvantage, the overlaps are not perfect. Composite measure that encompass SES measures across the lifecourse, and therefore allow for social mobility, may be more revealing. Of course, inequalities in health expectancy by SES may reflect health behaviours and lifestyle. Models that incorporate these, as confounders or mediating factors, can reveal where best to target prevention strategies. Current health expectancy software such as IMaCh (Interpolation of Markov Chains) (Lièvre et al. 2003) and SPACE (Stochastic Population Analysis for Complex Events) (Cai et al. 2010) remain somewhat limited in their ability to incorporate many confounders and further development in this area would be welcome.

The Inter-Relationship Between Different Health Dimensions

From Chap. 1 it is clear that no single health dimension can cover all health domains. Moreover, the specific characteristics of instruments may need different adaptations for specific research goals and study designs (see Chap. 12). Several dimensions of health that have a role in

the disablement process or that highlight specific aspects of ill-health and disability have not yet been used to their full potential. A good example is frailty that has both practical clinical implications as well as the potential to inform public health interventions.

A further gap is our understanding of the role of pain in the disablement process (Chap. 16). In contrast to physical health, mental health has been more neglected, although there is a growing integration of mental and physical health in healthy life expectancy, especially cognitive health of older people. This offers an improved approach, not only to defining healthy life, but especially towards formal and informal care planning in ageing populations (Chaps. 10 and 17). Ageing and societal changes create opportunities for new developments such as the extension of the concept from health towards wellbeing and happiness (Chap. 19). Changes in societal expectations strengthen the need for outcome-oriented care with a return of investment in health care. A more systematic inclusion of health expectancies as outcome measure for health care systems will require adaption of the measures to address this and to be more actionable in clinical settings (Chap. 15). Outcome-orientated policy is not confined to health and social care and Chap. 18 begins this in comparing health expectancy with working life expectancy. Nevertheless, there is room to integrate health fully into working life expectancies, to produce healthy working life expectancies that address more directly the potential to extend working lives.

This book documents past, present, and future trends in health expectancies and exposing gaps both between and within countries. We hope this book provides a solid resource for those working in academia, industry, government or policy who are interested in extending healthy life expectancy, whether they are new to the topic or established researchers in the field.

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