RESEARCH PAPER

Successful ageing from old to very old: a longitudinal study of 12,432 women from Australia

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Abstract

Objectives: We examined the development of disease and disability in a large cohort of older women, the extent to which these conditions exempt them from being classified as successful agers and different trajectories of disease, disability and longevity across women's later life.

Methods: We used survey data from 12,432 participants of the 1921–26 birth cohort of the Australian Longitudinal Study of Women's Health from 1996 (age 70–75) to 2016 (age 90–95). Repeated measures latent class analysis (RMLCA) identified trajectories of the development of disease with or without disability and according to longevity. Bivariate analyses and multivariable multinomial logistic regression models were used to examine the association between participants' baseline characteristics and membership of the latent classes.

Results: Over one-third of women could be considered to be successful agers when in their early 70s, few women could still be classified in this category throughout their later life or by the end of the study when they were in their 90s (∼1%). RMLCA identified six trajectory groups including managed agers long survivors (9.0%) with disease but little disability, usual agers long survivors (14.9%) with disease and disability, usual agers (26.6%) and early mortality (25.7%). A small group of women having no major disease or disability well into their 80s were identified as successful agers (5.5%). A final group, missing surveys (18.3%), had a high rate of non-death attrition. Groups were differentiated by a number of social and health factors including marital status, education, smoking, body mass index, exercise and social support.

Conclusions: The study shows different trajectories of disease and disability in a cohort of ageing women, over time and through to very old ages. While some women continue into very old age with no disease or disability, many more women live long with disease but little disability, remaining independent beyond their capacity to be classified as successful agers.

Keywords: *successful ageing, longitudinal data, latent patterns, older women, Australia*

Key points

- Successful ageing across later life.
- RMLCA.
- Trajectories of disease, disability and longevity across women's later life.

Introduction

There is great interest in the positive potential for ageing well, especially into advanced old age. The concept of successful ageing was introduced as early as 1961 [1], well before the emergence of significant numbers of very old people with high prevalence of disease and multi-morbidity [2]. Rowe and Kahn [3] defined successful ageing as the maintenance of physical and cognitive well-being in later life, with no major disease or disability, and high levels of engagement in life including productive activities and interpersonal relations. This premium state emphasises the positive potential for ageing well and contrasts with 'usual ageing' with higher risk and disability, and 'pathological ageing' affected by major diseases, and importantly, allows for differentiation of 'pure ageing' from disease [4].

Successful ageing has been operationalized in numerous ways [5], with the prevalence of successful ageing among people aged 65 years and over generally estimated at around 20–25% [6–9]. However, estimates range widely depending on the definition and the population groups studied, with a review of 69 studies citing prevalence ranging from 0.04% to 91.7% [8]. Where objective criteria such as disease and disability were applied, the average prevalence was 26%, but when participants were asked to rate their own successful ageing, the prevalence was 71.3%. In larger population-based studies from European countries, the USA and Canada, prevalence of successful ageing ranged from 8.55 to 37.2% among adults aged 65 years and older [10–12].

Pooled results from 22 studies that included disability/physical function in their definitions of successful ageing estimated the proportion of successful agers at 27.2% (SD: 18.7; median: 20.8, range: 0.4–63.0), with prevalence inversely related to the minimum age of the study samples [5]. Other researchers have found very low prevalence of successful ageing among the very old [6, 13]. Across most studies, age is the strongest and most consistent predictor of successful ageing. Few studies have examined how successful ageing unfolds over time in a large population of very old people. Moreover, most studies do not take into account the effect of early mortality, which may overestimate successful ageing [5].

We seek to address this knowledge gap by examining how disease and disability develop among a large cohort of older women, the extent to which these conditions exempt them from being classified as successful agers and alternative trajectories, which differentiate disease, disability and longevity across women's later life. We hypothesise that decreasing proportions of women will meet criteria for successful ageing as women reach advanced age and that distinctly different groups of women can be identified according to when they developed disease and disability, and their age at death.

Data and methods

Data

We used survey data from 12,432 participants of the 1921–26 birth cohort of the Australian Longitudinal Study of

Women's Health (ALSWH) between 1996 (age 70–75 at baseline) to 2016, and their death records obtained from the National Death Index. Participants were randomly sampled from the Medicare Australia (national universal health insurance) database with oversampling of women from rural and remote areas by a factor of two [14]. The current study included six-waves of 3-yearly surveys (1996–2011) and eight waves of 6-monthly surveys (2012–16). Details about the ALSWH have been published [15, 16], and surveys, data books and other details are available at www.alswh.org.au.

Measures

Baseline demographic, social and health factors

Demographic factors included area of residence (major cities, remote/inner/regional areas), country of birth (Australia, overseas), educational qualification, marital status and difficulty in managing income. Social support was assessed using the Duke 10-item social support score (0–30). Health risk factors included body mass index (BMI) (underweight <18.5/accepted 18.5–24.9, overweight 25.0–30.0, and obese) [17], smoking and vigorous exercise lasting for 20 minutes/more in a normal week. Missing values were replaced by available values from Survey 2 (1999).

Self-reported chronic disease was ascertained at each survey point (except 6-monthly waves). Participants were asked 'Have you ever (or in the last 3 years) been diagnosed with or treated for: arthritis, heart problem, diabetes, asthma or cancer (excluding skin cancer)?' Arthritis was not captured in the baseline survey, instead arthritis at Survey 1 was estimated by combining reported symptoms of stiff or painful joints (sometimes/often) at Survey 1 and self-reported doctor diagnosed arthritis in Survey 2. By 2011, only a small proportion of women were disease free, and these data were no longer collected. Conditions were considered as enduring.

Physical functioning scores were determined at each survey point using the Medical Outcomes Study Form-36 (SF-36). The raw scores were linearly transformed to produce subscale scores ranging from 0 to 100 (with higher scores indicating better health). The subscale scores were categorized considering a cut-off point ≤ 40, with scores above this threshold considered to reflect better functional capacities.

Need of regular help with daily tasks

At each survey point, participants were asked 'Do you regularly need help with daily tasks because of long term disease, disability or frailty?' (Yes/No).

Successful ageing

At each survey point, successful ageing was determined using following three indicators: (i) no arthritis, heart problem, diabetes, asthma or cancer (excluding skin cancer); (ii) physical functioning score ≥ 40 and (iii) no need of regular help with daily tasks because of long-term disease, disability or frailty.
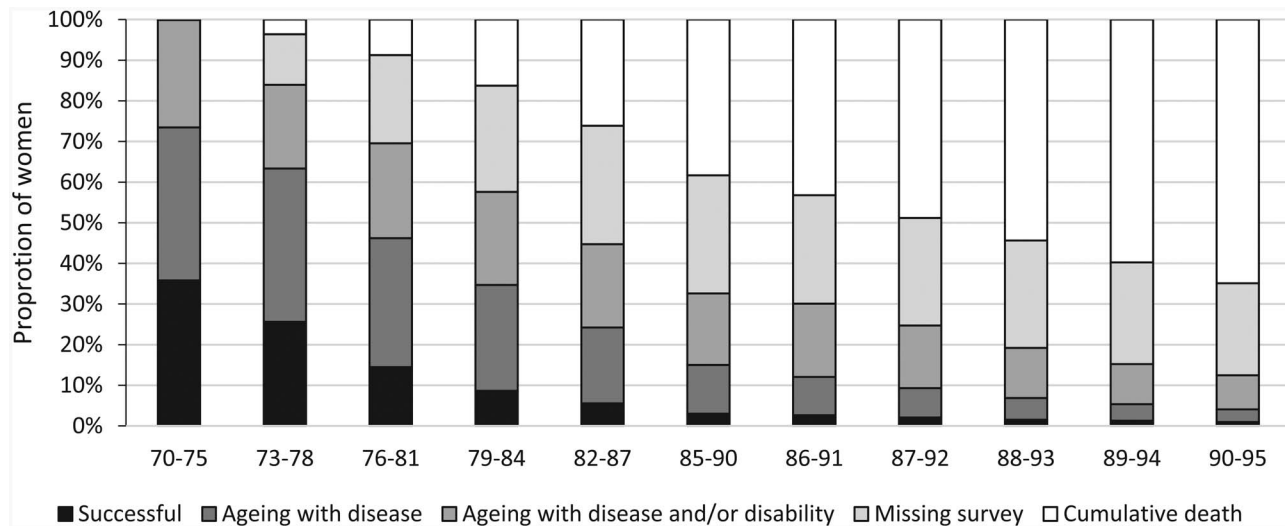
Figure 1. Distribution of the sample by indicator variables (ageing status) over the period 1996–2016 ($n = 12,432$).

Longitudinal analysis

Women were assigned to five mutually exclusive categories at each 3-yearly survey point until 2011 and then for each year up to 2016 (taking data from the first 6-monthly survey in each year). The categories were (i) successful ageing, (ii) ageing with disease, (iii) ageing with disease and/or disability, (iv) missing surveys and (v) deceased. Categories 4 and 5 did not apply to baseline data but were included to deal with death and non-death attrition, which are often problems in the analysis and interpretation of longitudinal data from older cohorts.

Repeated measures latent class analysis (RMLCA) was used to identify distinct trajectories of ageing experience over time. This technique captures time-dependent patterns for different subgroups without imposing any restriction on the shape of the relationship over time [18]. A one-class model served as a comparative baseline for models with more than one class. In order to select the optimum number of classes, a sequence of models with two classes, three classes, up to k classes was fitted until the best model was observed based on guidelines of fit indices (Akaike information criterion (AIC), Bayesian information criterion (BIC), the likelihood ratio G^2 diagnostics and value of entropy) and interpretability of the classes. [19]. Participants were classified into mutually exclusive latent classes based on the maximum posterior probability.

Associations between participants' baseline characteristics and membership of the latent classes were explored first using chi-square test and then multi-variable multinomial logistic regression models, reported as odds ratios (ORs) and 95% confidence intervals (CI). Variables in the model were included by a combination of forward stepwise selection and change in estimate criterion [20]. The likelihood ratio test was used to assess whether each step made any significant changes in the whole model. The Hosmer and Lemeshow goodness-of-fit test was used to assess fit of the final model. Statistical tests were two-sided, $P < 0.05$. Analyses were conducted using SAS, version 9.4 (SAS Institute, Inc., Cary, NC) with RMLCA performed using PROC LCA.

This research has approval from the University of Newcastle Human Research Ethics Committee.

Results

Of 12,432 participants at baseline (1996), 67% had died by the end of the study (2016). Non-death attrition increased over time with only 1,069 out of the 4,064 surviving women (26%) completing a survey in 2016 (Figure 1). Few women met all three criteria for successful ageing by 2016. Major chronic diseases, in particular arthritis, were the key exclusions from successful ageing, but the contribution of 'disease', 'poor physical function' and 'need for help in daily tasks' to these exclusions increasingly overlapped over time (Figure 2). For example, in 1996, 67.3% of the women not classified as successful agers were excluded on the basis of disease alone but not due to disability or the need for help with daily tasks. By 2011, this proportion was only 46.3% with most of those with disease also having disability and/or needing help with daily tasks. At both time points, few women had disability without disease.

We performed eight RMLCA models with 1–8 classes. As the number of classes increased, AIC and BIC values continued to decline but only moderately after the six-class model (Figure 2; Supplementary Table 1). Although AIC and BIC values of the models with seven and eight classes were lower than the six-class model, the additional classes were very small and also failed to represent meaningful groups. Thus, a six-class model was selected and interpreted. Furthermore, the average posterior probability for each of the
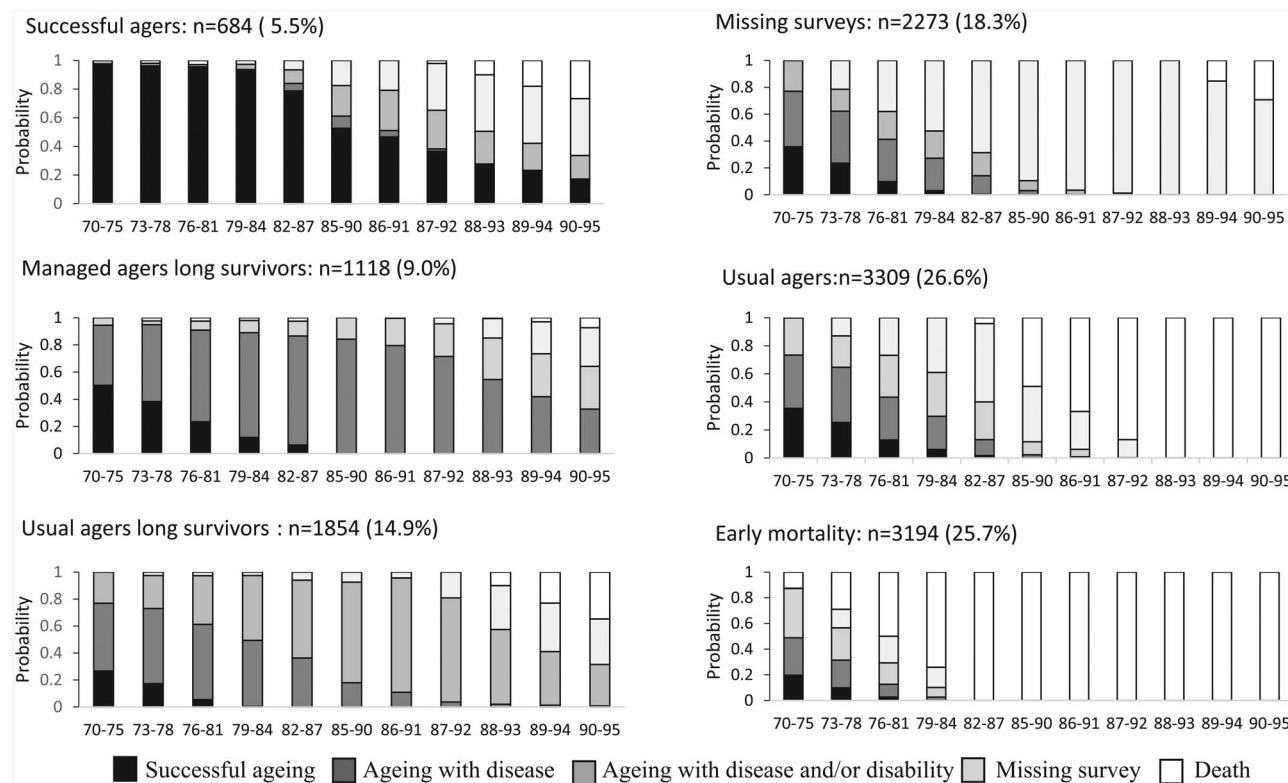
Figure 2. Different patterns of ageing experience among the participants of the Australian Longitudinal Study on Women's Health (ALSWH) from 1996 to 2016 (Note: x-axis represents age of the cohort at the 3-yearly ALSWH survey points until 2011 and then for each year up to 2016 (taking data from the first 6-monthly survey in each year)).

six classes was 0.97, demonstrating that participants could be confidently classified into distinct latent classes [18].

Class 1: successful agers

Only 5.5% (684) of the 12,432 women were classified as ageing successfully, having the highest chance of surviving longer without experiencing chronic disease, disability or need for help. Most of the women in this group were classified as successful agers until 2008 (age 82–87), but thereafter their chances of reporting chronic conditions and/or disability as well as non-response to subsequent surveys sharply increased until the end of the study.

Class 2: managed agers long survivors

Approximately 9% (1,118) of all women were in this group, with most surviving until 2016 but with chronic disease. Almost half were successful agers at baseline, but over time, increasing proportions had both disease and disability, and from 2013 (age 87–92), increasing proportions did not return a survey.

Class 3: usual agers long survivors

Comprised 14.9% (1,854) of women who could be described as having had a very high chance of surviving longer but with chronic disease and disability. While almost

a quarter of this group were successful agers at baseline, after 2002 (age 76–81), very few were.

Class 4: missing surveys

Around 18.3% (2,273) of women failed to respond to follow-up surveys, but they had similar survival patterns to the successful agers and the usual agers. In terms of disease and disability, this group resembled 'usual agers long survivors' up to 2005 (age 79–84), with a higher rate of missing surveys observed thereafter.

Class 5: usual agers

Over one-quarter (26.6%, $n = 3,309$) of women were classified as 'usual agers'. Almost one-third were classified as successful agers at baseline, but their chances of reporting chronic disease and/or disability sharply increased in subsequent surveys, as did their likelihood of non-response. In contrast to 'usual agers long survivors', the probability of death of 'usual agers' dramatically increased after 2008 when they were aged over 82, and all had died by 2014.

Class 6: early mortality

Around one-quarter (25.7%, $n = 3,194$) of women had died by 2008, with the majority reporting chronic disease and/or disability at baseline.

Baseline characteristics of latent classes

We compared the latent classes in terms of baseline demographic and lifestyle factors, with the usual agers class as the reference group (Table 1).

- Women in regional/inner/remote areas were less likely than women in major cities to be in the missing surveys class (OR = 0.84, 95% CI: 0.74–0.96).
- Women born overseas, compared to those born in Australia, were less likely to be usual agers long survivors (OR = 0.82, 95% CI: 0.70–0.96) but more likely to be in the missing surveys class (OR = 1.27, 95% CI: 1.10–1.47).
- Being widowed/divorced/separated/never married was associated with a lower odds of belonging to any of the latent classes (except early mortality) ($P < 0.05$).
- Women who had difficulty managing on their income some/all of the time were less likely to be members of managed agers long survivors (OR = 0.76, 95% CI: 0.61–0.91) and more likely to be members of the early mortality class (OR = 1.15, 95% CI: 1.01–1.30).
- Women with less than high school education had 41%, 42% and 23% decreased odds of being a member of the successful agers, managed agers long survivors and usual agers long survivors, respectively ($P < 0.05$).
- Smokers were 30% more likely to be in the early mortality group and less likely to be a member of any other class other than the usual agers.
- Compared with participants having underweight/normal BMI, overweight and obese women had decreased odds of being included in the successful agers and managed agers long survivors classes and increased odds of being usual agers long survivors. Overweight women had 24% lower odds of being in the early mortality class.
- Compared with those who engaged in vigorous exercise once or more per week, those who did not were more likely to be in the early mortality class and less likely to be successful agers or managed agers long survivors ($P < 0.05$).
- Higher social support score was associated with increased odds of being a member of the usual agers long survivors, managed agers long survivors, successful agers.

Discussion

We studied the development of disease and disability in a large cohort of older women as they age, identifying six distinct trajectories related to ageing. We performed RMLCA, which has the potential to enhance our understanding of the varying patterns of ageing experience across later life. This technique is a person-centred analytic approach that provides greater insights about individual ageing experience over time than traditional variable-centred analysis. Whilst over one-third of the women could be considered successful agers when in their early 70s, few women could still be classified in this category throughout later life (~1%). On RMLCA, 5.5% were classed as successful agers, and these women were more likely to be married and to have good health behaviours, were better educated and had better social support. The largest group identified was usual agers (27%), of whom a third were successful agers at baseline (aged 70–75) but were increasingly likely to report disease and disability or be non-responders thereafter and with particularly high death rates after age 82. Almost the same proportion (26%) was defined as early mortality, all of this group having died by age 82–87. They were more likely to have difficulty managing on their income, to smoke or have smoked, or to never participate in vigorous exercise. They were less likely to be overweight and had higher social support scores. Two other groups were identified based on the development of disease with or without disability, and according to their longevity, with a further group being identified as having a high rate of non-death attrition from the study.

Managed ager long survivors were less likely to be widowed, to have difficulty managing on income, to have less than higher school certificate, to smoke or have smoked, to be overweight or obese or to never participate in vigorous exercise. They were more likely to have higher social support scores. Usual ager long survivors were less likely to be born overseas, to live in remote/inner/outer regional areas, to be widowed, to have less than higher school certificate, to smoke or have smoked. They were more likely to be overweight or obese and had higher social support scores. Women in the missing surveys group were more likely to born overseas but less likely live in remote/inner/outer regional areas, to be widowed, to smoke or have smoked and to be obese.

The study shows the heterogeneity of ageing experiences across later life. The findings also fit well with Rowe and Kahn's conceptual model that, over time and with increasing age, many people will move from a high functioning/low-risk state to states of disease, disability and ultimately death [21, 22]. Few other studies have looked at the change in successful ageing over time or to very old ages. Mclaughlin et al. [9] estimated the prevalence of successful ageing at 11.9% across four data points for the US Health and Retirement Study. Based on these low prevalences, researchers consider the strict definition of successful ageing to be too narrow and to set unrealistic and unachievable expectations of older populations [23].

Some studies of centenarians have classified people as 'escapers' who have no chronic age-associated diseases, 'delayers' who developed disease after age 80 and 'survivors' who have lived to very old age despite earlier disease onset. For example, the Georgia Ageing Study [24] classified 32% of their centenarians as escapers, 36% as delayers and 43% as survivors. In most of these centenarian studies, however, people were recruited when they were already very old, usually over 90 years of age. These studies therefore lack data on the dynamics of change at younger ages. They also lack the ability to compare these people's younger years with those of people who did not achieve such longevity.

In conducting this analysis, we used a simplified definition of successful ageing. We only used disease, disability and need for help with daily tasks as exclusions. As Rowe and Kahn [21] note, successful ageing is more than absence

Table 1. OR and 95% CI of the membership of different latent patterns on the baseline characteristics (*n* = 10,062).

Covariates	*N* = 12,432, %	Usual ager	Successful ager	Managed ager, long survivors	Usual agers, long survivors	Missing surveys	Early mortality
Area of residence							
Major cities	41.6	Ref:					
Remote/inner/outer	58.4	1.00	1.01 (0.84, 1.22)	0.91 (0.78, 1.06)	0.89 (0.78, 1.00)*	0.84 (0.74, 0.96)	1.03 (0.92, 1.15)
Country of birth							
Australia	77.4	Ref:					
Overseas	22.6	1.00	0.91 (0.73, 1.14)	0.92 (0.76, 1.10)	0.82 (0.70, 0.96)*	1.27 (1.10, 1.47)*	0.92 (0.80, 1.05)
Marital status							
Married/de facto	56.8	Ref:					
Widowed/others[a]	43.2	1.00	0.68 (0.56, 0.82)*	0.76 (0.65, 0.88)*	0.87 (0.76, 0.99)*	0.83 (0.73, 0.94)*	1.05 (0.94, 1.17)
Managing income							
Easy/not too bad	73.5	Ref:					
Difficult some/all time	26.5	1.00	0.81 (0.64, 1.01)	0.76 (0.63, 0.91)*	1.11 (0.96, 1.27)	1.13 (0.99, 1.29)	1.15 (1.01, 1.30)*
Highest qualification							
≥Higher school certificate	27.3	Ref:					
<Higher school certificate	72.7	1.00	0.59 (0.48, 0.71)*	0.58 (0.49, 0.69)*	0.77 (0.67, 0.89)*	1.11 (0.96, 1.27)	1.01 (0.88, 1.15)
Smoking status							
Never smoked	62.4	Ref:					
Used to/occasionally/regular	37.6	1.00	0.62 (0.51, 0.76)*	0.69 (0.59, 0.81)*	0.78 (0.68, 0.89)*	0.74 (0.63, 0.84)*	1.30 (1.16, 1.45)*
BMI							
Under weight/accepted	53.2	Ref:					
Over weight	33.6	1.00	0.56 (0.46, 0.69)*	0.71 (0.60, 0.83)*	1.24 (1.09, 1.43)*	0.97 (0.84, 1.10)	0.76 (0.67, 0.86)*
Obese	13.2	1.00	0.28 (0.19, 0.41)*	0.44 (0.33, 0.58)*	1.55 (1.29, 1.85)*	0.82 (0.68, 1.00)*	1.07 (0.91, 1.25)
Vigorous exercise[b]							
Once or more in a week	22.1	Ref:					
Never	77.9	1.00	0.75 (0.61–0.92)*	0.69 (0.59–0.82)*	0.99 (0.85–1.15)	1.07 (0.92–1.25)	1.45 (1.28–1.68)*
Social support score[c]	29 (27–30)	1.00	1.06 (1.02–1.10)*	1.07 (1.03–1.09)*	1.04 (1.01–1.06)*	1.00 (0.98–1.02)	0.98 (0.97–1.00)*

[a]Others include divorced/separated/never married. [b]Lasting for 20 minutes or more. [c]Median score with inter-quartile range and Ref., Reference. *Indicates significant at *P* < 0.

of disease and the maintenance of functional capacities. We should also have included measures of engagement with life and cognition. The addition of these variables would potentially further reduce the size of the successful ageing group. Importantly, we did not include a measure of dementia, which is a condition of high prevalence and concern among old individuals. From other analysis of ALSWH data, few women will have dementia who do not also have other comorbid conditions, disability or need for help [25]. We also did not include depression as it is also very common among women with disease and disability [26]. We did model non-death attrition in the form of missing surveys, and it is possible that these women had higher rates of morbidity over time and potentially more problems with cognition.

A more common trajectory was managed ageing where women lived long, with chronic conditions, but little disability. As Bowling and Dieppe [27] note, it is not possible for a large proportion of the population to age without disease. In Australia, around 87% of people aged 65 years and over have one or more of the eight most prevalent conditions namely arthritis, asthma, back pain, cancer, cardiovascular disease (CVD), chronic obstructive pulmonary disease (COPD) diabetes and mental health conditions [28]. Burns *et al*. [29] suggested that chronic disease is a normative part of the ageing process and should not be used to define ageing well. In keeping with this stance, other studies demonstrated

discrepancies between the objective operationalization of successful ageing and the subjective perspective expressed by older people [30]. This is known as the ageing paradox [31].

In recognition of the diversity of needs across later life, the World Health Organization has developed a goal of 'healthy ageing' as a 'process of developing and maintaining the functional ability that enables well-being in older age'. Our results underscore the inclusion of very old people who develop disease, with a goal to reduce the onset of disability, and very old people who develop disability, to meet their needs for care and assistance. Healthy ageing therefore considers the dynamic interaction between a person's intrinsic capacity, including chronic disease and disabilities, and the support provided by their extrinsic environment. The balance between these factors will change over time as a person ages, with different trajectories of physical capacity arising depending on the balance between adversity, resistance, reserves and other resources, and physical ability also changing depending on the external environment and availability of external supports. The concept of 'healthy ageing' changes late life goals from ageing without disease or disability, to an emphasis on their capacity for community participation, social interaction and enjoyment. Healthy ageing is inclusive of those with greater levels of need, allowing for management of chronic illness and access to care in later life. Incorporating objectives for better and integrated management of chronic conditions, prevention of disability

for those with disease, environmental supports and care for older people is an essential response to ageing. This approach is crucial if we are to meet the needs of the many people who live long but with some disease and disabililty.

Conclusions

The later period of life is often characterized in terms of increasing burden of disease and disability, decline in physical function and increased needs for health and social care. The successful ageing paradigm emphasizes the potential for people to age successfully, with fewer health needs and limitations and less reliance on care. However, as shown by this and many other studies, there is also a great heterogeneity of ageing experience. In very old age, the majority of people do not fit a definition of successful agers, despite living long and without disability.

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