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Contribution of chronic conditions to gender disparities in health expectancies in Belgium, 2001, 2004 and 2008

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Background: We aimed to investigate the contribution of chronic conditions to gender differences in disability-free life expectancy (DFLE) and life expectancy with disability (LED) in Belgium in 2001, 2004 and 2008. **Methods:** Data on disability and chronic conditions from participants of the 2001, 2004 and 2008 Health Interview Surveys in Belgium were used to estimate disability prevalence by cause using the attribution method. Disability prevalence was applied to life tables to estimate DFLE and LED using the Sullivan method. Decomposition techniques were used to assess the contribution of mortality and disability and further of causes of death and disability to gender disparities in DFLE and LED. **Results:** Higher LE, DFLE and LED were observed for women compared with men in all years studied. A decrease in the gender gap in LE (2001: 5.9; 2004: 5.6; 2008: 5.3) was observed in our cross-sectional approach followed by a decrease in gender differences in DFLE (2001: 1.9; 2004: 1.3; 2008: 0.5) and increase in LED (2001: 4.0; 2004: 4.4; 2008: 4.8). The higher LED in women was attributed to their lower mortality due to lung/larynx/trachea cancer, ischaemic heart diseases, and external causes (2001 and 2004) and higher disability prevalence due to musculoskeletal conditions (2008). Higher DFLE was observed in women owing to their lower mortality from lung/larynx/trachea cancer, ischaemic heart diseases, digestive cancer and chronic respiratory diseases. **Conclusion:** To promote healthy ageing of populations, priority should be given to reduce the LED disadvantage in women by targeting non-fatal diseases, such as musculoskeletal conditions.

Introduction

The longer female life expectancy (LE) observed worldwide does not necessarily mean that women live longer in better health than men. In most countries, the female mortality advantage is offset by a morbidity disadvantage: women tend to live more years in poor health than men, also known as the health-survival paradox.[1,2] Several hypotheses have been proposed to explain this paradox, which includes biological, behavioural and social gender differentials.[1]

With population ageing, LE is no longer sufficient to assess population health. Health expectancies (HEs) combine morbidity and mortality in a single indicator.[3,4] HEs can be defined based on various health dimensions (disease, disability, self-perceived health).[5] Disability-free LE (DFLE) is one of the most commonly used measure, representing how many years an individual is expected to live without disability. LE with disability (LED) is then calculated as the difference between LE and DFLE.[6] HEs have been previously used to better understand the male–female health-survival paradox.[2,6,7]

The gender gap in DFLE and LED can be partitioned into two components: (i) the mortality effect, when the gap is attributed to differences in mortality and (ii) the disability effect, when the gap is due to disparities in disability. These differences can be decomposed by cause, reflecting how much each cause of death and cause of disability contributes to gender differences in DFLE and LED.[8]

Although few studies used decomposition techniques to assess the contribution of mortality and disability,[2,8] and of causes of death and disability to gender disparities in HE,[8] the time trends of these differences have not been previously investigated. Looking at changes in gender disparities in DFLE and LED over time can be useful to better understand the underlying mechanisms contributing to these differences.

Therefore, the aim of this study was to investigate the contribution of selected chronic conditions to gender differences in DFLE and LED in Belgium and to compare these differences over time (2001, 2004 and 2008).

Methods

Data

Two different data sources are required for the decomposition of differences in DFLE and LED by cause: disability and mortality data by cause.

Disability data by cause

Self-reported disability and chronic conditions from individuals aged ≥15 years who participated in one of the Health Interview Surveys (HIS) in Belgium in 2001 ($N = 10\,156$), 2004 ($N = 11\,220$) or 2008 ($N = 9651$) were used to obtain the disability prevalence by cause. The HIS are national household surveys representative of the Belgian population, selected with a multistage design. The response rate varied from 55% in 2008 to 61% in 2001 and 2004. The sample included older individuals living in nursing homes and homes for the elderly (2001 = 30; 2004 = 345; 2008 = 321) and proxy interviews (2001 = 437; 2004 = 1148; 2008 = 1251) were allowed. Sampling

weights were included in the analysis to take into account the sampling design. More information about the HIS methodology can be found elsewhere.[9]

Disability was defined based on six activities of daily living (ADL)—transfer in-and-out of bed, transfer in-and-out of chair, dressing/undressing, washing hands and face, feeding and using the toilet—and mobility limitations. Disability was considered present in individuals who reported some difficulty, a lot of difficulty, or inability to perform the task by him/herself to at least one ADL question or who were unable to walk 200 m or more without stopping or severe discomfort.

The disability and chronic conditions questions were selected based on their availability in the three HIS. In total, 28 496 individuals with complete data on disability and chronic conditions were included in the analysis (Supplementary file S1).

Mortality data by cause

Abridged life tables with 5 years age interval for 2001, 2004 and 2008 in Belgium were obtained from Statistics Belgium.[10] Causes of death by age group and gender were obtained from the death certificates and extracted from the mortality register[11] and were classified according to the International Statistical Classification of Diseases and Related Health Problems, 10th Revision.[12] Supplementary file S2 shows the definition of chronic conditions or groups and corresponding disability and mortality causes.

Statistical analysis

Age-adjusted cause-specific mortality rates and age-adjusted contribution of chronic conditions to the disability prevalence were estimated using direct standardization,[13] with the total 2004 Belgian population as standard.

To estimate the disability prevalence by cause using cross-sectional data, the attribution method was used.[8,14,15] Briefly, the method aims to attribute disability cases reported in a survey to self-reported chronic conditions, taking into account multimorbidity and that disability can be present in absence of chronic conditions (background).[8,14,15] The background can represent the effect of age-related losses in functioning, medical and non-medical causes not included in the analysis, and underreported and undiagnosed diseases/conditions. The method is based on the binomial additive hazard model.[15]

LE was estimated using standard life tables for the Belgian population for 2001, 2004, and 2008 by gender. DFLE and LED were estimated using the Sullivan method,[16] which uses the age-specific disability prevalence to divide the number of person-years into years with and without disability in the life table.

Two families of decompositions were used[8,17]: first, the gender gap in DFLE and LED was partitioned into (i) mortality effect, i.e. difference in the number of person-years lived with and without disability due to the gender gap in mortality; and (ii) disability effect, i.e. difference in the number of person-years lived with and without disability due to the gender gap in the disability prevalence. Next, these differences were decomposed by causes of death and disability.

All analyses were carried out in R, version 3.2.3.[18] The attribution[14] and decomposition[17] tools developed by Nusselder and Looman[8] were used to obtain the disability prevalence by cause and the decomposition of gender differences in DFLE and LED by kind of effect and by cause, respectively.

Results

Highest mortality rates were observed for 'other diseases' and cardiovascular diseases (ischaemic heart diseases, stroke and other) in men and women, and for lung/larynx/trachea cancer in men. Men showed higher mortality rates for all diseases, except for diabetes, mental, neurological and musculoskeletal disorders. The lowest mortality rates were observed for mental and musculoskeletal disorders. A decreasing trend over time in mortality was observed for chronic and acute respiratory diseases (only men), lung/larynx/trachea cancer (only men), cardiovascular diseases and 'other diseases'. Conversely, an increasing trend in mortality was observed for Alzheimer/dementia and lung/larynx/trachea cancer (only women) (figure 1).

Background, arthritis/back pain/osteoporosis, and chronic respiratory diseases were the main causes of disability in men and women in all 3 years. A higher contribution of background, arthritis/back pain/osteoporosis, stroke (2004, 2008), diabetes (2004) and depression (2004, 2008) was observed among women. While an increasing trend over time was observed for background, the opposite was observed for arthritis/back pain/osteoporosis and chronic respiratory conditions (figure 2). Musculoskeletal conditions, other diseases and chronic respiratory diseases were the most common conditions (Supplementary file S3).

For 15-years old men, LE increased by 1.6 years (2001: 60.5; 2004: 61.4; 2008: 62.1), DFLE increased by 0.7 years (2001: 54.1; 2004: 54.9; 2008: 54.8) and LED increased by 0.9 years (2001: 6.4; 2004: 6.4; 2008: 7.3). For women, LE increased by 1 year (2001: 66.4; 2004: 67.0; 2008: 67.4), DFLE decreased by 0.7 years (2001: 56.0; 2004: 56.2; 2008: 55.3) and LED increased by 1.7 years (2001: 10.4; 2004: 10.8; 2008: 12.1). In all the 3 years women showed higher LE, DFLE and LED than men. While the gender gap in LE (2001: 5.9; 2004: 5.6; 2008: 5.3) and DFLE (2001: 1.9; 2004: 1.3; 2008: 0.5) showed a decreasing trend over time, the gender gap in LED (2001: 4.0; 2004: 4.4; 2008: 4.8) increased (table 1).

Women lived longer without disability mainly due to their lower mortality compared with men. Nonetheless, for LED a change in the pattern over time was observed: although the mortality difference between men and women showed a modest reduction in the study period (0.2 years), the gender disparity in the disability prevalence showed a substantial increase (1 year). The higher disability prevalence in women compared with men almost nullified the mortality advantage of women in 2008, resulting in gender difference of only 0.5 years in DFLE, compared with 1.9 years in 2001. For LED, the gender differentials in mortality were almost constant over time, whilst the increase in the gender gap in disability (higher female prevalence in all years) resulted in an increase in the gender disparities in LED from 4.0 years in 2001 to 4.8 years in 2008 (table 1).

Higher DFLE in women was attributed to their lower mortality rates from external causes, lung/larynx/trachea cancer, ischaemic heart diseases, digestive cancer and chronic respiratory diseases. Most causes of death showed a decreasing trend in the gender mortality differential, except for diabetes and Parkinson/epilepsy, which showed a stable trend, and digestive cancer, which showed a small increase over time for DFLE. For the disability causes, women showed higher disability prevalence than men due to arthritis/back pain/osteoporosis and background in all years, with a decreasing trend over time. Other important contributors to the increase in the female disability disadvantage over time were other diseases, depression and stroke (table 2).

Women lived longer than men with disability owing to their lower mortality from lung/larynx/trachea cancer, ischaemic heart diseases and other diseases. Similar to the mortality differential in DFLE, a reduction in the gender gap in LED in all causes of death was observed, except for other cardiovascular diseases, which showed constant gender difference; and digestive cancer, which increased slightly the gender gap over time. By definition, the results of the contribution of chronic conditions to gender differences in LED due to changes in the disability prevalence are the same as for DFLE, but with opposite direction (table 2).

Discussion

To our knowledge, this is the first study to assess the contribution of causes of death and disability to gender differences in HEs over time.

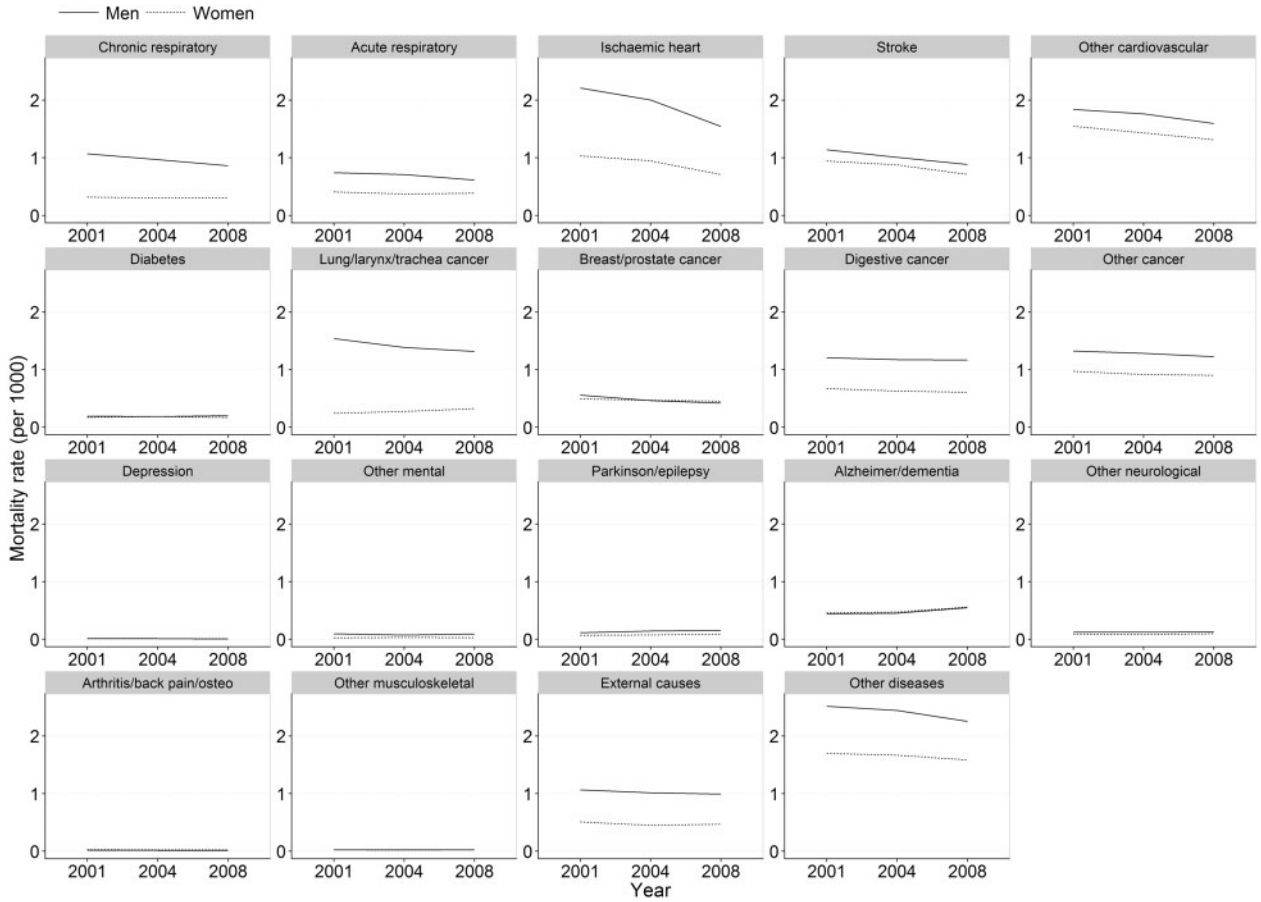

Figure 1 Age-adjusted cause-specific mortality rates (per 1000). Belgium, 2001, 2004 and 2008

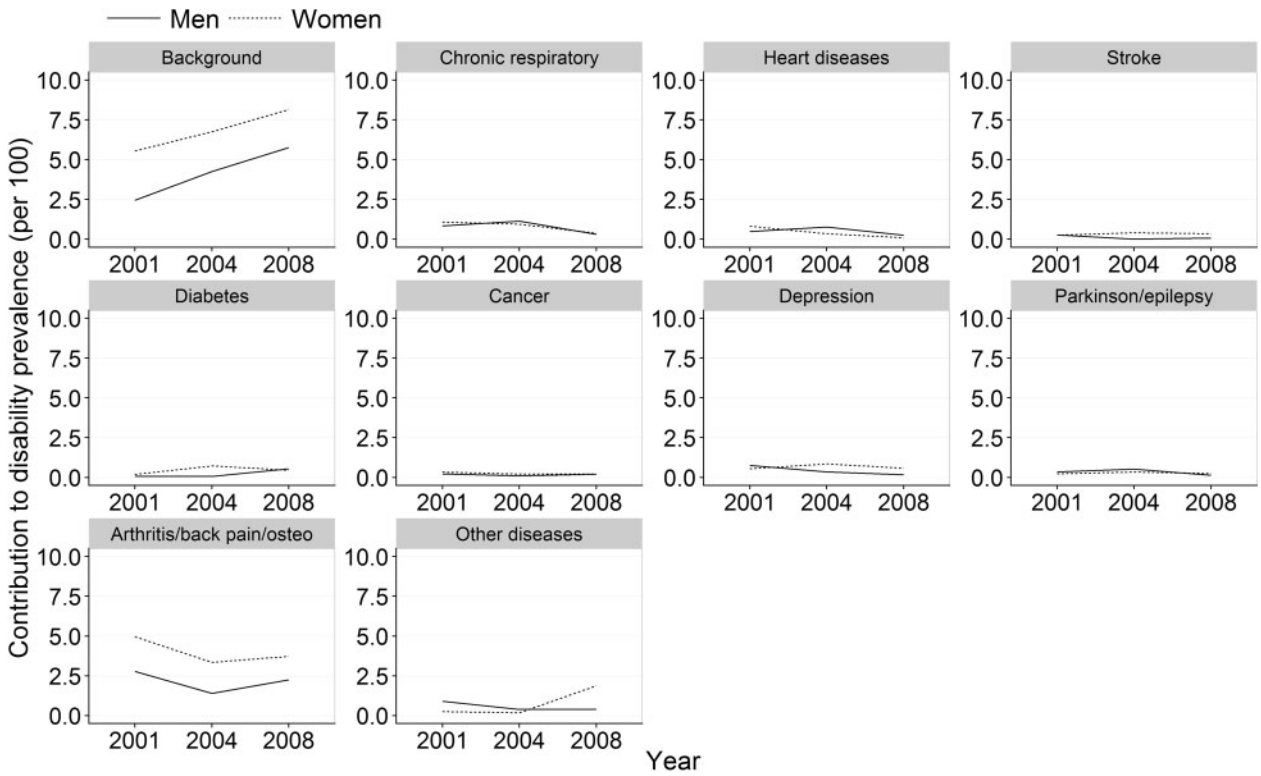

Figure 2 Age-adjusted contribution of chronic conditions and background to the disability prevalence. Belgium, 2001, 2004 and 2008. Background: causes of disability not included in the analysis

Table 1 Life expectancy (LE), disability-free LE (DFLE), LE with disability (LED) at age 15, and decomposition of gender differences into mortality and disability effects, Belgium, 2001, 2004 and 2008

	2001			2004			2008		
	DFLE	LED	LE	DFLE	LED	LE	DFLE	LED	LE
Women	56.0	10.4	66.4	56.2	10.8	67.0	55.3	12.1	67.4
Men	54.1	6.4	60.5	54.9	6.4	61.4	54.8	7.3	62.1
Gender difference (women–men)	1.9	4.0	5.9	1.3	4.4	5.6	0.5	4.8	5.3
Decomposition by kind of effect									
Mortality effect	3.6	2.3	5.9	3.4	2.3	5.6	3.2	2.1	5.3
Disability effect	−1.7	1.7	0	−2.1	2.1	0	−2.7	2.7	0
Total	1.9	4.0	5.9	1.3	4.4	5.6	0.5	4.8	5.3

Table 2 Decomposition of gender differences into mortality and disability effects by cause, Belgium, 2001, 2004 and 2008

Cause	DFLE						LED					
	Mortality			Disability			Mortality			Disability		
	2001	2004	2008	2001	2004	2008	2001	2004	2008	2001	2004	2008
Chronic respiratory	0.23	0.20	0.18	−0.03	0.25	0.00	0.24	0.23	0.20	0.03	−0.25	0.00
Acute respiratory	0.08	0.09	0.07	–	–	–	0.09	0.11	0.08	–	–	–
Ischaemic heart	0.57	0.52	0.44	−0.14	0.42	0.18	0.42	0.41	0.33	0.14	−0.42	−0.18
Stroke	0.10	0.07	0.08	0.11	−0.27	−0.17	0.08	0.06	0.07	−0.11	0.27	0.17
Other CVD	0.19	0.20	0.20	–	–	–	0.11	0.13	0.13	–	–	–
Diabetes	0.03	0.02	0.03	−0.05	−0.42	0.13	0.01	0.00	0.02	0.05	0.42	−0.13
Cancer	–	–	–	−0.04	−0.05	0.04	–	–	–	0.04	0.05	−0.04
Lung/larynx/trachea cancer	0.69	0.57	0.54	–	–	–	0.49	0.44	0.41	–	–	–
Prostate/breast cancer	−0.19	−0.20	−0.20	–	–	–	−0.02	−0.04	−0.04	–	–	–
Digestive cancer	0.31	0.32	0.36				0.20	0.22	0.23	–	–	–
Other cancer	0.14	0.16	0.14	–	–	–	0.12	0.14	0.12	–	–	–
Depression	0.00	0.00	0.00	0.19	−0.32	−0.26	0.00	0.00	0.00	−0.19	0.32	0.26
Other mental	0.09	0.05	0.08	–	–	–	0.03	0.02	0.03	–	–	–
Parkinson/epilepsy	0.02	0.03	0.02	0.13	0.16	−0.04	0.02	0.02	0.02	−0.13	−0.16	0.04
Alzheimer/dementia	0.01	0.01	0.01	–	–	–	0.00	0.00	0.00	–	–	–
Other neurological	0.02	0.04	0.03	–	–	–	0.01	0.02	0.01	–	–	–
Arthritis/back pain/osteoporosis	0.00	0.00	0.00	−1.12	−1.19	−0.78	0.00	0.00	0.00	1.12	1.19	0.78
Other musculoskeletal	0.00	0.00	0.00	–	–	–	0.00	0.00	0.00	–	–	–
External causes	0.86	0.86	0.78	–	–	–	0.24	0.25	0.24	–	–	–
Other diseases	0.48	0.44	0.39	0.51	0.15	−0.93	0.31	0.30	0.27	−0.51	−0.15	0.93
Background	–	–	–	−1.22	−0.81	−0.87	–	–	–	1.22	0.81	0.87
Total	3.63	3.37	3.16	−1.67	−2.08	−2.71	2.36	2.32	2.12	1.67	2.08	2.71

Background: disability causes not included in the analysis. Positive values represent male disadvantage and negative values represent female disadvantage.

Our results, using Belgian data, showed that the male–female health-survival paradox was observed in all 3 years studied, with women living longer, but most of the female survival advantage is lived with disability. Our analysis over time highlighted a reduction in the gender gap in DFLE, mainly attributed to an increase in the female disability disadvantage, while the opposite trend was observed for LED, owing to a reduction in the female mortality advantage and increased female disability disadvantage. Women spent more years free of disability owing to their lower mortality from lung/larynx/trachea cancer, ischaemic heart diseases, and to a lesser extent from digestive cancer and chronic respiratory diseases. The mortality and disability contributions to the female disadvantage in LED changed in the period: while in 2001 and 2004 women lived longer with disability owing to the their lower mortality due to lung/larynx/trachea cancer, ischaemic heart diseases and external causes, in 2008 the higher number of years lived with disability by women was mainly attributed to their higher disability prevalence due to musculoskeletal conditions.

It is well known that women have a higher LE than men and previous studies showed that this gender gap has been narrowing in Western Europe since the 80s.[1,2,7,19] Several explanations have been suggested to the reduction in the mortality differential between men and women, including biological, social and behavioural factors, with the change in the smoking pattern in men and women being among the main factors.[20] Besides the recent decline in the smoking prevalence for both men (2001: 34%; 2004: 32%; 2008: 28%) and women (2001: 24%; 2004: 23%; 2008: 21%) in Belgium,[21] the excess mortality at older ages is not directly related to their recent smoking habits, but also to their smoking behaviour in the early adult life. The smoking behaviour evolved differently in men and women in the past century in Europe: while most of the men born in the early 1900s started smoking a substantial number of cigarettes from a young age, most women started smoking later, reaching a peak in 1960s to 1970s.[22] The slower rise of smoking among women has been attributed to their lower socioeconomic status and social disapproval of women's smoking.[23] Currently, although the smoking prevalence is still higher among men, the gender gap in smoking has narrowed, owing to a greater decline in the smoking prevalence among men than in women. This may at least partly explain the reduction in gender inequalities in LE and LED, as smoking is the leading cause of premature mortality[24,25] and has also been associated with disability in middle-aged adults in Belgium.[26] The increase in the gender difference in the prevalence of physical inactivity and the decrease in the prevalence of excess alcohol consumption also suggests that women's health is getting worse than men in the 3 years studied (Supplementary file S4).

Our findings are consistent with the results of a prior study conducted with the data from the European Community

Household Panel (1995–2003) of 14 European countries: gender disparities in LE reduced while the gender gap in LED increased over time. Although different patterns between countries were observed for DFLE, Belgium also showed a decreasing trend,[27] similar to our results.

Reductions in the female mortality advantage, counterbalanced by an increasing disability disadvantage, resulted in increased burden among women: increase in the gender gap in LED and nearly no gender difference in DFLE in 2008. The almost null gender difference in DFLE was also found in a previous study with the Dutch data from 1990 to 1994,[8] indicating that men and women lived almost the same amount of years without disability, owing to lower mortality but higher disability in women.

Higher LED among women was also attributed to their higher disability prevalence in the Dutch study.[8] Similar findings for DFLE and LED were also reported in a prior study, using data from the 2006 Survey on Income and Living Conditions in 25 European countries.[2]

In Belgium, the female mortality advantage in DFLE was mainly related to external causes, lung/larynx/trachea cancer, ischaemic heart diseases, digestive cancer and chronic respiratory diseases, while the disability disadvantage was mainly due to musculoskeletal conditions and background. Life-threatening conditions are more common among men[1,8]; they are also often associated with unhealthier behaviours such as smoking, unhealthy diet, harmful alcohol consumption and unsafe driving.[1] Conversely, non-fatal diseases, such as musculoskeletal conditions, are more frequent in women; these conditions could be related to the higher prevalence of obesity[1,28] and physical inactivity, lower muscle strength and bone density[8] in women. The high background contribution to gender differences in disability can represent disability causes not included in the analysis, such as dementia, which disproportionately affects women,[29] but also other important disability causes, such as accidents.

Besides gender differences in lifestyle risk factors, higher male mortality can also be attributed to biological differences, such as: (i) hormonal, e.g. protective effect of oestrogen on serum lipids and brain cells, preventing degenerative diseases, such as cardiovascular diseases; (ii) immunological, due to the immunosuppressant effect of testosterone, resulting in greater male susceptibility to infectious and autoimmune diseases; and (iii) genetic factors, as the presence of two X chromosomes has been associated with higher survival. Other factors associated with higher disability among women include: (i) greater willingness to report health problems; (ii) higher rate of functional decline; (iii) lower recovery rates from disability; (iv) lower socioeconomic position; (v) detrimental work exposures and (vi) higher rates of unemployment. Selection bias may also play an important role, as women are more likely to participate in health surveys than men.[1]

This study has some limitations that should be acknowledged. Although plausible,[30] the causal relationship between diseases and disability cannot be assessed with cross-sectional data. Consequently, diseases were incorrectly considered disability causes when disability occurred before diseases.[8] In addition, the use of self-reports for chronic conditions and disability may have biased the results, in particular because the reporting behaviour may differ between men and women: while men tend to underreport health problems, women tend to over-report severe diseases and arthritis.[1] We were not able to use the 2013 HIS data, due to changes in some questions for chronic conditions and disability. Another limitation is the use of groups of chronic conditions that are not exactly the same for mortality and disability, hampering comparability between the contributions of causes of death and disability. This study is based on a short-time period, which may not be enough to assess changes in gender differences in mortality and disability. Finally, the use of the Sullivan method to estimate HEs may have biased the results if large and sudden changes in disability transition rates were present in the study period.[31]

The key strength of this study was the use of representative data for morbidity and cause-specific mortality for the Belgian population aged $\geq$15 years from 2001, 2004 and 2008.

The findings of this study offered valuable insights to better understand the gender inequalities in LE and HE in Belgium in the early 2000s, providing useful information for public health policy. To reduce gender inequalities and to promote healthy ageing of populations, priority should be given to reduce the LED disadvantage in women, which showed an increasing trend over time. This could be achieved by aiming at non-fatal diseases, especially musculoskeletal conditions (the main contributor to the female disability disadvantage in LED), by promoting physical activity and reducing obesity.

Attention should also be given to the male mortality disadvantage, by focusing on lung/larynx/trachea cancer, chronic respiratory diseases, cardiovascular diseases, digestive cancer and external causes. In this respect, actions towards detrimental individual behaviours, which are preventable and modifiable, are crucial (e.g. reducing smoking, sedentary and risky behaviours; and promoting physical activity, healthy diets and safe driving), as well as actions towards macro factors such as environmental factors (e.g. reducing air pollution and building public spaces to promote physical activity).

Future studies could focus on clarifying which other causes of disability not included in this analysis (grouped as 'background') are contributing to a significant part of the gender gap in DFLE and LED.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Key points

- The male–female health-survival paradox was observed in Belgium in 2001, 2004 and 2008: women lived longer than men, spending more years without but also with disability in all years.
- Our analysis over time highlighted a reduction in the gender gap in DFLE, mainly attributed to an increase in the female disability disadvantage, while the opposite trend was observed for LED, owing to a reduction in the female mortality advantage and increased female disability disadvantage.
- This is the first study to assess the contribution of causes of death and disability to gender differences in health expectancies over time. Women spent more years free of disability owing to their lower mortality from lung/larynx/trachea cancer, ischaemic heart diseases and to a lesser extent from digestive cancer and chronic respiratory diseases.
- The contribution of mortality and disability to gender differences in LED changed in the period: while in 2001 and 2004 women lived more years with disability owing to their lower mortality due to lung/larynx/trachea cancer, ischaemic heart diseases and external causes, in 2008 the female disadvantage in LED was mainly attributed to their higher disability prevalence due to musculoskeletal conditions.
- To reduce the LED disadvantage in women, public health policies should focus on non-fatal diseases, especially musculoskeletal conditions, by promoting physical activity and reducing obesity.

References

1 Oksuzyan A, Juel K, Vaupel J, Christensen K. Men: good health and high mortality. Sex differences in health and aging. *Aging Clin Exp Res* 2008;20:91–102.

2 Van Oyen H, Nusselder W, Jagger C, et al. Gender differences in healthy life years within the EU: an exploration of the ''health-survival'' paradox. *Int J Public Health* 2013;58:143–55.

3 Jagger C, Gillies C, Moscone F, et al. Inequalities in healthy life years in the 25 countries of the European Union in 2005: a cross-national meta-regression analysis. *Lancet* 2008;372:2124–31.

4 Robine JM, Michel JP, Branch LG. Measurement and utilization of healthy life expectancy: conceptual issues. *Bull World Health Organ* 1992;70:791–800.

5 Robine JM, Jagger C, Egidi V, et al. Creating a coherent set of indicators to monitor health across Europe: the Euro-REVES 2 project. *Eur J Publ Health* 2003;13:6–14.

6 Nusselder WJ, Looman CW, Van OH, et al. Gender differences in health of EU10 and EU15 populations: the double burden of EU10 men. *Eur J Ageing* 2010;7:219–27.

7 Oksuzyan A, Bronnum-Hansen H, Jeune B. Gender gap in health expectancy. *Eur J Ageing* 2010;7:213–8.

8 Nusselder WJ, Looman CWN. Decomposition of differences in health expectancy by cause. *Demography* 2004;41:315–34.

9 Demarest S, Van der Heyden J, Charafeddine R, et al. Methodological basics and evolution of the Belgian Health Interview Survey 1997–2008. *Arch Public Health* 2013;71:24.

10 Statistics Belgium. Life Tables obtained through the Human Mortality Database. Available at: www.mortality.org or www.humanmortality.de (30 May 2017, date last accessed).

11 Public Health and Surveillance—Scientific Institute of Public Health BB. SPMA: Standardized Procedures for Mortality Analysis—Belgium, 2017. Available at: https://spma.wiv-isp.be/.

12 World Health Organization. *International Statistical Classification of Diseases and Related Health Problems*. 10th revision. Geneva: WHO, 2011.

13 Breslow NE, Day NE. Rates and Rate Standardization. Statistical Methods in Cancer Research. Vol. II. *The Design and Analysis of Cohort Studies*, 82 edn. Lyon: IARC, World Health Organization, 1987; 48–79.

14 Nusselder WJ, Looman CWN. WP7: Decomposition Tools. Technical Report on Attribution Tool. European Health Expectancy Monitoring Unit (EHEMU), June, Report No. 7.1, 2010.

15 Yokota RT, Van OH, Looman CW, et al. Multinomial additive hazard model to assess the disability burden using cross-sectional data. *Biom J* 2017;59:901–17.

16 Sullivan DF. A single index of mortality and morbidity. *HSMHA Health Rep* 1971;86:347–54.

17 Nusselder W, Jagger C, Cox B, et al. WP7: Decomposition Tools. Technical Report on Decomposition. Montpellier, France, Report No. 2010_7.1, 2010.

18 R: A Language and Environment for Statistical Computing [Computer Program]. Version 3.2.3. Vienna, Austria: R Foundation for Statistical Computing; 2015.

19 Barford A, Dorling D, Smith G, Shaw M. Life expectancy: women now on top everywhere. *BMJ* 2006;332:808.

20 Thorslund M, Wastesson JW, Agahi N, et al. The rise and fall of women's advantage: a comparison of national trends in life expectancy at age 65 years. *Eur J Ageing* 2013;10:271–7.

21 Charafeddine R, Demarest S, Drieskens S, et al. Highlights of the Belgian Health Interview Survey 2008. WIV-ISP, 2012.

22 Pirie K, Peto R, REEVES GK, et al. The 21st century hazards of smoking and benefits of stopping: a prospective study of one million women in the UK. *Lancet* 2013;381:133–41.

23 Hitchman SC, Fong GT. Gender empowerment and female-to-male smoking prevalence ratios. *Bull World Health Organ* 2011;89:195–202.

24 World Health Organisation. *WHO Global Report: Mortality Attributable to Tobacco*. Geneva: WHO, 2012.

25 Van Oyen H, Berger N, Nusselder W, et al. The effect of smoking on the duration of life with and without disability, Belgium 1997–2011. *BMC Public Health* 2014;14:723.

26 Yokota R, Nusselder W, Robine JM, et al. Contribution of chronic conditions to the disability burden across smoking categories in middle-aged adults, Belgium. *PLoS One* 2016;11:e0153726.

27 Robine JM, Jagger C, Van Oyen H, et al. Are we living longer, healthier lives in the EU? Disability-Free Life Expectancy (DFLE) in EU countries from 1991 to 2003 based on the European Household Panel (ECHP). Montpellier, 2005.

28 Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. *Bull World Health Organ* 2003;81:646–56.

29 Mazure CM, Swendsen J. Sex differences in Alzheimer's disease and other dementias. *Lancet Neurol* 2016;15:451–2.

30 Verbrugge LM, Jette AM. The disablement process. *Soc Sci Med* 1994;38:1–14.

31 Mathers CD, Robine JM. How good is Sullivan's method for monitoring changes in population health expectancies. *J Epidemiol Community Health* 1997;51:80–6.