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# Contribution of chronic conditions to smoking differences in life expectancy with and without disability in Belgium

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**Background:** Smoking is the leading cause of premature mortality and morbidity. This study aimed at assessing the impact of smoking on life expectancy (LE) and LE with (LED) and without disability (DFLE). We further estimated the contribution of disability and mortality and their causes to differences in LED and DFLE by smoking. **Methods:** Data on disability, chronic conditions, and smoking from 17 148 participants of the 1997, 2001, 2004 Belgian Health Interview Surveys were used to estimate causes of disability using the attribution method. A 10-year mortality follow-up of survey participants was used. The Sullivan method was applied to estimate LED and DFLE. The contribution of disability and mortality and of causes of disability and death to smoking differences in LED and DFLE was assessed using decomposition methods. **Results:** Never smokers live longer than daily smokers. DFLE advantage at age 15 of +8.5/+4.3 years (y) in men/women never compared with daily smokers was the result of lower mortality (+6.2y/+3y) and lower disability (2.3y/1.3y). The extra 0.3y/1.6y LED in never smokers was due to lower mortality (+2.6y/+2.9y) and lower disability (−2.3y/−1.3y). Lower mortality from lung/larynx/trachea cancer, chronic respiratory, and ischaemic heart diseases was the main contributor to higher LED and DFLE in never smokers. Lower disability from musculoskeletal conditions in men and chronic respiratory diseases in women increased LED and DFLE in never smokers. **Conclusions:** Mortality and disability advantage among never smokers contributed to longer DFLE, while mortality advantage contributed to their longer LED.

## Introduction

Smoking is a major cause of preventable and premature mortality,[1] being responsible for more than 6.4 million deaths (11.5%) globally in 2015.[2] Beyond its effect on mortality, smoking has also been associated with disability, mainly for being a risk factor common to several chronic conditions[1] and due to its role in increasing the severity of existing conditions. Besides its impact on population health, smoking also imposes an economic burden, increasing the costs of medical care and loss of productivity.[1]

In Belgium, a reduction in the smoking prevalence has been observed in the last decades (30% in 1997; 23% in 2013).[3] In middle-aged adults, a higher disability prevalence was observed in Belgium among heavy (men: 7.6%; women: 12.0%) compared with never smokers (men: 4.8%; women: 10.7%). Cardiovascular diseases, chronic respiratory diseases, depression and diabetes showed a higher contribution to the disability prevalence in heavy compared with never smokers.[4]

Smokers bear a reduction of 10 years in life expectancy (LE) compared with never smokers, but cessation at age 40 can reduce the excess mortality associated with continued smoking in later ages by 90%.[5,6] Despite the well-known mortality advantage of non-smokers compared with smokers (higher LE without disability), contradictory results have been reported for LE with disability (LED): higher[7,8] and lower[9–11] LED has been reported among non-smokers and the absence of difference in LED between never and current smokers.[12]

One study conducted in Belgium found higher LE, DFLE and LED at age 30 in never compared with current smokers.[8] Lower mortality and lower disability in never compared with current smokers contributed almost equally to the higher number of years lived without disability among never smokers (men: 6.8; women: 6.3 years). However, the mortality advantage in never smokers exceeded their disability advantage for LED, resulting in a slightly higher number of years lived with disability among never smokers (men: 1.07; women: 1.92 years).[8]

To our knowledge, no previous study has investigated which conditions are contributing most to smoking differences in DFLE and LED in terms on disability and mortality. Such information can provide insights to better understand the impact of smoking on DFLE and LED. This study aimed to (i) assess the impact of smoking on LE, DFLE and LED; (ii) to estimate the contribution of disability and mortality to differences in DFLE and LED between never and daily smokers; and (iii) to investigate the contribution of chronic conditions to these differences in Belgium.

## Methods

### *Disability data*

Pooled data from the 1997, 2001, and 2004 Belgian Health Interview Surveys (BHIS) were used to estimate the disability prevalence by cause and smoking status. The BHIS are representative of the Belgian

population, with a multistage, stratified (regions and provinces) and clustered (municipalities and households) sampling technique. The response rate was 59% in 1997 and 61% in 2001 and 2004. More information about the BHIS methodology can be found elsewhere.[13]

Disability was based on activity of daily living (ADL) and mobility limitations. Disability was considered present in participants who reported either some difficulty, a lot of difficulty or inability to perform at least one of the following ADL tasks: transferring in-and-out of bed or chair, dressing, washing hands and face, feeding and using the toilet; or inability to walk without stopping for $\geq$200 m.

The presence of chronic conditions was assessed based on self-reports of nine chronic conditions: chronic respiratory diseases (asthma, chronic bronchitis and chronic pulmonary diseases), ischaemic heart diseases, stroke, diabetes, cancer, depression, Parkinson/epilepsy, arthritis/back pain/osteoporosis and other diseases.

The present study included only individuals who reported being never or daily smokers.

From the 21 861 individuals aged 15 years or older participants of one of the BHIS, 17148 (78%) were included after excluding individuals with missing information on smoking status ($N = 3289$), disability ($N = 1272$) or chronic conditions ($N = 567$).

### Mortality data

A 10-year mortality follow-up of the BHIS participants was obtained through the linkage with the National Register and cause-specific mortality data in Belgium. Participants of the 1997, 2001 and 2004 BHIS were followed until their date of death or 31 December 2007, 31 December 2010 and 31 December 2013, respectively. Participants who emigrated before the end of the follow-up period were censored at the date of emigration.

To obtain the causes of death of the BHIS participants, two steps were required. First, individual data of BHIS participants were linked to the National Population Register, which contains information about the death and emigration status of the population. The linkage was performed through the National Identification Number – a unique identifier for each resident in Belgium. After identifying the BHIS participants who died during the corresponding 10-years follow-up period, these deaths were linked to the cause-specific mortality database by combining the information on: date of birth, date of death, gender and municipality of death.

Of the 17 148 BHIS participants, 1785 (10%) died in the 10-year follow-up period and the cause of death was available for 1749 (98%) of them. Causes of death were classified according to the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10).[14] Supplementary file S1 shows the definition of causes of disability and mortality.

### Statistical analysis

The disability causes were estimated with the attribution method.[15–17] Briefly, the disability prevalence estimated using the BHIS data was partitioned into the additive contribution of chronic conditions, taking into account multimorbidity and the fact that disability can be present even in the absence of chronic conditions (labelled as 'background'). The background can represent underdiagnosed or underreported chronic conditions, other causes of disability that were not included in the analysis, and disability that is not associated with any condition, such as the effect of age-related functioning losses. The attribution of disability to chronic conditions depends on the prevalence of chronic conditions and the cause-specific cumulative rate of disability (disabling impacts), which were estimated with the binomial additive hazard model.[16,17] To obtain the disability causes by age group, reduced rank regression[18] was used.

A 10-year mortality follow-up of the BHIS participants was used to obtain abridged life tables (5-years age group) by gender and smoking status, starting at age 15. Lexis expansion[19] was used to take into account the age changes during the follow-up period, by splitting the person-years at risk of each survey participant into several 1-year age bands, i.e. the original dataset with 17 148 observations was expanded to 162 313 observations. A Poisson regression was fitted to estimate the mortality rates by age, gender and smoking status with the expanded follow-up period used as offset in the model. Survey weights were used in the analysis. LE was estimated using the life tables generated with the mortality rates described earlier. The disability prevalence by age, gender and smoking status was integrated in the life tables to estimate DFLE and LED at age 15 using the Sullivan method.[20] Decomposition techniques[15,21] were used to assess the contribution of mortality and disability and of causes of death and disability to smoking differences in DFLE and LED. First, smoking differences in DFLE and LED between never and daily smokers were decomposed by kind of effect: difference in the number of person-years lived without and with disability due to differences in the mortality rates (mortality effect) and in the prevalence of disability (disability effect) between never and daily smokers. Next, these smoking-related differentials were decomposed by causes of death and disability (decomposition by cause).

All the analysis were carried out in R, version 3.2.3.[22] The R package *Epi*[23] was used for the Lexis expansion. The disability prevalence by cause was estimated using the attribution tool developed in R by Nusselder and Looman.[16] The decomposition of smoking differences in DFLE and LED by kind of effect and by cause was performed with the decomposition tool developed in R by the same authors.[15,21]

## Results

Individuals aged 15-years-old who never smoked are expected to live longer than daily smokers (men: 8.8 years; women: 5.9 years). Of the 8.8 years that men never smokers are expected to live longer than men daily smokers, 8.5 years are free of disability and 0.3 are with disability. Among women, of the 5.9 years longer LE in never smokers, 4.3 and 1.6 years are expected to be lived without and with disability, respectively (table 1).

Looking at the results of the decomposition by kind of effect, the DFLE advantage in never smokers is mainly due to their lower mortality (73% in men and 70% in women) and to a lesser extent to their lower disability prevalence compared with daily smokers. Likewise, lower mortality in women never compared with daily smokers was also the main contributor to the smoking disparities in LED (mortality: 2.9; disability: -1.3 years), resulting in 1.6 more years lived with disability in never smokers. Conversely, for men, the mortality advantage of never smokers (2.6 years) was almost

**Table 1** Smoking differences in LE, DFLE and LED at age 15, and contribution of mortality and disability by gender, Belgium, 1997, 2001 and 2004

| Smoking groups | LE (years) | DFLE (years) | LED (years) |
|---|---|---|---|
| Men never | 66.5 | 59.8 | 6.7 |
| Men daily | 57.7 | 51.3 | 6.4 |
| Difference (Men never – Men daily) | 8.8 | 8.5 | 0.3 |
| Decomposition by kind of effect | | | |
| Mortality contribution | 8.8 | 6.2 | 2.6 |
| Disability contribution | 0.0 | 2.3 | -2.3 |
| Women never | 69.9 | 58.6 | 11.3 |
| Women daily | 64.0 | 54.3 | 9.7 |
| Difference (Women never – Women daily) | 5.9 | 4.3 | 1.6 |
| Decomposition by kind of effect | | | |
| Mortality contribution | 5.9 | 3.0 | 2.9 |
| Disability contribution | 0.0 | 1.3 | -1.3 |

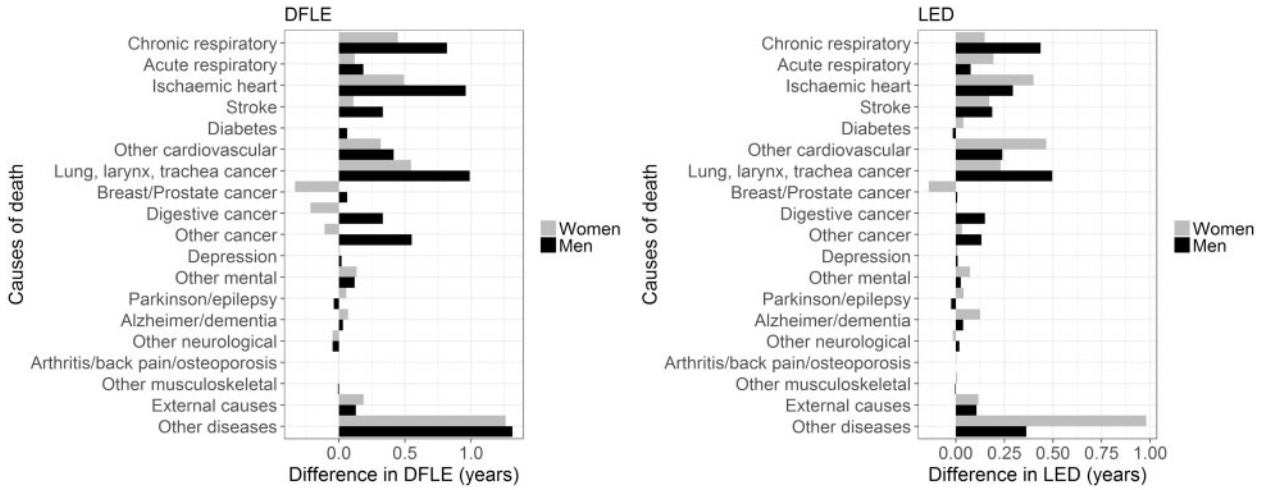


**Figure 1** Contribution of causes of death to differences in DFLE and LED between never and daily smokers, Belgium 1997, 2001, and 2004

nullified by their disability advantage (2.3 years), resulting in 0.3 more years lived with disability in never smokers.

Figure 1 and Supplementary file S2 show the contribution of causes of death to differences in DFLE and LED between never and daily smokers in Belgium. Lower mortality from other diseases, lung/larynx/trachea cancer, ischaemic heart diseases, and chronic respiratory diseases in never compared with daily smokers were the main contributors to the higher DFLE and LED in men and women never smokers.

The contribution of causes of disability to smoking differences in DFLE and LED is presented in figure 2 and Supplementary file S3. In figure 2, a positive (negative) number of years in DFLE (LED) indicates that DFLE (LED) is higher (lower) in never compared with daily smokers due to lower disability prevalence caused by the diseases. The lower disability prevalence in never smokers caused by arthritis/back pain/osteoporosis, ischaemic heart diseases, and chronic respiratory in men and by background, chronic respiratory diseases, and arthritis/back pain/osteoporosis in women contributed to their disability advantage.

## Discussion

Our findings not only confirm the negative effect of smoking on survival and on the length of life without disability but also showed that daily smokers are expected to live less years with disability than never smokers. Although compression of morbidity in daily smokers may seem contradictory, our results indicate that premature mortality among daily smokers may play an important role in the smoking differences in DFLE and LED, i.e. daily smokers may not live long enough to develop disability, which is more common at older ages.[8,10,24]

The number of years lived with disability was almost the same in never and daily smokers men, indicating that both higher mortality and higher disability in daily smokers showed similar contributions to the smoking differentials in LED. This suggests that the disabling effects of smoking may precede male premature death and is supported by the differences in the contributions across age groups to the mortality and disability effects: while excess mortality was observed in almost all age groups among men daily smokers (Supplementary file S4), excess disability in men daily smokers was more pronounced between 35 and 74 years, with an inversion after age 75.

Increased or almost no difference in the number of years lived with disability among non-smokers compared with smokers has also been previously reported.[7,8,12] Conversely, some studies found lower number of years lived with disability in non-smokers.[9–11] Although these differences may represent real differences between countries and time periods, they should be carefully interpreted, as they can be influenced by the different disability and smoking definitions, different methods to estimate HE, and the age group investigated.

To our knowledge, only one study investigated the contribution of mortality and disability to smoking differences in DFLE and LED.[8] This study was also conducted in Belgium, but it was restricted to the BHIS data from 1997 and 2001. Our results were very similar to this previous study, confirming longer LE, DFLE and LED in never smokers compared with daily smokers in Belgium. However, the results of the decomposition by kind of effect were slightly different. For DFLE, lower mortality was also the main contributor to the greater number of years lived free of disability in men never smokers, but for women, the lower disability prevalence in never smokers was the main contributor to their DFLE advantage. For LED, the lower mortality in never smokers was the main contributor to the higher number of years lived with disability in men and women. Possible explanations for the differences between the studies include: (i) change in the mortality and disability contributions, as our study includes additional data from the 2004 BHIS; (ii) differences in the age range that DFLE and LED were estimated (in the previous study DFLE and LED were estimated at age 30); and (iii) differences in the disability indicator, as the previous study included urinary incontinence and sensorial limitations in their disability definition.

The higher mortality rates observed among daily smokers for nearly all causes of death investigated in the present study are consistent with the well-known effect of smoking on mortality.[25] For disability, our results are in line with those from a previous study with middle-aged adults in Belgium,[4] using the same disability definition: men daily smokers showed a higher contribution of chronic respiratory, ischaemic heart, and musculoskeletal conditions to disability than never smokers, whilst a higher contribution of chronic respiratory diseases and depression was observed among women daily compared with never smokers.

Another important finding is related to the contributions of causes of death and disability to differences in DFLE and LED between daily and never smokers. Besides the well-known excess mortality from chronic respiratory diseases and ischaemic heart diseases among smokers,[6,26] these diseases were also important contributors to the higher disability prevalence in men daily smokers. Higher mortality from lung/larynx/trachea cancer and higher disability from musculoskeletal conditions also contributed to smoking differences in DFLE and LED. Cardiovascular diseases, cancer, and chronic respiratory diseases were also identified as the three leading causes of smoking-attributable disability-adjusted life

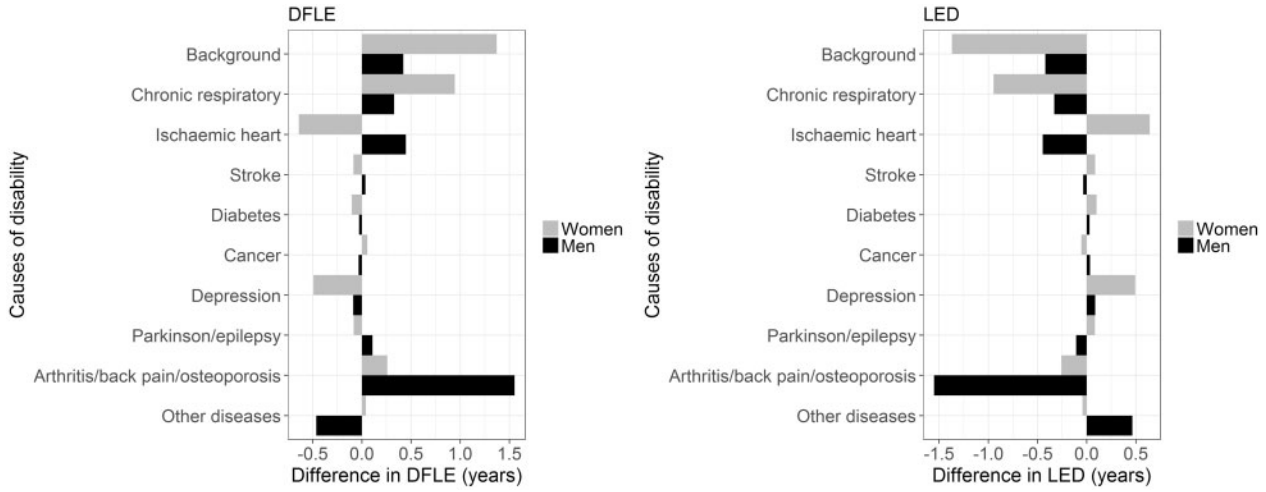


**Figure 2** Contribution of causes of disability to differences in DFLE and LED between never and daily smokers, Belgium 1997, 2001 and 2004

years (DALY) in 2015.[2] The higher burden of musculoskeletal conditions among smokers was also found in a Danish study,[27] regardless of education level. This higher burden can be related to the physical occupational activities that are more common in workers who smoke.[28] These findings suggest that intervention strategies focusing on smoking may reduce not only mortality from chronic respiratory and ischaemic heart diseases but also disability associated with these diseases.

The contribution of disability causes depends on the prevalence of chronic conditions and their disabling impacts.[15–17] Arthritis/back pain/osteoporosis (men) and chronic respiratory diseases (women) were the main contributors to smoking differences in DFLE and LED owing to their high difference in the disabling impact and prevalence between never and daily smokers (Supplementary files S5 and S6). The high contribution of chronic respiratory diseases in men and arthritis/back pain/osteoporosis in women was mainly due to their higher prevalence in daily smokers. Finally, the high contribution of ischaemic heart diseases in men was mainly due to their higher disabling impact in daily smokers.

This study has some limitations that should be carefully considered. The attribution method used to estimate causes of disability with cross-sectional data relies on the causality assumption between smoking, diseases, and disability. Despite its plausibility,[29] temporal bias may have occurred,[30] resulting in overestimation of the contribution of diseases to disability in cases where the disability occurred before the chronic condition.

Selection bias might have occurred due to the high non-response rates (approximately 40%) in the surveys. Due the small sample size in other smoking categories, we were unable to assess the effects of these other smoking subgroups on DFLE and LED. Data from 1997, 2001, and 2004 were pooled due to the small number of smokers, especially among older women. However, the similarity in the disability prevalence in the three surveys supports the use of pooled data (Supplementary file S7).

The contribution of diseases to disability may have been under or overestimated, as the validity of self-reported diseases is disease-specific.[31] The use of self-reported smoking status may have resulted in misclassification, but this might be minimal, as good accuracy of self-reports were found compared with biomarkers for smoking.[32] The disability contribution and consequently LED might have been underestimated as our disability definition was restricted to ADL and mobility limitations. An overestimation of the background contribution to disability differences between never and daily smokers might have occurred as important disability causes at old ages, such as dementia, were not included in the analysis. Although the analysis was stratified by smoking status, we were not able to take into account other important confounders, such as education attainment.

The use of the Sullivan method,[20] a prevalence-based approach, to estimate DFLE and LED assumes constant transition rates between disability states in the study period. Our results might be biased if large changes in the disability transition rates were present in the follow-up period. Additionally, we assumed that the smoking behaviour of the survey participants remained unchanged during the 10-year follow-up period. This may be more realistic for never smokers, as smoker initiation is less likely to occur after 30 years of age,[8,33] but the smoking behaviour is more likely to change among smokers, with smoking cessation becoming more common after the onset of health problems.[34]

Our study provides an overall overview of the effects of smoking on mortality and disability and how these effects contribute to differences in DFLE and LED between never and daily smokers. Never smokers enjoyed longer LE, accompanied by a longer LE free of disability. Nonetheless, they also experienced longer life with disability, which is mainly related to premature mortality in daily smokers.

Reducing smoking could not only reduce mortality more than any other single public health intervention, but it can also improve and preserve the quality of life of individuals, due to the smoking impact on disability.[30]

## Supplementary data

Supplementary data are available at *EURPUB* online.

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*Conflicts of interest*: None declared.

## Key points

- Individuals aged 15- years-old who never smoked are expected to live longer than daily smokers (men: 8.8 years;

women: 5.9 years), with most of these years being free of disability (men: 8.5 years; women: 4.3 years). Nonetheless, never smokers also spend more years with disability than daily smokers (men: 0.3 years; women: 1.6 years), which is related to premature mortality in daily smokers.
- Lower mortality and disability in never smokers contributed to their higher DFLE compared with daily smokers while lower mortality was the main contributor to lower LED in never smokers.
- Lower mortality from other diseases, lung/larynx/trachea cancer, ischaemic heart diseases, and chronic respiratory diseases in never compared with daily smokers were the main contributors to the higher DFLE and LED in never smokers.
- The higher disability prevalence in daily smokers caused by arthritis/back pain/osteoporosis, ischaemic heart diseases, and chronic respiratory in men and by background, chronic respiratory diseases, and arthritis/back pain/osteoporosis in women contributed to their disability disadvantage.

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