BMJ Public Health

Burden of disease attributable to high body mass index in Belgium: a comparative risk assessment analysis

Vanessa Gorasso ,[1] Stefanie Vandevijvere,[1] Wilma Johanna Nusselder,[2] Robby De Pauw,[1,3] Henk Hilderink,[4] Sarah Nayani ,[1] Johan Van der Heyden,[1] Delphine De Smedt,[5] Brecht Devleesschauwer[1,6]

To cite: Gorasso V, Vandevijvere S, Nusselder WJ, *et al*. Burden of disease attributable to high body mass index in Belgium: a comparative risk assessment analysis. *BMJ Public Health* 2025;**3**:e002446. doi:10.1136/bmjph-2024-002446

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjph-2024-002446).

Received 6 December 2024
Accepted 17 December 2024

For numbered affiliations see end of article.

Correspondence to
Dr Vanessa Gorasso;
vanessa.gorasso@sciensano.be

ABSTRACT

Background and methods High body mass index (BMI) is a major risk factor for several non-communicable diseases. The increasing concern about the health and economic burden of BMI makes it essential for countries to track their progress on major modifiable risk exposures. The aim of the study is to estimate the burden attributable to high BMI in Belgium, in terms of years of life lost due to disability (YLD), years of life lost due to premature mortality (YLL) and disease costs, using comparative risk assessment. We followed the general framework established in the Global Burden of Diseases, Injuries and Risk Factors study. Population attributable fractions were calculated for the year 2018 for selected health outcomes using local estimates of BMI and burden of disease estimates from the Belgian Burden of Disease study.

Results According to our figures, around 37 800 YLD, 56 000 YLL and €1.85 billion in healthcare costs can be attributed to a high BMI. Diabetes had the highest number of YLD attributable to high BMI followed by musculoskeletal disorders. Cardiovascular diseases accounted for the highest burden in terms of YLL attributable to high BMI, followed by diabetes and different forms of cancers (i.e., breast, colon and rectum and oesophageal cancer).

Conclusion A substantial proportion of the burden of disease could be prevented when reducing BMI in Belgium. This evidence on the impact of risk factors is important for monitoring disease burdens and setting priorities for health prevention policies.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ High body mass index (BMI) is a major risk factor for several non-communicable diseases. In Belgium, like in other Western countries, the average BMI of the population has increased over the past decades. The Global Burden of Diseases, Injuries and Risk Factors (GBD) study provides estimates on the burden attributable to high BMI at global level. These often are not produced with the best available data, which is why local burden of disease studies have been launched in several countries to have more local estimates.

WHAT THIS STUDY ADDS

⇒ The study provides an estimation of the burden attributable to high BMI in Belgium, using locally available data sources. This work is part of the national burden of disease study (Belgian Burden of Disease [BeBOD]) which aims to calculate the burden for diseases and risk factors in Belgium.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ If the GBD estimates provide an important tool for comparison of the burden across countries, the estimates presented in this study (and in general in BeBOD) represent a better fit for comparison of diseases and subgroups within Belgium. This paper highlights the urgent need for interventions to reduce the burden of high BMI.

INTRODUCTION

High body mass index (BMI) is a major risk factor for cardiovascular diseases,[1] type 2 diabetes mellitus[1] and several cancers,[2] and is associated with important musculoskeletal disorders, such as osteoarthritis.[3] According to the World Health Organization (WHO), almost 60% of adults (63% of males and 54% of females) and nearly one in three school-aged children (29% of boys and 27% of girls) are living with overweight or obesity in the European region. More than 13% of all deaths across the WHO European region are attributed to overweight and obesity.[4] High BMI has been considered for years a growing public health crisis and an epidemic.[5] The exposure to an increasingly 'obesogenic' environment increased the consumption of foods and beverages that are unhealthy, as well as promoted sedentary lifestyles through reductions in opportunities for active mobility in daily lives.[6] Concerns about the health and economic burden of increasing BMI have led to overweight and obesity being included among the global non-communicable disease targets of the Sustainable Development

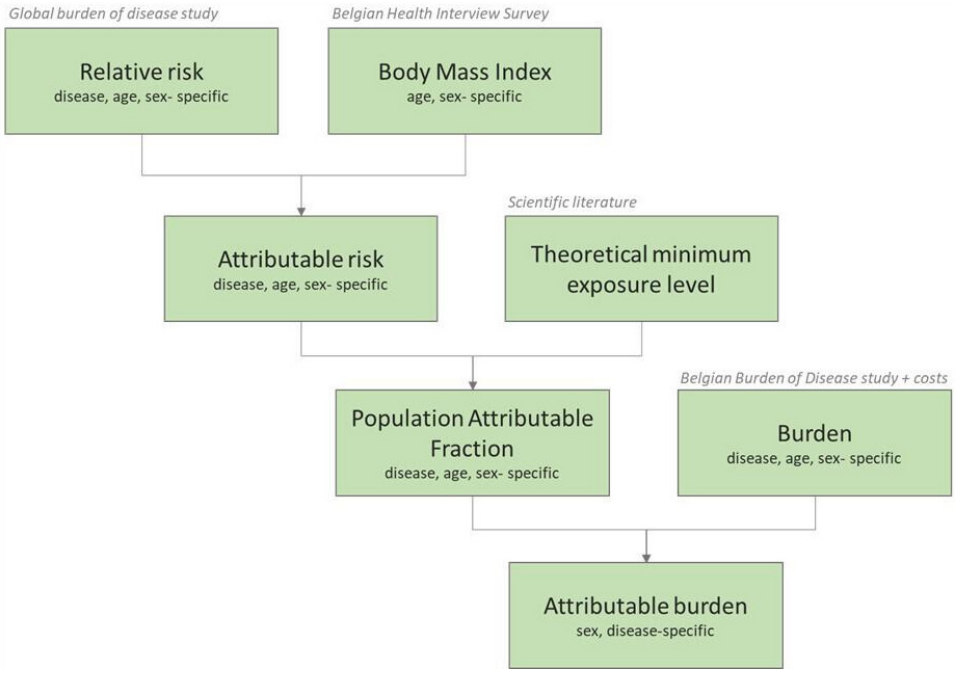

Figure 1 Flowchart of data analysis—in lighter grey the data sources.

Goals.[7] In Belgium, like in other Western countries, the average BMI of the population has increased over the past decades among both children and adults.[8] According to the Belgian Health Examination Survey, in 2018, more than half of the adult population was affected by overweight and 16% was affected by obesity.[8] This is predicted to increase among Belgian adults within the next 10 years.[9] It is therefore essential for countries, including Belgium, to track their progress on high BMI.

The aim of the study is to estimate the attributable burden of high BMI in Belgium, in terms of years of life lost due to disability (YLD), years of life lost due to premature mortality (YLL) and disease costs. We used comparative risk assessment to quantify the fraction of the burden of specific diseases that could be avoided if the risk factor—in this specific case of high BMI—had been maintained at healthy levels.

METHODS

The estimation of the attributable to high BMI (≥25 kg/m^2) followed the general framework established for comparative risk assessment, as used in the Global Burden of Diseases, Injuries and Risk Factors (GBD) study[10] (see figure 1). Population attributable fractions (PAF) were calculated for the year 2018 for selected health outcomes using international literature (GBD study) and local estimates of BMI and burden of disease estimates from the Belgian Burden of Disease (BeBOD) study.[11] All the analyses were conducted in R V.4.2.2.[12] In what follows, each of these steps will be described in more detail.

Estimation of population exposure

BMI estimates were computed using self-reported height and weight from the Belgian Health Interview Survey (BHIS) of 2018. The BHIS is a cross-sectional population survey conducted every 5 years in Belgium.

A stratified multi-stage, clustered sampling method is applied based on the national register number, as described in detail elsewhere.[13] The data included in this study are from the survey conducted between January and December 2018 among a representative sample of the Belgian population (N=11 611) and comprises data on health and related-health behaviours and other determinants. Interviews were performed using face-to-face interview questionnaire, supplemented with a self-administered questionnaire covering more sensitive topics.[13] We included in our analysis only the respondents of the survey, meaning everyone aged 15 years and older. In our analysis, we opted for a continuous distribution of BMI.

Relative risk estimates

We included 15 risk-outcome pairs derived from the systemic assessments conducted in the GBD study 2019.[10] These included: oesophageal cancer, colon and rectum cancer, gallbladder and biliary tract cancer, pancreatic cancer, breast cancer, uterine cancer, ovarian cancer, kidney cancer, thyroid cancer, ischaemic heart disease, ischaemic stroke, intracerebral haemorrhage, subarachnoid haemorrhage, type 2 diabetes, osteoarthritis hip, osteoarthritis knee and low back pain. We adopted the relative risks used in the GBD study 2019 (online supplemental appendix section 1), as also used in other national burden of disease studies.[14] These assumed that people younger than 20 years have no increased risk due to their BMI and that the same risk applies for morbidity and mortality outcomes of each disease.

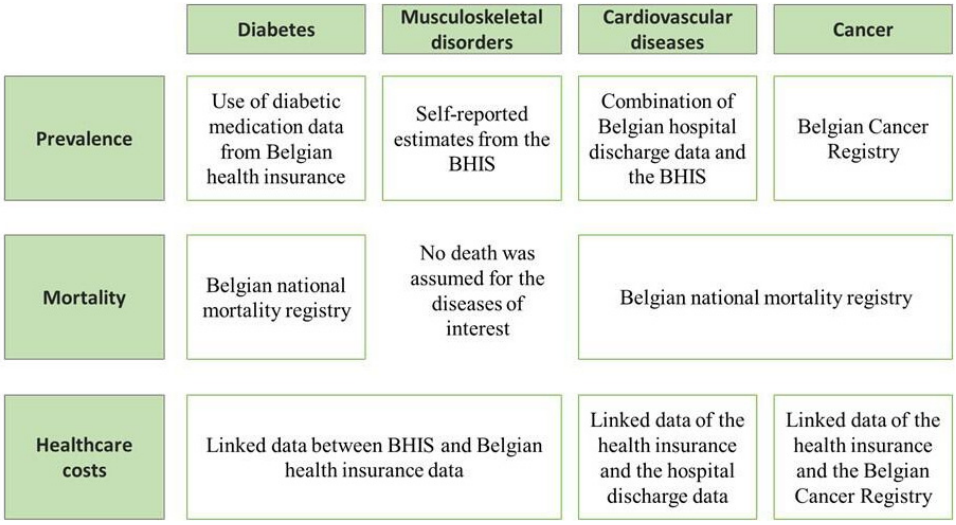

Figure 2 Summary of data sources used for each disease and outcome. BHIS, Belgian Health Interview Survey.

An exponential function was used to characterise the shape of the relative risk across BMI units: $\mathrm{RR}^{(\mathrm{BMI}-25)/5}$. Meaning that for every 5 kg/m^2 units increase in BMI an increase in risk equal to the age, sex and disease-specific relative risk was estimated. Furthermore, no risk increase was accounted for BMI below 25.[10]

Population attributable fraction

The PAF was calculated based on the comparative risk assessment approach, using the following formula:

$$\mathrm{PAF}_d = \frac{\int \mathrm{P}(x)\,\mathrm{RR}(x)_d - 1}{\int \mathrm{P}(x)\,\mathrm{RR}(x)_d}$$

where $\mathrm{P}(x)$ is the prevalence of the BMI value (x) for the participants in the BHIS and $\mathrm{RR}(x)_d$ the relative risk of disease d associated with a BMI equal to x. $\mathrm{P}(x)\ \mathrm{RR}(x)_d$ was computed at individual level based on the individual BMI and the corresponding age- and sex-specific relative risk. For each age and sex combination, a survey weighted average of the combination of BMI and RR was computed and applied in the PAF formula. Age groups- and sex-specific PAFs were calculated for each risk-outcome pair.

Attributable burden of disease

The burden of disease attributable to high BMI was derived by multiplying age- and sex-specific PAFs of each disease by the corresponding burden. Figure 2 summarises the data sources used for each outcome. These included YLD and YLL, and total attributable healthcare costs. We used the prevalence approach for the computation of YLD,[15] with estimates from the BeBOD study (see online supplemental appendix section 1 for details on the data sources used for each disease) and disability weights derived from the GBD study 2019.[10] The data source for YLL computation was the national mortality registry, and the results can be found in Devleesschauwer and Scohy.[16] Healthcare costs were computed using data linkages (see online supplemental appendix section 2 for more details). The health and economic burden of all the disease categories refer to the year 2018. The methods and the results for the burden computation are described in online supplemental appendix sections 3 and 4. For each disease, the sum of the attributable burden was then divided by the sum of the total burden to have the total sex-specific PAFs. This might have caused a difference in PAF for morbidity and mortality outcomes (even if the risk functions were the same), as the burden distribution among the ages is not equally distributed for morbidity and mortality outcomes.

For some diseases, the definition used for the relative risks of the GBD study did not match the BeBOD disease list. This was due to the GBD's disaggregating causes to a further level. For example, osteoarthritis was disaggregated by GBD in different types of osteoarthritis (hip, knee, hand and other types of osteoarthritis), out of which osteoarthritis of the knee and osteoarthritis of the hip had an increased risk linked to high BMI. In the BeBOD study, osteoarthritis was estimated as a single disease. To adjust for the mismatch, a range of sources were used to identify the proportion of the total prevalence of the disease that would correspond to the disaggregation available for the relative risk. For example, the GBD study provides the proportion of osteoarthritis of the hip and knee of the total prevalence of osteoarthritis. PAFs were calculated at the GBD cause level and then multiplied by the proportions summarised in online supplemental appendix table 3 to calculate the attributable burden. In addition, the data source used for the computation of the burden of diabetes does not allow to differentiate between diabetes type 1 and type 2. This means that the PAF computed here is specific to diabetes type 2 but applied to the overall burden of diabetes.

Uncertainty analysis

We used 1000 Monte Carlo simulations to propagate the uncertainty in the different inputs (i.e., distribution of BMI, relative risk). The survey weighted mean and standard error of the $\mathrm{P}(x)\ \mathrm{RR}(x)_d$ by age and sex were

used to have 1000 draws taken from a normal distribution assumed for the average risk. Uncertainty around the relative risk input was estimated using 1000 draws from a gamma distribution. The parameters of the latter (i.e., shape and scale) were computed based on the mean and confidence intervals available in GBD 2019. The two were combined resulting in 1000×1000 PAFs. The 95% CIs are presented for the age- and sex-specific PAF estimates only.

RESULTS

High BMI (≥25 kg/m^2) significantly contributed to the burden of the 15 diseases studied. The results of the contribution of high BMI to the disease outcomes can be found in online supplemental appendix section 4. More specifically, online supplemental appendix table 6 shows the PAF and the attributable burden by sex and disease. The highest PAF was the one for type 2 diabetes which accounted for 41.5% of the morbidity burden for females and 44.5% for males. Uterine cancer represented the second highest attributable fraction for females (around 24% of the overall burden), whereas for males subarachnoid haemorrhage was the second highest (23.0% of the burden). In terms of mortality PAF, diabetes was still the highest (but lower compared with morbidity PAF) with 25.4% for females and 38.8% for males. Age-specific PAF estimates can be found in online supplemental appendix section 4 (Zenodo dataset). Diabetes type 2 was the disease for which the attributable burden was the highest in ages 25–35 years. For most diseases, the peak PAF was observed in the age group 55–65.

The burden attributable to high BMI summed up to around 37 800 YLD, 55 995 YLL and €1.85 billion in healthcare costs attributable to high BMI in Belgium in 2018. Within the diseases studied, type 2 diabetes had the highest attributable burden equal to 9109 YLD, 2556 YLL and €345 million in healthcare costs for females and 9905 YLD, 4762 YLL and €380 million for males. The second highest contributor to the YLD attributable to high BMI was low back pain with 3276 YLD for females and 2798 YLD for males. Low back pain was also the second highest contributor to the attributable healthcare costs with almost 67 million € for females and 57 million € for males. In terms of attributable YLL, the highest burden was for ischaemic heart disease with 5709 YLL for females and 14 767 YLL for males. Ischaemic heart disease was also the disease for which the attributable healthcare cost was the highest.

Figure 3 compares the total burden of the disease and the burden attributable to high BMI in terms of YLD. Musculoskeletal disorders had the highest total number of YLD among the selected diseases (178 065 YLD). 12 332 YLD within musculoskeletal disorders could be attributed to a high BMI. Similarly, almost half of the total burden of diabetes (88 393 YLD) and 5151 YLD of the total burden of cardiovascular disorders (31 772 YLD)

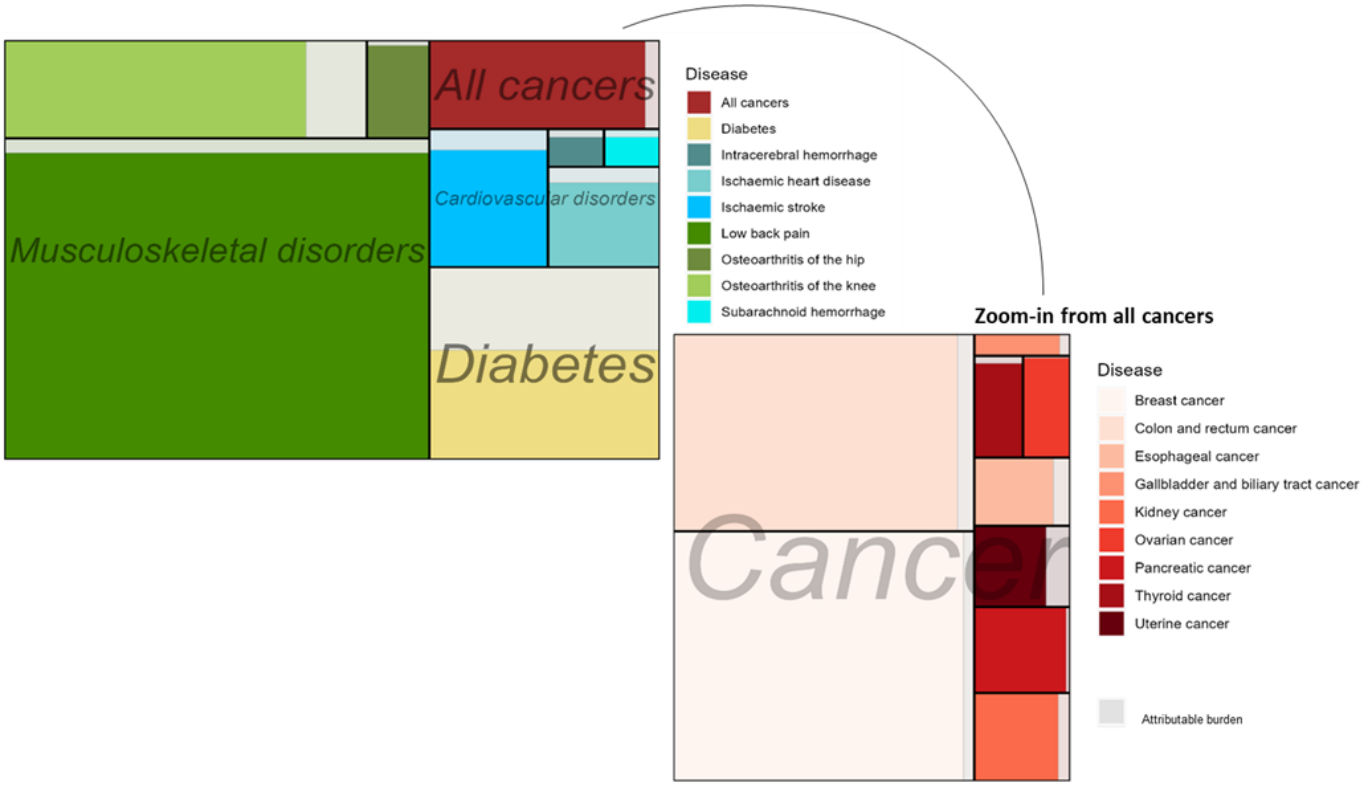

Figure 3 Total and attributable years of life lost due to disability (YLD) per disease—each rectangle represents the total burden in terms of YLD for each of the diseases (colours represent disease groups). The grey area inside each rectangle represents the burden in terms of YLD attributable to high body mass index. The bigger the area the bigger the number of YLD.

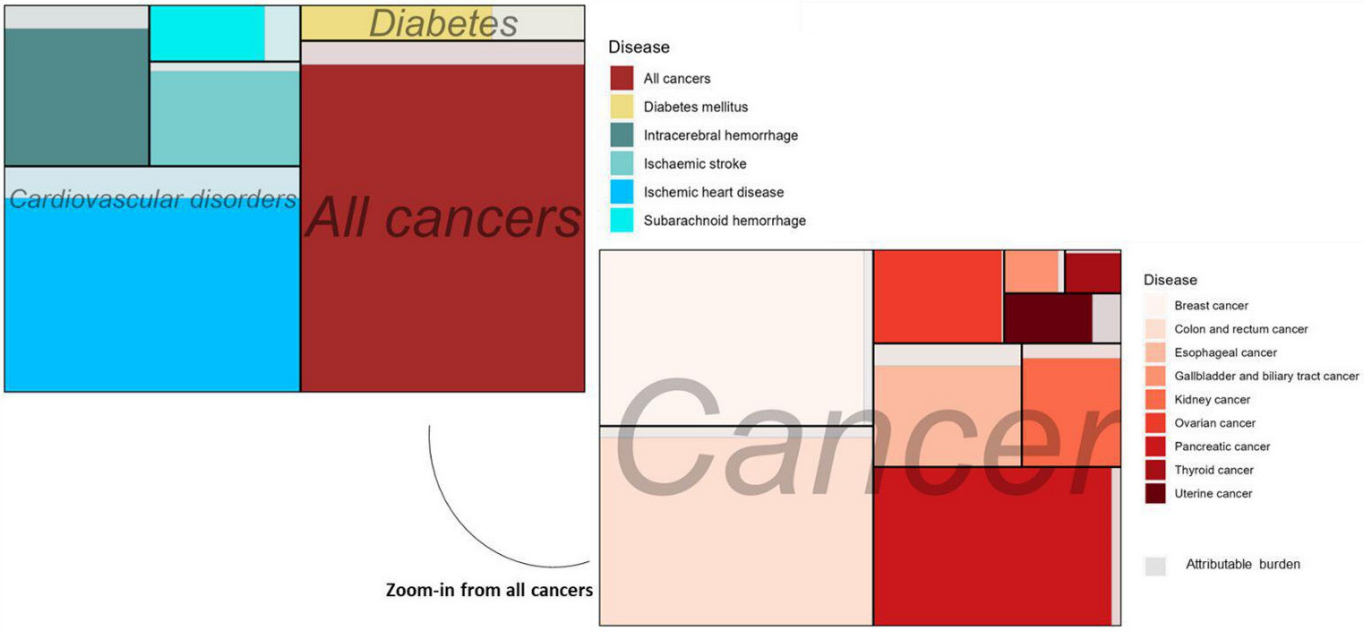

Figure 4 Total and attributable (YLL) per disease—each rectangle represents the total burden in terms of YLL for each of the diseases (colours represent disease groups). The grey area inside each rectangle represents the burden in terms of YLL attributable to high body mass index. The bigger the area the bigger the number of YLL.

could be attributed to a high BMI. The total burden of the selected cancers amounted to 20 417 YLD, out of which 1274 could be attributed to high BMI.

In terms of YLL, cardiovascular disorders had the highest burden with 249 037 YLL in 2018, out of which 31 893 YLL were attributable to high BMI. For all observed cancers, 14 746 YLL could have been avoided within the total burden of 219 040 YLL. Type 2 diabetes had a total burden of 22 321 YLL and 7318 YLL were attributable to high BMI (see figure 4).

DISCUSSION

This study aimed to quantify the burden attributable to high BMI in terms of YLD, YLL and healthcare costs. According to the figures of 2018, around 37 800 YLD, 56 000 YLL and €1.85 billion in healthcare costs could be attributed to high BMI. In particular, diabetes had the highest number of YLD attributable to high BMI followed by musculoskeletal disorders. Cardiovascular diseases accounted for the highest burden in terms of YLL attributable to high BMI, followed by diabetes and different forms of cancers (ie, breast, colon and rectum and oesophageal cancer).

Our results are based on the comparative risk assessment approach in line with the methodology used in the GBD study. Nevertheless, we used exposure and burden estimates locally available from the BeBOD study. Our attributable burden estimates are in general lower than those estimated for Belgium by GBD the study for 2019 but the conclusions are the same regarding the contribution of high BMI to type 2 diabetes and ischaemic heart disease.[10] The differences might be explained by the use of different data inputs for the exposure, the prevalence and mortality. Our estimates are derived from nationally representative data sources that are more accurate to describe the Belgian burden. Nevertheless, GBD estimates account for self-reported bias of BMI and mediation of different risk factors that might also lead to higher results.

Compared with other European studies that used comperative risk assessment as measure of attributable burden, our estimates were lower than the PAF calculated for cardiovascular disease mortality based on a study in the Netherlands (14% vs 50%, respectively)[17] but were similar to those of a study conducted in the England and Wales.[18] However, within the latter study, the PAF for mortality for type 2 diabetes was much higher than the one found in our study (77% vs 33%, respectively). When comparing our estimates to a Swedish study that computed high BMI PAF, they found a much bigger difference among sexes in the PAF for circulatory diseases compared with our study, while the estimates of PAF for musculoskeletal disorders in the same study aligned with ours.[19] These differences could be explained by a number of different methods employed. For example, the above-mentioned Dutch study combines BMI and waist circumference to predict cardiovascular disease mortality within a cohort study.

The implications of this analysis are multiple. Considering that overweight and obesity are growing problems globally, monitoring the burden of high BMI contributes to shedding light on the urgency of implementing internationally recommended effective policy actions to address obesogenic food environments, via, among others, the implementation of food and drink restrictions and taxation, restrictions on food marketing and advertising. The importance of estimating the impact

of risk factors lies not only in the need to inform health policies but also to identify research priorities and form a basis for future modelling of trends and interventions. The same methodology (comparative risk assessment) can be used to estimate the possible impact of different interventions on the burden attributable to a risk factor by altering the counterfactual scenario.

Strength and limitations

One important strength of the study is the use of nationally available data sources for BMI and the burden of the different diseases. These were selected considering the specificity and sensitivity of the data sources as being the most suitable available ones in Belgium. Some of these, like the mortality registry and the cancer registry data, represent a complete coverage of the events occurring in Belgium. Nevertheless, since the exposure estimates were self-reported by survey participants, they are subject to recall and social desirability biases. A recent study conducted on the data of BHIS of 2018 found that using self-reported BMI allowed to detect only 78% of BHIS participants with overweight and 69% of BHIS participants with obesity.[20] This led to an underestimation of our PAF estimates, which might explain some of the differences with the other studies. Data availability also affected the possibility to analyse all the diseases that are related to high BMI. For instance, cardiovascular diseases like atrial fibrillation and hypertensive heart disease are also linked to high BMI but since no burden of disease estimates are yet available in the Belgian national burden of disease study, it was not possible to include them. In addition, different European studies have evaluated PAF of high BMI for prostate cancer[21 22] but the GBD study 2019 did not provide relative risks for this risk-outcome pair. This may have led to an underestimation of the total attributable burden.

Our study did not consider the joint effects that a combination of risk factors or comorbidities can have on the risk attributable burden. For example, physical inactivity and high blood pressure share a common causal pathway with high BMI in the development of cardiovascular disease and type 2 diabetes. The burden might also be affected by the co-occurrence of different diseases, for example diabetes can be a risk factor for cardiovascular diseases. In addition, the relative risks provided by GBD consider the same increased risk for morbidity and mortality outcomes, which represents a simplification of the actual risk. These are estimated by pooling together into a pooled cohorts, or meta-analyses of cohorts of different studies that include prospective observational studies (cohort, pooled cohort and case–control studies) and randomised controlled trials.[10] Relative risks from studies that controlled for confounding were incorporated but not the ones that accounted for factors along the causal pathway between exposure and outcome.[10] Limited information is given on which confounders are included. The absence of, or the limited, control for appropriate confounders might undermine the causal claims made through the PAF. The PAF bias will depend on the magnitude of the confounding, the prevalence of confounding variable and the strength of association between exposure and outcome.[23]

Future research could look at the estimates here presented together with other major factors such as smoking and alcohol. Martin-Moreno and colleagues evaluated the proportions of cancer incidence attributable to different avoidable risk factors in Europe and high BMI ranked third in men (after smoking and alcohol) and second in women (after smoking).[24] This ranking may alter, and in the next decade, as smoking prevalence decreases in some countries, obesity may become the biggest attributable cause of cancer in women.

CONCLUSION

A substantial proportion of the burden of disease, in particular the burden related to type 2 diabetes, low back pain, cardiovascular diseases and some types of cancer can be attributed to high BMI. This evidence on the impact of risk factors is important for monitoring disease burdens and setting priorities for health prevention policies.

Author affiliations
[1]Department of Epidemiology and Public Health, Sciensano, Brussel, Belgium
[2]Department of Public Health, Erasmus MC, Rotterdam, The Netherlands
[3]Department of Rehabilitation Sciences, Ghent University, Gent, Belgium
[4]Centre for Public Health Forecasting, National Institute for Public Health and the Environment, Utrecht, The Netherlands
[5]Department of Public Health and Primary Care, Ghent University, Gent, Belgium
[6]Department of Translational Physiology, Infectiology and Public Health, Ghent University, Gent, Belgium

Contributors The work in this paper was also published in the context of the first author's (VG) PhD thesis. VG designed the model and the computational framework. VG is considered the guarantor of this study. VG carried out the implementation and performed the calculations, under the supervision of DDS and BD. VG wrote the manuscript with input from all authors. All the authors (SV, WJN, RDP, HH, SN, JVdH) approved the manuscript. VG accepts full responsibility for the finished work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Ethical approval was not acquired in the context of this study as it involved the use of secondary data.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data produced in this study is available either with the paper and its appendices or via the Zenodo platform cited in the paper and the appendices. The authors declare that they have not used any type of generative artificial intelligence for the writing of this manuscript, nor for the creation of images, graphics, tables or their corresponding captions.

ORCID iDs
Vanessa Gorasso http://orcid.org/0000-0001-6884-9316
Sarah Nayani http://orcid.org/0000-0002-4842-9645

REFERENCES

1 Singh GM, Danaei G, Farzadfar F, *et al*. The age-specific quantitative effects of metabolic risk factors on cardiovascular diseases and diabetes: a pooled analysis. *PLoS One* 2013;8:e65174.
2 Lauby-Secretan B, Scoccianti C, Loomis D, *et al*. Body Fatness and Cancer--Viewpoint of the IARC Working Group. *N Engl J Med* 2016;375:794–8.
3 Kulkarni K, Karssiens T, Kumar V, *et al*. Obesity and osteoarthritis. *Maturitas* 2016;89:22–8.
4 World Health Organization, Regional office for Europe. Monitoring noncommunicable disease commitments in europe 2021: are we on track to reach targets 10 years after the Moscow declaration and first United Nations high-level meeting. Copenhagen World Health Organization, Regional Office for Europe; 2021. Available: https://apps.who.int/iris/handle/10665/350457
5 Hurt RT, Kulisek C, Buchanan LA, *et al*. The obesity epidemic: challenges, health initiatives, and implications for gastroenterologists. *Gastroenterol Hepatol* 2010;6:780–92.
6 Osei-Assibey G, Dick S, Macdiarmid J, *et al*. The influence of the food environment on overweight and obesity in young children: a systematic review. *BMJ Open* 2012;2:e001538.
7 Ralston J, Cooper K, Powis J. Obesity, SDGs and ROOTS: a Framework for Impact. *Curr Obes Rep* 2021;10:54–60.
8 Sciensano. Health interview survey. Available: https://www.sciensano.be/en/projects/health-interview-survey [Accessed 20 Feb 2023].
9 De Pauw R, Claessens M, Gorasso V, *et al*. Past, present, and future trends of overweight and obesity in Belgium using Bayesian age-period-cohort models. *BMC Public Health* 2022;22:1309.
10 Vos T, Lim SS, Abbafati C, *et al*. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 2020;396:1204–22.
11 De Pauw R, Gorasso V, Scohy A, *et al*. *Belgian National Burden of Disease Study. Guidelines for the Calculation of DALYs in Belgium*. Brussels, Belgium: Sciensano, 2023.
12 R Core Team. R: a language and environment for statistical computing. Vienna, Austria R Foundation for Statistical Computing; 2022. Available: https://www.R-project.org/
13 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.
14 Australian Institute of Health and Welfare. Australian burden of disease study 2018: interactive data on risk factor burden. Available: https://www.aihw.gov.au/reports/burden-of-disease/abds-2018-interactive-data-risk-factors/contents/about [Accessed 20 Feb 2023].
15 von der Lippe E, Devleesschauwer B, Gourley M, *et al*. Reflections on key methodological decisions in national burden of disease assessments. *Arch Public Health* 2020;78:137.
16 Devleesschauwer B, Scohy A. BeBOD estimates of mortality and years of life lost, 2004-2019. Zenodo; 2023.
17 Dis Ineke van, Kromhout D, Geleijnse JM, *et al*. Body mass index and waist circumference predict both 10-year nonfatal and fatal cardiovascular disease risk: study conducted in 20 000 Dutch men and women aged 20–65 years. *Eur J Cardiovasc Prev Rehabil* 2009;16:729–34.
18 Kelly C, Pashayan N, Munisamy S, *et al*. Mortality attributable to excess adiposity in England and Wales in 2003 and 2015: explorations with a spreadsheet implementation of the Comparative Risk Assessment methodology. *Popul Health Metr* 2009;7:11.
19 Ringbäck Weitoft G, Eliasson M, Rosén M. Underweight, overweight and obesity as risk factors for mortality and hospitalization. *Scand J Public Health* 2008;36:169–76.
20 Pelgrims I, Devleesschauwer B, Vandevijvere S, *et al*. Using random-forest multiple imputation to address bias of self-reported anthropometric measures, hypertension and hypercholesterolemia in the Belgian health interview survey. *BMC Med Res Methodol* 2023;23:69.
21 Bergström A, Pisani P, Tenet V, *et al*. Overweight as an avoidable cause of cancer in Europe. *Int J Cancer* 2001;91:421–30.
22 Renehan AG, Soerjomataram I, Tyson M, *et al*. Incident cancer burden attributable to excess body mass index in 30 European countries. *Int J Cancer* 2010;126:692–702.
23 Darrow LA, Steenland NK. Confounding and Bias in the Attributable Fraction. *Epidemiology (Sunnyvale)* 2011;22:53–8.
24 Martin-Moreno JM, Soerjomataram I, Magnusson G. Cancer causes and prevention: A condensed appraisal in Europe in 2008. *Eur J Cancer* 2008;44:1390–403.