

# Health burden and costs of obesity and overweight in Germany: an update

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**Abstract** In 2011, Konnopka et al. (Eur J Health Econ 12:345–352, 2011) published a top-down cost of illness study on the health burden, and direct and indirect costs of morbidity and mortality attributable to excess weight (BMI  $\geq 25$  kg/m<sup>2</sup>) in Germany in 2002. The objective of the current study was to update the 2002 estimates to the year 2008. To simplify comparisons, we closely followed the methods and assumptions of the original study, using 2008 data for most input parameters (e.g. prevalence, mortality, resource use, costs). Excess weight related deaths increased by 31 % (from 36,653 to 47,964) and associated years of potential life lost (from 428,093 to 588,237) and quality adjusted life years lost (from 367,722 to 505,748) by about 37 %, respectively. Excess weight caused €16,797 million in total costs in 2008 (+70 %), of which €8,647 million were direct costs (corresponding to 3.27 % of total German health care expenditures in 2008). About 73 % (€12,235 million) of total excess weight related costs were

attributable to obesity (BMI  $\geq 30$  kg/m<sup>2</sup>). The main drivers of direct costs were endocrinological (44 %) and cardiovascular (38 %) diseases. Indirect costs amounted to €8,150 million in 2008 (+62 %), of which about two-thirds were indirect costs from unpaid work. The great majority of indirect costs were due to premature mortality (€5,669 million). The variation of input parameters (univariate sensitivity analyses) resulted in attributable costs between €8,978 million (−47 % compared to base case) and €25,060 million (+49 %). The marked increase in excess weight related costs can largely be explained by increases in the prevalence of overweight and obesity, and to a lesser extent from increases in resource consumption, as well as increases in (unit) costs and wages (comprising 5.5 % inflation).

**Keywords** Overweight · Obesity · Population attributable fraction · Cost analysis · Germany

**JEL Classification** I00 · I10 · I19 · H42 · H51

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## Introduction

Characterized by an excess of adipose tissue, obesity is a chronic condition with complex genetic-environmental aetiology [1, 2], which promotes the development of serious diseases, such as hypertension, stroke, diabetes, certain forms of cancer, and osteoarthritis [3]. Over the last two decades, obesity has emerged as one of the main risk factors for non-communicable diseases globally [4–6]. According to the World Health Organization (WHO), around one-third of the world's adult population was overweight or obese in 2008 [body mass index (BMI) = kg/m<sup>2</sup>  $\geq 25$  kg/m<sup>2</sup>] [7]. In Germany, 37 % of

adults are currently overweight ( $25 \text{ kg/m}^2 \leq \text{BMI} < 30 \text{ kg/m}^2$ ), and another 23 % are obese ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ) [8]. Research has linked excess weight to decreases in physical functioning [9], health-related quality of life [10], and life expectancy [11, 12], amongst others. Affected individuals were also shown to use more health care services and to generate higher direct and indirect costs, than comparable persons with normal weight [13–15].

In 2011, Konnopka et al. [16] published a top-down cost of illness (COI) study on the health burden and direct and indirect costs of morbidity and mortality attributable to overweight and obesity ( $\text{BMI} \geq 25 \text{ kg/m}^2$ ) in Germany in the year 2002. The direct (i.e. inpatient, outpatient, rehabilitation and other direct) costs amounted to €4,854 million, while the indirect (i.e. sickness absence, early retirement and mortality) costs amounted to €5,019 million. Since preparation and publication of this study, more recent estimates for several input parameters, particularly more up-to-date and valid data on the prevalence of overweight and obesity became available [8]. Therefore, the objective of this update study was, by closely following the methods and assumptions of the original study (OS) [16], to estimate the health burden and direct and indirect costs attributable to overweight and obesity in Germany in the year 2008, and to explain how differences between the OS and the update came about.

## Methods

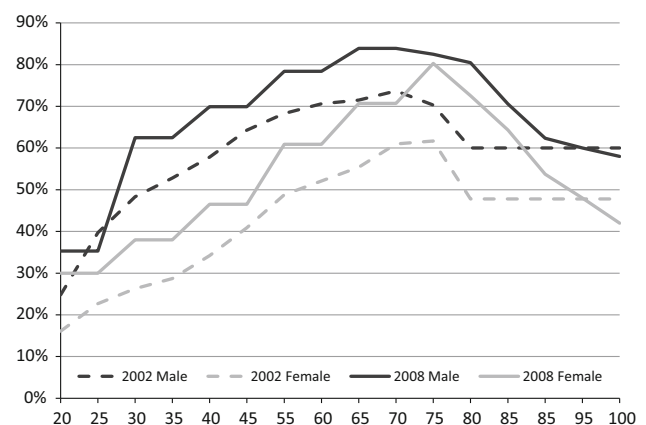
Because this update closely follows the methodological approach of the OS [16], we provide only a brief overview of the methods, in which the emphasis is put on the changes made in the process of the update and on providing the core (corresponding) new references. More detailed information on the calculation of specific morbidity and cost estimates can be found in the OS [16]. In the process of this update, 2008 estimates for the majority of (data) input parameters were used; for instance, prevalence data, mortality data, (unit) cost data, rehabilitation days, inpatient days, sick leave days. Note that the OS and update study used nominal monetary values that refer to different costing years, i.e. 2002 in the OS and 2008 in the update, not corrected for inflation.

The starting point for the study was the calculation of age- and gender-specific population-attributable fractions (PAF) for each considered disease. The PAF method combines (nationally representative) prevalence data with relative risk (RR) estimates for overweight and obesity related diseases [17–19]. To facilitate comparisons, we calculated PAF for the same 19 conditions, using the same RR values [20, 21] and BMI risk classes as in the OS. Prevalence data for the population aged 18–74 years were

taken from the German Health Interview and Examination Survey for Adults (DEGS1) [8]. DEGS1 is a population representative study for Germany, conducted from 2008 through 2011, in which anthropometric measurements of height and weight were used to calculate respondents' BMI. For the population aged 75–100 years, we used data from the population representative German Study on Ageing, Cognition and Dementia in Primary Care Patients (AgeCoDe) [22] to calculate gender-specific prevalences. A graphical juxtaposition of the age- and gender-specific prevalence of excess weight ( $\text{BMI} \geq 25 \text{ kg/m}^2$ ) in Germany in the years 2002 (OS) and 2008 (update) is depicted in Fig. 1. More detailed information is available in the Electronic Supplementary Material (ESM), Table S1.

Subsequently, the updated PAF estimates were used to calculate attributable mortality [23], years of potential life lost (YPLL) [24], and quality-adjusted life years (QALY) lost [25], as well as direct and indirect costs using routine statistics covering the year 2008. Direct costs were estimated for inpatient [26–28] and outpatient treatment [29], rehabilitation [30], as well as for health protection, ambulance, administration, research and education, investments, and other facilities (which are cumulatively presented as “other direct costs”) [29, 31]. Indirect costs were calculated as loss of productivity from paid [32–35] and unpaid work [36] due to sickness absence [37], early retirement [38], and mortality [23], applying the human capital approach using nominal values from the year 2008 (while in the OS nominal values from the year 2002 were used). Costs were calculated from a societal perspective.

Finally, we varied the same set of parameters in univariate sensitivity analyses to evaluate the robustness of our base case results as in the OS. In particular, we (1) calculated PAF with RR values of the 95 % confidence interval, (2) discounted future costs by 0 %, 3 %, and 10 %, (3) calculated indirect costs using the friction cost approach (with a friction



**Fig. 1** Age (x-axis) and gender-specific prevalence (y-axis) of excess weight ( $\text{BMI} \geq 25 \text{ kg/m}^2$ ) in Germany in the years 2002 and 2008

**Table 1** Range of population attributable fractions (PAF) for included excess weight related diseases in the original study (2002) and the update study (2008)

Disease (ICD10) <sup>a</sup>	PAF (%)			
	Male		Female	
	2002	2008	2002	2008
<b>Neoplasms of</b>				
Esophagus (C15) <sup>C</sup>	3–13	7–16	0	0
Stomach (C16) <sup>C</sup>	1–6	3–11	0	0
Colon (C18) <sup>C</sup>	4–18	9–22	2–10	5–16
Liver (C22) <sup>C</sup>	6–25	14–36	1–9	5–17
Gallbladder (C23) <sup>C</sup>	7–25	14–30	4–21	12–34
Pancreas (C25) <sup>C</sup>	3–13	7–17	2–11	6–19
Postmenopausal breast (C50) <sup>C</sup>	0	0	5–22	13–30
Cervix uteri (C53) <sup>C</sup>	0	0	5–23	13–34
Ovary (C56) <sup>C</sup>	0	0	2–10	5–15
Prostate (C61) <sup>C</sup>	2–8	4–11	0	0
Kidney (C64) <sup>C</sup>	4–15	8–19	5–23	14–34
Non Hodgkin's lymphoma (C82–85) <sup>C</sup>	3–13	6–18	3–14	8–21
Multiple myeloma (C90) <sup>C</sup>	4–16	8–21	2–12	6–19
Leukemia (C91–96) <sup>C</sup>	3–14	7–18	0	0
<b>Endocrinological diseases</b>				
Diabetes mellitus type 2 (E11) <sup>M</sup>	36–73	34–79	26–60	28–69
Adiposity (E65–68) <sup>M</sup>	100	100	100	100
Hyperlipidemia (E78.5, E78.9) <sup>M</sup>	5–17	7–19	9–28	6–33
<b>Cardiovascular diseases</b>				
Hypertension (I10–15) <sup>M</sup>	9–39	8–45	8–37	7–49
Coronary heart disease (I20–25) <sup>M</sup>	1–9	4–15	4–20	12–30
<b>Digestive diseases</b>				
Gallbladder disease (K80) <sup>M</sup>	17–48	21–58	12–39	17–49

PAF vary because age-dependent prevalences of overweight and obesity were used for calculation

<sup>a</sup> Relative risk estimates for the calculation of PAF taken from <sup>C</sup> Calle et al. [20], and <sup>M</sup> Must et al. [21]

period of 4 months), (4) valued unpaid work using work costs (net salary plus contributions to social security), and (5) did not value unpaid work.

## Results

PAF, mortality, and associated YPLL and QALY loss

Table 1 shows the (age dependent) PAF ranges for each of the 19 considered excess weight related diseases and obesity (adiposity) itself, from the OS and the 2008 update. Compared to the 2002 ranges, PAF estimates increased in almost all age groups. Whereas, for example, 39 % of

gallbladder disease cases in women aged 50–54 years were attributable to excess weight in 2002, this portion increased to 49 % in the year 2008 (ESM Table S2a).

A total of 47,964 excess weight related deaths were estimated for the year 2008, which corresponds to an increase of almost 31 % compared to 2002 (Table 2). The increase was disproportionately driven by deaths resulting from endocrinological diseases (+70 %) and neoplasms (+41 %). Similar to 2002, the vast majority of all excess weight related deaths were due to cardiovascular diseases and neoplasms (90 %). Deaths caused a total of 588,237 YPLL, or 12.26 YPLL per deceased person. This corresponds to an increase of 37 % compared to 2002. The estimated YPLL correspond to 505,748 QALYs lost (+38 % compared to 2002), or 10.54 QALYs lost per deceased person.

### Direct and indirect costs

Excess weight related diseases led to 440,405 hospital stays (+38 % compared to 2002), 102,031 rehabilitations (+44 %), 11,478,208 sickness absence days (+95 %), and 3,782 early retirements (+1 %) in 2008. Overall, males used more resources than females.

Total costs attributable to excess weight (BMI  $\geq 25$  kg/m<sup>2</sup>) in Germany in the year 2008 amounted to €16,797 million (+70 % compared to 2002). Of these, €8,647 million were direct costs (Table 3), which corresponds to 3.27 % of total German health care expenditures in the year 2008. Total direct costs were about equally distributed across both genders, with 53 % caused by females. About three-fourths of the total direct costs were due to outpatient (€4,696 million) and inpatient care (€1,975 million), with inpatient costs having increased more strongly (+91 %) than outpatient costs (+66 %), compared to 2002. Differentiated by diagnostic groups, 44 % (€3,834 million) of total direct costs were attributable to endocrinological diseases, 38 % (€3,282 million) to cardiovascular diseases, 13 % (€1,106 million) to neoplasms, and 5 % (€425 million) to digestive diseases. Among the excess weight related diseases, diabetes mellitus (E11) contributed the largest share to total direct costs with €2,984 million, followed by hypertension (I10–15) with €1,941 million and coronary heart disease (I20–25) with €1,340 million.

Total excess weight related indirect costs amounted to €8,150 million in 2008 (+62 % compared to 2002), of which about two-thirds (€5,276 million) were costs of unpaid work (Table 3). Overall, the increase in indirect costs of unpaid work was more pronounced (+75 %) than the increase in indirect costs of paid work (+43 %). While total indirect costs were relatively equally distributed across both genders, with 54 % caused by males, there were pronounced gender differences, especially in the

**Table 2** Mortality, YPLL, and QALY loss attributable to excess weight in Germany in 2008 by disease group

	Deaths				YPLL				QALYs					
	Male		Both genders		Male		Both genders		Male		Both genders		± (%) <sup>a</sup>	
Neoplasms	8,339	8,941	17,281	+40.5	119,213	132,543	251,869	+42.3	106,260	111,426	217,686	+41.9		
Endocrinological diseases	2,113	2,581	4,693	+70.1	34,115	31,271	65,385	+72.0	30,599	26,303	56,902	+72.2		
Cardiovascular diseases	8,369	17,444	25,813	+20.4	111,391	157,912	269,303	+27.3	99,130	130,603	229,733	+27.7		
Digestive diseases	63	113	177	+18.7	653	1,027	1,680	+7.3	577	850	1,427	+6.4		
Sum	18,885	29,079	47,964	+30.9	265,484	322,752	588,237	+37.4	236,566	269,183	505,748	+37.5		
± (%) <sup>b</sup>	+48.3	+21.6	+30.9		+51.2	+27.8	+37.4		+50.8	+27.6	+37.5			

<sup>a</sup> Columns show the disease group-specific percentage change in deaths, YPLL, and QALYs lost between 2002 (OS) and 2008 (update) for both genders

<sup>b</sup> Row shows the gender-specific (and combined) percentage change of total deaths, YPLL, and QALYs lost between 2002 (OS) and 2008

indirect cost of paid work, 71 % of which was caused by males. The great majority of indirect costs (€5,669 million) were due to premature mortality. Stratifying total indirect costs by diagnostic groups reveals that almost 80 % were attributable to neoplasms (€3,216 million) and cardiovascular diseases (€3,301 million). Coronary heart disease (I20–25) was the excess weight related disease contributing the largest share (40 %) to total indirect costs.

#### Differentiating between overweight and obesity

Unlike the OS, where all reported findings pertain to excess weight (defined as BMI  $\geq 25$  kg/m<sup>2</sup>), these estimates were calculated separately for overweight (25 kg/m<sup>2</sup>  $\leq$  BMI  $< 30$  kg/m<sup>2</sup>) and obesity (BMI  $\geq 30$  kg/m<sup>2</sup>) in this update (compare ESM Tables S3, S4a–c, S5). When limiting the calculations to individuals with obesity, PAF were necessarily lower than when both overweight and obesity were considered together. Going back to the example above, the PAF for gallbladder disease decreased from 49 to 33 % in females aged 50–54 years when only obesity was considered. In other words, 67 % of all excess weight related cases of gallbladder disease in females aged 50–54 years fell upon obese women. Of the total excess weight related deaths, YPLL, and QALYs lost, 71 %, 74 %, and 75 % were attributable to obesity, respectively, with larger obesity related shares (80 %) observed in males (ESM Table S3).

A similar picture emerged for direct and indirect costs. Around 74 % (€12,235 million) of total excess weight related costs of €16,796 million were attributable to obesity. However, these shares differed by cost categories, disease groups, and individual diseases. While 70 % of total direct excess weight related costs were related to individuals with BMI  $\geq 30$  kg/m<sup>2</sup>, this proportion was 6 % higher for indirect costs (paid and unpaid work combined). When differentiating total (direct and indirect) costs by disease group, obesity related shares ranged from 68 % in digestive diseases to 76 % in cardiovascular diseases (Table S4a). Further variation was found when considering individual diseases in each disease group. For example, the share of total excess weight related costs attributable to obesity ranged from 32 % in hyperlipidemia (E78.5, E78.9) to 95 % in liver cancer (C22) in females [excluding adiposity (E65–68), where the share is by definition 100 %]. Thus, whereas in the former around two-thirds of total costs were related to overweight, the respective share was only about 5 % in the latter.

#### Sensitivity analyses

The results of the univariate sensitivity analyses are shown in Table 4. Using the low and high bound of the RR values

**Table 3** Costs attributable to excess weight (BMI  $\geq 25$  kg/m<sup>2</sup>) in Germany in the years 2002 and 2008 (in millions of euros)

	Neoplasms		Endocrinological		Cardiovascular		Digestive		ALL						
	2002	2008	± (%)	2002	2008	± (%)	2002	2008	± (%)	2002	2008	± (%)			
<b>Direct costs</b>															
Inpatient	277	424	+53.1	284	523	+84.1	315	793	+151.9	160	235	+47.0	1,036	1,975	+90.7
Outpatient	202	359	+77.6	1,345	2,433	+80.9	1,196	1,800	+50.5	80	104	+30.5	2,823	4,696	+66.3
Rehabilitation	60	94	+56.8	78	79	+1.2	39	77	+97.2	0	0	+32.8	177	250	+41.3
Other <sup>a</sup>	122	229	+88.1	369	799	+116.6	285	612	+114.8	42	85	+101.8	818	1,726	+111.0
Total	660	1,106	+67.6	2,076	3,834	+84.7	1,835	3,282	+78.9	282	425	+50.6	4,853	8,647	+78.2
<b>Indirect costs paid work</b>															
Mortality	438	604	+38.0	143	265	+85.4	346	503	+45.2	3	2	-35.0	930	1,374	+47.7
Early retirement	141	193	+37.0	295	306	+3.7	158	142	-10.4	1	0	-58.2	595	641	+7.8
Sickness absence	58	169	+191.1	141	174	+23.7	247	450	+82.1	35	65	+85.2	481	858	+78.5
<b>Indirect costs unpaid work</b>															
Mortality	1,059	1,924	+81.7	212	462	+118.0	1,171	1,897	+62.0	9	12	+29.7	2,451	4,295	+75.2
Early retirement	117	195	+67.0	176	244	+38.4	104	120	+15.1	0	0	-120.3	397	559	+40.8
Sickness absence	37	129	+249.4	41	71	+72.8	74	190	+156.9	13	32	+145.9	165	422	+155.9
Total indirect costs	1,850	3,216	+73.8	1,008	1,522	+51.0	2,100	3,301	+57.2	61	111	+82.0	5,019	8,150	+62.4
Direct and indirect costs	2,510	4,322	+72.2	3,084	5,356	+73.7	3,935	6,583	+67.3	343	536	+56.2	9,872	16,797	+70.2

<sup>a</sup> Includes costs for health protection, ambulance, administration, research and education, investments, and other facilities



**Table 4** Results of univariate sensitivity analyses results changing key model parameters

Parameter changed	Direct costs		Indirect costs		Total costs	
	EUR <sup>a</sup>	± (%) <sup>b</sup>	EUR <sup>a</sup>	± (%) <sup>b</sup>	EUR <sup>a</sup>	± (%) <sup>b</sup>
Base case values	8,647		8,150		16,797	
Relative risks high values	12,042	+39	13,018	+60	25,060	+49
Relative risks low values	5,181	-40	3,797	-53	8,978	-47
Friction cost approach	8,647	0	6,246	-23	14,893	-11
Discount rate 0 %	8,647	0	11,403	+40	20,050	+19
Discount rate 3 %	8,647	0	9,169	+13	17,816	+6
Discount rate 10 %	8,647	0	6,499	-20	15,146	-10
No valuation of unpaid work	8,647	0	2,874	-65	11,521	-31
High valuation of unpaid work	8,647	0	14,476	+78	23,123	+38

<sup>a</sup> Costs are in millions of euros

<sup>b</sup> Columns show the percentage change in direct, indirect and total costs, in comparison to the base case

resulted in total excess weight related costs between €8,978 million (-47 %) and €25,060 million (+49 %). The remaining sensitivity analyses affected only indirect costs. When unpaid work was not valued, indirect costs decreased by 65 % to €2,874 million, while using the friction cost approach (instead of the human capital approach) decreased indirect costs by 23 % to €6,246 million. Indirect costs markedly increased (+78 %) when unpaid work was calculated using work costs (i.e. net salary plus contributions to social security), and when future costs were not discounted (+40 %).

## Discussion

This update study estimated the health burden and direct and indirect costs attributable to overweight and obesity in Germany in the year 2008. It closely followed the methodological approach of Konnopka et al. [16], using 2008 estimates for the majority of (data) input parameters. In addition to the 2008 morbidity and cost estimates, the percentage changes between 2002 and 2008 were presented and explained.

### Summary of the main results

Excess weight related deaths increased by 31 % (from 36,653 to 47,964), and associated YPLL (from 428,093 to 588,237) and lost QALYs (from 367,722 to 505,748) by

about 37 %, respectively. Increases in attributable mortality, YPLL, and lost QALYs between 2002 and 2008 were disproportionately driven by males, which is largely the result of stronger prevalence increases in the overweight ( $25 \text{ kg/m}^2 \leq \text{BMI} < 30 \text{ kg/m}^2$ ) and obese ( $30 \text{ kg/m}^2 \leq \text{BMI} < 35 \text{ kg/m}^2$ ) risk classes in men, compared to women. While women experienced more attributable deaths in 2008 than men, only 61 % of all attributable deaths fell upon women in 2008, compared to 76 % in 2002. As in 2002, these differences came about largely from gender differences in the mortality from coronary heart disease. Because of the higher attributable mortality and (minor) increases in life expectancy, excess weight led to an additional 0.58 YPLL and 0.51 QALYs lost per deceased person in 2008, compared to 2002.

Total excess weight ( $\text{BMI} \geq 25 \text{ kg/m}^2$ ) related costs increased from €9,873 million in 2002 to €16,797 million in 2008 (+70 %). Of these, about half were direct costs, which increased by 78 % to €8,647 million in 2008. The growth in excess weight related direct costs between 2002 and 2008 was much more pronounced than that of total German health care expenditures in the same time period (+15.8 %). As a result, 3.27 % of total German health care expenditures were attributable to excess weight in 2008, compared to 2.1 % in 2002. Similar to 2002, outpatient costs contributed the largest share to total direct costs (54 %), driven by outpatient drug costs for endocrinological and circulatory diseases. Overall, costs for these two disease groups also contributed the largest share to overall direct costs. Cost for rehabilitations increased by 41 % since 2002. Yet, there were marked differences between disease groups. While costs for rehabilitation of circulatory diseases nearly doubled between 2002 and 2008, those for endocrinological diseases remained almost unchanged. This pattern came about as a result of actual decreases in the rehabilitation cases and days in the endocrinological and digestive diseases, but increases of rehabilitation cases and days in the neoplasms and cardiovascular diseases.

Indirect costs increased from €5,019 million in 2002 to €8,150 million in 2008 (+62 %), of which about two-thirds were indirect costs from unpaid work. The majority of indirect costs from paid work appeared in men, because of higher employment rates and higher average salaries of men. Unlike in 2002, total indirect costs in unpaid work appeared about equally in both genders (54 % in women). Increases in indirect costs of unpaid work were generally more pronounced than increases in indirect costs of paid work. Although this is not easily explained (and differs in extent between cost categories), the main reason was the stronger increase in work costs per hour applied to unpaid work, compared to increases of average salaries in paid work, combined with different age dependent employment rates in the year 2008. Indirect costs from early retirement,

particularly those from paid work, increased comparatively less between 2002 and 2008 than those of mortality and sickness absence. When differentiated by disease groups, it becomes obvious that the increase was driven by cancer related early retirement, while the other disease groups' increase was not as strong (or costs even decreased, as was the case in indirect costs from paid work of circulatory and digestive diseases). The observed increases were the consequence of increases in PAF and (remaining) lifetime productivity; the raw number of early retirements for the considered diseases was lower in 2008 than in 2002.

Calculating the total excess weight ( $\text{BMI} \geq 25 \text{ kg/m}^2$ ) related health burden and separated costs for overweight ( $25 \text{ kg/m}^2 \leq \text{BMI} < 30 \text{ kg/m}^2$ ) and obesity ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ), demonstrates that the majority of deaths (71 %), YPLL (74 %), QALYs (75 %), and direct and indirect costs were due to obesity. Of the total excess weight related costs of €16,797 in 2008, around 74 % were attributable to obesity (the remaining 26 % thus to overweight). When considering individual diseases, these obesity-attributable shares show wide variation, as a consequence of differences in the age-specific prevalence of overweight and obesity in combination with differences in the RR values drawn upon to calculate PAF (ESM Table S5).

#### Cost differences explained

Overall, excess weight related morbidity, mortality, and direct and indirect costs were markedly higher in Germany in the year 2008, compared to the year 2002. Yet, costs did not increase in a similar fashion for all cost categories and diseases (and accordingly disease groups), and even decreased in a few cases, as has been shown above. Although the update study closely followed the methods and assumptions of the OS, several crucial input parameters/data were changed in the process. As a consequence of their complex interplay, the resultant differences in the 2002 and 2008 cost estimates evade simple explanations in most cases.

The main driver behind the cost increases was the rise in the prevalence of overweight and obesity in Germany between 2002 and 2008 [8]. With the exception of the youngest and oldest age groups, the prevalence data drawn upon to calculate PAF was (markedly) higher in 2008, compared to the 2002 values (see Fig. 1). Since the same RR values as in the OS were used for the update, PAF estimates necessarily increased in almost all age groups (particularly in the risk classes with  $\text{BMI} \geq 30 \text{ kg/m}^2$ ). It should be noted, however, that the prevalence data used in the OS was based on self-reported height and weight. It has been shown that BMI based on self-reports of height and weight is typically lower than BMI calculated with data from objective (anthropometric) measurements [39, 40].

Thus, the 2002 PAF likely underestimated the real PAF, and hence mortality and costs, leading to an exaggeration of the percentage differences between the 2002 and 2008 estimates.

Another source of varying cost increases or decreases were differing increases or decreases in resource consumption (e.g. inpatient days) and cost data (e.g. average salaries, unit costs) between 2002 and 2008, which had been used to derive attributable estimates. As has been indicated above, resource consumption of some considered services actually decreased between 2002 and 2008 (e.g. total rehabilitation days for diabetes mellitus (E11) decreased by 8 %, from 564,216 in 2002 to 521,748 in 2008). The minor increase in the rehabilitation costs for endocrinological diseases of 1.2 % was a consequence of the increase in PAF and unit costs. Because nominal values were used to calculate percentage differences in costs, the reported percentage changes include overall inflation in Germany between 2002 and 2008 (5.5 %). Another relevant cause for cost differences, particularly relevant in the estimation of indirect costs, are changes in the population structure and employment rates of men and women.

#### Comparison with the literature

Over the last two decades, excess weight related costs have been estimated for a variety of countries. The findings have been summarized in several review articles [13, 15, 41–44]. Various methods were employed to derive cost estimates [13, 15], which may broadly be categorized into database studies, modelling studies, and PAF based studies. Several of these reported nationally aggregated or total population costs [13, 15, 41, 43]. As direct comparisons of national cost estimates between studies conducted in different countries are impeded by differences in population size, prevalence of overweight and obesity, and in health care systems, amongst others, we will focus on three studies from Germany [40, 45, 46].

Besides the OS by Konnopka et al. [16], three further studies reported excess weight related total population costs for Germany. Two of these are PAF based (top-down) studies providing (comprehensive) direct and indirect costs estimates for the population with  $\text{BMI} \geq 30 \text{ kg/m}^2$  [45, 46], the other is a database (bottom-up) COI study, which was limited to sickness absence costs (from paid work) for individuals with  $\text{BMI} \geq 25 \text{ kg/m}^2$  in 2008 [40]. The two PAF based studies reported total population costs of €4,240 million (€4,541 million in 2008 euros), with 52 % being indirect costs [46] and €13,067 million (€13,662 million in 2008 euros), with 13 % being indirect costs [45], whereas in this update study we found obesity attributable costs of €12,235 million, with 51 % being indirect costs (€8,277 million, with 27 % being indirect costs, when only indirect

costs of paid work are considered). The database COI study [40], in which excess weight ( $\text{BMI} \geq 25 \text{ kg/m}^2$ ) related per worker excess costs were first calculated using a representative sample of the German working population which were then extrapolated to the total working population in Germany, reported sickness absence costs of €2,180 million, which is about 2.5 times as much as the €858 million found in this update study. While the specific reasons for this pronounced discrepancy are difficult to disentangle, it has been shown that database studies typically report higher costs, compared to PAF based studies [15]. Because the three PAF based studies are—in theory—more easily comparable, the following paragraph will elaborate on differences and similarities of the studies by Knoll and Hauner [45] and Sander and Bergemann [46] to the current update study.

As top-down COI studies typically estimate costs for diseases associated with some risk factor, a good starting point to compare such studies are assumptions concerning the risk factor itself, as well as the follow-up diseases considered. Unlike this update, both previous German top-down studies are limited to the cost of obesity ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ). Constricting the analysis to obesity ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ) leads to, *ceteris paribus*, lower costs than when overweight ( $25 \text{ kg/m}^2 \leq \text{BMI} < 30 \text{ kg/m}^2$ ) is considered as well. In the current update, about 26 % of total costs fell upon individuals with overweight. Apart from the definition of the risk classes itself, the estimation of PAF is moreover highly dependent on the prevalence and the RR values within each of the risk classes. Based on the information provided, it was not possible to determine whether age- and gender-specific risk classes were employed to calculate PAF in the other two German COI studies [45, 46]. Concerning the number and types of excess weight related diseases included, the three available German COI studies starkly differed from each other as well. Whereas 19 excess weight related diseases were considered in this update, Knoll and Hauner [45] considered 11, while Sander and Bergemann [46] considered only four. What is more, the diseases only partly overlap between the three studies, i.e. while all studies included diabetes, hypertension, cardiovascular conditions (with definitional ambiguities, though), Knoll and Hauner [45] also considered some conditions not included in the current update study (i.e. osteoarthritis, depression, sleep apnea). Not including economically relevant diseases shown to be associated with excess weight [47], results in, *ceteris paribus*, lower and thus more conservative cost estimates [15, 46]. Another methodological aspect which has a straightforward impact on obtained cost estimates is the type of costs considered, as well as assumptions surrounding their calculation (e.g. approach in evaluating indirect costs, discount rate applied). While all three studies calculated direct and

indirect costs, only in the current update study were indirect costs of unpaid work considered (in addition to indirect costs in paid work). For the population with obesity, we found that 32 % (or €3,958 million) of the total obesity attributable costs of €12,235 million were associated with productivity losses in unpaid work.

However, as total costs, specific cost categories and the respective shares of direct and indirect costs differed, even for specific diseases (considered in all three studies), further methodological differences in input data, assumptions, and calculations must have had a substantial impact on the obtained cost estimates. For instance, the total obesity attributable costs (i.e. the direct and indirect costs of paid work) of hypertension ranged from €788 million (€823 million in 2008 euros) [45] to €3,862 million (€4,136 million in 2008 euros) [46], while the current study found €1,536 million. Unfortunately, due to lack of sufficient methodological information about these studies, we were not able to explain how these stark variations in cost estimates (even for particular diseases and within specific cost categories) may have come about.

#### Limitations

This update study has several limitations, many of which stem from its methodological (top-down) PAF based approach, and the attempt to update the 2002 estimates to 2008 using the same methodological framework. Since several limitations have already been extensively discussed in the OS, which similarly apply to this update study, we will briefly summarize these to begin with, before further limitations are presented. First, the prevalence based approach chosen unrealistically assumes that the risk factor and resulting diseases occur within the same time period, which leads to problems, particularly when the prevalence of the risk factor is not stable over time. Second, possible interactions between the included diseases are not captured in the RR values used. Third, transferring RR from epidemiological studies from the USA to Germany goes along with uncertainty. Third, the underweight ( $\text{BMI} < 18.5 \text{ kg/m}^2$ ) and normal weight ( $18.5 \text{ kg/m}^2 \leq \text{BMI} < 25 \text{ kg/m}^2$ ) prevalence groups were, for technical purposes, combined to calculate PAF. Fourth, it was assumed that length of stay in hospital and in rehabilitation was equal in patients with normal weight and those with excess weight. Fifth, some of the cost estimates presented were calculated based on highly aggregated (cost and service use) data. Preparing and employing these data made several assumptions necessary, which are subject to uncertainty. Together, these limitations have likely led to an overestimation of total excess weight related costs [16].

In addition to the points above, this update study has further limitations. First, not all possible excess weight



related conditions were considered (e.g. asthma, osteoarthritis, sleep apnea, congestive heart failure, stroke) [47]. For reasons of comparability we limited the considered conditions to those of the OS. Omitting costly diseases such as congestive heart failure and stroke will have led to an underestimation of the actual excess weight related costs. Second, lost productivity as a result of presenteeism (i.e. reduced productivity at work) was not considered, because no corresponding data was available for Germany. Internationally, research has repeatedly shown that excess weight is a significant predictor for presenteeism [47], and that presenteeism may be responsible for a considerable share of overall productivity loss in overweight and obese workers [48]. Therefore, recognizing lost productivity from presenteeism would have resulted in higher indirect and hence total costs. Combined, these two limitations may have contributed to a conservative cost estimate of excess weight in Germany. Using the same RR values as in the OS may be another limitation. However, assuming that the physiological susceptibility to develop obesity related diseases because of excess weight is largely independent of time and thus of secular trends as well, the methodological quality of a study is likely of greater importance than the point in time a study was conducted. Comparing the RR values used in the OS and update study to those from a meta-analysis from Guh et al. [47] indicates that the above conjecture is (empirically) plausible.

### Conclusions and policy implications

The findings of this update study have shown that excess weight (BMI  $\geq 25$  kg/m<sup>2</sup>) related direct (health care) and indirect (lost productivity) costs are formidable and emphasize the large economic and societal burden accompanied by this risk factor/disease in Germany. Our results stress the importance and need for further therapeutic and particularly preventive health promotion efforts in Germany in order to curtail the negative consequences of this (modern) lifestyle and health problem. Effective interventions should be evaluated regarding their cost-effectiveness, and if found to offer good value (health improvements) for the money invested, be implemented. Very few interventions, particularly interventions focusing on prevention [49], have so far been evaluated regarding their cost-effectiveness in the German setting, however, although several preventive interventions have been shown to be cost-effective in the long-term in the international literature [50]. Further research is needed.

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