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# Beyond the healthcare sector: A systematic review of indirect cost of overweight and obesity

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# Beyond the healthcare sector: A systematic review of indirect cost of overweight and obesity

Running title: Indirect cost of overweight and obesity

Anna Grosse[*1], Andrea Goettler[*1], Diana Sonntag[1, 2] PhD

Affiliations:

[1] Mannheim Institute of Public Health, Social and Preventive Medicine, University Medicine Mannheim, Heidelberg University, Mannheim, Germany

[2] Department of Health Sciences, University of York, York YO10 5DD, UK

[*] These authors contributed equally to this work.

Corresponding author:

Diana Sonntag, PhD,

Mannheim Institute of Public Health, Social and Preventive Medicine, University Medicine Mannheim, Heidelberg University, Ludolf-Krehl-Straße 7-11, 68167 Mannheim, Germany

Phone: +49-621-383-9922

Fax: +49-621-383-9920

E-mail: mail@diana-sonntag.eu

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ABSTRACT

Objective: The increasingly high levels of overweight and obesity among the workforce are accompanied by a hidden cost burden due to losses in productivity. This study reviews the extent of indirect cost of overweight and obesity.

Methods: A systematic search was conducted in eight electronic databases (PubMed, Cochrane Library, Web of Science Core Collection, PsychInfo, Cinahl, EconLit, and ClinicalTrial.gov). Additional studies were added from reference lists of original studies and reviews. Studies were eligible if they included monetary estimates of indirect costs of overweight and obesity. The authors reviewed studies independently and assessed their quality.

Results: Of the 3 369 search results, 43 studies met the inclusion criteria. A narrative synthesis of the reviewed studies revealed substantial costs due to lost productivity among workers with obesity. Especially absenteeism and presenteeism contribute to high indirect costs. The results however vary greatly, especially regarding the cost of overweight, which was even associated with lower indirect costs than normal weight in three studies.

Conclusion: The evidence predominantly confirms substantial short- and long-term indirect costs of overweight and obesity in the absence of effective customised prevention programmes and thus demonstrates the extent of the burden of obesity beyond the healthcare sector.

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Strength and limitations of this study

- This is the first international study that provides a comprehensive overview about all major cost categories of indirect costs including absenteeism, presenteeism, disability, premature mortality and worker compensation.
- This is the only review that presents an extensive comparison of monetary consequences of all indirect cost categories on the microeconomic and macroeconomic level.
- The question of causality between obesity and costs is briefly addressed and rounded off by recommendations.

- Due to the heterogeneity of the studies and their methodologies it is not possible to conduct a meta-analysis of the results and present an indirect costs average based on the literature.
- Publication bias (whereby positive studies are more likely to be published than negative studies) and selection bias (owing to our language limitation) limit the generalizability of findings.

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ABBREVIATIONS

US = United States

COI = Cost-Of-Illness

BMI = Body Mass Index

PAF = Population Attributable Fraction

FCA = Friction Cost Approach

HCA = Human Capital Approach

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## INTRODUCTION

The obesity epidemic has become a global public health concern[1]. The rising rates of overweight and obesity are accompanied in adulthood by a higher risk of type 2 diabetes, hypertension, coronary heart disease, and stroke[2], which cause substantial healthcare costs. In 2008 the estimated annual medical cost of obesity in the United States was $147 billion due to 42% higher medical spending per capita[3]. Although the United States has significantly high obesity costs, other countries such as Germany also struggle with substantial overweight and obesity related medical costs of $9.2 billion[4]. The rising prevalence of overweight and obesity is also related to indirect costs resulting from morbidity and mortality[5-7]. Indirect costs are defined as the losses from reduced work productivity. In particular, obesity is associated with an increased risk of temporary work loss (sick leave, presenteeism) and permanent work loss (disability pension, premature death)[5, 6]. Indeed, recent reviews have found strong evidence that temporary and permanent work loss attributable to obesity result in a substantial burden for national health and insurance pension systems[8, 9].

While a number of systematic reviews have analysed lost productivity of overweight and obesity among workers, their range is relatively narrow. For example, several do not include the monetary value of the indirect costs[5-7, 10], while others focus only on the combined direct and indirect costs of obesity[10, 11]. Similarly, a few limit their range by concentrating on specific countries[9, 12] or specific cost categories, such as absenteeism and disability[5-7, 10]. Indeed, only one review provides a more extensive overview of the economic consequences of absenteeism, presenteeism, disability, premature mortality, and worker compensation costs[13]. However, even this review does not comprehensively assess the monetary value of indirect cost or provide a quality assessment of the included studies. In addition, it identifies several weaknesses among the included studies, such as the paucity of longitudinal studies and presenteeism assessments, and the need for presenting comparable results such as the monetary values of missed work.



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Our review addresses the shortcomings of previous systematic reviews and includes studies which acknowledge the research gaps noted by Trogdon et al[13]. With its broad range, our review is the only international review that presents an extensive comparison of monetary consequences of all indirect cost categories. We systematically review and critically assess both the current evidence for each type of indirect costs and the methodology and research design used. In addition, we address briefly the question of causality between obesity and costs.

## Methods

This review was conducted according to the Centre for Reviews and Dissemination guidance for undertaking reviews in healthcare[14].

### Search strategy

In cooperation with a Cochrane expert from the University Library of Heidelberg, we developed a search strategy to identify all published studies on indirect costs of overweight and obesity. A keyword search was carried out using the following electronic databases and study registers from inception to May 2015: PubMed, Cochrane Library, Web of Science Core Collection, PsychInfo, Cinahl, EconLit, and ClinicalTrial.gov. The search terms and the search strategy are outlined in Supporting Information S1 and S2.

### Inclusion and exclusion criteria

Studies were included if they contained a monetary estimate of indirect costs of overweight and obesity. Indirect costs were defined as costs of overweight and obesity on labour market outcomes (absenteeism, presenteeism, short- and long-term disability, premature death). We excluded studies published in languages other than English or German, published before the



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year 2000, located in a developing country due to substantial differences in labour markets, and connected to age or other illnesses. Furthermore, only peer-reviewed studies with a full-text available were included.

**Study selection procedure and data extraction**

Two reviewers independently applied the inclusion and exclusion criteria. All studies underwent a title and abstract screening, and potentially relevant citations were additionally checked in a full-text screening. Disagreements were resolved through discussion and reasons for exclusion recorded. Finally, 43 studies were identified as eligible. The PRISMA diagram (Figure 1) illustrates the study selection process. Data extracted included study design, target population, time horizon, effect groups, cost category and measurement, and background characteristics such as authors and years of study and publication. Costs were first inflated to 2015 rates using country-specific gross domestic product inflators from the Organisation for Economic Co-Operation and Development (http://stats.oecd.org) and then converted to November 2015 US dollars. If the year of costing was missing, the authors of the cost-of-illness (COI) study were contacted by e-mail.

**Quality assessment**

In the absence of a checklist for COI studies, we conducted a quality assessment by adapting the checklist by Stuhldreher and co-authors, which evaluates the quality of COI studies[15]. We assessed the following items: scope, general economic characteristics, calculation of costs, study design and analyses, and presentation of results (see Table S3). We performed the detailed assessments independently and resolved all discrepancies and uncertainties through consensus.

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RESULTS

We identified 3 369 articles from the database searches. Title and abstract screening reduced these further to 263 studies, which were retrieved in full text. Reviewing reference lists of relevant papers, studies, and systematic reviews added four potentially relevant studies (Figure 1). Following full-text review, we excluded 220 of these studies, leaving 43 studies to be included in the review.

[Insert Figure 1]

**General characteristics of the studies**

There was a wide variety among the included studies in terms of costs, target population, and methodology. Table S4 shows the sample, methodology, quality, and results of the studies. Most studies were conducted in the United States (23 studies), followed by Germany (7 studies), Canada (4 studies), Australia (2 studies), Sweden (2 studies), Finland (1 study), Ireland and Northern Ireland (1 study), Korea (1 study), New Zealand (1 study), and the Netherlands (1 study). For cost estimations a microeconomic or a macroeconomic approach was applied. While the macroeconomic approach captures the national economic loss of resources measured as national cost, the microeconomic approach measured indirect cost that occur per capita or employee. More specifically, most studies assessed the costs of absenteeism, presenteeism, short- and long-term disability, and premature death. Only five[16-20] included insurance claims, such as indemnity claims, workers' compensation and other microeconomic costs related to recruitment, training, traffic, nursing, or injuries. The majority of the studies included the costs of more than one of these cost categories.

Both the human capital approach (HCA) and the friction cost method (FCM) were used to calculate productivity losses. The HCA estimates costs based on the lost productivity of one individual, for example the entire working time lost due to early retirement. The FCM only



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estimates the value of productivity lost until the employee is replaced. For example, if a worker goes into early retirement, the FCM would only count the period of working time lost until the worker is replaced[19, 21].

The effect measure was exclusively the body mass index (BMI). BMI cut-off points were based on standard World Health Organisation recommendations, with the exception of two studies[18, 22]. Few studies estimated indirect costs related due to obesity-related co-morbidities[20, 22-35]. Some controlled for physical and psychological comorbidities in regression analyses[36, 37] or created subgroups for the costs of additional, related diseases[18, 38, 39].

In Table S4 the search results were grouped by methodology into cross-sectional, longitudinal, population attributable risk, and modelling studies. The majority were cross-sectional studies, which focused on annual per capita costs by assessing the overweight and obesity prevalence at a specific point in time. Longitudinal studies evaluated excess weight over a timespan of four[40] to 38 years[21]. The attributable risk studies applied the population attributable fraction (PAF) method to estimate national costs. Only one study modelled the future costs of overweight and obesity based on disease prevalence among teenagers[41]. Eight studies were categorised separately as “other studies”, which were not as representative. This category includes one intervention analysis[32] and studies with non-representative samples, such as bariatric surgery eligible patients[27, 29, 42], military participants[33, 43], parents of children with overweight or obesity[22], and hospital staff working with patients with obesity[34].

**Microeconomic findings**

The cross-sectional and longitudinal studies mostly focused on the per capita or per employee indirect costs of overweight and obesity. Figure 2 displays excess cost by weight category due to absenteeism, presenteeism, and disability. One cost analysis study did not focus on



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productivity loss but analysed the injury costs among hospital staff attributable to heavy patients[34].

[Insert Figure 2]

Absenteeism

Defined as time away from work due to overweight and obesity, absenteeism was probably due to ease of measurement, the most common measure of indirect costs. The majority of studies (36 out of the 43 included ones) assessed the costs of short-term sick leave from work by comparing sick leave days of employees with normal weight with sick leave days of employees with overweight and obesity. The excess costs of overweight were estimated to be between $54[44] and $161[28] and the obesity-related costs between $88[38, 45] and $1 566[46]. The suggestions of Durden et al. were significantly higher for both overweight ($1 712) and obesity ($1 844)[26]. By contrast, other studies did not use an excess-cost approach but calculated the total yearly expenses due to absenteeism for normal, overweight, and obesity samples. The cost for overweight ranged from $29 to $1 087[30, 31, 33, 39, 47] and $55 to $1 745 for obesity[18, 30, 33, 40, 42, 47].

In one study the costs associated with healthy weight ($292) were higher than overweight ($93) but lower than the costs for obesity ($399)[39]. Three studies assessed the costs for men and women separately. For women with obesity, the cost was between $169 and $1 382, which was higher than the cost for men with obesity ($88-$1 122)[28, 38, 45]. Gussenhoven and Kyrolainen estimated the costs of excess weight (BMI>25) between $903[43] and $4 248[32]. Another study assessed the relationship between children with overweight or obesity and parental work absence and found that while the cost ($140) for children with obesity was higher than the cost of healthy weight children ($118), the cost of children with overweight was lower ($101)[22].



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Wolfenstetter assessed weight changes over ten years and the related costs per group and found that the cost of a person with overweight or obesity is higher than the economic loss of a healthy weight or previously healthy weight person[35]. Neovius et al. also applied a longitudinal approach with data from 1969 and a 38-year follow-up. They estimated lifetime productivity losses of $17 818 using the HCA (FCA: $12 817) for overweight and $19 125 (FCA: $14 121) for obesity[21]. Another long-term study evaluated the yearly cost of a 20 000 workforce over 30 years at $6.5 million[24].

Presenteeism

Eight studies included the effect of reduced productivity at work (presenteeism) due to overweight or obesity, which was assessed by using an employee survey[28, 30, 31, 37, 40, 42, 44, 48]. While costs due to presenteeism among individuals with overweight ranged between $-607[28] and $1 657[31], costs among individuals with obesity were between $11[42] and $4 144[28]. Surprisingly, in Peake's study, the cost of presenteeism among employees with overweight ($468) was lower than for individuals with normal weight ($686)[33]. Similarly, Finkelstein et al. estimated lower costs among men with overweight compared to men with normal weight[28]. The excess cost of obesity ranged from $427 to $4 144 for men and from $921 to $3 317 for women[28]. Another study by Finkelstein measured the quarterly indirect costs of bariatric surgery patients to be $11[42]. The cost of moderate or extreme obesity was estimated to be $694[44], $1 674[31], $1 975[30], and $2 380[40]. Peake and co-authors differentiated between the cost of having a BMI higher than 30 with restricted body fat (≤28% for females, ≤24% for males) ($1 114) and having a BMI higher than 30 without body fat restriction ($971)[33].

Insurance Claims



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Insurance claims were measured as indemnity claims[20] or workers' compensation expenditures due to work absence[16, 18]. The only study which exclusively assessed insurance claims estimated indemnity claim costs at $187 per full-time equivalent[20]. For workers' compensation, the additional costs of overweight were estimated to be $178 and from $518 to $698 for grade I-III obesity[16]. Kleinman et al. assumed the costs of overweight at $62 and those of obesity at $104[18].

Short- and Long-term Disability

Four studies considered indirect costs due to permanent loss of productivity resulting from short- and long-term disability due to a permanent inability to work[16, 21, 42, 44]. While excess costs due to disability were estimated to be $30[16] and $40[44] among individuals with overweight, obesity was associated with costs between $21 and $433[44]. Kleinman et al. estimated $156 for overweight and $239 for obesity[18]. The lifetime cost of disability and disability pensions varied substantially depending on methodology; while estimations of cost based on the human capital approach (HCA) varied between $30 642 (overweight) and $32 253 (obesity), estimations of cost based on the FCA were $2 615 (overweight) and $3 075 (obesity)[21].

Premature Mortality

Work loss due to early mortality was assessed by two studies[21, 44]. Excess productivity costs related to these indirect costs were $29 for overweight and from $209 to $1 155 for grade I-III obesity[44]. Neovius et al. calculated the lifetime productivity losses and found $86 075 (HCA) or $19 811 (FCA) for overweight and $113 168 (HCA) or $22 777 (FCA) for obesity[21].

**Macroeconomic findings**



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Among the studies focusing on macroeconomic costs all but two studies focused on national costs for one year and found costs ranging from $78 million in New Zealand[19] to $40 billion for three US states[48]. Figure 3 displays the national costs per country and Figure S5 shows per capita estimates of the macroeconomic findings. Knoll and Hauner estimated that the cost of obesity would increase from $1.8 billion in 2003 to $3.6 billion in 2020[49]. Lightwood and co-authors estimated future costs in the United States on current adolescent obesity and proposed a rise in costs from $942 million in 2020 to $36 billion in 2050[41].

[Insert Figure 3]

The majority of the PAF studies included costs of absenteeism, disability, and premature death (for detailed information see Table S4). The PAF approach indicates the aetiologic fraction of morbidity and mortality of disease prevalence caused by a risk factor (see equation 1):

$$PAF = \frac{\sum_{i=1}^{n} Pi\ RRi - \sum_{i=1}^{n} P'i\ RRi}{\sum_{i=1}^{n} Pi\ RRi}, \quad (1)$$

$P_i$ = proportion of population at exposure level $i$, current exposure,

$P'_i$ = proportion of population at exposure level $i$, counterfactual or ideal level of exposure,

$RR$ = the relative risk at exposure level $i$,

$n$ = the number of exposure levels.

More specifically, there is strong evidence for higher risk of comorbidities such as type 2 diabetes, hypertension, coronary heart disease, and stroke in individuals with overweight and obesity[50, 51]. Since overweight and obesity cause only a fraction of comorbidity-related costs, multiplying the PAF by the costs of each comorbidity and then summing up across all diseases estimates total obesity-attributable costs.



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Four studies assessed the costs of excess weight in Germany[4, 49, 52, 53]. Lehnert et al. estimated the costs at $9.4 billion[4], Konnopka et al. at $6.4 billion[52], Knoll and Hauner at $1.8 billion[49], and Sander and Bergeman at $278 million[53]. The costs for Canada were suggested to be $2.7 billion by Katzmaryk and Janssen[54], $4.3 billion by Anis et al.[55], and $527 million (for Alberta only) by Moffat et al.[56]. The economic loss of the Republic of Ireland was between $757 million (FCA) and $830 million (HCA). For Northern Ireland the cost was proposed to be between $290 million (FCA) and $485 million (HCA)[57]. In addition to costs of absenteeism and premature death, Lal et al. assessed training and recruitment costs for New Zealand and suggested a national loss between $78 million (FCA) and $178 million (HCA)[19]. In Korea, the productivity loss of excess weight was proposed to be at $861 million due to premature death, hospital admission, nursing costs and fees, and transportation costs[17]. The economic loss associated with excess weight in Australia was estimated to be at $629 million[58]. For three US states (California, North Carolina, Massachusetts), Chenoweth and Leutzinger assumed a productivity loss of $40 billion[48].

While the majority applied the PAF approach, nine studies assessed the national costs based on lost workdays due to work absence, loss of productivity, and premature death[23, 25, 27, 29, 36-38, 45, 59]. Seven studies assessed the economic loss in the United States. The costs for obesity were estimated to be $169 million for grade III obesity by Klarenbach et al.[59], $3.8 billion due to non-diabetic and morbidly obese[38]. The costs of obesity were $5.4 billion[45] by Cawley and co-authors, and $9 billion by Andreyeva et al.[23]. Ricci and Chee were the only ones to consider the excess costs of absenteeism and presenteeism in the United States, which they estimated to be $15.5 billion for obesity. The costs of overweight and normal weight did not differ significantly[37]. Two studies focused on the economic loss of obesity in specific US regions ($404 million in a region of Texas[27] and $2 billion in New Mexico[29]). For Germany, the cost of overweight and obesity due to absenteeism was $2.5



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billion[36]. Economic loss due to premature death was estimated for Sweden at $4.7 million for overweight and $378 million for obesity[25].

**Quality assessment**

The quality of the included studies was quite diverse (see Table S3). Overall, the majority of studies met 75% of quality criteria. Three studies met all criteria[16, 21, 31]. Walden et al. probably received the lowest quality score, as this study focused primarily on the prevention of injuries rather than on the costs of excess weight and thus did not include information on discounting, standard deviations, and cost perspective and valuation[34].

Criteria regarding introduction, discussion, and conclusion were mostly fulfilled. Quality was lacking in the categories “calculation of costs”, “presentation of results”, and “study design” and “analysis”. Fourteen studies did not state from what perspective they calculated the costs and only included one cost category[17, 18, 20, 24, 32-35, 38, 40, 43, 48, 49, 53]. Study design and analysis were not fulfilled as over half of the studies did not report a sensitivity analysis and lacked information on the proportion of missing data or the imputation method. Furthermore, sample sizes and demographics were not always presented and only 26 studies provided standard deviations or confidence intervals of their results.

DISCUSSION

This review assessed 43 COI studies on indirect costs of overweight and obesity. The studies applied various methodologies and were mostly of good quality. Although the results varied, most studies found that excess weight entailed substantial indirect costs. While the cost category primarily considered was sick leave, there was also frequent assessment of presenteeism, disability, and premature death. Compared to employees with normal weight, individuals with obesity missed more time from work and worked less productively, resulting



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in higher indirect costs. Even if the literature suggests substantial indirect costs of overweight and obesity, the findings should be interpreted with caution. The results differ greatly, especially regarding the cost of overweight, which has even been suggested to be cost saving compared to normal weight[33, 39, 42].

The heterogeneity of the results raises the question whether the studies' estimations validly reflect the actual indirect costs of overweight and obesity. Most of the included studies used a top-down approach, which can be easier to carry out as it is based on secondary data and thus requires only few country-specific estimates. However, its results are conservative compared to a bottom-up approach because multiple diagnoses (plus their related costs) and the interactions between various obesity-attributable diseases (e.g. sleep disorders, orthopaedic complaints, psychological problems) may be underestimated. While these comorbidities can be a consequence of excess weight, they can also contribute to gaining weight. This interdependence of overweight and comorbidities makes it difficult to only assess the cost of excess weight. On the one hand, costs may be overestimated, as weight status is easier to measure and may thus be more frequently stated as the reason for productivity loss. On the other hand, costs may be underestimated, as comorbidities or secondary diseases of obesity (e.g. stroke or orthopaedic diseases) justify early retirement whereas weight status alone does not.

Furthermore, the comprehensiveness of costs included in the analysis affects the reliability of the final result. If indirect costs consist of absenteeism costs alone, they will differ from indirect costs due to absenteeism and presenteeism combined. Additional workplace costs, such as transport costs, special training for hospital staff, together with non-monetary costs (e.g. quality-of-life losses) were included in a minority of the studies. Differences in indirect costs of overweight and obesity in the workplace can partly be explained by individual incomes. Individual wages (only captured by Kleinman et al.[18]) consider occupation-



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specific incomes and the fact that women with overweight and men with obesity earn lower wages than normal weight workers[60, 61]. Most of the assessed COI studies calculated indirect costs based on estimations of the income of employees. These heterogeneous estimations of cost may be partly explained by occupation-specific incomes and different wage estimates (range: $6 per hour[59] to $500 daily wage[40]).

Besides costs measured by income in workplace-related productivity losses, costs from unpaid work can occur. In our review one study made costs from unpaid work a subject of discussion and found that reduced household production activities of caregivers cause sizable indirect costs comparable with those of paid work[52]. Moreover, this cost category is also important as the prevalence of childhood overweight and obesity has increased dramatically during the past few years, confronting (grand)parents and caregivers with time losses from unpaid work. A longer measurement period may influence the accuracy of the assessed costs. Two of the studies reviewed considered the impact of childhood overweight and obesity[22, 41]. Lightwood et al. recorded a long timeframe including indirect costs from adolescence and calculated high indirect costs of excess weight for future years[41].

Finally, the lack of evidence for the causal link of obesity and productivity loss has been noted in previous reviews[5, 6, 13]. Recent studies have tried to address this shortcoming by applying longitudinal study designs and controlling for confounding factors, including socio-demographic, work- and health-related covariates[21, 36, 40]. However, all these studies assume that obesity is a direct cause of productivity loss and may thus overestimate the effect on indirect cost. None of them comprehensively address the question, together with associated statistical challenges, that obesity could also serve as a biological mediator on the causal pathway or an effect modifier. Indeed, obesity may act both as direct explanatory variable and mediator when studying the relationship between cardiorespiratory fitness and productivity loss due to increased metabolic syndrome[62]. Additionally, obesity could also serve as an



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effect modifier as different levels of obesity modify the association between cardiorespiratory fitness and productivity loss. Moreover, the loss of productivity with increasing BMI declines with age as a higher BMI is rather protective (, e.g. reduce bone density loss and osteoporosis[63, 64].

Clearly, a causal framework for a meaningful assignment of indirect costs of obesity requires disentangling obesity as a cause, a mediator or an effect modifier. More specifically, prospective analyses are urgently needed to ask about the time of occurrence e.g. which diseases occur before (after) an individual has become overweight or obese. Together with such prospective analyses, valid measurements of productivity losses have to be developed and new studies have to be initiated that measure productivity among employees before and after an effective obesity intervention to allow the application of more sophisticated econometric models.

Overall, most studies met most of the quality criteria but could be improved in three major areas. Firstly, the scope could be increased by including more than one cost category. Secondly, estimations of cost would be more accurate if they included obesity-related diseases and were based on individual income. Thirdly, the reliability of the long-term economic consequences would be improved by taking childhood obesity into account. To translate lifetime consequences of childhood obesity into economic calculations, it is important to develop dynamic models of obesity-related productivity losses projected over a timeframe longer than the one-year period usually used in cost-of-obesity estimations[65, 66].

The included studies exhibited methodological inconsistencies and varying levels of quality. Nevertheless, they consistently confirm that overweight and obesity have substantial short- and long-term indirect costs both on the micro and macro level. Indeed, additional public health programmes, together with effective customised in-house programmes, could help to reduce improve productivity of workers who are currently overweight or obese.



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Contribution Statement

Diana Sonntag (DS) conceived the study and wrote the first draft of an earlier version; A. Grosse and A. Goettler performed the literature search and data extraction; A. Grosse, A. Goettler and DS analysed the data. All authors were involved in writing the paper and had final approval of the submitted and published version.

Data Sharing Statement

All unpublished data is only available to the authors.

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FIGURE LEGENDS

Figure 1: PRISMA flow diagram

Figure 2: Microeconomic excess cost of overweight and obesity

[+] Adapted productivity losses per person[44], no information on costs of normal weight

*Adapted indemnity claims cost per 100 full-time equivalents 1997-2004[20], no information on costs of normal weight

Excess per capita costs are displayed for each cost category for overweight, obesity, and excess weight. Mean costs were estimated for studies which only had sex or obesity-grade specific costs available. If not available, excess costs were calculated by subtracting the cost of normal weight from overweight or obesity costs. The figure shows that obesity costs are significantly higher than the costs of overweight alone and overweight and obesity combined. Interestingly, the cost of overweight is not necessarily higher than the cost of healthy weight. Absenteeism and presenteeism were considerably higher and more commonly assessed than disability and premature death.

Figure 3: Macroeconomic costs of overweight and obesity

Ricci & Chee[37], Lightwood et al.[41], and Chenoweth & Leutzinger[48] are outliers (coloured in grey).

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* Costs of the three US states California, North Carolina, Massachusetts, + Costs of the province Alberta, ** Costs of New Mexico, ++ Costs of South Plains of Texas

Almost analogous to country size and high prevalence rates, the United States has the highest national costs. Its lower values are related to particular states. The lowest costs were found in 2006 in New Zealand. National costs seem to increase in future years.

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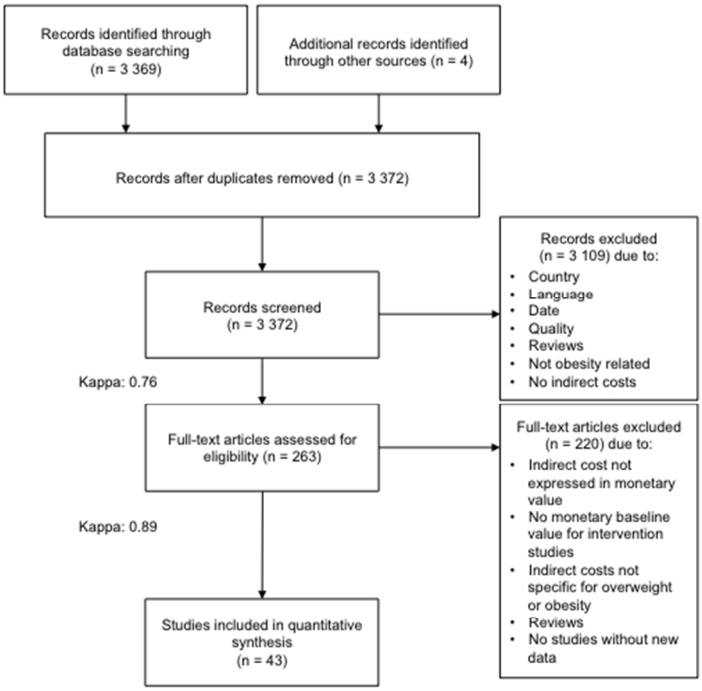


PRISMA flow diagram

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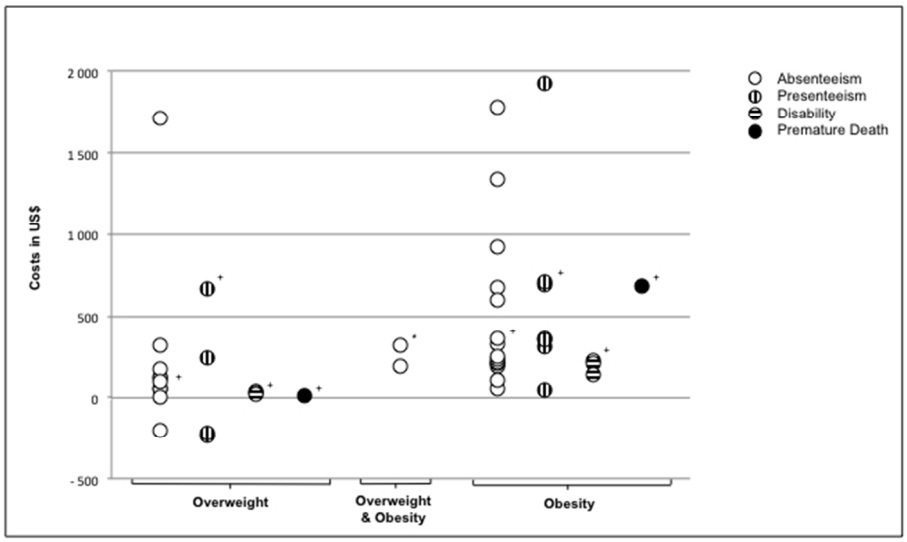


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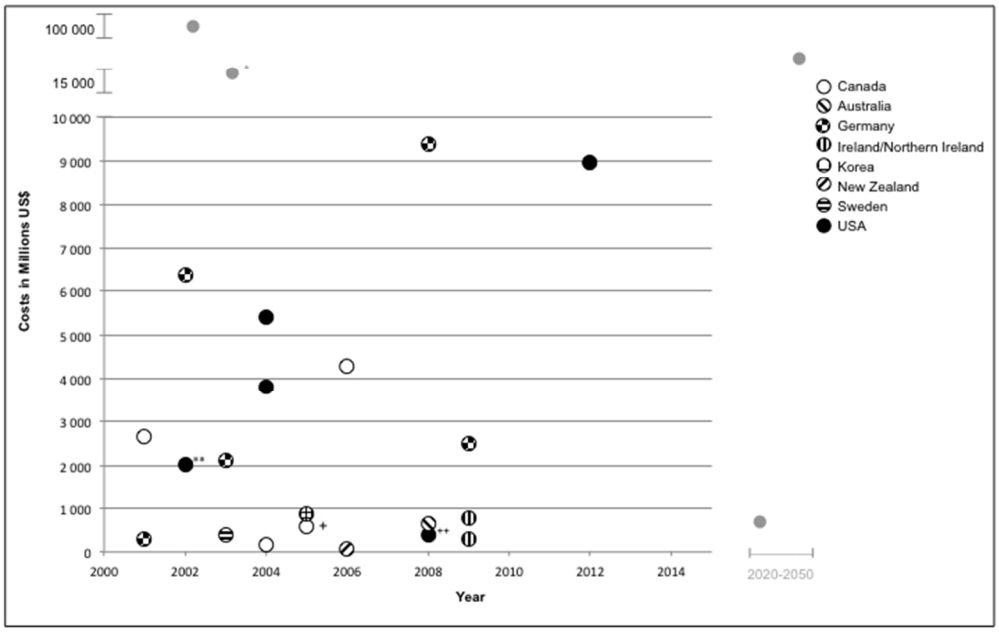


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* Costs of the three US states California, North Carolina, Massachusetts, + Costs of the province Alberta, ** Costs of New Mexico, ++ Costs of South Plains of Texas
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# Beyond the health care sector: A systematic review of indirect cost of overweight and obesity

Supporting Information

Anna Grosse[1*], Andrea Goettler[1*], Diana Sonntag[1, 2] PhD

[1] Mannheim Institute of Public Health, Social and Preventive Medicine, University Medicine Mannheim, Heidelberg University, Mannheim, Germany; E-mail: mail@diana-sonntag.eu

[2] Department of Health Sciences, University of York, York YO10 5DD, UK

* These authors contributed equally.

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**Supporting Information 1: Search strategy**

The following electronic databases were searched in June 2015:
PubMed
Cochrane Library
Web of Science Core Collection
PsychInfo
Cinahl
EconLit
ClinicalTrial.gov (study register)

**PubMed, 1798 results**
1. ("Obesity"[Mesh] OR Obes*[tw] OR "Obesity, Morbid"[Mesh] OR "Overweight"[Mesh] OR Overweight*[tw] OR "Excess Weight"[tw] OR "Overnutrition"[Mesh] OR Overnutr*[tw] OR "Adiposity"[Mesh] OR Adipos*[tw] OR "Body Mass Index"[Mesh] OR "Body Mass Index" [tw] OR BMI[tw] OR "Skinfold Thickness"[Mesh] OR Skinfold Thick*[tw] OR "Body Fat" [tw] OR "Waist-Hip Ratio"[Mesh] OR Waist Hip Ratio* [tw] OR "Waist Circumference"[Mesh] OR Waist Circumference*[tw])

2. ("Sick Leave"[Mesh] OR Sick Leave*[tw] OR Sickness Absen*[tw] OR Sick Absen*[tw] OR Sick Day*[tw] OR Work Absen*[tw] OR Work Leave* [tw] OR Illness Day*[tw] OR Illness absen*[tw] OR "Absenteeism"[Mesh] OR Absenteeism[tw] OR Absence Day*[tw] OR Absent Day*[tw] OR Presenteeism[tw] OR Work Productivit*[tw] OR Productivity Loss*[tw] OR Work Abilit*[tw] OR Work Disabilit*[tw] OR Disability Pension*[tw] OR Early Retirement*[tw] OR "Mortality, Premature"[Mesh] OR Premature Mortal*[tw] OR Premature Death*[tw] OR "Employment"[Mesh] OR Employment*[tw] OR Employee*[tw] OR Workloss*[tw] OR Workplace*[tw] OR Workday*[tw] OR Worker*[tw] OR Labour*[tw] OR Labor*[tw] OR Occupation*[tw] OR Job*[tw])

3. (Cost[tw] OR Costs[tw] OR Economic*[tw] OR Indirect Expenditure*[tw] OR Indirect Expense*[tw] OR "Cost of Illness"[Mesh] OR "Costs and Cost Analysis"[Mesh])

4. 1 AND 2 AND 3

**Cochrane Library, 35 results**
1. [mh Obesity] or Obes*:ti,ab,kw or [mh "Obesity, Morbid"] or [mh Overweight] or (Overweight* or "Excess Weight"):ti,ab,kw or [mh Overnutrition] or Overnutr*:ti,ab,kw or [mh Adiposity] or Adipos*:ti,ab,kw or [mh "Body Mass Index"] or ("Body Mass Index" or BMI):ti,ab,kw or [mh "Skinfold Thickness"] or ("Skinfold Thick*" or "Body Fat"):ti,ab,kw or [mh "Waist-Hip Ratio"] or "Waist Hip Ratio*":ti,ab,kw or [mh "Waist Circumference"] or "Waist Circumference*":ti,ab,kw

2. [mh Obesity] or Obes*:ti,ab,kw or [mh "Obesity, Morbid"] or [mh Overweight] or (Overweight* or "Excess Weight"):ti,ab,kw or [mh Overnutrition] or Overnutr*:ti,ab,kw or [mh Adiposity] or Adipos*:ti,ab,kw or [mh "Body Mass Index"] or ("Body Mass Index" or BMI):ti,ab,kw or [mh "Skinfold Thickness"] or ("Skinfold Thick*" or "Body Fat"):ti,ab,kw or [mh "Waist-Hip Ratio"] or "Waist Hip Ratio*":ti,ab,kw or [mh "Waist Circumference"] or "Waist Circumference*":ti,ab,kw

3.. (Cost or Costs or Economic* or "Indirect Expenditure*" or "Indirect Expense*"):ti,ab,kw or [mh "Cost of Illness"] or [mh "Costs and Cost Analysis"]



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4. 1 AND 2 AND 3

**Web of Science, 519 results**
1. TOPIC: (Obes* OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*")

2. TOPIC: ("Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR Employment* OR Employee* OR Workloss* OR Workplace* OR Workday* OR Worker* OR Labour* OR Labor* OR Occupation* OR job*)

3. TOPIC: (Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*")

4. 1 AND 2 AND 3

**PsychInfo, 259 results**
1. DE "Obesity" OR Obes* OR DE "Overweight" OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR DE "Body Mass Index" OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*"

2. .DE "Employee Leave Benefits" OR "Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR DE "Employee Absenteeism" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR DE "Employment Status" OR Employment* OR Employee* OR Worker* OR Workloss* OR Workplace* OR Workday* OR Labour* OR Labor* OR Occupation* OR job*

3. DE "Health Care Costs" OR DE "Costs and Cost Analysis" OR Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*"

4. 1 AND 2 AND 3

**Cinahl, 199 results**
1. Obes* OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*"

2. "Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR Employment* OR Employee* OR Workloss* OR Workplace* OR Workday* OR Worker* OR Labour* OR Labor* OR Occupation* OR job*



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3. Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*"

4. 4. 1 AND 2 AND 3

**EconLit, 465 results**
1. (Obes* OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*")

2.. ("Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR Employment* OR Employee* OR Workloss* OR Workplace* OR Workday* OR Worker* OR Labour* OR Labor* OR Occupation* OR job*)

3. (Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*")

4. 1 AND 2 AND 3

**ClinicalTrial.gov, 94 results**
1. (Obesity OR Overweight OR “Excess Weight” OR Overnutrition OR Adiposity OR "Body Mass Index" OR BMI OR "Skinfold Thickness" OR “Body Fat” OR "Waist Hip Ratio" OR "Waist Circumference")

2. ("Sick Leave" OR "Sickness Absence" OR "Sick Absence" OR "Sick Day" OR "Work Absence" OR "Work Leave" OR "Illness Day" OR "Illness absence" OR Absenteeism OR "Absence Day" OR "Absent Day" OR Presenteeism OR "Work Productivity" OR "Productivity Loss" OR "Work Ability" OR "Work Disability" OR "Disability Pension" OR "Early Retirement" OR "Premature Mortality" OR "Premature Death" OR Employment OR Employee OR Worker OR Workloss OR Workplace OR Workday OR Labour OR Labor OR Occupation OR job*) AND

3. (Cost OR Costs OR Economic OR "Indirect Expenditure" OR "Indirect Expense")

4. 1 AND 2 AND 3

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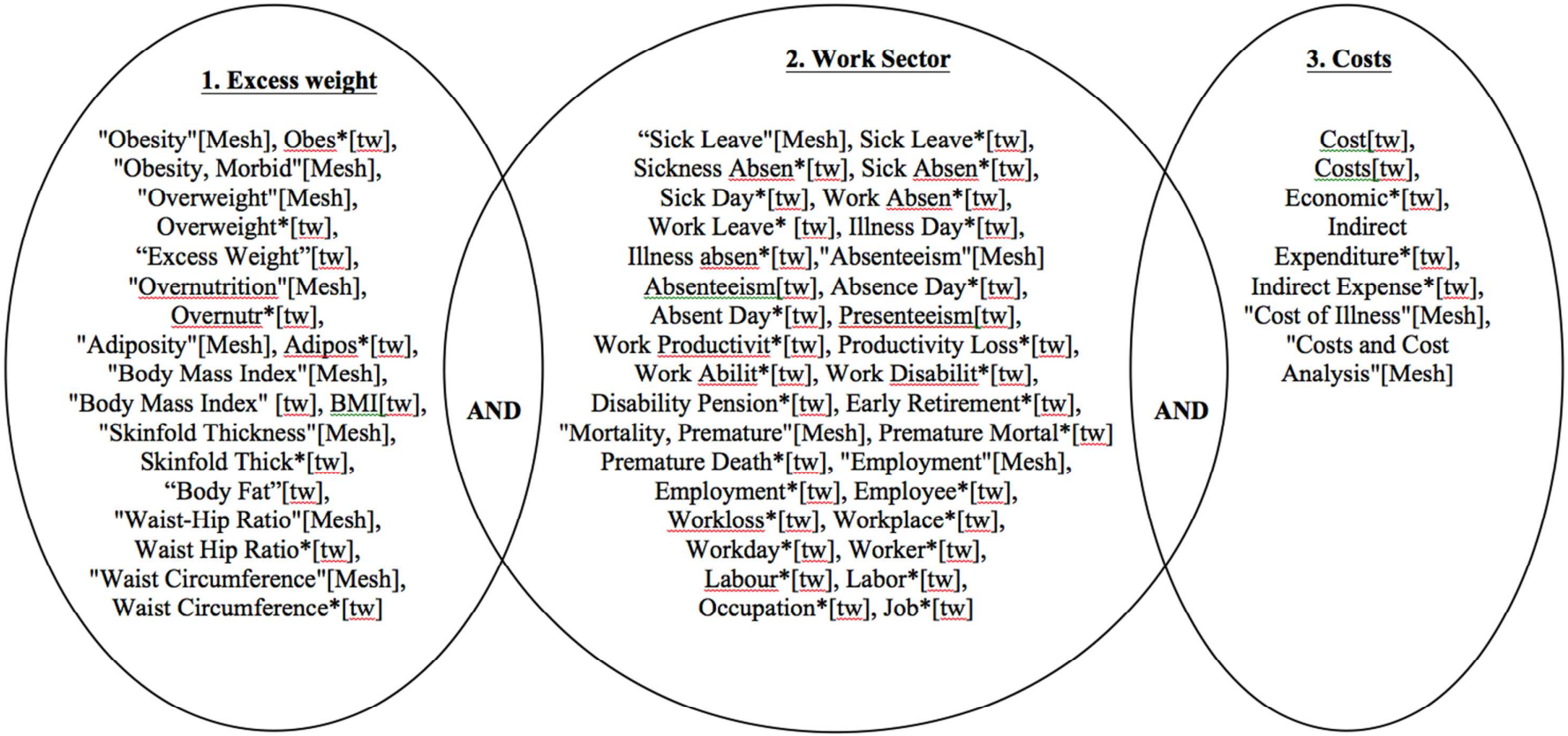
**Supporting Information 2: Search strategy (PubMed)**




All Keywords in the concepts are connected with the OR-operator (was removed for practicability reasons).

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## Supporting Information 3: Quality Scoring

| Author | Year | 1. Scope | | | 2. General economic characteristics | | 3. Calculation of costs | | | | | | | 4. Study design and analysis | | | 5. Presentation of results | | | 6. Discussion | | | Quality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Study objective* | *Inclusion and exclusion criteria* | *Disease and diagnostic criteria* | *Cost-description* | *Nondiseased comparison group or disease-specific costs* | *Currency* | *Reference year* | *Perspective* | *Costs incorporated from more than one category* | *Data source* | *Valuation of costs* | *Discounting* | *Missing data, imputation method* | *Statistics appropriate* | *Sensitivity analyses* | *Sample size (subgroup)* | *Demographics* | *Arithmetic mean costs Standard deviations (errors)* | *Results discussed with respect to other studies* | *Limitations discussed* | *Conclusions appropriate regarding uncertainty in results* | % |
| Andreyeva et al. | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Anis et al. | 2010 | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a | | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | 80% |
| Bhojani et al. | 2014 | ✓ | | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | 62% |
| Borg et al. | 2005 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 86% |
| Breitfelder et al. | 2011 | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 95% |
| Cadilhac et al. | 2011 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Cawley et al. | 2007 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | n.a | | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | 75% |
| Cawley et al. | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Chenoweth & | 2006 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | n.a | | ✓ | | | ✓ | | | ✓ | ✓ | 60% |
| Dall et al. | 2009 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | 75% |
| Dee et al. | 2015 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a | | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | 80% |
| Durden et al. | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Ewing et al. | 2011 | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | 67% |
| Finkelstein et al. | 2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Finkelstein et al. | 2012 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Finkelstein et al. | 2005 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a | | ✓ | | ✓ | ✓ | | | ✓ | ✓ | 75% |
| Frezza et al. | 2006 | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | 71% |
| Gates et al. | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a | | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | 80% |
| Goetzel et al. | 2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 100% |
| Gussenhoven et al. | 2013 | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Henke et al. | 2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 100% |
| Kang et al. | 2011 | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Katzmarzyk & Janssen | 2004 | ✓ | | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a | | ✓ | ✓ | | | | ✓ | ✓ | ✓ | 60% |
| Kirkham et al. | 2015 | ✓ | | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 67% |

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| Author | Year | 1. Scope | | | 2. General economic characteristics | | 3. Calculation of costs | | | | | | | 4. Study design and analysis | | | 5. Presentation of results | | | 6. Discussion | | | Quality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Study objective* | *Inclusion and exclusion criteria* | *Disease and diagnostic criteria* | *Cost-description* | *Nondiseased comparison group or disease-specific costs* | *Currency* | *Reference year* | *Perspective* | *Costs incorporated from more than one category* | *Data source* | *Valuation of costs* | *Discounting* | *Missing data, imputation method* | *Statistics appropriate* | *Sensitivity analyses* | *Sample size (subgroup)* | *Demographics* | *Arithmetic mean costs Standard deviations (errors)* | *Results discussed with respect to other studies* | *Limitations discussed* | *Conclusions appropriate regarding uncertainty in results* | % |
| Klarenbach et al. | 2006 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a | ✓ | ✓ | | | ✓ | | ✓ | ✓ | ✓ | 75% |
| Kleinman et al. | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | n.a | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Knoll & Hauner | 2008 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | ✓ | | | ✓ | ✓ | 71% |
| Konnopka et al. | 2011 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | ✓ | 86% |
| Kyrolainen et al. | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | n.a | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | 65% |
| Lal et al. | 2012 | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | 80% |
| Lehnert et al. | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | 90% |
| Lehnert et al. | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | 85% |
| Lightwood | 2009 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | | ✓ | 95% |
| Moffatt et al. | 2011 | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | n.a | | ✓ | | | | | ✓ | ✓ | ✓ | 62% |
| Neovius et al. | 2012 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 100% |
| Ostbye et al. | 2007 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | 62% |
| Peake et al. | 2012 | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 86% |
| Ricci & Chee | 2005 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | n.a | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 95% |
| Sander & Bergmann | 2003 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | 85% |
| Sullivan et al. | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 80% |
| Tsai et al. | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | | | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | 71% |
| Walden et al. | 2013 | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | | | ✓ | | | | ✓ | | | | | n.a. | ✓ | ✓ | 53% |
| Wolfenstetter | 2012 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |

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## Supporting Information 4: Characteristics and costs of the 43 studies included in the review

| Study | Sample | Data source and year | Quality[1] | BMI categories[2] | Considered factors | Costs in 2015 dollar[3] |
|---|---|---|---|---|---|---|
| *Cross-sectional studies (Regression models, descriptive methods)* | | | | | | |
| Andreyeva et al. (2014)[23] | Nationally representative, NHANES: N=14,975, n(overweight)=5,116, n(obesity I,II, III)=4,747, BRFSS: N=182,227, n(overweight)=66,695, n(obesity I, II, III)=57,583, USA | NHANES (1998-2008), BRFSS (2012), Integrated Public UseMicrodata Series-Current Population Survey (2011) | 90% | BMI (WHO): normal, overweight, obesity grade I, II, III | - | The US total loss in productivity (in 2012) because of obesity-related absenteeism was estimated at $8.98 billion per year. The obesity-attributable fraction (%) in total absenteeism costs varied from 6.5% in District of Columbia to 12.6% in Arkansas, with the US average of 9.3%. |
| Kleinman et al. (2014)[18] | Communications, transportation, finance, healthcare, and retail employees, N = 1,700,000, n(overweight)=14,281, n(obesity)=18,801, USA | Human Capital Management Services Research Reference Database (2001–2012) | 85% | BMI: normal weight: BMI<27, overweight: BMI 27-30, obesity: BMI>30 | Sub cohorts for physical comorbidities | Adjusted annual costs (in 2014) were $1,106 for overweight (sick leave 80.2%, short-term disability 13.2%, long-term disability 0.9%, workers' compensation 5.6%), $1,383 for obese (sick leave 75.2%, short-term disability 15.4%, long-term disability 1.9%, workers' compensation 7.5%) and $989 for normal weight (sick leave 79.7%, short-term disability 14.0%, long-term disability 1.9%, workers' compensation 4.3%). |
| Lehnert et al. (2014)[36] | Nationally representative, N=7,990, n(overweight)=3,022, n(obese)=1,369, Germany | German Socio-Economic Panel (2009-2010) | 85% | BMI (WHO): Excess weight: BMI>25 | Adjusted model for physical and psychosocial comorbidities | The total population costs associated with overweight- and obesity-related excess sick leave days in Germany (in 2009) were $2.5 billion. |
| Finkelstein et al. (2010)[28] | Nationally representative, NHWS: N=24,140, n(overweight)=8,594, n(obese I)=4,683, n(obese II)=2,148, n(obese III)=1,569, MEPS: N=8,875, n(overweight)=3,373, n(obese I)=1,597, n(obese II)=612, n(obese III)=320, USA | NHWS (2008), MEPS (2006) | 90% | BMI (WHO): overweight, obesity grade I, II, III | - | Productivity losses (in 2010) due to excess weight compared to normal weight for men were $-514 for overweight (absenteeism $93, presenteeism -$607), $730 for grade I obese (absenteeism 41.5%, presenteeism 58.5%), $1,822 for grade II obese (absenteeism 39.4%, presenteeism 60.6%) and $5,266 for grade III obese (absenteeism 21.3%, presenteeism 78.7%). For women the costs were $293 for overweight (absenteeism 54.9%, presenteeism 45.1%), $1,366 for grade I obese (absenteeism 32.6%, presenteeism 67.4%), $1,727 for grade II obese (absenteeism 4.2%, presenteeism 95.8%) and $4,699 for grade III obese (absenteeism 29.4%, presenteeism 70.6%). |
| Goetzel et al. (2010)[31] | Employees from multiple professions and worksites, N=10,026, n(overweight)= 3,180, n(obese)=3,834, USA | National Heart, Lung, and Blood Institute (2005-2007) | 100% | BMI (WHO): normal weight, overweight, obese: BMI>30 | - | Estimated annual costs per employee (in 2006): $2,744 for overweight (absenteeism 39.6%, presenteeism 60.4%), $3,071 for obese (absenteeism 45.5%, presenteeism 54.5%), $2,451 for normal weight (absenteeism 42.1%, presenteeism 57.9%). |
| Henke et al. (2010)[16] | Pepsi Bottling Group employees, N=11,217, n(overweight)=5,003, n(obese I)=2,344. n(obese II)=673, n(obese III)=269, USA | StayWell HealthPath HRA data from the Thomson Reuters MarketScan and Advantage Suite Databases (2004-2006) | 100% | BMI (WHO): normal weight, overweight, obesity grade I, II, III | Costs for physical and psychosocial comorbidities and behavioral factors. | Annual average additional costs (in 2008) of excess weight compared to normal weight ($951 for normal weight employees): Additional costs were $208 for overweight (workers' compensation 85.6%, short-term disability 14.4%), $636 for grade I obese (workers' compensation 81.4%, short-term disability 18.6%), $688 for grade II obese (workers' compensation 88.0%, short-term disability 12.0%) and $1,089 for grade III obese (workers' compensation 61.4%, short-term disability 38.6%) |
| Dall et al. (2009)[44] | Nationally representative, N=1,000,000, overweight 33%, obese I 17%, obese II or obese III | U.S. Census Bureau (2007), NHANES (1999-2004), National Health Interview survey (2006) | 75% | BMI (WHO): normal, overweight, obesity grade I and II, III combined | Including costs of physical comorbidities. | Excess productivity loss per person (in 2007) were $792 for overweight (absenteeism 6.8%, presenteeism 84.5%, disability 5.0%, premature mortality 3.6%), $1,044 for obese I (absenteeism 11.5%, |



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| Study | Sample | Data source and year | Quality[1] | BMI categories[2] | Considered factors | Costs in 2015 dollar[3] |
|---|---|---|---|---|---|---|
| | 12%, USA | | | | | presenteeism 66.5%, disability 2.0%, premature mortality 20.0%), $2,579 for obese II and III (absenteeism 11.8%, presenteeism 26.6%, disability 16.8%, premature mortality 44.8%). |
| Cawley (2008)[38] | Nationally representative, N(men)=14,187, obese 78.7%, morbidly obese 21.3% N(women)=19,402 women, obese 88.0%, morbidly obese 12.0%, USA | MEPS (2000 –2004) | 85% | BMI (WHO) obesity: BMI 30-40, morbid obesity: BMI>40 | Additional sample with physical comorbidities. | National aggregate annual costs of job absenteeism (in 2004) for obese nondiabetic were $2.8 billion ($726 million for men, $2,051 million for women). Costs for morbidly obese nondiabetic were $1.0 billion ($232 million for men, $771 million for women). Per-capita annual increases in absenteeism costs associated with obesity, as compared with healthy weight nondiabetics were $88 for men and $169 for women. For morbidly obese, the costs were $223 for men and $285 for women. |
| Gates et al. (2008)[30] | Manufacturing employees, N=341, n(overweight)=143, n(mildly obese)=79, n(moderately/extremely obese)=43, USA | Survey in eight manufacturing countries in Kentucky (-) | 80% | BMI (WHO): normal weight, overweight, mild obesity: BMI 30-35, moderate or extreme obesity: BMI>35 | - | The annual per-person costs of moderately or extreme obese workers were $3,720 (absenteeism 46.9%, presenteeism 53.1%). The annual costs of all other workers were $2,681 (absenteeism 52.8%, presenteeism 47.2%). (Year of costing assumed: 2008)[4] |
| Sullivan et al. (2008)[39] | Nationally representative, N= 43,221, n(obese)=10,970, USA | MEPS (2000–2002) | 80% | BMI (WHO) underweight, normal weight, overweight, obesity: BMI > 30 | Costs calculated with and without risk of physical comorbidities. | Annual costs of absenteeism (in 2007) per person without comorbidities were $93 for overweight and $399 for obese ($292 for normal weight). When controlling for chronic conditions, the costs were $72 for overweight and $286 for obese ($160 for normal weight). |
| Durden et al. (2008)[26] | Commercially insured employees, N=88,984, n(overweight)=34,259, n(severely obese)=8,780, n(obese)=14,826, USA | Self-reported data from MarketScan Research databases and MarketScan HRA Database (2003-2005) | 90% | BMI (WHO) underweight, normal weight, overweight, obese: BMI: 30-35 severely obese: BMI>35 | - | Estimated costs of workdays lost (in 2005) were $7,502 for overweight, $10,039 for obese, $10,287 for severely obese and $4,255 for normal weight. Marginal effects of the GLM of indirect costs due to absence, relative to the normal weight BMI group: $1,712 for overweight, $1,844 for obese and $1,725 for severely obese. |
| Cawley et al. (2007)[45] | Nationally representative, N= 54,970, overweight: 27% female, 42% male, obese: 21% female, 23% male, morbidly obese: 8% female 6% male, USA | MEPS (2000-2004) | 75% | BMI (WHO) healthy weight, overweight, obese: BMI 30-35 or 35-40 and no hypertension, hyperlipidemia, or diabetes, morbidly obese: BMI>40 or BMI 35-40 and hypertension, hyperlipidemia, or diabetes present | For obesity-diagnostic: physical comorbidities | Per capita increases in absenteeism costs associated with obesity (in 2004) were 88$ for men and $179 for women compared with healthy weight nondiabetic subjects. Per capita increases in absenteeism costs associated with morbid obesity were $250 for men and $300 for women compared with healthy weight nondiabetic subjects. Estimated national aggregate costs of absenteeism were $5.4 billions for obesity in 2004. |
| Klarenbach et al. (2006)[58] | N= 58,289 (of all weight classes), estimated prevalence rate of obesity class III: 1%, Canada | Canadian Community Health Survey (2000 - 2001) | 75% | BMI (WHO) normal weight, obesity grade I, II, III | Physical and psychosocial comorbidities | Total lost productivity due to absenteeism (in 2004) for Class III obesity is estimated to be $169 million. |
| Ricci & Chee (2005)[37] | National population-based, N=6,894 employed adults, n(overweight)=2,490 , n(obese)=1,536, USA | The Caremark American Productivity Audit, The Caremark Work and Health Interview (2001-2003) | 95% | BMI (WHO) overweight, obese BMI>30 | Covariates in Logistic Regression Models: physical and psychosocial | Total cost of health-related lost productive time (in 2002) were $73 billion for overweight (absenteeism 30.7%, presenteeism 69.3%) and $56 billion for obese (absenteeism 32.2%, presenteeism 67.8%). |



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| Study | Sample | Data source and year | Quality[1] | BMI categories[2] | Considered factors | Costs in 2015 dollar[3] |
|---|---|---|---|---|---|---|
| | | | | | comorbidities and behavioral factors | |
| Finkelstein et al. (2005)[46] | Nationally representative, N= 25,427, n(overweight)=9,813*, n(obese)=5,736, USA | National Health Interview Survey (2001-2002) | 85% | BMI (WHO) overweight, obesity grade I, II, III | Regressions controlled any functional limitations not self-reported as obesity-related (e.g. difficulty walking, standing, sitting, stooping, reaching, or grasping) | Value of increased absenteeism in 2004 associated with overweight were $125, with grade-I obesity $470, with grade-II obesity $1,993, and with grade-III obesity $1,566. |
| *Longitudinal studies* | | | | | | |
| Kirkham et al. (2015)[40] | Large computer manufacture employees, N = 17,089, obesity: 7-9%, USA | HRA survey data, human resources records, and employee insurance eligibility records (2006–2010) | 67% | BMI (WHO): obesity: BMI>35 | Health Risk levels of physical and psychosocial comorbidities and behavioral factors | Annual productivity costs (in 2014) of being at risk for BMI≥35: $3,559 (absenteeism 33.1%, presenteeism 66.9%). Costs of BMI<35: $3,044 (absenteeism 31.1%, presenteeism 68.9%). |
| Bhojani et al. (2014)[24] | Petrochemical workers (Shell), N=20,000 to 28,000, obesity 14%-42% from 1980-2009, USA | Physical examination records in the Shell Health Surveillance System (1980-2009) | 62% | BMI (WHO): obesity: BMI>30 | - Behavioral factors | At the end of 30 years, and assuming a workforce of 20,000 employees, the potential economic impact due to illness-absence from obesity would be $6.54 million/year. (Assumed year of costing: 2014)[4] |
| Neovius (2012)[21] | Nationwide cohort of men, who performed mandatory military conscription tests at age 18 (follow-up after 38 years), N=45,920, n(overweight)=2,623, n(obese)=367, Sweden | Military Service Conscription Register, Social Insurance Register, Register of the Total Population, Population and Housing Censuses (1969/1970, 1986-2005) | 100% | BMI (WHO): underweight, normal weight, overweight, obese | Covariates: behavioral and environmental factors | Lifetime productivity losses (in 2010) according to the human capital approach: $86,075 for overweight (sick leave 20.7%, disability pension 35.6%, mortality 43.8%), $113,168 for obesity (sick leave 16.9%, disability pension 28.5%, mortality 54,6%), $65,953 for normal weight (sick leave 22.5%, disability pension 32.3%, mortality 45.2%).<br>Fiction cost method: $19,811 for overweight (sick leave 64.7%, disability pension 13.2%, mortality 21.6%), $22,777 for obesity (sick leave 62.0%, disability pension 13.5%, mortality 24.5%), $15,662 for normal weight (sick leave 70.2%, disability pension 11.5%, mortality 18.3%). |
| Wolfenstetter (2012)[35] | Population-representative, N=2,581, n(overweight)=786, n(obese)=406, n(healthy weight) = 679; n(healthy to overweight) = 299, n(healthy to obese)= 10, n(overweight to healthy)= 92, n(overweight to obese) = 257, n=(obese to healthy) = 2, n(obese to overweight)= 50, Germany | MONICA/KORA (Cooperative Health Research in the Region of Augsburg) survey-S3 (1994/95), KORA follow-up survey-F3 (2004/05) | 90% | BMI (WHO): normal weight, overweight, obese Changes in health status from 1994/1995 to 2004/2005 | - Healthcare utilization by physician visits and therapy | Costs of absenteeism per year per group (in 2005). Costs of participants who remained in the same weight group: $2,626 (healthy weight), $3,576 (overweight), $3,576 (obesity).<br>Costs of participants who changed the weight group: $3,576 (Healthy to overweight), $599 (healthy to obese), $2,625 (overweight to healthy), $4,156 (overweight to obese), $280 (obese to healthy), $3,213 (obese to overweight). |
| Tsai et al. (2008)[47] | Shell Oil Company employees, 1994: N=4,153, n(overweight)=1,854, n(obese)=1,204, 2003: N=4,513, | Shell Health Surveillance System (1994), follow-up 2003 | 71% | BMI (WHO) normal weight, overweight, obese: BMI >30 | Physical comorbidities | Costs of absences lasting 6 or more days per year: these excess workdays lost resulted in a loss of $2.15 million with $862,849 due to overweight employees ($465 per employee) and $1.29 million due to |



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| Study | Sample | Data source and year | Quality[1] | BMI categories[2] | Considered factors | Costs in 2015 dollar[3] |
|---|---|---|---|---|---|---|
| | n(overweight)=1,719, n(obese)=1,732, USA | | | | | obese employees ($1,072 per employee). (Year of costing assumed: 2007)[4] |
| Ostbye et al. (2007)[20] | Health care and university employees, N=11,728, 29.9% overweight, 14.2% obesity class I, 6.8% obesity class II, 4.9% obesity class III, USA | Duke University Health System and Duke University (1997-2004) | 62% | BMI (WHO) underweight, recommended weight, overweight, obesity grade I, II, III | - Behavioral factors | Indemnity claims costs (in 2005) for lost workdays from 1997-2004: $6.6 million; per 100 full-time equivalents $18,798. |
| Borg et al. (2005)[25] | Middle-aged subjects living in Malmö, N= 33,346, n(overweight)=10,775, n(obese)=2,450, Sweden | Malmö Prevention Project (1974-1984) and a mean follow-up of 17 years | 86% | BMI (WHO) overweight, obesity: BMI>30 | - | Average annual indirect cost (in 2003) due to death before retirement age, projected over 15 years were $4.67 million for overweight and $378 million for obesity. |
| *Attributable risk studies (PAF)* | | | | | | |
| Dee et al. (2015)[11] | Nationally representative, N= -, Island of Ireland | Central Statistics Office (2007-2009), Department of Social Protection illness benefit data for (2009), Department of Social Development (Northern Ireland), Northern Ireland Statistics and Research Agency | 80% | BMI (WHO) overweight and obesity: BMI>30 | Overweight and physical comorbidities were included in the PAF analysis. | The estimated annual costs (in 2009) for the Republic of Ireland for absenteeism were $155 million (human capital approach) or $82 million (friction costs method). The costs of premature mortality were $675 million.<br>The costs of absenteeism in Northern Ireland were $299 million (human capital approach) or $104 million (friction costs method). The cost of premature mortality was $186 million. |
| Lehnert et al. (2014)[4] | Nationally representative, N= -, overweight 37%, obese 23%, Germany | Prevalence data: German Health Interview, Examination Survey for Adults (DEGSI) (2008-2011), Population: population representative German Study (AgeCoDe) (2008) | 90% | BMI (WHO): Excess weight BMI>25 | Obesity and overweight attributable costs of physical comorbidities | The total indirect costs attributable to excess weight in 2008 in Germany were $9.4 billions.<br>Indirect costs paid work: mortality (16.9%), early retirement (7.9%), sickness absences (10.5%). Indirect costs unpaid work: mortality (52.7%), early retirement (6.9%), sickness absence (5.2%) |
| Lal et al. (2012)[19] | Nationally representative, N= -, New Zealand | Burden of Disease Estimates Data Set (WHO), NZ Ministry of Health (2006) | 80% | BMI (WHO): overweight, obese: BMI>30 | Obesity and overweight attributable costs of physical comorbidities | Productivity losses in New Zealand (in 2006) according to the human capital approach: $178 million (premature death 64.4%, short-term absenteeism 35.6%). Costs according to the friction capital approach: $78 million (premature death 9.2%, recruitment and training costs 9.2%, short-term absenteeism 81.6%). |
| Kang et al. (2011)[17] | National representative, N=1,910,194, overweight men (women): 27.4% (22.0%), obese I men (women): 31.5% (24.6%), obese II men (women): 3.6% (3.4%), Korea | National Health Insurance Corporation, Korea National Health and Nutrition Examination Survey (2005) | 85% | BMI: normal weight: BMI: 18.5-22.9, overweight: BM:I 23-24.9, obesity I: BMI: 25-29.9, obesity II: BMI>30 | Obesity and overweight attributable costs of physical comorbidities | Total socioeconomic indirect costs (in 2005) were $861 million (loss of productivity due to premature deaths 62.8%, loss of productivity due to admission 62.8%, traffic costs 14%, nursing costs 9.9%, nursing fees 2.2%). Indirect costs were $256 million for overweight, $459 million for grade I obesity and $146 million for grade II obesity. |
| Konnopka et al. (2011)[52] | Nationally representative, N= -, Germany | Statistics from the German Federal Statistical Office, German Retirement Insurance Office (2002) | 86% | BMI (WHO): 4 risk classes: 0: BMI<25, 1: 25<BMI<30, 2: 30<BMI<35, 3: 35<BMI<40, 4: BMI>40 | Attributable costs of physical comorbidities. | Costs attributable to obesity and overweight (in 2002): $6.4 billion. (Costs unpaid work: mortality 48.8%, early retirement 7.9%, sickness absence 3.3%; costs paid work: mortality 18.5%, early retirement 11.8%, sickness absence 9.6%) |
| Moffat et al. (2011)[56] | N= -, Canada | Canadian Community Health Survey (2004-2005), Public Health Agency of Canada (Economic Burden of Illness in 2000) | 62% | BMI (WHO): excess weight: BMI>25 | Obesity and overweight attributable costs of physical | Indirect costs (in 2005): $576 million (long-term disability 32.5%, short-term disability 9.8%, premature mortality 57.6%) in Alberta |



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| Study | Sample | Data source and year | Quality[1] | BMI categories[2] | Considered factors | Costs in 2015 dollar[3] |
|---|---|---|---|---|---|---|
| | | | | | comorbidities | |
| Anis et al. (2010)[55] | N= -, overweight men: 42%-51%, obese men: 22%-27% overweight women: 30%-37%, obese women: 23%-29% (rates vary for different age groups), Canada | Canadian Heart Health Survey (1986-1992), Economic Burden of Illness in Canada (1998) | 62% | BMI (WHO): overweight, obesity | Obesity and overweight attributable costs of physical comorbidities | The cost attributable to excess weight in Canada (in 2006) is $4.3 billion ($1.5 billion for overweight and $2.7 billion for obesity). |
| Cadilhac et al. (2010)[58] | Population simulation for 2008, N about 17 million, Australia | Mainly: Australian Burden of Disease (BoD) study 2003 other input data: National Health Survey (2004-2005), Australian average weekly earnings (2008), Time Use Survey (2008), Disease Costs & Impact Study (200-2001) | 90% | BMI (WHO): Excess weight: BMI>25, normal weight, underweight | Including costs of behavioral factors | Total potential attributable opportunity cost savings due to workforce participation and absenteeism (in 2008) for excess weight according to FCA: $629 million. |
| Knoll & Hauner (2008)[51] | n(obese in 2003)=13,200,000, Germany | Federal Statistical Office, statements from insurance companies, German pension insurance, professional associations (1997-2004) | 71% | BMI (WHO) obesity: BMI > 30 | Physical and psychosocial comorbidities | Annual indirect costs (in 2003) with 4% discounting were $2.1 billion (disability 46%, incapacity for work 35%, mortality 19%). Costs with a 6% discounting rate were $1.8 billion (disability 42%, incapacity for work 41%, mortality 17%). In 2010 indirect costs were projected to be $2.4 billion, in 2015 $2.9 billion, in 2020 $3.6 billion. |
| Chenoweth & Leutzinger (2006)[48] | 7 U.S. states, N=77 Mio, state-specific prevalence rates for excess weight: 35%-60%, USA | Obtained from various health plans and state agencies in seven states and published studies | 65% | BMI (WHO) excess weight BMI>25 | Physical comorbidities | Productivity loss cost per year (in 2003) for excess weight (estimated lost hours used in one state-wide cost analyses) subtotal $25 billion (absences 22.8%, short term disability 27.2%, presenteeism 50%). Productivity loss for California, North Carolina and Massachusetts were $40 billion. |
| Katzmarzyk & Janssen (2004)[54] | N= -, overweight: 33%, obese: 14.7%, Canada | Economic Burden of Illness in Canada (1998) and data taken from literature | 60% | BMI (WHO) Obesity: BMI>30 | Attributable costs of physical comorbidities. | Estimated indirect costs attributable to obesity in Canada (in 2001) (value of economic output lost due to illness, injury related work-disability or premature death): $2.66 billion. |
| Sander & Bergemann (2003)[53] | Representative population data from publications attributed to 12.24 million obese adults in Germany (of whom 2.9 million suffer from selected comorbidities), Germany | German National Survey (1998) and data taken from the literature and official German publications | 85% | BMI (WHO) Obesity: BMI>30 | 3 scenarios refer to the physical comorbidities (in the base case) | Annual Indirect costs of obesity (in 2001) due to mortality, work loss and disability: $278 million. |
| *Simulation studies (Markov model)* | | | | | | |
| Lightwood et al. (2009)[41] | Projected overweight adult prevalence (resulting from adolescent overweight) from n= 330,000 in 2020 to more than n= 9,700,000 in 2050, USA | NHANES (1971-2000) | 90% | BMI (WHO): Obesity: BMI>30 | Includes costs of physical comorbidities; Simulation designs on base case-, prevention- and treatment-settings | Projected excess costs attributable to current adolescent obesity to 2020 to 2050. Costs are expected to rise from $942 million in 2020 to $36 billion in 2050. |
| *Other studies* | | | | | | |
| Walden et al. (2013)[34] | Hospital staff, N > 800, lift team technicians for mobilizing the obese patient, USA | Hospital financial reports, non-validated staff satisfaction survey (2012) | 53% | Patient's weight>100kg, with a Braden Scale score<18 and/or the presence of pressure ulcers | - | Cost savings (in 2012) due to decreased injuries among staff from patient handling were $967,851. |



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| Study | Sample | Data source and year | Quality[1] | BMI categories[2] | Considered factors | Costs in 2015 dollar[3] |
|---|---|---|---|---|---|---|
| Gussenhoven et al. (2013)[32] | Employees from seven Dutch companies, N = 460 (control group), only participants with excess weight were included, mean BMI=29, Netherlands | ALIFE@Work RCT (2004) | 85% | BMI (WHO): Excess weight: BMI>25 | - | Sick leave costs (in 2004) based on GLDP (= gross lost productivity days, total number of calendar days that workers were partially or fully sick-listed) were $4,248, sick leave costs based on NLPD (= net lost productivity days; multiplying the number of sick leave days with the absenteeism percentage; for the assumption that partially sick listed employees were fully productive when at work) were $3,228. |
| Finkelstein et al. (2012)[42] | Full-time employees and eligible for LAGB, MEPS (N=134), mean BMI=44, NHWS (N=2,164), mean BMI=43, USA | MEPS (2005-2006), NHWS (2008) | 75% | BMI (WHO) eligible for bariatric surgery: BMI>40 or BMI 35-40 with a significant comorbidity | For obesity diagnostic: physiological comorbidities | Costs for the quarter before LAGB (in 2010) for bariatric surgery candidates were $66 for (absenteeism 83.3%, presenteeism 16.7%). |
| Peake (2012)[33] | Australian Defense Force personnel from army, navy and air force service branches, N=679, n(overweight)=154, n(obese restricted body fat)=148, n(obese no restriction)=180, Australia | Directorate of Workforce Information, ADF Central Medical Records (2009-2010) | 86% | BMI (WHO): normal weight, overweight, obese with restricted body fat (≤28% for females, ≤24% for males), obese with no restriction | - Prevalence of injury or illness | Mean productivity loss per person from each cohort (in 2009-10). For full days off work per calendar day (underestimated): $29 for overweight, $56 for obese restricted body fat, $77 for obese no restriction on body fat and $12 for normal weight. For productivity loss from full days off work per workday (overestimated): $41 for overweight, $78 for obese restricted body fat, $109 for obese no restriction on body fat and $17 for normal weight. Productivity loss from restricted work days (50% limited activity) is $468 for overweight, $1,114 for obese restricted body fat, $971 for obese no restriction on body fat and $686 for normal weight. |
| Breitfelder et al. (2011)[22] | Parents of children, N(children)=3,508, n(overweight)=216, n(obese children)=69, Germany | GINI-plus (German Infant Nutritional Intervention study), LISA plus (Influence of lifestyle factors on the development of the immune system and allergies in East and West Germany) | 85% | Age- and sex-specific percentile cut-off points for children: Normal weight (P10–P90), Overweight (>P90 to P97), Obese (>P97) according to Kromeyer-Hausschild | - Utilization of healthcare services by physician visits, therapy and other therapies | Indirect costs for parental work absence (in 2007) were $101 for overweight, $140 for obese and $118 for normal weight children. (For severely underweight, the costs were $151) |
| Ewing (2011)[27] | Patients undergoing laparoscopic gastric bypass or laparoscopic banding surgery, N=150, in relation to data from the Bureau of Labor Statistics, USA | LAGB Patients. The Bureau of Labor Statistics, Bureau of Economic Analysis (2006), Texas Tech University Health Sciences Center (TTUHSC) (2003-2005) | 67% | Obesity (no cut-off points stated) | - | Total per year economic impacts on South Plains from obesity (in 2008): $404 million. |
| Kyrolainen et al. (2008)[43] | Finnish male military personnel, N=7,179, overweight: 46%, obese: 10%, Finland | Male military personnel data from personnel administration (2004) | 65% | BMI (WHO) normal weight, overweight, obese: BMI >30 | Behavioral factors | Costs of sick leave per year per person (in 2004) were $903 for excess weight and $587 for normal weight. |
| Frezza et al. (2006)[29] | Bariatric patients, N=150, in relation to data from the bureau of Labor Statistics (2005, lost work time rate and employment and earnings data), USA | Patients from New Mexico who underwent laparoscopic gastric bypass and laparoscopic banding (2003-2005). Bureau of Labor Statistics (2005) | 71% | Bariatric patient sample: not described Prevalence data of New Mexico: obesity: BMI > 30 | - | Total per year economic impacts of obesity for New Mexico (in 2002): $1.77 billion from output lost and $261 million from labor income lost. Cost per year to New Mexico household: $2,199 from output lost, $325 from labor income lost. |

BMI: Body mass index, WHO: World Health Organization, NHANES: National Health and Nutrition Examination Survey, BRFSS: Behavioral Risk Factor Surveillance System, LAGB: Laparoscopic adjustable gastric banding, MEPS: Medical Expenditure Panel Survey, NHWS: National Health and Wellness Survey

[1] Percentage of criteria fulfilled of quality assessment by Stuhldreher et al.[15]



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[2] Most studies used standard BMI classification as recommended by the World Health Organization: BMI (kg/m$^2$) normal weight: 18.5-24.99, overweight: 25.00-29.99, obese class I: 30.00-34.99, obese class II: 35.00-39.99, obese class III: ≥40.00. Excess weight was defined as overweight and obesity combined: BMI ≥25.00

[3] Costs were converted to 2015 US Dollar for comparison. The year of costing is given in parentheses.

[4] Authors who did not state the year of costing in their study were asked via email. If unable to reach, the date of submission or publication was assumed as the year of costing.

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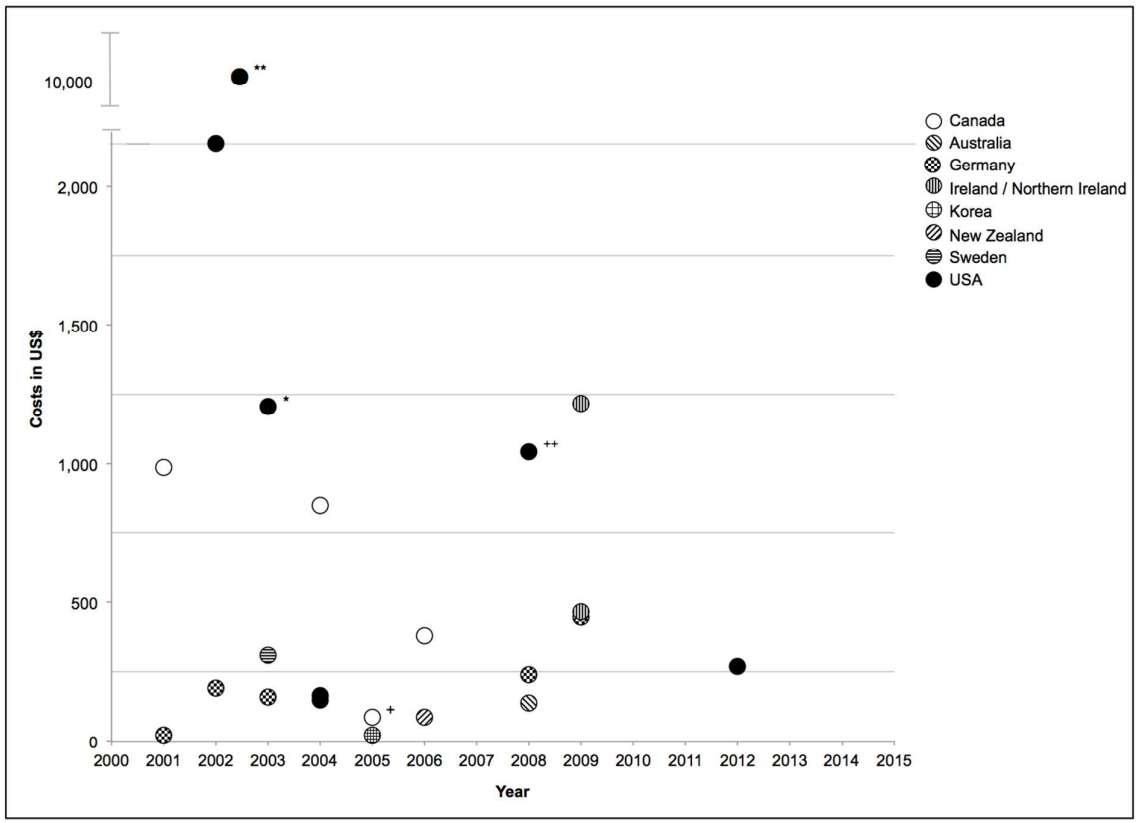
**Supporting Information 5: Excess costs per capita based on macroeconomic costs**




* Costs of the three US states California, North Carolina, Massachusetts, + Costs of the province Alberta, ** Costs of New Mexico, ++ Costs of South Plains of Texas

For better comparison, the per capita costs of the national costs studies are displayed. If not provided in the article, the per capita costs were calculated based on obese or overweight and obese adult population estimates in the year of costing.



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# PRISMA 2009 Checklist

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 2 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | 5-6 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 5-6 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | - |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 6-7 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 6 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | 6-7 |
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 6-7 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 7 |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 6-7 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 7 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | 7 |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$) for each meta-analysis. | 7 |

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# PRISMA 2009 Checklist



| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | - |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | n.a. |
| **RESULTS** | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | 8 |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | 8-9 |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). | - |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | 9, 13 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | n.a. |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | - |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). | 15 |
| **DISCUSSION** | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). | 15-16 |
| Limitations | 25 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). | 16-17 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | 17-18 |
| **FUNDING** | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. | 1 |

*From:* Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

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# Productivity loss due to overweight and obesity: A systematic review of indirect costs

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| Keywords: | obesity, indirect costs, absenteeism, productivity loss, overweight, presenteeism |
| | |

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# Productivity loss due to overweight and obesity: A systematic review of indirect costs

Running title: Indirect cost of overweight and obesity

Andrea Goettler[1], Anna Grosse[1], Diana Sonntag[1, 2] PhD

Affiliations:

[1] Mannheim Institute of Public Health, Social and Preventive Medicine, University Medicine Mannheim, Heidelberg University, Mannheim, Germany

[2] Department of Health Sciences, University of York, UK

Corresponding author:

Diana Sonntag, PhD,

Mannheim Institute of Public Health, Social and Preventive Medicine, University Medicine Mannheim, Heidelberg University, Ludolf-Krehl-Straße 7-11, 68167 Mannheim, Germany

Phone: +49-621-383-9922

Fax: +49-621-383-9920

E-mail: mail@diana-sonntag.eu

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ABSTRACT

Objective: The increasingly high levels of overweight and obesity among the workforce are accompanied by a hidden cost burden due to losses in productivity. This study reviews the extent of indirect cost of overweight and obesity.

Methods: A systematic search was conducted in eight electronic databases (PubMed, Cochrane Library, Web of Science Core Collection, PsychInfo, Cinahl, EconLit, and ClinicalTrial.gov). Additional studies were added from reference lists of original studies and reviews. Studies were eligible if they included monetary estimates of indirect costs of overweight and obesity. The authors reviewed studies independently and assessed their quality.

Results: Of the 3 626 search results, 50 studies met the inclusion criteria. A narrative synthesis of the reviewed studies revealed substantial costs due to lost productivity among workers with obesity. Especially absenteeism and presenteeism contribute to high indirect costs. However, the methodologies and results vary greatly, especially regarding the cost of overweight, which was even associated with lower indirect costs than normal weight in three studies.

Conclusion: The evidence predominantly confirms substantial short- and long-term indirect costs of overweight and obesity in the absence of effective customised prevention programmes and thus demonstrates the extent of the burden of obesity beyond the healthcare sector.

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Strengths and limitations of this study

- This is the first international study that provides a comprehensive overview of all major cost categories of indirect costs, including absenteeism, presenteeism, disability, premature mortality, and worker compensation.
- This is the only review that presents an extensive comparison of monetary consequences of all indirect cost categories on the microeconomic and macroeconomic level.
- The question of causality between obesity and costs is addressed and rounded off by recommendations.

- Due to the heterogeneity of the studies and their methodologies, it is not possible to conduct a meta-analysis of the results and present an indirect costs average based on the literature.
- Publication bias (whereby positive studies are more likely to be published than negative ones) and selection bias (owing to our language restrictions) limit the generalisability of findings.

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ABBREVIATIONS

US = United States

COI = Cost-of-illness

BMI = Body mass index

PAF = Population attributable fraction

FCA = Friction cost approach

HCA = Human capital approach

PPP = Purchasing power parity

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## INTRODUCTION

The obesity epidemic has become a global public health concern[1]. The rising rates of overweight and obesity are accompanied in adulthood by a higher risk of type 2 diabetes, hypertension, coronary heart disease, and stroke[2], which cause substantial healthcare costs. In 2008, the estimated annual medical cost of obesity in the United States was US$ 147 billion due to 42% higher medical spending per capita[3]. Not only the United States has significantly high obesity costs. Other countries also struggle with substantial overweight- and obesity-related medical costs; Germany, for example, had costs of $9.2 billion in 2008[4]. The rising prevalence of overweight and obesity is also related to indirect costs resulting from morbidity and mortality[5-7]. Indirect costs are defined as the losses from reduced work productivity due to short- and long-term inability to work. In particular, obesity is associated with an increased risk of temporary work loss such as sick leave (absenteeism) and reduced productivity while being present at work (presenteeism). It is also associated with permanent work loss, which includes disability pension and premature death[5, 6]. Indeed, recent reviews have found strong evidence that temporary and permanent work loss attributable to obesity result in a substantial burden for national health and insurance pension systems[8, 9].

While a number of systematic reviews have analysed lost productivity of overweight and obesity among workers, their range is relatively narrow. For example, several do not include the monetary value of the indirect costs[5-7, 10], while others focus only on the combined direct and indirect costs of obesity[10, 11]. Similarly, a few limit their range by concentrating on specific countries[9, 12] or specific cost categories such as absenteeism and disability[5-7, 10]. Indeed, only one review provides a more extensive overview of the economic consequences of absenteeism, presenteeism, disability, premature mortality, and worker compensation costs[13]. Yet even this review does not comprehensively assess the monetary value of indirect costs or provide a quality assessment of the included studies. However, it does identify several weaknesses among the included studies (e.g. paucity of both longitudinal



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studies and presenteeism assessments, as well as the need for monetary values of missed work).

Our review addresses the shortcomings of previous systematic reviews and includes studies which acknowledge the research gaps noted by Trogdon et al[13]. With its broad range, our review is the only international review that presents an extensive comparison of the monetary consequences of all indirect cost categories. We systematically review and critically assess both the current evidence for each type of indirect costs and the methodology and research design used. In addition, we address briefly the question of causality between obesity and costs.

## Methods

This review was conducted according to the Centre for Reviews and Dissemination guidance for undertaking reviews in healthcare[14].

### Search strategy

In cooperation with a Cochrane expert from the University Library of Heidelberg, we developed a search strategy to identify all published studies on the indirect costs of overweight and obesity. A keyword search was carried out using the following electronic databases and study registers from inception to June 2017: PubMed, Cochrane Library, Web of Science Core Collection, PsychInfo, Cinahl, EconLit, and ClinicalTrial.gov. The search terms and the search strategy are outlined in the Supplementary File (see Supporting Information 1 and Supporting Information 2).

### Inclusion and exclusion criteria



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Studies were included if they contained a monetary estimate of the indirect costs of overweight and obesity. Indirect costs were defined as costs of overweight and obesity on labour market outcomes (absenteeism, presenteeism, short- and long-term disability, premature death). We excluded studies, which were published in languages other than English or German, located in a developing country due to substantial differences in labour markets, or connected to other illnesses. We decided to exclude studies published before 2000 because of the rising prevalence of overweight and obesity in the last few decades, which led to significant increases of macroeconomic costs[1]. Instead, we placed our focus on recent results, which have not been covered in previous systematic reviews. Furthermore, only peer-reviewed studies with a full-text available were included.

**Study selection procedure and data extraction**

Two reviewers independently applied the inclusion and exclusion criteria. All studies underwent a title and abstract screening, and potentially relevant citations were additionally checked in a full-text screening. Disagreements were resolved through discussion and reasons for exclusion recorded. Finally, 50 studies were identified as eligible. The PRISMA diagram (Figure 1) illustrates the study selection process. Data extracted included study design, target population, time horizon, effect groups, cost category and measurement, and background characteristics such as authors and years of study and publication. Costs were first inflated to 2016 rates using country-specific gross domestic product inflators from the Organisation for Economic Co-Operation and Development (http://stats.oecd.org) and then converted to December 2016 US dollars. The third step was to multiply them with their respective power purchasing parity (PPP) value to achieve a comparable overview. If the year of costing was missing, the authors of the cost-of-illness (COI) study were contacted by e-mail.

**Quality assessment**



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In the absence of a checklist for COI studies, we conducted a quality assessment by adapting the checklist by Stuhldreher and co-authors, which evaluates the quality of COI studies[15]. We assessed the following items: scope, general economic characteristics, calculation of costs, study design and analyses, and presentation of results (see Supporting Information 3). Two authors performed the assessment independently. All discrepancies and uncertainties were resolved through consensus.

## RESULTS

We identified 3 626 articles from the database searches. Title and abstract screening reduced these further to 281 studies, which were retrieved in full text. Reviewing reference lists of relevant papers, studies, and systematic reviews added four potentially relevant studies (Figure 1). Following full-text review, we excluded 231 of these studies, leaving 50 studies to be included in the review.

[Insert Figure 1]

### General characteristics of the studies

There was a wide variety among the included studies in terms of costs, target population, and methodology. Supporting Information 4 shows the sample, methodology, quality, and results of the studies. Most studies were conducted in the United States (27), followed by Germany (8), Canada (5), Australia (2), Sweden (2), Finland (1), Korea (1), New Zealand (1), and the Netherlands (1). Two studies were multi-country (one covering Ireland and Nothern Ireland; the other covering France, Germany, Italy, Spain, and UK). For cost estimations a microeconomic or a macroeconomic approach was applied. While the macroeconomic approach captured the national economic loss of resources measured as national cost, the microeconomic approach measured indirect costs that occur per capita or per employee. More



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specifically, most studies assessed the costs of absenteeism, presenteeism, short- and long-term disability, and premature death. Only five[16-20] included insurance claims, such as indemnity claims, workers' compensation, and other microeconomic costs related to recruitment, training, traffic, nursing, or injuries. The majority of the studies included the costs of more than one of these cost categories.

Both the human capital approach (HCA) and the friction cost method (FCM) were used to calculate productivity losses. The HCA estimates costs based on the lost productivity of one individual, for example, the entire working time lost due to early retirement. The FCM only estimates the value of productivity lost until the employee is replaced. For example, if a worker goes into early retirement, the FCM would only count the period of working time lost until the worker is replaced[19, 21].

The effect measure was exclusively the body mass index (BMI). BMI cut-off points were based on standard World Health Organisation recommendations (overweight: 25.0 ≤ BMI ≤29.9, class I obesity: 30.0 ≤ BMI ≤ 34.9, class II obesity: 35.0 ≤ BMI ≤39.9, and class III obesity: BMI ≥ 40.0), with the exception of seven studies[17, 18, 22-26]. Few studies estimated indirect costs due to obesity-related comorbidities[20, 22, 24-36]. Some controlled for physical and psychological comorbidities in regression analyses[35, 37-41] or created subgroups for the costs of additional, related diseases[18, 40, 42, 43].

Supporting Information 4 displays the search results grouped by methodology into cross-sectional, longitudinal, population attributable risk, and modelling studies. The majority were cross-sectional studies, which focused on annual per capita costs by assessing the overweight and obesity prevalence at a specific point in time. Longitudinal studies evaluated excess weight over a timespan of four[44] to 38 years[21]. The attributable risk studies applied the population attributable fraction (PAF) method to estimate national costs. Only one study modelled the future costs of overweight and obesity based on disease prevalence among teenagers [45]. Eight studies were categorised separately as "other studies", which were not as



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representative. This category includes one intervention analysis[34] and studies with non-representative samples, such as bariatric surgery eligible patients[24, 25, 46], military participants[35, 47], parents of children with overweight or obesity[22], and hospital staff working with patients with obesity[26].

**Quality assessment**

The quality of the included studies was quite diverse (see Supporting Information 3). Overall, the majority of studies met 75% of quality criteria. Three studies met all criteria[16, 21, 33]. Walden et al. probably received the lowest quality score. This study focused primarily on the prevention of injuries rather than on the costs of excess weight and thus did not include information on discounting, standard deviations, and cost perspective and valuation[26].

Criteria regarding introduction, discussion, and conclusion were mostly fulfilled. Quality was lacking in the categories "calculation of costs", "presentation of results", and "study design and analysis". Fourteen studies did not state from what perspective they calculated the costs and only included one cost category[17, 18, 20, 26, 28, 34-36, 42, 44, 47-50]. Study design and analysis were not fulfilled as over half of the studies did not report a sensitivity analysis and lacked information on the proportion of missing data or the imputation method. Furthermore, sample sizes and demographics were not always presented and only 29 studies provided standard deviations or confidence intervals of their results.

**Microeconomic findings**

The cross-sectional and longitudinal studies mostly focused on the per capita or per employee indirect costs of overweight and obesity. Figure 2 displays excess cost (defined as the additional costs of overweight and obesity compared to normal weight) by weight category due to absenteeism, presenteeism, and disability. All micro- and macroeconomic results in this review are presented in US$PPP and estimate the annual indirect costs unless stated



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otherwise. One study[21] presented lifetime costs of overweight and another calculated the costs for a 10-year period[39]. One cost analysis study did not focus on productivity loss but analysed the injury costs among hospital staff attributable to heavy patients[26]. As shown in Figure 2, the costs for absenteeism range from $-200[31] to $1 724[30] for overweight and from $108[43] to $1 857[30]for obesity. While this shows that obesity is constantly associated with productivity costs, it also displays the divergence of the results. We will present the results for each cost category in detail in the following section.

[Insert Figure 2]

Absenteeism

Defined as time away from work due to overweight and obesity, absenteeism was probably due to ease of measurement, the most common measure of indirect costs. The majority of studies (39 out of the 50 included ones) assessed the annual costs of short-term sick leave from work by comparing sick leave days of employees with normal weight with sick leave days of employees with overweight and obesity. The excess costs of overweight were estimated to be between $54[51] and $161[31] and the obesity-related costs between $89[42, 52] and $1 586[53]. The suggestions of Durden et al. were significantly higher for both overweight ($1 738) and obesity ($1 857)[30]. By contrast, other studies did not use an excess-cost approach but calculated the total yearly expenses due to absenteeism for normal, overweight, and obesity samples. The cost for overweight ranged from $29 to $5 132[23, 32, 33, 41, 43, 54] and $57 to $6 759 for obesity per person[18, 23, 32, 35, 41, 44, 46, 54].

In one study the costs associated with healthy weight ($294) were higher than overweight ($94) but lower than the costs for obesity ($402)[43]. Three studies assessed the costs for men and women separately. For women with obesity, the cost was between $170 and $1 391, which was higher than the cost for men with obesity ($89-$1 130)[31, 42, 52]. Gussenhoven



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and Kyrolainen estimated the costs of excess weight (BMI>25) between $915[47] and $4 307[34]. Another study assessed the relationship between children with overweight or obesity and parental work absence and found that while the cost ($142) for children with obesity was higher than the cost of healthy weight children ($120), the cost of children with overweight was lower ($102)[22].

Wolfenstetter assessed weight changes over 10 years and the related costs per group and found that the cost of a person with overweight or obesity is higher than the economic loss of a healthy weight or previously healthy weight person[36]. Neovius et al. also applied a longitudinal approach with data from 1969 and a 38-year follow-up. They estimated lifetime productivity losses of $18 064 using the HCA (FCA: $12 995) for overweight and $19 390 (FCA: $14 317) for obesity[21]. Another long-term study evaluated the yearly cost of a 20 000 workforce over 30 years at $6.6 million[28].

Presenteeism

Nine studies included the effect of reduced productivity at work (presenteeism) due to overweight or obesity, which was assessed by using an employee survey[31-33, 38, 41, 44, 46, 48, 51]. While costs due to presenteeism among individuals with overweight ranged between $-611[31] and $1 669[33], costs among individuals with obesity were between $11[46] and $4 175[31]. Surprisingly, in Peake's study, the cost of presenteeism among employees with overweight ($474) was lower than for individuals with normal weight ($695)[35]. Similarly, Finkelstein et al. estimated lower costs among men with overweight compared to men with normal weight[31]. The excess cost of obesity ranged from $429 to $4 175 for men and from $927 to $3 341 for women[31]. Another study by Finkelstein measured the quarterly indirect costs of bariatric surgery patients to be $11[46]. The cost of moderate or extreme obesity was estimated to be $699[51], $1 684[33], $1 990[32], and $2 414[45]. Peake and co-authors differentiated between the cost of having a BMI higher than



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30 with restricted body fat (≤28% for females, ≤24% for males) ($1 129) and having a BMI higher than 30 without body fat restriction ($984)[35].

One study calculated the combined costs of absenteeism and presenteeism. The combined costs were $5 515 for overweight and from $6 402 to $9 104 for obesity classes I-III[40].

Insurance claims

Insurance claims were measured as indemnity claims[20] or workers' compensation expenditures due to work absence[16, 18]. The only study which exclusively assessed insurance claims estimated indemnity claim costs at $189 per full-time equivalent[20]. For workers' compensation, the additional costs of overweight were estimated to be $180 and the additional costs for obesity classes I-III ranged from $525 to $707[16]. Kleinman et al. assumed the costs of overweight at $63 and those of obesity at $105[18].

Short- and long-term disability

Four studies considered costs of lost productivity due to short- and long-term disability[16, 21, 46, 51]. While excess costs due to disability were estimated to range from $30[16] to $41[51] among individuals with overweight, obesity was associated with costs between $21 and $439[51]. Kleinman et al. estimated $158 for overweight and $242 for obesity[18]. The lifetime cost of disability and disability pensions varied substantially depending on methodology; while estimations of cost based on the HCA varied between $31 037 (overweight) and $32 668 (obesity), estimations of cost based on the FCA were $2 649 (overweight) and $3 115 (obesity)[21].

Premature mortality

Work loss due to early mortality was assessed by two studies[21, 51]. Excess productivity costs related to these indirect costs were $29 for overweight and from $212 to $1 170 for



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grade I-III obesity[51]. Neovius et al. calculated the lifetime productivity losses and found $87 184 (HCA) or $20 066 (FCA) for overweight and $114 626 (HCA) or $23 070 (FCA) for obesity[21].

**Macroeconomic findings**

Among the studies focusing on macroeconomic costs, all but two focused on national costs for one year and found costs ranging from $79 million in New Zealand[19] to $41 billion for three US states[48]. Figure 3 displays the national costs per country and Supporting Information 5 shows per capita estimates of the macroeconomic findings. Knoll and Hauner estimated that the cost of obesity would increase from $1.8 billion in 2003 to $3.6 billion in 2020[49]. Lightwood and co-authors estimated future costs in the United States on current adolescent obesity and proposed a rise in costs from $954 million in 2020 to $36 billion in 2050[45].

[Insert Figure 3]

The majority of the PAF studies included costs of absenteeism, disability, and premature death (for detailed information see Supporting Information 4). The PAF approach indicates the aetiologic fraction of morbidity and mortality of disease prevalence caused by a risk factor (see equation 1):

$$PAF = \frac{\sum_{i=1}^{n} PiRRi - \sum_{i=1}^{n} P'iRRi}{\sum_{i=1}^{n} PiRRi}, \quad (1)$$

$P_i$ = proportion of population at exposure level $i$, current exposure,

$P'_i$ = proportion of population at exposure level $i$, counterfactual or ideal level of exposure,

$RR$ = the relative risk at exposure level $i$,

$n$ = the number of exposure levels.



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More specifically, there is strong evidence for higher risk of comorbidities such as type 2 diabetes, hypertension, coronary heart disease, and stroke in individuals with overweight and obesity[55, 56]. Since overweight and obesity cause only a fraction of comorbidity-related costs, multiplying the PAF by the costs of each comorbidity and then summing up across all diseases estimates total obesity-attributable costs.

Five studies assessed the costs of excess weight in Germany[4, 49, 50, 57]. Lehnert et al. estimated the costs at $9.5 billion[4], Konnopka et al. at $6.5 billion[58], Knoll and Hauner at $1.8 billion[49], and Sander and Bergeman at $282 million[50]. The costs for Canada were suggested to be $2.7 billion by Katzmaryk and Janssen[58], $4.4 billion by Anis et al.[59] and $534 million (for Alberta only) by Moffat et al.[60]. The economic loss for the Republic of Ireland was between $767 million (FCA) and $840 million (HCA). For Northern Ireland the cost was proposed to be between $294 million (FCA) and $491 million (HCA)[61]. In addition to costs of absenteeism and premature death, Lal et al. assessed training and recruitment costs for New Zealand and suggested a national loss between $79 million (FCA) and $180 million (HCA)[19]. In Korea, the productivity loss of excess weight was proposed to be at $872 million due to premature death, hospital admission, nursing costs and fees, and transportation costs[17]. The economic loss associated with excess weight in Australia was estimated to be at $637 million[62]. For three US states (California, North Carolina, Massachusetts), Chenoweth and Leutzinger assumed a productivity loss of $41 billion[48].

While the majority applied the PAF approach, 12 studies assessed the national costs based on lost workdays due to work absence, loss of productivity, and premature death[24, 25, 27, 29, 37, 38, 42, 52, 63-66]. Eight studies assessed the economic loss in the United States. The costs for obesity were estimated to be $11.3 billion by Asay et al. [66], $171 million for grade III obesity by Klarenbach et al.[63], and $3.8 billion due to non-diabetic and morbidly obese by Cawley et al.[42]. The costs of obesity were assessed at $5.5 billion[52] by Cawley and



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co-authors and $9 billion by Andreyeva et al.[26]. Ricci and Chee were the only ones to consider the excess costs of absenteeism and presenteeism in the United States, which they estimated to be $15.7 billion for obesity. The costs of overweight and normal weight did not differ significantly[40]. Two studies focused on the economic loss due to obesity in specific US regions ($409 million in a region of Texas[30] and $2 billion in the state of New Mexico[32]). One study estimated the costs for the province of Quebec in Canada at $531 million[65]. For Germany, the cost of overweight and obesity was $2.5 billion according to a study by Lehnert et al.[39], and $5 billion according to a later study by Effertz et al.[64]. Economic loss due to premature death was estimated for Sweden at $4.8 million for overweight and $383 million for obesity[28].

## DISCUSSION

This review assessed 50 COI studies on the indirect costs of overweight and obesity. The studies applied various methodologies and were mostly of good quality. Although the results varied, most studies found that excess weight entailed substantial indirect costs. While the cost category primarily considered was sick leave, there was also frequent assessment of presenteeism, disability, and premature death. Compared to employees with normal weight, individuals with obesity missed more time from work and worked less productively, resulting in higher indirect costs. Even if the literature suggests substantial indirect costs of overweight and obesity, the results should be interpreted with caution.

Our findings identify and underscore the large variety in defining and measuring the indirect costs of overweight and obesity. Indeed, this large variety made it difficult to provide an estimate of these indirect costs. Moreover, these costs differ substantially due to dissimilar methodological approaches (e.g. HCA versus FCA) and varying analytic methods (e.g.



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simulation-based versus regression-based models) (see Supporting Information 4). This is especially true of excess indirect costs of overweight, which range between -517 US$PPP[31] and 3,271 US$PPP[30]. These methodological differences, in turn, hamper the comparability of cost estimations of overweight and obesity.

The heterogeneity of the results raises the question whether the cost estimates correctly reflect the actual indirect costs of overweight and obesity. Most of the included studies used a top-down approach, which is usually easier to carry out as it is based on secondary data and thus requires only few country-specific estimates. However, in contrast to the bottom-up approach, it often relies on high-level aggregation and approximation of service costs, and may also suffer from double-counting of resources. Moreover, the top-down approach does not take account of multiple obesity-attributable diseases (e.g. type 2 diabetes and coronary heart disease) and their interactions, which may lead to biased (usually upwards) results[67].

Furthermore, the comprehensiveness of costs included in an analysis affects the reliability of the final result. If indirect costs consist of absenteeism costs alone, they will differ from indirect costs due to absenteeism and presenteeism combined. Additional workplace costs, such as transport costs and special training for hospital staff, together with non-monetary costs (e.g. quality-of-life losses) were included in a minority of the studies. Differences in indirect costs of overweight and obesity in the workplace can partly be explained by individual incomes. Individual wages (only captured by Kleinman et al.[18]) consider occupation-specific incomes and the fact that women with overweight and men with obesity earn lower wages than normal-weight workers[68, 69]. Most of the assessed COI studies calculated indirect costs based on estimations of the income of employees. These heterogeneous estimations of cost may be partly explained by occupation-specific incomes and different wage estimates (range: $6 per hour[63] to $500 daily wage[44]).

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Besides costs measured by income in workplace-related productivity losses, costs from unpaid work can occur. In our review one study examined costs from unpaid work and found that reduced household production activities of caregivers cause sizable indirect costs comparable with those of paid work[58]. Moreover, this cost category is also important as the prevalence of childhood overweight and obesity has increased dramatically during the past few years, confronting (grand)parents and caregivers with time losses from unpaid work. A longer measurement period may influence the accuracy of the assessed costs. Two of the studies reviewed considered the impact of childhood overweight and obesity[22, 45]. Lightwood et al. recorded a long timeframe including indirect costs from adolescence and calculated high indirect costs of excess weight for future years[45].

Finally, the lack of evidence for the causal link between obesity and productivity loss has been noted in previous reviews[5, 6, 13]. Recent studies have tried to address this shortcoming by applying longitudinal study designs and controlling for confounding factors, including socio-demographic and work- and health-related covariates[21, 37, 44]. However, all these studies assume that obesity is a direct cause of productivity loss and may thus overestimate the effect on indirect cost. None of them comprehensively address the question, together with associated statistical challenges, whether obesity could also serve as a biological mediator on the causal pathway or an effect modifier. Indeed, obesity may act both as direct explanatory variable and mediator when studying the relationship between cardiorespiratory fitness and productivity loss due to increased metabolic syndrome[70]. Additionally, obesity could also serve as an effect modifier as different levels of obesity modify the association between cardiorespiratory fitness and productivity loss. Moreover, the loss of productivity with increasing BMI declines with age as a higher BMI tends to be protective (e.g. reduced bone density loss and osteoporosis)[71, 72].



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Clearly, a causal framework for a meaningful assignment of indirect costs of obesity requires establishing whether obesity acts as a cause, a mediator or an effect modifier. More specifically, prospective analyses are urgently needed to determine the time of occurrence, i.e. whether diseases occur before (after) an individual has become overweight or obese. Together with such prospective analyses, valid measurements of productivity losses have to be developed and new studies initiated which measure productivity among employees before and after an effective obesity intervention. Only then can there be a successful application of more sophisticated econometric models.

Overall, most studies met most of the quality criteria but could be improved in three major areas. Firstly, the scope could be increased by including more than one cost category. Secondly, estimations of cost would be more accurate if they included obesity-related diseases and were based on individual income. Thirdly, the reliability of long-term economic consequences would be improved by taking childhood obesity into account. To translate lifetime consequences of childhood obesity into economic calculations, it is important to develop dynamic models of obesity-related productivity losses projected over a timeframe longer than the one-year period usually used in cost-of-obesity estimations[73, 74].

One limitation of this review is the potential publication bias, whereby positive studies are more likely to be published than negative studies. For instance, 47 out of the 50 included studies reported higher costs of overweight and obesity. While all studies reported higher costs of obesity, three studies found lower costs of overweight compared to normal weight. Furthermore, due to financial and time restraints, we could only include studies published in English and German, which may result in a selection bias. However, our findings include results from 11 countries and regions which are neither English- and German-speaking.

The included studies exhibited methodological inconsistencies and varying levels of quality. Nevertheless, they consistently confirm that overweight and obesity have substantial short-



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and long-term indirect costs both on the micro- and macroeconomic level. Consequently, an increase in public health initiatives, together with effective company weight-loss programmes, could considerably improve the productivity of workers currently overweight or obese.

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Contribution Statement

Diana Sonntag (DS) conceived the study and wrote the first draft of an earlier version; A. Grosse and A. Goettler performed the literature search and data extraction; A. Grosse, A. Goettler and DS analysed the data. All authors were involved in writing the paper and had final approval of the submitted and published version.

Data Sharing Statement

All unpublished data is only available to the authors.

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FIGURE LEGENDS

Figure 1: PRISMA flow diagram

Figure 2: Microeconomic excess cost of overweight and obesity

[+] Adapted productivity losses per person[51], no information on costs of normal weight

*Adapted indemnity claims cost per 100 full-time equivalents 1997-2004[20], no information on costs of normal weight

Excess per capita costs are displayed for each cost category for overweight, obesity, and excess weight. Mean costs were estimated for studies which only had sex or obesity-grade specific costs available. If not available, excess costs were calculated by subtracting the cost of normal weight from overweight or obesity costs. The figure shows that the costs of obesity are significantly higher than those of overweight alone and those of overweight and obesity combined. Interestingly, the cost of overweight is not necessarily higher than the cost of healthy weight. Absenteeism and presenteeism were considerably higher and more commonly assessed than disability and premature death.

Figure 3: Macroeconomic costs of overweight and obesity

Ricci & Chee[38], Lightwood et al.[45], and Chenoweth & Leutzinger[48] are outliers (coloured in grey).

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* Costs of the three US states California, North Carolina, Massachusetts, + Costs of the province Alberta, ** Costs of the state New Mexico, ++ Costs of South Plains of Texas

Almost analogous to country size and high prevalence rates, the United States has the highest national costs. Its lower values are related to particular states. The lowest costs were found in 2006 in New Zealand. National costs seem to increase in future years.

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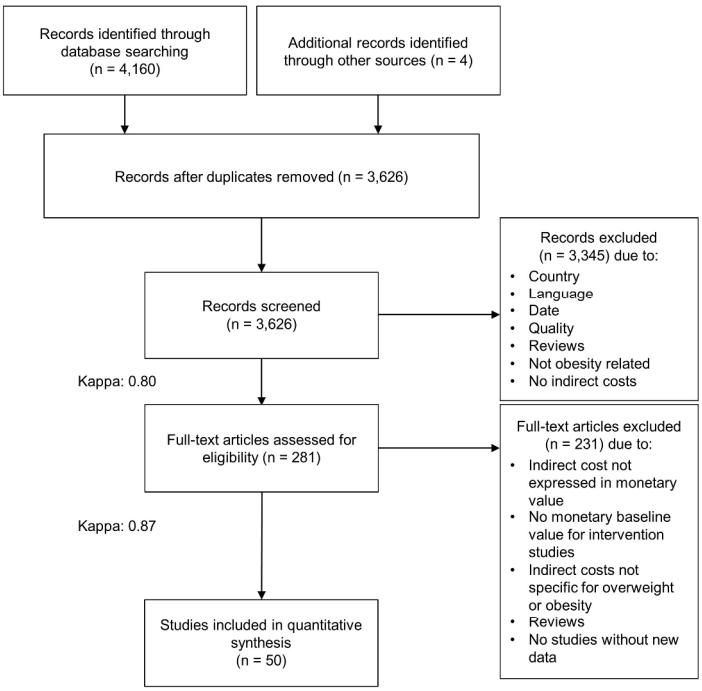


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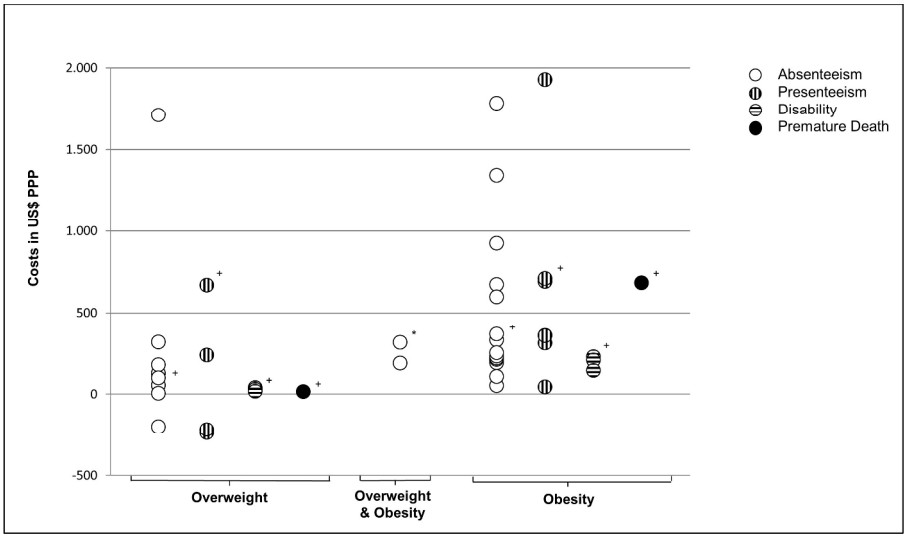


Microeconomic excess cost of overweight and obesity

+ Adapted productivity losses per person[51], no information on costs of normal weight
*Adapted indemnity claims cost per 100 full-time equivalents 1997-2004[20], no information on costs of normal weight
Excess per capita costs are displayed for each cost category for overweight, obesity, and excess weight. Mean costs were estimated for studies which only had sex or obesity-grade specific costs available. If not available, excess costs were calculated by subtracting the cost of normal weight from overweight or obesity costs. The figure shows that the costs of obesity are significantly higher than those of overweight alone and those of overweight and obesity combined. Interestingly, the cost of overweight is not necessarily higher than the cost of healthy weight. Absenteeism and presenteeism were considerably higher and more commonly assessed than disability and premature death.

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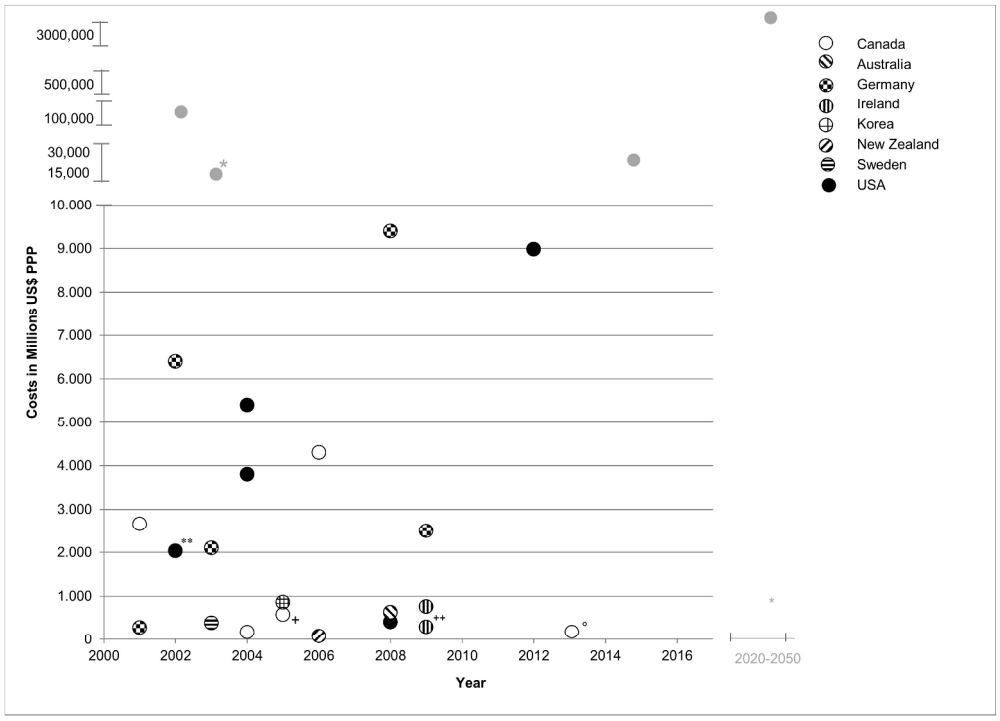


Macroeconomic costs of overweight and obesity

Ricci & Chee[38], Lightwood et al.[45], and Chenoweth & Leutzinger[48] are outliers (coloured in grey). * Costs of the three US states California, North Carolina, Massachusetts, + Costs of the province Alberta, ** Costs of the state New Mexico, ++ Costs of South Plains of Texas
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# Productivity loss due to overweight and obesity: A systematic review of indirect costs

Supplementary File

Andrea Goettler[1], Anna Grosse[1], Diana Sonntag[1, 2] PhD

[1] Mannheim Institute of Public Health, Social and Preventive Medicine, University Medicine Mannheim, Heidelberg University, Mannheim, Germany; E-mail: mail@diana-sonntag.eu

[2] Department of Health Sciences, University of York, UK

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**Supporting Information 1: Search strategy**

The following electronic databases were searched in June 2017:
PubMed
Cochrane Library
Web of Science Core Collection
PsychInfo
Cinahl
EconLit
ClinicalTrial.gov (study register)

**PubMed, 2167 results**
1. ("Obesity"[Mesh] OR Obes*[tw] OR "Obesity, Morbid"[Mesh] OR "Overweight"[Mesh] OR Overweight*[tw] OR “Excess Weight”[tw] OR "Overnutrition"[Mesh] OR Overnutr*[tw] OR "Adiposity"[Mesh] OR Adipos*[tw] OR "Body Mass Index"[Mesh] OR "Body Mass Index" [tw] OR BMI[tw] OR "Skinfold Thickness"[Mesh] OR Skinfold Thick*[tw] OR “Body Fat” [tw] OR "Waist-Hip Ratio"[Mesh] OR Waist Hip Ratio* [tw] OR "Waist Circumference"[Mesh] OR Waist Circumference*[tw])

2. ("Sick Leave"[Mesh] OR Sick Leave*[tw] OR Sickness Absen*[tw] OR Sick Absen*[tw] OR Sick Day*[tw] OR Work Absen*[tw] OR Work Leave* [tw] OR Illness Day*[tw] OR Illness absen*[tw] OR "Absenteeism"[Mesh] OR Absenteeism[tw] OR Absence Day*[tw] OR Absent Day*[tw] OR Presenteeism[tw] OR Work Productivit*[tw] OR Productivity Loss*[tw] OR Work Abilit*[tw] OR Work Disabilit*[tw] OR Disability Pension*[tw] OR Early Retirement*[tw] OR "Mortality, Premature"[Mesh] OR Premature Mortal*[tw] OR Premature Death*[tw] OR "Employment"[Mesh] OR Employment*[tw] OR Employee*[tw] OR Workloss*[tw] OR Workplace*[tw] OR Workday*[tw] OR Worker*[tw] OR Labour*[tw] OR Labor*[tw] OR Occupation*[tw] OR Job*[tw])

3. (Cost[tw] OR Costs[tw] OR Economic*[tw] OR Indirect Expenditure*[tw] OR Indirect Expense*[tw] OR "Cost of Illness"[Mesh] OR "Costs and Cost Analysis"[Mesh])

4. 1 AND 2 AND 3

**Cochrane Library, 60 results**
1. [mh Obesity] or Obes*:ti,ab,kw or [mh "Obesity, Morbid"] or [mh Overweight] or (Overweight* or "Excess Weight"):ti,ab,kw or [mh Overnutrition] or Overnutr*:ti,ab,kw or [mh Adiposity] or Adipos*:ti,ab,kw or [mh "Body Mass Index"] or ("Body Mass Index" or BMI):ti,ab,kw or [mh "Skinfold Thickness"] or ("Skinfold Thick*" or "Body Fat"):ti,ab,kw or [mh "Waist-Hip Ratio"] or "Waist Hip Ratio*":ti,ab,kw or [mh "Waist Circumference"] or "Waist Circumference*":ti,ab,kw

2. [mh Obesity] or Obes*:ti,ab,kw or [mh "Obesity, Morbid"] or [mh Overweight] or (Overweight* or "Excess Weight"):ti,ab,kw or [mh Overnutrition] or Overnutr*:ti,ab,kw or [mh Adiposity] or Adipos*:ti,ab,kw or [mh "Body Mass Index"] or ("Body Mass Index" or BMI):ti,ab,kw or [mh "Skinfold Thickness"] or ("Skinfold Thick*" or "Body Fat"):ti,ab,kw or [mh "Waist-Hip Ratio"] or "Waist Hip Ratio*":ti,ab,kw or [mh "Waist Circumference"] or "Waist Circumference*":ti,ab,kw

3.. (Cost or Costs or Economic* or "Indirect Expenditure*" or "Indirect Expense*"):ti,ab,kw or [mh "Cost of Illness"] or [mh "Costs and Cost Analysis"]



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4. 1 AND 2 AND 3

**Web of Science, 645 results**

1. TOPIC: (Obes* OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*")

2. TOPIC: ("Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR Employment* OR Employee* OR Workloss* OR Workplace* OR Workday* OR Worker* OR Labour* OR Labor* OR Occupation* OR job*)

3. TOPIC: (Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*")

4. 1 AND 2 AND 3

**PsychInfo, 311 results**

1. DE "Obesity" OR Obes* OR DE "Overweight" OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR DE "Body Mass Index" OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*"

2. .DE "Employee Leave Benefits" OR "Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR DE "Employee Absenteeism" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR DE "Employment Status" OR Employment* OR Employee* OR Worker* OR Workloss* OR Workplace* OR Workday* OR Labour* OR Labor* OR Occupation* OR job*

3. DE "Health Care Costs" OR DE "Costs and Cost Analysis" OR Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*"

4. 1 AND 2 AND 3

**Cinahl, 230 results**

1. Obes* OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*"

2. "Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR Employment* OR Employee* OR Workloss* OR Workplace* OR Workday* OR Worker* OR Labour* OR Labor* OR Occupation* OR job*

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3. Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*"

4. 4. 1 AND 2 AND 3

**EconLit, 108 results**
1. (Obes* OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*")

2.. ("Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR Employment* OR Employee* OR Workloss* OR Workplace* OR Workday* OR Worker* OR Labour* OR Labor* OR Occupation* OR job*)

3. (Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*")

4. 1 AND 2 AND 3

**ClinicalTrial.gov, 105 results**
1. (Obesity OR Overweight OR “Excess Weight” OR Overnutrition OR Adiposity OR "Body Mass Index" OR BMI OR "Skinfold Thickness" OR “Body Fat” OR "Waist Hip Ratio" OR "Waist Circumference")

2. ("Sick Leave" OR "Sickness Absence" OR "Sick Absence" OR "Sick Day" OR "Work Absence" OR "Work Leave" OR "Illness Day" OR "Illness absence" OR Absenteeism OR "Absence Day" OR "Absent Day" OR Presenteeism OR "Work Productivity" OR "Productivity Loss" OR "Work Ability" OR "Work Disability" OR "Disability Pension" OR "Early Retirement" OR "Premature Mortality" OR "Premature Death" OR Employment OR Employee OR Worker OR Workloss OR Workplace OR Workday OR Labour OR Labor OR Occupation OR job*) AND

3. (Cost OR Costs OR Economic OR "Indirect Expenditure" OR "Indirect Expense")

4. 1 AND 2 AND 3

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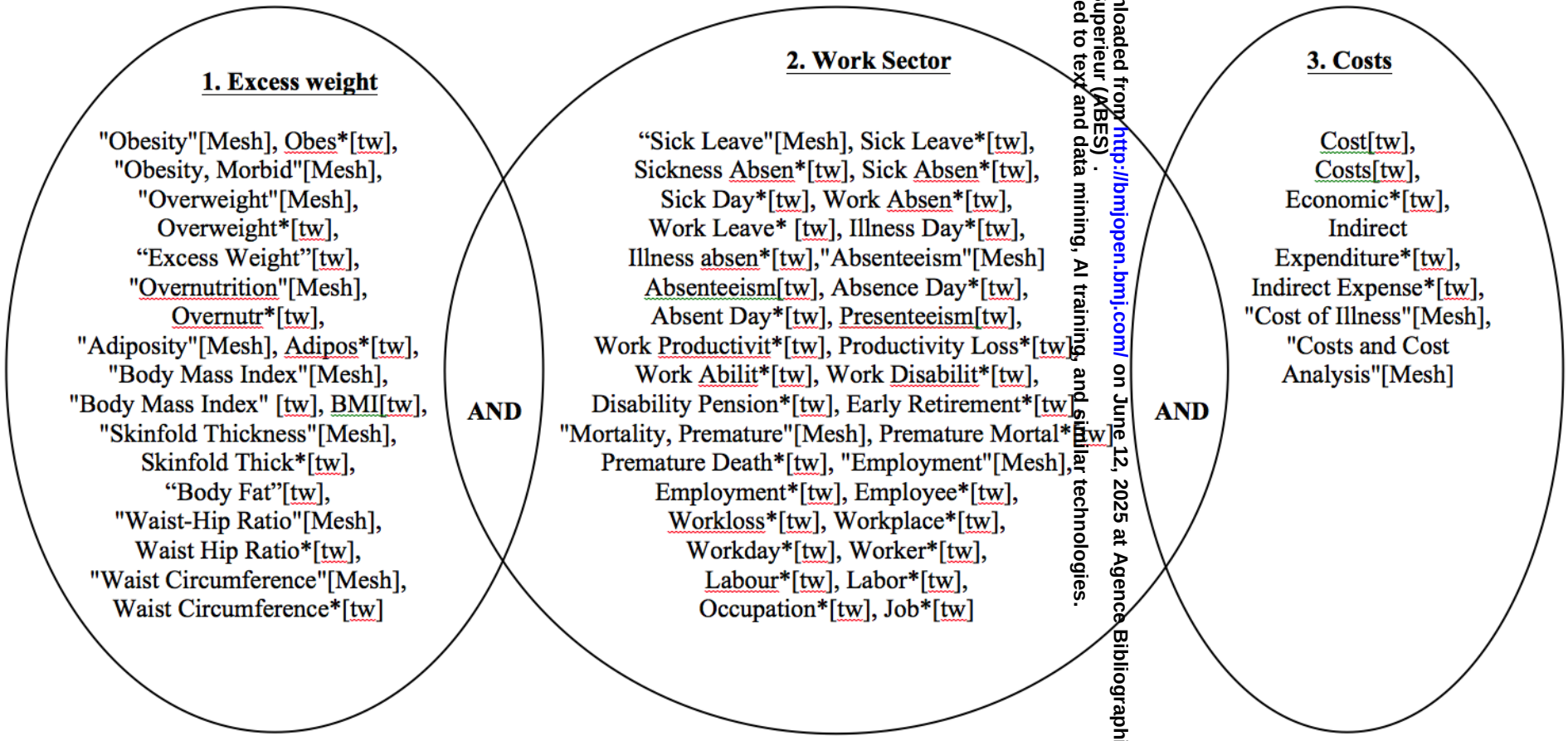
**Supporting Information 2: Search strategy (PubMed)**




All Keywords in the concepts are connected with the OR-operator (was removed for practicability reasons).

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## Supporting Information 3: Quality Scoring

| Author | Year | 1. Scope | | | 2. General economic characteristics | | 3. Calculation of costs | | | | | | 4. Study design and analysis | | | 5. Presentation of results | | | 6. Discussion | | | Quality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Study objective* | *Inclusion and exclusion criteria* | *Disease and diagnostic criteria* | *Cost-description* | *Nondiseased comparison group or disease-specific costs* | *Currency* | *Reference year* | *Perspective* | *Costs incorporated from more than one category* | *Data source* | *Valuation of costs* | *Discounting* | *Missing data, imputation method* | *Statistics appropriate* | *Sensitivity analysis* | *Sample size (subgroup)* | *Demographics* | *Arithmetic mean costs Standard deviations (errors)* | *Results discussed with respect to other studies* | *Limitations discussed* | *Conclusions appropriate regarding uncertainty in results* | % |
| Andreyeva et al.[26] | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a. | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Anis et al.[59] | 2010 | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | 80% |
| Asay et al.[66] | 2016 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 95% |
| Bhojani et al.[28] | 2014 | ✓ | | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | 62% |
| Blouin et al.[65] | 2017 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | | | | | | ✓ | ✓ | 71% |
| Borg et al.[29] | 2005 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 86% |
| Breitfelder et al.[22] | 2011 | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 95% |
| Cadilhac et al.[62] | 2011 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Cawley et al.[52] | 2007 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | n.a. | | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | 75% |
| Cawley et al.[42] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a. | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Chenoweth & Leutzinger[48] | 2006 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | n.a. | | ✓ | | | ✓ | | | ✓ | ✓ | 60% |
| Chenoweth et al.[23] | 2015 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | 75% |
| Dall et al.[51] | 2009 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | 75% |
| Dee et al.[61] | 2015 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | 80% |
| DiBonaventura et al.[40] | 2015 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a. | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | | 80% |
| Durden et al.[30] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a. | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Effertz et al.[64] | 2016 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | n.a. | | ✓ | | | | ✓ | ✓ | ✓ | ✓ | 71% |
| Ewing et al.[24] | 2011 | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | 67% |
| Finkelstein et al.[31] | 2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Finkelstein et al.[46] | 2012 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Finkelstein et al. [53] | 2005 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | | | ✓ | ✓ | 75% |
| Frezza et al. [25] | 2006 | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | 71% |

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| Author | Year | 1. Scope | | | 2. General economic characteristics | | 3. Calculation of costs | | | | | | 4. Study design and analysis | | | | 5. Presentation of results | | | 6. Discussion | | | Quality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Study objective* | *Inclusion and exclusion criteria* | *Disease and diagnostic criteria* | *Cost-description* | *Nondiseased comparison group or disease-specific costs* | *Currency* | *Reference year* | *Perspective* | *Costs incorporated from more than one category* | *Data source* | *Valuation of costs* | *Discounting* | *Missing data, imputation method* | *Statistics appropriate* | *Sufficient sample size (ABES)* | *Sample size (subgroup)* | *Demographics* | *Arithmetic mean costs Standard deviations (errors)* | *Results discussed with respect to other studies* | *Limitations discussed* | *Conclusions appropriate regarding uncertainty in results* | % |
| Gates et al. [32] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | 80% |
| Goetzel et al. [33] | 2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 100% |
| Gupta et al. [41] | 2015 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Gussenhoven et al. [34] | 2013 | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Henke et al. [16] | 2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 100% |
| Kang et al. [17] | 2011 | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Katzmarzyk & Janssen [58] | 2004 | ✓ | | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a. | | ✓ | | | | | ✓ | ✓ | ✓ | 60% |
| Kirkham et al. [44] | 2015 | ✓ | | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 67% |
| Klarenbach et al. [63] | 2006 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a. | ✓ | ✓ | | | ✓ | | ✓ | ✓ | ✓ | 75% |
| Kleinman et al. [18] | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Knoll & Hauner[49] | 2008 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | ✓ | | | ✓ | ✓ | 71% |
| Konnopka et al. [57] | 2011 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | ✓ | 86% |
| Kyrolainen et al. [47] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | 65% |
| Lal et al. [19] | 2012 | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | 80% |
| Lehnert et al. [37] | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | 90% |
| Lehnert et al. [4] | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | 85% |
| Lightwood[45] | 2009 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | | ✓ | 95% |
| Moffatt et al. [60] | 2011 | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | n.a. | | ✓ | | | | | ✓ | ✓ | ✓ | 62% |
| Neovius et al. [21] | 2012 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 100% |
| Ostbye et al. [20] | 2007 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | 62% |
| Peake et al. [35] | 2012 | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 86% |
| Ricci & Chee[38] | 2005 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | n.a. | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 95% |

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| Author | Year | 1. Scope | | | 2. General economic characteristics | | 3. Calculation of costs | | | | | | 4. Study design and analysis | | | 5. Presentation of results | | | | 6. Discussion | | | Quality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Study objective* | *Inclusion and exclusion criteria* | *Disease and diagnostic criteria* | *Cost-description* | *Nondiseased comparison group or disease-specific costs* | *Currency* | *Reference year* | *Perspective* | *Costs incorporated from more than one category* | *Data source* | *Valuation of costs* | *Discounting* | *Missing data, imputation method* | *Statistics appropriate* | *Sample size (subgroup)* | *Demographics* | *Arithmetic mean costs Standard deviations (errors)* | *Results discussed with respect to other studies* | *Limitations discussed* | *Conclusions appropriate regarding uncertainty in results* | % |
| Sander & Bergmann[50] | 2003 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | 85% |
| Su et al. [39] | 2015 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | | | | ✓ | ✓ | ✓ | 75% |
| Sullivan et al. [43] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | 80% |
| Tsai et al. [54] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | 71% |
| Walden et al. [26] | 2013 | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | | | ✓ | | | | ✓ | | | | | n.a. | ✓ | ✓ | 53% |
| Wolfenstetter[36] | 2012 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | 90% |

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## Supporting Information 4: Characteristics and costs of the 50 studies included in the review

| Study | Sample | Data source and year | Quality[1] | BMI categories[2] | Considered factors | Costs in 2016 PPP Dollar[3] |
|---|---|---|---|---|---|---|
| *Cross-sectional studies (Regression models, descriptive methods)* | | | | | | |
| Blouin et al. (2017)[65] | Quebec, NPHS: N=2,359, Canada | National Population Health Survey Household (NPHS) (1994-2011), National Health Expenditure Database (NHEX) (2011) | 71% | BMI (WHO): normal, overweight, obese | - | The economic burden in Quebec associated with obesity due to absence (in 2013) caused by disability and loss of productivity is $53.3 million. |
| Asay et al. (2016)[66] | MHR: N=356,758, n(obese)=92,910, civilian, noninstitutionalized, MEPS: N=24,006, n(obese)=7,190 USA | MarketScan Health Risk Assessment, Medical Expenditure Panel Survey (MEPS) (2008-2011) | 95% | BMI (WHO): obesity: >30 | - | The annual cost of absenteeism for US employers because of obesity (in 2015) was $272. The total US cost per year is $11.3 billion. In an alternative scenario where work lost work was taken up by a college costs amounted to $4.86- $18.1 billion. |
| Effertz et al. (2016)[64] | Nationally representative, TK: N=146,000, Germany | Techniker Krankenkasse (2008 - mid-2012) | 71% | BMI WHO): obesity grade I, II, III | - | The costs due to sick leave (in 2016) sum to $4.97 billion. The individual losses are $1.98 billion from lost productivity. The $2.99 billion is borne by the employer. |
| Chenoweth et al. (2015)[23] | Municipal employees in North Carolina, N=3,951 claims, USA | North Carolina League of Municipalities: Claims Management System (2000 – 2009) | 75% | BMI: normal: 18.5-24.9, overweight – class I: 25.0-27.0, overweight – class II: 27.1-29.9, obesity grade I, II, III | - | Average annual total lost workday income (in 2015) was between $4,891 and $5,132 for class I and II overweight. The total lost workday income for obesity classes I to III ranged from $6,402 to $6,839, the average cost in the normal weight group was $4,047. |
| DiBonaventura et al. (2015)[40] | Nationally representative, NHWS: N=71,530, n(overweight)=23,852 n(obese I)=13,037, n(obese II)=5,948, n(obese III)=4,683, USA | NHWS (2013) | 80% | BMI (WHO): normal, overweight, obesity grade I, II, III | Costs calculated with and without risk of physical comorbidities (diabetes). | The cost of overweight without pre-diabetes or type 2 diabetes for a combined measurement of absenteeism and presenteeism (in 2015) was $5,515 for overweight, $6,173 for obesity class I, $6,906 for obesity class II and $9,104 for obesity class III, the cost of normal weight was $4913 |
| Gupta et al. (2015)[41] | Nationally representative, NHWS: N=62,000, n(overweight)=20,135, n(obese I)=7,268, n(obese II)=2,360, n(obese III)=1,251, France, Germany, Italy, Spain, UK | EU5 NHWS (2013) | 85% | BMI (WHO): normal, overweight, obesity grade I, II, III | Generalized linear regression models controlled for obesity related comorbidities. | Estimated annual costs on average (in 2013): $3,624 or overweight (absenteeism 30.0%, presenteeism 70.0%), $3,751 for obese class I (absenteeism 28.0%, presenteeism 72.0%), $4,209 for obese class II (absenteeism 31.5%, presenteeism 68.5%), $5,480 for obese class III (absenteeism 32.0%, presenteeism 68.0%), $3,520 for normal weight (absenteeism 26.3%, presenteeism 73.3%). |
| Su et al. (2015)[39] | Nationally representative, N=11,755, n(normal)=6,534, n(obesity I, II, III)=5,221, USA | NHANES (2005-2012) | 75% | BMI: normal, obesity grade I, II, III | Sub cohorts for physical comorbidities | The cumulative outcome for the burden of obesity (in 2013) was $3,611 (over 5 years) and $7.732 (over 10 years). This leads to a excess costs of $1.134 (over 5 years) and $2.268 (over 10 years) when compared to the normal weight population. |
| Andreyeva et al. (2014)[26] | Nationally representative, NHANES: N=14,975, n(overweight)=5,116, n(obesity I,II, III)=4,747, BRFSS: N=182,227, n(overweight)=66,695, n(obesity I, II, III)=57,583, USA | NHANES (1998-2008), BRFSS (2012), Integrated Public UseMicrodata Series-Current Population Survey (2011) | 90% | BMI (WHO): normal, overweight, obesity grade I, II, III | - | The US total loss in productivity (in 2012) because of obesity-related absenteeism was estimated at $9.04 billion per year. The obesity-attributable fraction (%) in total absenteeism costs varied from 6.5% in District of Columbia to 12.6% in Arkansas, with the US average of 9.3%. |
| Kleinman et al. (2014)[18] | Communications, transportation, finance, healthcare, and retail | Human Capital Management Services Research Reference | 85% | BMI: normal weight: BMI<27, | Sub cohorts for physical | Adjusted annual costs (in 2014) were $1,081 for overweight (sick leave 80.2%, short-term disability 13.2%, long-term disability 0.9%, |



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| | | | | | | |
|---|---|---|---|---|---|---|
| | employees, N = 1,700,000, n(overweight)=14,281, n(obesity)=18,801, USA | Database (2001–2012) | | overweight: BMI 27-30, obesity: BMI>30 | comorbidities | workers' compensation 5.6%), $1,350 for obese (sick leave 75.2%, short-term disability 15.4%, long-term disability 1.9%, workers' compensation 7.5%) and $966 for normal weight (sick leave 79.7%, short-term disability 14.0%, long-term disability 1.9%, workers' compensation 4.3%). |
| Lehnert et al. (2014)[37] | Nationally representative, N=7,990, n(overweight)=3,022, n(obese)=1,369, Germany | German Socio-Economic Panel (2009-2010) | 85% | BMI (WHO): Excess weight: BMI>25 | Adjusted model for physical and psychosocial comorbidities | The total population costs associated with overweight- and obesity-related excess sick leave days in Germany (in 2009) were $3 billion. |
| Finkelstein et al. (2010)[31] | Nationally representative, NHWS: N=24,140, n(overweight)=8,594, n(obese I)=4,683, n(obese II)=2,148, n(obese III)=1,569, MEPS: N=8,875, n(overweight)=3,373, n(obese I)=1,597, n(obese II)=612, n(obese III)=320, USA | NHWS (2008), MEPS (2006) | 90% | BMI (WHO): overweight, obesity grade I, II, III | - | Productivity losses (2010) due to excess weight compared to normal weight for men were $-517 for overweight (absenteeism $94, presenteeism -$611), $735 for grade I obese (absenteeism 41.5%, presenteeism 58.5%), $1,835 for grade II obese (absenteeism 39.4%, presenteeism 60.6%) and $5,305 for grade III obese (absenteeism 21.3%, presenteeism 78.7%). For women, the costs were $295 for overweight (absenteeism 54.9%, presenteeism 45.1%), $1,376 for grade I obese (absenteeism 32.6%, presenteeism 67.4%), $1,740 for grade II obese (absenteeism 4.2%, presenteeism 95.8%) and $4,733 for grade III obese (absenteeism 29.4%, presenteeism 70.6%). |
| Goetzel et al. (2010)[33] | Employees from multiple professions and worksites, N=10,026, n(overweight)= 3,180, n(obese)=3,834, USA | National Heart, Lung, and Blood Institute (2005-2007) | 100% | BMI (WHO): normal weight, overweight, obese: BMI>30 | - | Estimated annual costs per employee (in 2006): $2,764 for overweight (absenteeism 39.6%, presenteeism 60.4%), $3,090 for obese (absenteeism 45.5%, presenteeism 54.5%), $2,469 for normal weight (absenteeism 42.1%, presenteeism 57.9%). |
| Henke et al. (2010)[16] | Pepsi Bottling Group employees, N=11,217, n(overweight)=5,003, n(obese I)=2,344. n(obese II)=673, n(obese III)=269, USA | StayWell HealthPath HRA data from the Thomson Reuters MarketScan and Advantage Suite Databases (2004-2006) | 100% | BMI (WHO): normal weight, overweight, obesity grade I, II, III | Costs for physical and psychosocial comorbidities and behavioral factors. | Annual average additional costs (in 2008) of excess weight compared to normal weight ($958 for normal weight employees): Additional costs were $210 for overweight (workers' compensation 85.6%, short-term disability 14.4%), $640 for grade I obese (workers' compensation 81.4%, short-term disability 18.6%), $693 for grade II obese (workers' compensation 88.0%, short-term disability 12.0%) and $1,098 for grade III obese (workers' compensation 61.4%, short-term disability 38.6%) |
| Dall et al. (2009)[51] | Nationally representative, N=1,000,000, overweight 33%, obese I 17%, obese II or obese III 12%, USA | U.S. Census Bureau (2007), NHANES (1999-2004), National Health Interview survey (2006) | 75% | BMI (WHO): normal, overweight, obesity grade I and II, III combined | Including costs of physical comorbidities. | Excess productivity loss per person (in 2007) were $798 for overweight (absenteeism 6.8%, presenteeism 84.5%, disability 5.0%, premature mortality 3.6%), $1,051 for obese I (absenteeism 11.5%, presenteeism 66.5%, disability 2.0%, premature mortality 20.0%), $2,598 for obese II and III (absenteeism 11.8%, presenteeism 26.6%, disability 16.8%, premature mortality 44.8%). |
| Cawley (2008)[42] | Nationally representative, N(men)=14,187, obese 78.7%, morbidly obese 21.3% N(women)=19,402 women, obese 88.0%, morbidly obese 12.0%, USA | MEPS (2000 –2004) | 85% | BMI (WHO) obesity: BMI 30-40, morbid obesity: BMI>40 | Additional sample with physical comorbidities. | National aggregate annual costs of job absenteeism (in 2004) for obese nondiabetic were $2.8 billion ($731 million for men, $2,066 million for women). Costs for morbidly obese nondiabetic were $1.01 billion ($234 million for men, $777 million for women). Per-capita annual increases in absenteeism costs associated with obesity, as compared with healthy weight nondiabetics were $89 for men and $170 for women. For morbidly obese, the costs were $284 for men and $287 for women. |

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| Gates et al. (2008)[32] | Manufacturing employees, N=341, n(overweight)=143, n(mildly obese)=79, n(moderately/extremely obese)=43, USA | Survey in eight manufacturing countries in Kentucky (-) | 80% | BMI (WHO): normal weight, overweight, mild obesity: BMI 30-35, moderate or extreme obesity: BMI>35 | - | The annual per-person costs of moderately or extreme obese workers were $3,247 (absenteeism 46.9%, presenteeism 53.1%). The annual costs of all other workers were $2,700 (absenteeism 52.8%, presenteeism 47.2%). (Year of costing assumed: 2008)4 |
| Sullivan et al. (2008)[43] | Nationally representative, N= 43,221, n(obese)=10,970, USA | MEPS (2000–2002) | 80% | BMI (WHO) underweight, normal weight, overweight, obesity: BMI > 30 | Costs calculated with and without risk of physical comorbidities. | Annual costs of absenteeism (in 2007) per person without comorbidities were $94 for overweight and $402 for obese ($294 for normal weight). When controlling for chronic conditions, the costs were $83 for overweight and $288 for obese ($161 for normal weight). |
| Durden et al. (2008)[30] | Commercially insured employees, N=88,984, n(overweight)=34,259, n(severely obese)=8,780, n(obese)=14,826, USA | Self-reported data from MarketScan Research databases and MarketScan HRA Database (2003-2005) | 90% | BMI (WHO) underweight, normal weight, overweight, obese: BMI: 30-35 severely obese: BMI>35 | - | Estimated costs of workdays lost (in 2005) were $7,557 for overweight, $10,113 for obese, $10,362 for severely obese and $4,224 for normal weight. Marginal effects of the GLM of indirect costs due to absence, relative to the normal weight BMI group: $1,324 for overweight, $1,857 for obese and $1,738 for severely obese. |
| Cawley et al. (2007)[52] | Nationally representative, N= 54,970, overweight: 27% female, 42% male, obese: 21% female, 23% male, morbidly obese: 8% female 6% male, USA | MEPS (2000-2004) | 75% | BMI (WHO) healthy weight, overweight, obese: BMI 30-35 or 35-40 and no hypertension, hyperlipidemia, or diabetes, morbidly obese: BMI>40 or BMI 35-40 and hypertension, hyperlipidemia, or diabetes present | For obesity-diagnostic: physical comorbidities | Per capita increases in absenteeism costs associated with obesity (in 2004) were $89 for men and $181 for women compared with healthy weight nondiabetic subjects. Per capita increases in absenteeism costs associated with morbid obesity were $252 for men and $303 for women compared with healthy weight nondiabetic subjects. Estimated national aggregate costs of absenteeism were $5.5 billions for obesity in 2004. |
| Klarenbach et al. (2006)[63] | N= 58,289 (of all weight classes), estimated prevalence rate of obesity class III: 1%, Canada | Canadian Community Health Survey (2000 - 2001) | 75% | BMI (WHO) normal weight, obesity grade I, II, III | Physical and psychosocial comorbidities | Total lost productivity due to absenteeism (in 2004) for Class III obesity is estimated to be $171 million. |
| Ricci & Chee (2005)[38] | National population-based, N=6,894 employed adults, n(overweight)=2,490 , n(obese)=1,536, USA | The Caremark American Productivity Audit, The Caremark Work and Health Interview (2001-2003) | 95% | BMI (WHO) overweight, obese BMI>30 | Covariates in Logistic Regression Models: physical and psychosocial comorbidities and behavioral factors | Total cost of health-related lost productive time (in 2002) were $73 billion for overweight (absenteeism 30.7%, presenteeism 69.3%) and $56 billion for obese (absenteeism 32.2%, presenteeism 67.8%). |
| Finkelstein et al. (2005)[53] | Nationally representative, N= 25,427, n(overweight)=9,813*, n(obese)=5,736, USA | National Health Interview Survey (2001-2002) | 85% | BMI (WHO) overweight, obesity grade I, II, III | Regressions controlled any functional limitations not self-reported as obesity-related (e.g. difficulty walking, standing, sitting, stooping, reaching, or grasping) | Value of increased absenteeism in 2004 associated with overweight were $128, with grade-I obesity $476, with grade-II obesity $2,019, and with grade-III obesity $1,586. |



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| *Longitudinal studies* | | | | | | |
| Kirkham et al. (2015)[44] | Large computer manufacture employees, N = 17,089, obesity: 7-9%, USA | HRA survey data, human resources records, and employee insurance eligibility records (2006–2010) | 67% | BMI (WHO): obesity: BMI>35 | Health Risk levels of physical and psychosocial comorbidities and behavioral factors | Annual productivity costs (in 2014) of being at risk for BMI≥35: $3,608 (absenteeism 33.1%, presenteeism 66.9%). Costs of BMI<35: $3,086 (absenteeism 31.1%, presenteeism 68.9%). |
| Bhojani et al. (2014)[28] | Petrochemical workers (Shell), N=20,000 to 28,000, obesity 14%-42% from 1980-2009, USA | Physical examination records in the Shell Health Surveillance System (1980-2009) | 62% | BMI (WHO): obesity: BMI>30 | - Behavioral factors | At the end of 30 years, and assuming a workforce of 20,000 employees, the potential economic impact due to illness-absence from obesity would be $6.59 million/year. (Assumed year of costing: 2014) |
| Neovius (2012)[21] | Nationwide cohort of men, who performed mandatory military conscription tests at age 18 (follow-up after 38 years), N=45,920, n(overweight)=2,623, n(obese)=367, Sweden | Military Service Conscription Register, Social Insurance Register, Register of the Total Population, Population and Housing Censuses (1969/1970, 1986-2005) | 100% | BMI (WHO): underweight, normal weight, overweight, obese | Covariates: behavioral and environmental factors | Lifetime productivity losses (in 2010) according to the human capital approach: $87,264 for overweight (sick leave 20.7%, disability pension 35.6%, mortality 43.8%), $114,731 for obesity (sick leave 16.5%, disability pension 28.5%, mortality 54,6%), $66,864 for normal weight (sick leave 22.5%, disability pension 32.3%, mortality 45.2%). Friction cost method: $20,085 for overweight (sick leave 64.7%, disability pension 13.2%, mortality 21.6%), $23,092 for obesity (sick leave 62.0%, disability pension 13.5%, mortality 24.5%), $15,878 for normal weight (sick leave 70.2%, disability pension 11.5%, mortality 18.3%). |
| Wolfenstetter (2012)[36] | Population-representative, N=2,581, n(overweight)=786, n(obese)=406, n(healthy weight) = 679; n(healthy to overweight) = 299, n(healthy to obese)= 10, n(overweight to healthy)= 92, n(overweight to obese) = 257, n=(obese to healthy) = 2, n(obese to overweight)= 50, Germany | MONICA/KORA (Cooperative Health Research in the Region of Augsburg) survey-S3 (1994/95), KORA follow-up survey-F3 (2004/05) | 90% | BMI (WHO): normal weight, overweight, obese Changes in health status from 1994/1995 to 2004/2005 | - Healthcare utilization by physician visits and therapy | Costs of absenteeism per year per group (in 2005). Costs of participants who remained in the same weight group: $2,662 (healthy weight), $3,625 (overweight), $3,625 (obesity). Costs of participants who changed the weight group: $3,625 (Healthy to overweight), $607 (healthy to obese), $2,661 (overweight to healthy), $4,213 (overweight to obese), $284 (obese to healthy), $3,257 (obese to overweight). |
| Tsai et al. (2008)[54] | Shell Oil Company employees, 1994: N=4,153, n(overweight)=1,854, n(obese)=1,204, 2003: N=4,513, n(overweight)=1,719, n(obese)=1,732, USA | Shell Health Surveillance System (1994), follow-up 2003 | 71% | BMI (WHO) normal weight, overweight, obese: BMI >30 | Physical comorbidities | Costs of absences lasting 6 or more days per year: these excess workdays lost resulted in a loss of $2.18 million with $874,767 due to overweight employees ($471 per employee) and $1.31 million due to obese employees ($1,087 per employee). (Year of costing assumed: 2007)4 |
| Ostbye et al. (2007)[20] | Health care and university employees, N=11,728, 29.9% overweight, 14.2% obesity class I, 6.8% obesity class II, 4.9% obesity class III, USA | Duke University Health System and Duke University (1997-2004) | 62% | BMI (WHO) underweight, recommended weight, overweight, obesity grade I, II, III | - Behavioral factors | Indemnity claims costs (in 2005) for lost workdays from 1997-2004: $6.7 million; per 100 full-time equivalents $19,058. |
| Borg et al. (2005)[29] | Middle-aged subjects living in Malmö, N= 33,346, n(overweight)=10,775, n(obese)=2,450, Sweden | Malmö Prevention Project (1974-1984) and a mean follow-up of 17 years | 86% | BMI (WHO) overweight, obesity: BMI>30 | - | Average annual indirect cost (in 2003) due to death before retirement age, projected over 15 years were $4.73 million for overweight and $383 million for obesity. |



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| *Attributable risk studies (PAF)* | | | | | | |
| Dee et al. (2015)[61] | Nationally representative, N= -, Island of Ireland | Central Statistics Office (2007-2009), Department of Social Protection illness benefit data for (2009), Department of Social Development (Northern Ireland), Northern Ireland Statistics and Research Agency | 80% | BMI (WHO) overweight and obesity: BMI>30 | Overweight and physical comorbidities were included in the PAF analysis. | The estimated annual costs (in 2009) for the Republic of Ireland for absenteeism were $157 million (human capital approach) or $83 million (friction costs method). The costs of premature mortality were $684 million. The costs of absenteeism in Northern Ireland were $305 million (human capital approach) or $105 million (friction costs method). The cost of premature mortality was $189 million. |
| Lehnert et al. (2014)[4] | Nationally representative, N= -, overweight 37%, obese 23%, Germany | Prevalence data: German Health Interview, Examination Survey for Adults (DEGSI) (2008-2011), Population: population representative German Study (AgeCoDe) (2008) | 90% | BMI (WHO): Excess weight BMI>25 | Obesity and overweight attributable costs of physical comorbidities | The total indirect costs attributable to excess weight in 2008 in Germany were $9.5 billions. Indirect costs paid work: mortality (16.0%), early retirement (7.9%), sickness absences (10.5%). Indirect costs unpaid work: mortality (52.7%), early retirement (6.9%), sickness absence (5.2%) |
| Lal et al. (2012)[19] | Nationally representative, N= -, New Zealand | Burden of Disease Estimates Data Set (WHO), NZ Ministry of Health (2006) | 80% | BMI (WHO): overweight, obese: BMI>30 | Obesity and overweight attributable costs of physical comorbidities | Productivity losses in New Zealand (in 2006) according to the human capital approach: $180 million (premature death 64.4%, short-term absenteeism 35.6%). Costs according to the friction capital approach: $79 million (premature death 9.2%, recruitment and training costs 9.2%, short-term absenteeism 81.6%). |
| Kang et al. (2011)[17] | National representative, N=1,910,194, overweight men (women): 27.4% (22.0%), obese I men (women): 31.5% (24.6%), obese II men (women): 3.6% (3.4%), Korea | National Health Insurance Corporation, Korea National Health and Nutrition Examination Survey (2005) | 85% | BMI: normal weight: BMI: 18.5-22.9, overweight: BMI: 23-24.9, obesity I: BMI: 25-29.9, obesity II: BMI>30 | Obesity and overweight attributable costs of physical comorbidities | Total socioeconomic indirect costs (in 2005) were $873 million (loss of productivity due to premature deaths 62.8%, loss of productivity due to admission 62.8%, traffic costs 14%, nursing costs 9.9%, nursing fees 2.2%). Indirect costs were $260 million for overweight, $405 million for grade I obesity and $148 million for grade II obesity. |
| Konnopka et al. (2011)[57] | Nationally representative, N= -, Germany | Statistics from the German Federal Statistical Office, German Retirement Insurance Office (2002) | 86% | BMI (WHO): 4 risk classes: 0: BMI<25, 1: 25<BMI<30, 2: 30<BMI<35, 3: 35<BMI<40, 4: BMI>40 | Attributable costs of physical comorbidities. | Costs attributable to obesity and overweight (in 2002): $6.5 billion. (Costs unpaid work: mortality 48.8%, early retirement 7.9%, sickness absence 3.3%; costs paid work: mortality 18.5%, early retirement 11.8%, sickness absence 9.6%) |
| Moffat et al. (2011)[60] | N= -, Canada | Canadian Community Health Survey (2004-2005), Public Health Agency of Canada (Economic Burden of Illness in 2000) | 62% | BMI (WHO): excess weight: BMI>25 | Obesity and overweight attributable costs of physical comorbidities | Indirect costs (in 2005): $584 million (long-term disability 32.5%, short-term disability 9.8%, premature mortality 57.6%) in Alberta |
| Anis et al. (2010)[59] | N= -, overweight men: 42%-51%, obese men: 22%-27% overweight women: 30%-37%, obese women: 23%-29% (rates vary for different age groups), Canada | Canadian Heart Health Survey (1986-1992), Economic Burden of Illness in Canada (1998) | 62% | BMI (WHO): overweight, obesity | Obesity and overweight attributable costs of physical comorbidities | The cost attributable to excess weight in Canada (in 2006) is $4.4 billion ($1.5 billion for overweight and $2.7 billion for obesity). |
| Cadilhac et al. (2010)[62] | Population simulation for 2008, N about 17 million, Australia | Mainly: Australian Burden of Disease (BoD) study 2003 other input data: National Health Survey (2004-2005), Australian average weekly earnings (2008), Time Use Survey (2008), Disease | 90% | BMI (WHO): Excess weight: BMI>25, normal weight | Including costs of behavioral factors | Total potential attributable opportunity cost savings due to workforce participation and absenteeism (in 2008) for excess weight according to FCA: $638 million. |



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| | | Costs & Impact Study (200-2001) | | | | |
| Knoll & Hauner (2008)[49] | n(obese in 2003)=13,200,000, Germany | Federal Statistical Office, statements from insurance companies, German pension insurance, professional associations (1997-2004) | 71% | BMI (WHO) obesity: BMI > 30 | Physical and psychosocial comorbidities | Annual indirect costs (in 2003) with 4% discounting were $2.1 billion (disability 46%, incapacity for work 35%, mortality 19%). Costs with a 6% discounting rate were $1.8 billion (disability 42%, incapacity for work 41%, mortality 17%). In 2010 indirect costs were projected to be $2.4 billion, in 2015 $2.9 billion, in 2020 $3.6 billion. |
| Chenoweth & Leutzinger (2006)[48] | 7 U.S. states, N=77 Mio, state-specific prevalence rates for excess weight: 35%-60%, USA | Obtained from various health plans and state agencies in seven states and published studies | 65% | BMI (WHO) excess weight BMI>25 | Physical comorbidities | Productivity loss cost per year (in 2003) for excess weight (estimated lost hours used in one state-wide cost analyses) subtotal $25 billion (absenteeism 22.8%, short term disability 27.2%, presenteeism 50%). Productivity loss for California, North Carolina and Massachusetts were $41 billion. |
| Katzmarzyk & Janssen (2004)[58] | N= -, overweight: 33%, obese: 14.7%, Canada | Economic Burden of Illness in Canada (1998) and data taken from literature | 60% | BMI (WHO) Obesity: BMI>30 | Attributable costs of physical comorbidities. | Estimated indirect costs attributable to obesity in Canada (in 2001) (value of economic output lost due to illness, injury related work-disability or premature death): $2.7 billion. |
| Sander & Bergemann (2003)[50] | Representative population data from publications attributed to 12.24 million obese adults in Germany (of whom 2.9 million suffer from selected comorbidities), Germany | German National Survey (1998) and data taken from the literature and official German publications | 85% | BMI (WHO) Obesity: BMI>30 | 3 scenarios refer to the physical comorbidities (in the base case) | Annual Indirect costs of obesity (in 2001) due to mortality, work loss and disability: $282 million. |
| *Simulation studies (Markov model)* | | | | | | |
| Lightwood et al. (2009)[45] | Projected overweight adult prevalence (resulting from adolescent overweight) from n= 330,000 in 2020 to more than n= 9,700,000 in 2050, USA | NHANES (1971-2000) | 90% | BMI (WHO): Obesity: BMI>30 | Includes costs of physical comorbidities; Simulation designs on base case-, prevention- and treatment-settings | Projected excess costs attributable to current adolescent obesity to 2025 to 2050. Costs are expected to rise from $942 million in 2020 to $36 billion in 2050. |
| *Other studies* | | | | | | |
| Walden et al. (2013)[26] | Hospital staff, N > 800, lift team technicians for mobilizing the obese patient, USA | Hospital financial reports, non-validated staff satisfaction survey (2012) | 53% | Patient's weight>100kg, with a Braden Scale score<18 and/or the presence of pressure ulcers | - | Cost savings (in 2012) due to decreased injuries among staff from patient handling were $987,219. |
| Gussenhoven et al. (2013)[34] | Employees from seven Dutch companies, N = 460 (control group), only participants with excess weight were included, mean BMI=29, Netherlands | ALIFE@Work RCT (2004) | 85% | BMI (WHO): Excess weight: BMI>25 | - | Sick leave costs (in 2004) based on GLDP (= gross lost productivity days, total number of calendar days that workers were partially or fully sick listed) were $4,307, sick leave costs based on NLPD (= net lost productivity days; multiplying the number of sick leave days with the absenteeism percentage; for the assumption that partially sick listed employees were fully productive when at work) were $3,273. |
| Finkelstein et al. (2012)[46] | Full-time employees and eligible for LAGB, MEPS (N=134), mean BMI=44, NHWS (N=2,164), mean BMI=43, USA | MEPS (2005-2006), NHWS (2008) | 75% | BMI (WHO) eligible for bariatric surgery: BMI>40 or BMI 35-40 with a significant comorbidity | For obesity diagnostic: physiological comorbidities | Costs for the quarter before LAGB (in 2010) for bariatric surgery candidates were $67 for (absenteeism 83.3%, presenteeism 16.7%). |
| Peake (2012)[35] | Australian Defense Force personnel from army, navy and air force | Directorate of Workforce Information, ADF Central Medical | 86% | BMI (WHO): normal weight, | - Prevalence of injury | Mean productivity loss per person from each cohort (in 2009-10). For full days off work per calendar day (underestimated): $29 for |



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| | service branches, N=679, n(overweight)=154, n(obese restricted body fat)=148, n(obese no restriction)=180, Australia | Records (2009-2010) | | overweight, obese with restricted body fat (≤28% for females, ≤24% for males), obese with no restriction | or illness | overweight, $57 for obese restricted body fat, $78 for obese no restriction on body fat and $12 for normal weight. For productivity loss from full days off work per workday (overestimated): $42 for overweight, $79 for obese restricted body fat, $110 for obese no restriction on body fat and $17 for normal weight. Productivity loss from restricted work days (50% limited activity) is $474 for overweight, $1129 for obese restricted body fat, $984 for obese no restriction on body fat and $695 for normal weight. |
| Breitfelder et al. (2011)[22] | Parents of children, N(children)=3,508, n(overweight)=216, n(obese children)=69, Germany | GINI-plus (German Infant Nutritional Intervention study), LISA plus (Influence of lifestyle factors on the development of the immune system and allergies in East and West Germany) | 85% | Age- and sex-specific percentile cut-off points for children: Normal weight (P10–P90), Overweight (>P90 to P97), Obese (>P97) according to Kromeyer-Hausschild | - Utilization of healthcare services by physician visits, therapy and other therapies | Indirect costs for parental work absence (in 2007) were $102 for overweight, $142 for obese and $120 for normal weight children. (For severely underweight, the costs were $153) |
| Ewing (2011)[24] | Patients undergoing laparoscopic gastric bypass or laparoscopic banding surgery, N=150, in relation to data from the Bureau of Labor Statistics, USA | LAGB Patients. The Bureau of Labor Statistics, Bureau of Economic Analysis (2006), Texas Tech University Health Sciences Center (TTUHSC) (2003-2005) | 67% | Obesity (no cut-off points stated) | - | Total per year economic impacts on South Plains from obesity (in 2003): $210 million. |
| Kyrolainen et al. (2008)[47] | Finnish male military personnel, N=7,179, overweight: 46%, obese: 10%, Finland | Male military personnel data from personnel administration (2004) | 65% | BMI (WHO) normal weight, overweight, obese: BMI >30 | Behavioral factors | Cost of sick leave per year per person (in 2004) were $915 for excess weight and $595 for normal weight. |
| Frezza et al. (2006)[25] | Bariatric patients, N=150, in relation to data from the bureau of Labor Statistics (2005, lost work time rate and employment and earnings data), USA | Patients from New Mexico who underwent laparoscopic gastric bypass and laparoscopic banding (2003-2005). Bureau of Labor Statistics (2005) | 71% | Bariatric patient sample: not described Prevalence data of New Mexico: obesity: BMI > 30 | - | Total per year economic impacts of obesity for New Mexico (in 2003): $1.79 billion from output lost and $265 million from labor income lost. Cost per year to New Mexico household: $2,229 from output lost, $329 from labor income lost. |

[1]BMI: Body mass index, WHO: World Health Organization, NHANES: National Health and Nutrition Examination Survey, BRFSS: Behavioral Risk Factor Surveillance System, LAGB: Laparoscopic adjustable gastric banding, MEPS: Medical Expenditure Panel Survey, NHWS: National Health and Wellness Survey

Percentage of criteria fulfilled of quality assessment by Stuhldreher et al.[15]

[2] Most studies used standard BMI classification as recommended by the World Health Organization: BMI (kg/m$^2$) normal weight: 18.5-24.99, overweight: 25.00-29.99, obese class I: 30.00-34.99, obese class II: 35.00-39.99, obese class III: ≥40.00. Excess weight was defined as overweight and obesity combined: BMI ≥25.00

[3] Costs were converted to 2016 PPP Dollar for comparison. The year of costing is given in parenthesethors who did not state the year of costing in their study were asked via email. If unable to reach, the date of submission or publication was assumed as the year of c



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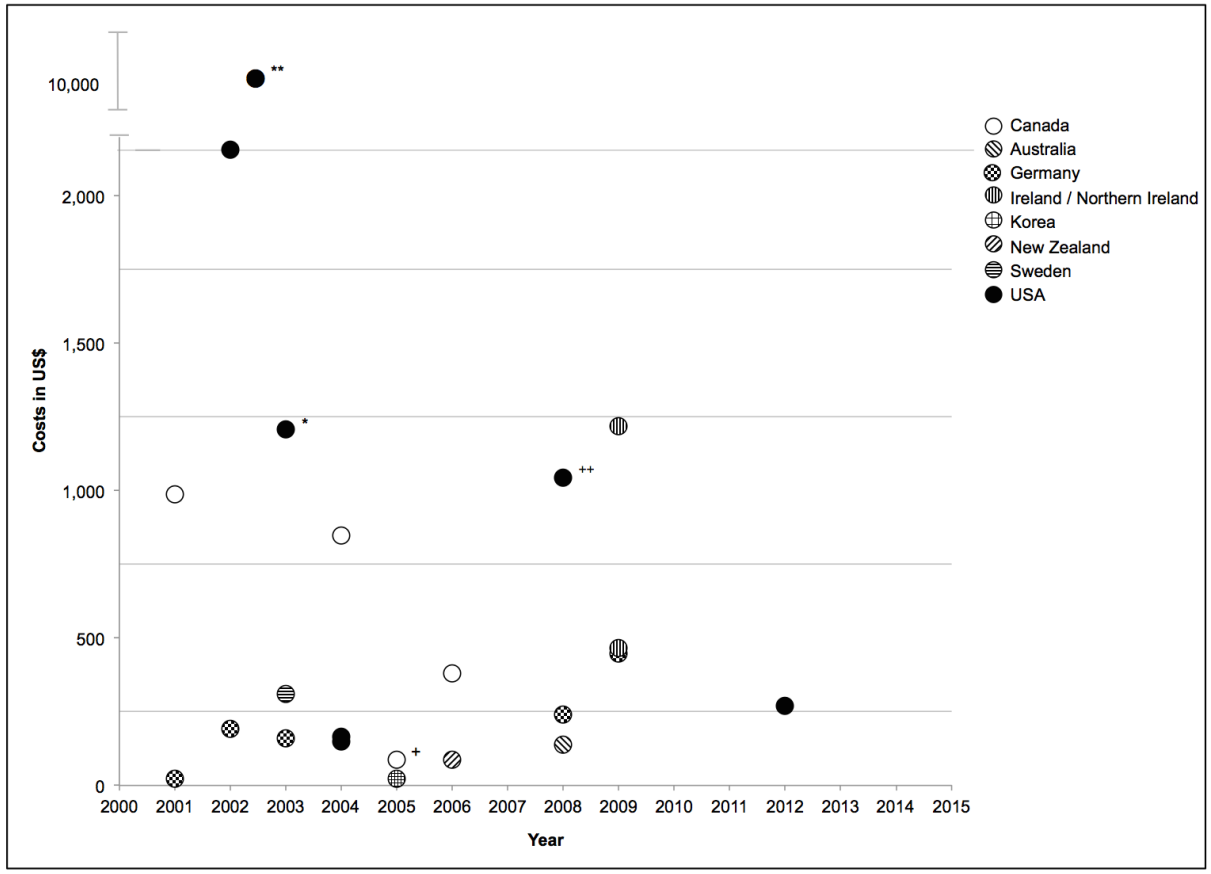
## Supporting Information 5: Excess costs per capita based on macroeconomic costs




* Costs of the three US states California, North Carolina, Massachusetts, + Costs of the province Alberta, ** Costs of the state of New Mexico, ++ Costs of South Plains of Texas

For better comparison, the per capita costs of the national costs studies are displayed. If not provided in the article, the per capita costs were calculated based on obese or overweight and obese adult population estimates in the year of costing.



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# PRISMA 2009 Checklist

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 2 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | 5-6 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 5-6 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | - |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 6-7 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 6 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | 6-7 |
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 6-7 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 7 |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 6-7 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 7 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | 7 |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$) for each meta-analysis. | 7 |

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# PRISMA 2009 Checklist



| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | 19 |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | n.a. |
| **RESULTS** | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | 8 |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | 8-9 |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). | - |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | 9, 13 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | n.a. |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | - |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). | 15 |
| **DISCUSSION** | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). | 15-16 |
| Limitations | 25 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). | 16-17 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | 17-18 |
| **FUNDING** | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. | 1 |

*From:* Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

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BMJ Open

# Productivity loss due to overweight and obesity: A systematic review of indirect costs

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| Secondary Subject Heading: | Nutrition and metabolism, Public health |
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| | |

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# Productivity loss due to overweight and obesity: A systematic review of indirect costs

Running title: Indirect cost of overweight and obesity

Andrea Goettler[1], Anna Grosse[1], Diana Sonntag[1, 2] PhD

Affiliations:

[1] Mannheim Institute of Public Health, Social and Preventive Medicine, University Medicine Mannheim, Heidelberg University, Mannheim, Germany

[2] Department of Health Sciences, University of York, UK

Corresponding author:

Diana Sonntag, PhD,

Mannheim Institute of Public Health, Social and Preventive Medicine, University Medicine Mannheim, Heidelberg University, Ludolf-Krehl-Straße 7-11, 68167 Mannheim, Germany

Phone: +49-621-383-9922

Fax: +49-621-383-9920

E-mail: mail@diana-sonntag.eu

Keywords:

obesity; overweight; absenteeism; presenteeism; indirect costs; productivity loss

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ABSTRACT

Objective: The increasingly high levels of overweight and obesity among the workforce are accompanied by a hidden cost burden due to losses in productivity. This study reviews the extent of indirect cost of overweight and obesity.

Methods: A systematic search was conducted in eight electronic databases (PubMed, Cochrane Library, Web of Science Core Collection, PsychInfo, Cinahl, EconLit, and ClinicalTrial.gov). Additional studies were added from reference lists of original studies and reviews. Studies were eligible if they were published between January 2000 and June 2017 and included monetary estimates of indirect costs of overweight and obesity. The authors reviewed studies independently and assessed their quality.

Results: Of the 3 626 search results, 50 studies met the inclusion criteria. A narrative synthesis of the reviewed studies revealed substantial costs due to lost productivity among workers with obesity. Especially absenteeism and presenteeism contribute to high indirect costs. However, the methodologies and results vary greatly, especially regarding the cost of overweight, which was even associated with lower indirect costs than normal weight in three studies.

Conclusion: The evidence predominantly confirms substantial short- and long-term indirect costs of overweight and obesity in the absence of effective customised prevention programmes and thus demonstrates the extent of the burden of obesity beyond the healthcare sector.

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Strengths of this study

- It presents results on all major indirect costs categories such as absenteeism, presenteeism, disability, premature mortality, and worker compensation from 50 studies and discusses the issue of causality.
- It assesses comprehensively the monetary value of the indirect costs of overweight and obesity which allows (inter-)national comparisons among all indirect cost categories. This in turn gives policymakers and intervention developers the basis they need to make informed decisions on (re-)allocating resources to address those cost categories with the highest burden.
- It applies an extensive quality assessment of approaches, methods and estimates of indirect costs of overweight and obesity which helps to better understand the utility and applicability of included cost-of-illness studies.

Limitations of this study

- Due to diverging BMI groups and indirect cost categories among the studies included, a graphical comparison of the average costs per person or per country of each study was conducted (instead of a meta-analysis).
- Publication bias (whereby positive studies are more likely to be published than negative ones) and selection bias (exclusion of studies written in languages other than English or German) limit the generalisability of the findings of this review.

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ABBREVIATIONS

US = United States

COI = Cost-of-illness

BMI = Body mass index

PAF = Population attributable fraction

FCA = Friction cost approach

HCA = Human capital approach

PPP = Purchasing power parity

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## INTRODUCTION

The obesity epidemic has become a global public health concern[1]. The rising rates of overweight and obesity are accompanied in adulthood by a higher risk of type 2 diabetes, hypertension, coronary heart disease, and stroke[2], which cause substantial healthcare costs. In 2008, the estimated annual medical cost of obesity in the United States was US$ 147 billion due to 42% higher medical spending per capita[3]. Not only the United States has significantly high obesity costs. Other countries also struggle with substantial overweight- and obesity-related medical costs; Germany, for example, had costs of $9.2 billion in 2008[4]. The rising prevalence of overweight and obesity is also related to indirect costs resulting from morbidity and mortality[5-7]. Indirect costs are defined as the losses from reduced work productivity due to short- and long-term inability to work. In particular, obesity is associated with an increased risk of temporary work loss such as sick leave (absenteeism) and reduced productivity while being present at work (presenteeism). It is also associated with permanent work loss, which includes disability pension and premature death[5, 6]. Indeed, recent reviews have found strong evidence that temporary and permanent work loss attributable to obesity result in a substantial burden for national health and insurance pension systems[8, 9].

While a number of systematic reviews have analysed lost productivity of overweight and obesity among workers, their range is relatively narrow. For example, several do not include the monetary value of the indirect costs[5-7, 10], while others focus only on the combined direct and indirect costs of obesity[10, 11]. Similarly, a few limit their range by concentrating on specific countries[9, 12] or specific cost categories such as absenteeism and disability[5-7, 10]. Indeed, only one review provides a more extensive overview of the economic consequences of absenteeism, presenteeism, disability, premature mortality, and worker compensation costs[13]. Yet even this review does not comprehensively assess the monetary value of indirect costs or provide a quality assessment of the included studies. However, it does identify several weaknesses among the included studies (e.g. paucity of both longitudinal



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studies and presenteeism assessments, as well as the need for monetary values of missed work).

Our review addresses the shortcomings of previous systematic reviews and includes studies which acknowledge the research gaps noted by Trogdon et al[13]. With its broad range, our review is the only international review that presents an extensive comparison of the monetary consequences of all indirect cost categories. We systematically review and critically assess both the current evidence for each type of indirect costs and the methodology and research design used. In addition, we address briefly the question of causality between obesity and costs.

## Methods

This review was conducted according to the Centre for Reviews and Dissemination guidance for undertaking reviews in healthcare[14].

### Search strategy

In cooperation with a Cochrane expert from the University Library of Heidelberg, we developed a search strategy to identify all published studies on the indirect costs of overweight and obesity. A keyword search was carried out using the following electronic databases and study registers from inception to June 2017: PubMed, Cochrane Library, Web of Science Core Collection, PsychInfo, Cinahl, EconLit, and ClinicalTrial.gov. The search terms and the search strategy are outlined in the Supplementary File (see Supporting Information 1 and Supporting Information 2).

### Inclusion and exclusion criteria



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Studies were included if they contained a monetary estimate of the indirect costs of overweight and obesity. Indirect costs were defined as costs of overweight and obesity on labour market outcomes (absenteeism, presenteeism, short- and long-term disability, premature death). We excluded studies, which were published in languages other than English or German, located in a developing country due to substantial differences in labour markets, or connected to other illnesses. We decided to exclude studies published before 2000 because of the rising prevalence of overweight and obesity in the last few decades, which led to significant increases of macroeconomic costs[1]. Instead, we placed our focus on recent results, which have not been covered in previous systematic reviews. Furthermore, only peer-reviewed studies with a full-text available were included.

**Study selection procedure and data extraction**

Two reviewers independently applied the inclusion and exclusion criteria. All studies underwent a title and abstract screening, and potentially relevant citations were additionally checked in a full-text screening. Disagreements were resolved through discussion and reasons for exclusion recorded. Finally, 50 studies were identified as eligible. The PRISMA diagram (Figure 1) illustrates the study selection process. Data extracted included study design, target population, time horizon, effect groups, cost category and measurement, and background characteristics such as authors and years of study and publication. Costs were first inflated to 2016 rates using country-specific gross domestic product inflators from the Organisation for Economic Co-Operation and Development (http://stats.oecd.org) and then converted to December 2016 US dollars. The third step was to multiply them with their respective power purchasing parity (PPP) value to achieve a comparable overview. If the year of costing was missing, the authors of the cost-of-illness (COI) study were contacted by e-mail.

**Quality assessment**



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In the absence of a checklist for COI studies, we conducted a quality assessment by adapting the checklist by Stuhldreher and co-authors, which evaluates the quality of COI studies[15]. We assessed the following items: scope, general economic characteristics, calculation of costs, study design and analyses, and presentation of results (see Supporting Information 3). Two authors performed the assessment independently. All discrepancies and uncertainties were resolved through consensus.

## RESULTS

We identified 3 626 articles from the database searches. Title and abstract screening reduced these further to 281 studies, which were retrieved in full text. Reviewing reference lists of relevant papers, studies, and systematic reviews added four potentially relevant studies (Figure 1). Following full-text review, we excluded 231 of these studies, leaving 50 studies to be included in the review.

[Insert Figure 1]

### General characteristics of the studies

There was a wide variety among the included studies in terms of costs, target population, and methodology. Supporting Information 4 shows the sample, methodology, quality, and results of the studies. Most studies were conducted in the United States (27), followed by Germany (8), Canada (5), Australia (2), Sweden (2), Finland (1), Korea (1), New Zealand (1), and the Netherlands (1). Two studies were multi-country (one covering Ireland and Nothern Ireland; the other covering France, Germany, Italy, Spain, and UK). For cost estimations a microeconomic or a macroeconomic approach was applied. While the macroeconomic approach captured the national economic loss of resources measured as national cost, the microeconomic approach measured indirect costs that occur per capita or per employee. More



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specifically, most studies assessed the costs of absenteeism, presenteeism, short- and long-term disability, and premature death. Only five[16-20] included insurance claims, such as indemnity claims, workers' compensation, and other microeconomic costs related to recruitment, training, traffic, nursing, or injuries. The majority of the studies included the costs of more than one of these cost categories.

Both the human capital approach (HCA) and the friction cost method (FCM) were used to calculate productivity losses. The HCA estimates costs based on the lost productivity of one individual, for example, the entire working time lost due to early retirement. The FCM only estimates the value of productivity lost until the employee is replaced. For example, if a worker goes into early retirement, the FCM would only count the period of working time lost until the worker is replaced[19, 21].

The effect measure was exclusively the body mass index (BMI). BMI cut-off points were based on standard World Health Organisation recommendations (overweight: 25.0 ≤ BMI ≤29.9, class I obesity: 30.0 ≤ BMI ≤ 34.9, class II obesity: 35.0 ≤ BMI ≤39.9, and class III obesity: BMI ≥ 40.0), with the exception of seven studies[17, 18, 22-26]. Few studies estimated indirect costs due to obesity-related comorbidities[20, 22, 24-36]. Some controlled for physical and psychological comorbidities in regression analyses[35, 37-41] or created subgroups for the costs of additional, related diseases[18, 40, 42, 43].

Supporting Information 4 displays the search results grouped by methodology into cross-sectional, longitudinal, population attributable risk, and modelling studies. The majority were cross-sectional studies, which focused on annual per capita costs by assessing the overweight and obesity prevalence at a specific point in time. Longitudinal studies evaluated excess weight over a timespan of four[44] to 38 years[21]. The attributable risk studies applied the population attributable fraction (PAF) method to estimate national costs. Only one study modelled the future costs of overweight and obesity based on disease prevalence among teenagers [45]. Eight studies were categorised separately as "other studies", which were not as



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representative. This category includes one intervention analysis[34] and studies with non-representative samples, such as bariatric surgery eligible patients[24, 25, 46], military participants[35, 47], parents of children with overweight or obesity[22], and hospital staff working with patients with obesity[26].

**Quality assessment**

The quality of the included studies was quite diverse (see Supporting Information 3). Overall, the majority of studies met 75% of quality criteria. Three studies met all criteria[16, 21, 33]. Walden et al. received the lowest quality score. This study focused primarily on the prevention of injuries rather than on the costs of excess weight and thus did not include information on discounting, standard deviations, and cost perspective and valuation[26].

Criteria regarding introduction, discussion, and conclusion were mostly fulfilled. Quality was lacking in the categories "calculation of costs", "presentation of results", and "study design and analysis". Fourteen studies did not state from what perspective they calculated the costs and only included one cost category[17, 18, 20, 26, 28, 34-36, 42, 44, 47-50]. Study design and analysis were not fulfilled as over half of the studies did not report a sensitivity analysis and lacked information on the proportion of missing data or the imputation method. Furthermore, sample sizes and demographics were not always presented and only 29 studies provided standard deviations or confidence intervals of their results.

**Microeconomic findings**

The cross-sectional and longitudinal studies mostly focused on the per capita or per employee indirect costs of overweight and obesity. Figure 2 displays excess cost (defined as the additional costs of overweight and obesity compared to normal weight) by weight category due to absenteeism, presenteeism, and disability. All micro- and macroeconomic results in this review are presented in US$PPP and estimate the annual indirect costs unless stated



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otherwise. One study[21] presented lifetime costs of overweight and another calculated the costs for a 10-year period[39]. One cost analysis study did not focus on productivity loss but analysed the injury costs among hospital staff attributable to heavy patients[26]. As shown in Figure 2, the costs for absenteeism range from $-200[31] to $1 724[30] for overweight and from $108[43] to $1 857[30]for obesity. While this shows that obesity is constantly associated with productivity costs, it also displays the divergence of the results. We will present the results for each cost category in detail in the following section.

[Insert Figure 2]

Absenteeism

Defined as time away from work due to overweight and obesity, absenteeism was probably due to ease of measurement, the most common measure of indirect costs. The majority of studies (39 out of the 50 included ones) assessed the annual costs of short-term sick leave from work by comparing sick leave days of employees with normal weight with sick leave days of employees with overweight and obesity. The excess costs of overweight were estimated to be between $54[51] and $161[31] and the obesity-related costs between $89[42, 52] and $1 586[53]. The suggestions of Durden et al. were significantly higher for both overweight ($1 738) and obesity ($1 857)[30]. By contrast, other studies did not use an excess-cost approach but calculated the total yearly expenses due to absenteeism for normal, overweight, and obesity samples. The cost for overweight ranged from $29 to $5 132[23, 32, 33, 41, 43, 54] and $57 to $6 759 for obesity per person[18, 23, 32, 35, 41, 44, 46, 54].

In one study the costs associated with healthy weight ($294) were higher than overweight ($94) but lower than the costs for obesity ($402)[43]. Three studies assessed the costs for men and women separately. For women with obesity, the cost was between $170 and $1 391, which was higher than the cost for men with obesity ($89-$1 130)[31, 42, 52]. Gussenhoven



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and Kyrolainen estimated the costs of excess weight (BMI>25) between $915[47] and $4 307[34]. Another study assessed the relationship between children with overweight or obesity and parental work absence and found that while the cost ($142) for children with obesity was higher than the cost of healthy weight children ($120), the cost of children with overweight was lower ($102)[22].

Wolfenstetter assessed weight changes over 10 years and the related costs per group and found that the cost of a person with overweight or obesity is higher than the economic loss of a healthy weight or previously healthy weight person[36]. Neovius et al. also applied a longitudinal approach with data from 1969 and a 38-year follow-up. They estimated lifetime productivity losses of $18 064 using the HCA (FCA: $12 995) for overweight and $19 390 (FCA: $14 317) for obesity[21]. Another long-term study evaluated the yearly cost of a 20 000 workforce over 30 years at $6.6 million[28].

Presenteeism

Nine studies included the effect of reduced productivity at work (presenteeism) due to overweight or obesity, which was assessed by using an employee survey[31-33, 38, 41, 44, 46, 48, 51]. While costs due to presenteeism among individuals with overweight ranged between $-611[31] and $1 669[33], costs among individuals with obesity were between $11[46] and $4 175[31]. Surprisingly, in Peake's study, the cost of presenteeism among employees with overweight ($474) was lower than for individuals with normal weight ($695)[35]. Similarly, Finkelstein et al. estimated lower costs among men with overweight compared to men with normal weight[31]. The excess cost of obesity ranged from $429 to $4 175 for men and from $927 to $3 341 for women[31]. Another study by Finkelstein measured the quarterly indirect costs of bariatric surgery patients to be $11[46]. The cost of moderate or extreme obesity was estimated to be $699[51], $1 684[33], $1 990[32], and $2 414[45]. Peake and co-authors differentiated between the cost of having a BMI higher than



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30 with restricted body fat (≤28% for females, ≤24% for males) ($1 129) and having a BMI higher than 30 without body fat restriction ($984)[35].

One study calculated the combined costs of absenteeism and presenteeism. The combined costs were $5 515 for overweight and from $6 402 to $9 104 for obesity classes I-III[40].

Insurance claims

Insurance claims were measured as indemnity claims[20] or workers' compensation expenditures due to work absence[16, 18]. The only study which exclusively assessed insurance claims estimated indemnity claim costs at $189 per full-time equivalent[20]. For workers' compensation, the additional costs of overweight were estimated to be $180 and the additional costs for obesity classes I-III ranged from $525 to $707[16]. Kleinman et al. assumed the costs of overweight at $63 and those of obesity at $105[18].

Short- and long-term disability

Four studies considered costs of lost productivity due to short- and long-term disability[16, 21, 46, 51]. While excess costs due to disability were estimated to range from $30[16] to $41[51] among individuals with overweight, obesity was associated with costs between $21 and $439[51]. Kleinman et al. estimated $158 for overweight and $242 for obesity[18]. The lifetime cost of disability and disability pensions varied substantially depending on methodology; while estimations of cost based on the HCA varied between $31 037 (overweight) and $32 668 (obesity), estimations of cost based on the FCA were $2 649 (overweight) and $3 115 (obesity)[21].

Premature mortality

Work loss due to early mortality was assessed by two studies[21, 51]. Excess productivity costs related to these indirect costs were $29 for overweight and from $212 to $1 170 for



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grade I-III obesity[51]. Neovius et al. calculated the lifetime productivity losses and found $87 184 (HCA) or $20 066 (FCA) for overweight and $114 626 (HCA) or $23 070 (FCA) for obesity[21].

**Macroeconomic findings**

Among the studies focusing on macroeconomic costs, all but two focused on national costs for one year and found costs ranging from $79 million in New Zealand[19] to $41 billion for three US states[48]. Figure 3 displays the national costs per country and Supporting Information 5 shows per capita estimates of the macroeconomic findings. Knoll and Hauner estimated that the cost of obesity would increase from $1.8 billion in 2003 to $3.6 billion in 2020[49]. Lightwood and co-authors estimated future costs in the United States on current adolescent obesity and proposed a rise in costs from $954 million in 2020 to $36 billion in 2050[45].

[Insert Figure 3]

The majority of the PAF studies included costs of absenteeism, disability, and premature death (for detailed information see Supporting Information 4). The PAF approach indicates the aetiologic fraction of morbidity and mortality of disease prevalence caused by a risk factor (see equation 1):

$$PAF = \frac{\sum_{i=1}^{n} PiRRi - \sum_{i=1}^{n} P'iRRi}{\sum_{i=1}^{n} PiRRi}, \quad (1)$$

$P_i$ = proportion of population at exposure level $i$, current exposure,

$P'_i$ = proportion of population at exposure level $i$, counterfactual or ideal level of exposure,

$RR$ = the relative risk at exposure level $i$,

$n$ = the number of exposure levels.



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More specifically, there is strong evidence for higher risk of comorbidities such as type 2 diabetes, hypertension, coronary heart disease, and stroke in individuals with overweight and obesity[55, 56]. Since overweight and obesity cause only a fraction of comorbidity-related costs, multiplying the PAF by the costs of each comorbidity and then summing up across all diseases estimates total obesity-attributable costs.

Five studies assessed the costs of excess weight in Germany[4, 49, 50, 57]. Lehnert et al. estimated the costs at $9.5 billion[4], Konnopka et al. at $6.5 billion[58], Knoll and Hauner at $1.8 billion[49], and Sander and Bergeman at $282 million[50]. The costs for Canada were suggested to be $2.7 billion by Katzmaryk and Janssen[58], $4.4 billion by Anis et al.[59] and $534 million (for Alberta only) by Moffat et al.[60]. The economic loss for the Republic of Ireland was between $767 million (FCA) and $840 million (HCA). For Northern Ireland the cost was proposed to be between $294 million (FCA) and $491 million (HCA)[61]. In addition to costs of absenteeism and premature death, Lal et al. assessed training and recruitment costs for New Zealand and suggested a national loss between $79 million (FCA) and $180 million (HCA)[19]. In Korea, the productivity loss of excess weight was proposed to be at $872 million due to premature death, hospital admission, nursing costs and fees, and transportation costs[17]. The economic loss associated with excess weight in Australia was estimated to be at $637 million[62]. For three US states (California, North Carolina, Massachusetts), Chenoweth and Leutzinger assumed a productivity loss of $41 billion[48].

While the majority applied the PAF approach, 12 studies assessed the national costs based on lost workdays due to work absence, loss of productivity, and premature death[24, 25, 27, 29, 37, 38, 42, 52, 63-66]. Eight studies assessed the economic loss in the United States. The costs for obesity were estimated to be $11.3 billion by Asay et al. [66], $171 million for grade III obesity by Klarenbach et al.[63], and $3.8 billion due to non-diabetic and morbidly obese by Cawley et al.[42]. The costs of obesity were assessed at $5.5 billion[52] by Cawley and



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co-authors and $9 billion by Andreyeva et al.[26]. Ricci and Chee were the only ones to consider the excess costs of absenteeism and presenteeism in the United States, which they estimated to be $15.7 billion for obesity. The costs of overweight and normal weight did not differ significantly[40]. Two studies focused on the economic loss due to obesity in specific US regions ($409 million in a region of Texas[30] and $2 billion in the state of New Mexico[32]). One study estimated the costs for the province of Quebec in Canada at $531 million[65]. For Germany, the cost of overweight and obesity was $2.5 billion according to a study by Lehnert et al.[39], and $5 billion according to a later study by Effertz et al.[64]. Economic loss due to premature death was estimated for Sweden at $4.8 million for overweight and $383 million for obesity[28].

## DISCUSSION

This review assessed 50 COI studies on the indirect costs of overweight and obesity. The studies applied various methodologies and were mostly of good quality. Although the results varied, most studies found that excess weight entailed substantial indirect costs. While the cost category primarily considered was sick leave, there was also frequent assessment of presenteeism, disability, and premature death. Compared to employees with normal weight, individuals with obesity missed more time from work and worked less productively, resulting in higher indirect costs. Even if the literature suggests substantial indirect costs of overweight and obesity, the results should be interpreted with caution.

Our findings identify and underscore the large variety in defining and measuring the indirect costs of overweight and obesity. Indeed, this large variety made it difficult to provide an estimate of these indirect costs. Moreover, these costs differ substantially due to dissimilar methodological approaches (e.g. HCA versus FCA) and varying analytic methods (e.g.



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simulation-based versus regression-based models) (see Supporting Information 4). This is especially true of excess indirect costs of overweight, which range between -517 US$PPP[31] and 3,271 US$PPP[30]. These methodological differences, in turn, hamper the comparability of cost estimations of overweight and obesity.

The heterogeneity of the results raises the question whether the cost estimates correctly reflect the actual indirect costs of overweight and obesity. Most of the included studies used a top-down approach, which is usually easier to carry out as it is based on secondary data and thus requires only few country-specific estimates. However, in contrast to the bottom-up approach, it often relies on high-level aggregation and approximation of service costs, and may also suffer from double-counting of resources. Moreover, the top-down approach does not take account of multiple obesity-attributable diseases (e.g. type 2 diabetes and coronary heart disease) and their interactions, which may lead to biased (usually upwards) results[67].

Furthermore, the comprehensiveness of costs included in an analysis affects the reliability of the final result. If indirect costs consist of absenteeism costs alone, they will differ from indirect costs due to absenteeism and presenteeism combined. Additional workplace costs, such as transport costs and special training for hospital staff, together with non-monetary costs (e.g. quality-of-life losses) were included in a minority of the studies. Differences in indirect costs of overweight and obesity in the workplace can partly be explained by individual incomes. Individual wages (only captured by Kleinman et al.[18]) consider occupation-specific incomes and the fact that women with overweight and men with obesity earn lower wages than normal-weight workers[68, 69]. Most of the assessed COI studies calculated indirect costs based on estimations of the income of employees. These heterogeneous estimations of cost may be partly explained by occupation-specific incomes and different wage estimates (range: $6 per hour[63] to $500 daily wage[44]).

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Besides costs measured by income in workplace-related productivity losses, costs from unpaid work can occur. In our review one study examined costs from unpaid work and found that reduced household production activities of caregivers cause sizable indirect costs comparable with those of paid work[58]. Moreover, this cost category is also important as the prevalence of childhood overweight and obesity has increased dramatically during the past few years, confronting (grand)parents and caregivers with time losses from unpaid work. A longer measurement period may influence the accuracy of the assessed costs. Two of the studies reviewed considered the impact of childhood overweight and obesity[22, 45]. Lightwood et al. recorded a long timeframe including indirect costs from adolescence and calculated high indirect costs of excess weight for future years[45].

Finally, the lack of evidence for the causal link between obesity and productivity loss has been noted in previous reviews[5, 6, 13]. Recent studies have tried to address this shortcoming by applying longitudinal study designs and controlling for confounding factors, including socio-demographic and work- and health-related covariates[21, 37, 44]. However, all these studies assume that obesity is a direct cause of productivity loss and may thus overestimate the effect on indirect cost. None of them comprehensively address the question, together with associated statistical challenges, whether obesity could also serve as a biological mediator on the causal pathway or an effect modifier. Indeed, obesity may act both as direct explanatory variable and mediator when studying the relationship between cardiorespiratory fitness and productivity loss due to increased metabolic syndrome[70]. Additionally, obesity could also serve as an effect modifier as different levels of obesity modify the association between cardiorespiratory fitness and productivity loss. Moreover, the loss of productivity with increasing BMI declines with age as a higher BMI tends to be protective (e.g. reduced bone density loss and osteoporosis)[71, 72].



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Clearly, a causal framework for a meaningful assignment of indirect costs of obesity requires establishing whether obesity acts as a cause, a mediator or an effect modifier. More specifically, prospective analyses are urgently needed to determine the time of occurrence, i.e. whether diseases occur before (after) an individual has become overweight or obese. Together with such prospective analyses, valid measurements of productivity losses have to be developed and new studies initiated which measure productivity among employees before and after an effective obesity intervention. Only then can there be a successful application of more sophisticated econometric models.

Overall, most studies met most of the quality criteria but could be improved in three major areas. Firstly, the scope could be increased by including more than one cost category. Secondly, estimations of cost would be more accurate if they included obesity-related diseases and were based on individual income. Thirdly, the reliability of long-term economic consequences would be improved by taking childhood obesity into account. To translate lifetime consequences of childhood obesity into economic calculations, it is important to develop dynamic models of obesity-related productivity losses projected over a timeframe longer than the one-year period usually used in cost-of-obesity estimations[73, 74].

One limitation of this review is the potential publication bias, whereby positive studies are more likely to be published than negative studies. For instance, 47 out of the 50 included studies reported higher costs of overweight and obesity. While all studies reported higher costs of obesity, three studies found lower costs of overweight compared to normal weight. Furthermore, due to financial and time restraints, we could only include studies published in English and German, which may result in a selection bias. However, our findings include results from 11 countries and regions which are neither English- and German-speaking.

The included studies exhibited methodological inconsistencies and varying levels of quality. Nevertheless, they consistently confirm that overweight and obesity have substantial short-



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and long-term indirect costs both on the micro- and macroeconomic level. Consequently, an increase in public health initiatives, together with effective company weight-loss programmes, could considerably improve the productivity of workers currently overweight or obese.

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Contribution Statement

Diana Sonntag (DS) conceived the study and wrote the first draft of an earlier version; A. Grosse and A. Goettler performed the literature search and data extraction; A. Grosse, A. Goettler and DS analysed the data. All authors were involved in writing the paper and had final approval of the submitted and published version.

Data Sharing Statement

All unpublished data is only available to the authors.

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FIGURE LEGENDS

Figure 1: PRISMA flow diagram

Figure 2: Microeconomic excess cost of overweight and obesity

[+] Adapted productivity losses per person[51], no information on costs of normal weight

*Adapted indemnity claims cost per 100 full-time equivalents 1997-2004[20], no information on costs of normal weight

Excess per capita costs are displayed for each cost category for overweight, obesity, and excess weight. Mean costs were estimated for studies which only had sex or obesity-grade specific costs available. If not available, excess costs were calculated by subtracting the cost of normal weight from overweight or obesity costs. The figure shows that the costs of obesity are significantly higher than those of overweight alone and those of overweight and obesity combined. Interestingly, the cost of overweight is not necessarily higher than the cost of healthy weight. Absenteeism and presenteeism were considerably higher and more commonly assessed than disability and premature death.

Figure 3: Macroeconomic costs of overweight and obesity

Ricci & Chee[38], Lightwood et al.[45], and Chenoweth & Leutzinger[48] are outliers (coloured in grey).

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* Costs of the three US states California, North Carolina, Massachusetts, + Costs of the province Alberta, ** Costs of the state New Mexico, ++ Costs of South Plains of Texas

Almost analogous to country size and high prevalence rates, the United States has the highest national costs. Its lower values are related to particular states. The lowest costs were found in 2006 in New Zealand. National costs seem to increase in future years.

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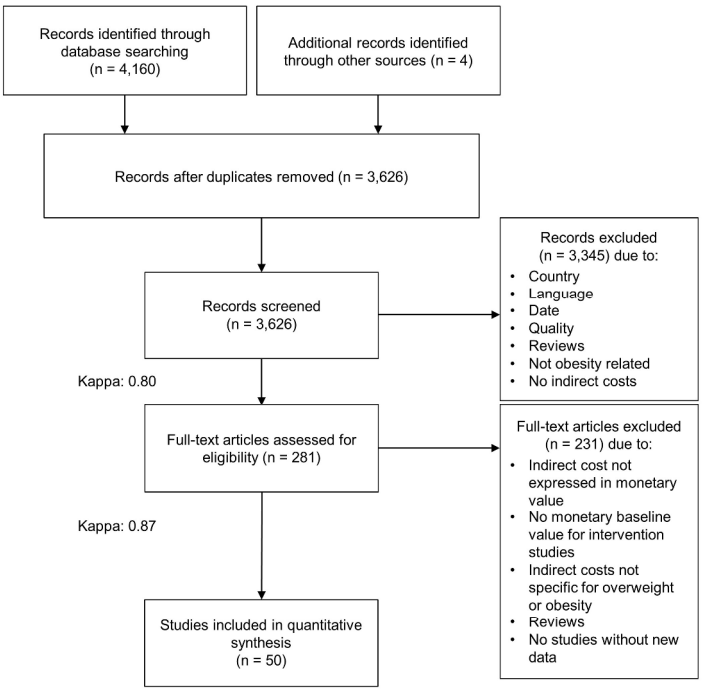


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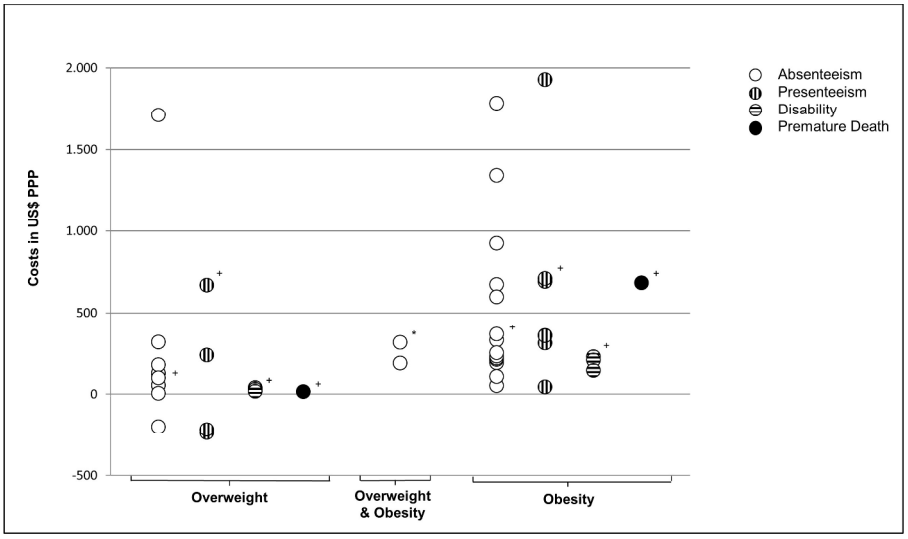


Microeconomic excess cost of overweight and obesity

+ Adapted productivity losses per person[51], no information on costs of normal weight
*Adapted indemnity claims cost per 100 full-time equivalents 1997-2004[20], no information on costs of normal weight
Excess per capita costs are displayed for each cost category for overweight, obesity, and excess weight. Mean costs were estimated for studies which only had sex or obesity-grade specific costs available. If not available, excess costs were calculated by subtracting the cost of normal weight from overweight or obesity costs. The figure shows that the costs of obesity are significantly higher than those of overweight alone and those of overweight and obesity combined. Interestingly, the cost of overweight is not necessarily higher than the cost of healthy weight. Absenteeism and presenteeism were considerably higher and more commonly assessed than disability and premature death.

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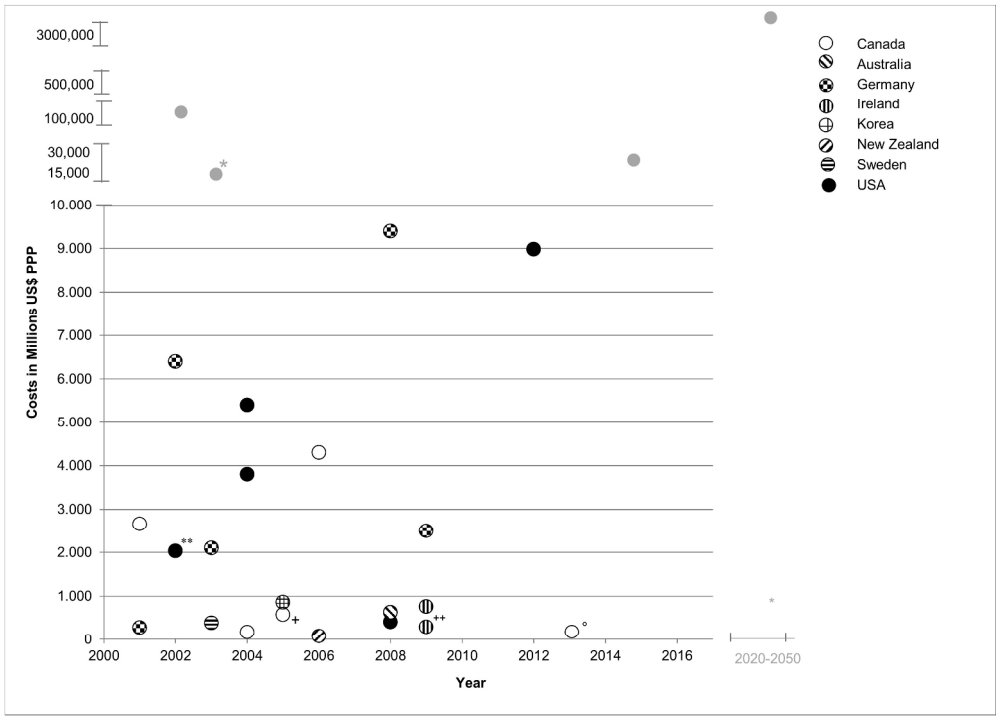


Macroeconomic costs of overweight and obesity

Ricci & Chee[38], Lightwood et al.[45], and Chenoweth & Leutzinger[48] are outliers (coloured in grey). * Costs of the three US states California, North Carolina, Massachusetts, + Costs of the province Alberta, ** Costs of the state New Mexico, ++ Costs of South Plains of Texas
Almost analogous to country size and high prevalence rates, the United States has the highest national costs. Its lower values are related to particular states. The lowest costs were found in 2006 in New Zealand. National costs seem to increase in future years.

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# Productivity loss due to overweight and obesity: A systematic review of indirect costs

Supplementary File

Andrea Goettler[1], Anna Grosse[1], Diana Sonntag[1, 2] PhD

[1] Mannheim Institute of Public Health, Social and Preventive Medicine, University Medicine Mannheim, Heidelberg University, Mannheim, Germany; E-mail: mail@diana-sonntag.eu

[2] Department of Health Sciences, University of York, UK

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**Supporting Information 1: Search strategy**

The following electronic databases were searched in June 2017:
PubMed
Cochrane Library
Web of Science Core Collection
PsychInfo
Cinahl
EconLit
ClinicalTrial.gov (study register)

**PubMed, 2167 results**
1. ("Obesity"[Mesh] OR Obes*[tw] OR "Obesity, Morbid"[Mesh] OR "Overweight"[Mesh] OR Overweight*[tw] OR “Excess Weight”[tw] OR "Overnutrition"[Mesh] OR Overnutr*[tw] OR "Adiposity"[Mesh] OR Adipos*[tw] OR "Body Mass Index"[Mesh] OR "Body Mass Index" [tw] OR BMI[tw] OR "Skinfold Thickness"[Mesh] OR Skinfold Thick*[tw] OR “Body Fat” [tw] OR "Waist-Hip Ratio"[Mesh] OR Waist Hip Ratio* [tw] OR "Waist Circumference"[Mesh] OR Waist Circumference*[tw])

2. ("Sick Leave"[Mesh] OR Sick Leave*[tw] OR Sickness Absen*[tw] OR Sick Absen*[tw] OR Sick Day*[tw] OR Work Absen*[tw] OR Work Leave* [tw] OR Illness Day*[tw] OR Illness absen*[tw] OR "Absenteeism"[Mesh] OR Absenteeism[tw] OR Absence Day*[tw] OR Absent Day*[tw] OR Presenteeism[tw] OR Work Productivit*[tw] OR Productivity Loss*[tw] OR Work Abilit*[tw] OR Work Disabilit*[tw] OR Disability Pension*[tw] OR Early Retirement*[tw] OR "Mortality, Premature"[Mesh] OR Premature Mortal*[tw] OR Premature Death*[tw] OR "Employment"[Mesh] OR Employment*[tw] OR Employee*[tw] OR Workloss*[tw] OR Workplace*[tw] OR Workday*[tw] OR Worker*[tw] OR Labour*[tw] OR Labor*[tw] OR Occupation*[tw] OR Job*[tw])

3. (Cost[tw] OR Costs[tw] OR Economic*[tw] OR Indirect Expenditure*[tw] OR Indirect Expense*[tw] OR "Cost of Illness"[Mesh] OR "Costs and Cost Analysis"[Mesh])

4. 1 AND 2 AND 3

**Cochrane Library, 60 results**
1. [mh Obesity] or Obes*:ti,ab,kw or [mh "Obesity, Morbid"] or [mh Overweight] or (Overweight* or "Excess Weight"):ti,ab,kw or [mh Overnutrition] or Overnutr*:ti,ab,kw or [mh Adiposity] or Adipos*:ti,ab,kw or [mh "Body Mass Index"] or ("Body Mass Index" or BMI):ti,ab,kw or [mh "Skinfold Thickness"] or ("Skinfold Thick*" or "Body Fat"):ti,ab,kw or [mh "Waist-Hip Ratio"] or "Waist Hip Ratio*":ti,ab,kw or [mh "Waist Circumference"] or "Waist Circumference*":ti,ab,kw

2. [mh Obesity] or Obes*:ti,ab,kw or [mh "Obesity, Morbid"] or [mh Overweight] or (Overweight* or "Excess Weight"):ti,ab,kw or [mh Overnutrition] or Overnutr*:ti,ab,kw or [mh Adiposity] or Adipos*:ti,ab,kw or [mh "Body Mass Index"] or ("Body Mass Index" or BMI):ti,ab,kw or [mh "Skinfold Thickness"] or ("Skinfold Thick*" or "Body Fat"):ti,ab,kw or [mh "Waist-Hip Ratio"] or "Waist Hip Ratio*":ti,ab,kw or [mh "Waist Circumference"] or "Waist Circumference*":ti,ab,kw

3.. (Cost or Costs or Economic* or "Indirect Expenditure*" or "Indirect Expense*"):ti,ab,kw or [mh "Cost of Illness"] or [mh "Costs and Cost Analysis"]



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4. 1 AND 2 AND 3

**Web of Science, 645 results**

1. TOPIC: (Obes* OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*")

2. TOPIC: ("Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR Employment* OR Employee* OR Workloss* OR Workplace* OR Workday* OR Worker* OR Labour* OR Labor* OR Occupation* OR job*)

3. TOPIC: (Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*")

4. 1 AND 2 AND 3

**PsychInfo, 311 results**

1. DE "Obesity" OR Obes* OR DE "Overweight" OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR DE "Body Mass Index" OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*"

2. .DE "Employee Leave Benefits" OR "Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR DE "Employee Absenteeism" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR DE "Employment Status" OR Employment* OR Employee* OR Worker* OR Workloss* OR Workplace* OR Workday* OR Labour* OR Labor* OR Occupation* OR job*

3. DE "Health Care Costs" OR DE "Costs and Cost Analysis" OR Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*"

4. 1 AND 2 AND 3

**Cinahl, 230 results**

1. Obes* OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*"

2. "Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR Employment* OR Employee* OR Workloss* OR Workplace* OR Workday* OR Worker* OR Labour* OR Labor* OR Occupation* OR job*

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3. Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*"

4. 4. 1 AND 2 AND 3

**EconLit, 108 results**
1. (Obes* OR Overweight* OR “Excess Weight” OR Overnutr* OR Adipos* OR "Body Mass Index" OR BMI OR "Skinfold Thick*" OR “Body Fat” OR "Waist Hip Ratio*" OR "Waist Circumference*")

2.. ("Sick Leave*" OR "Sickness Absen*" OR "Sick Absen*" OR "Sick Day*" OR "Work Absen*" OR "Work Leave*" OR "Illness Day*" OR "Illness absen*" OR Absenteeism OR "Absence Day*" OR "Absent Day*" OR Presenteeism OR "Work Productivit*" OR "Productivity Loss*" OR "Work Abilit*" OR "Work Disabilit*" OR "Disability Pension*" OR "Early Retirement*" OR "Premature Mortal*" OR "Premature Death*" OR Employment* OR Employee* OR Workloss* OR Workplace* OR Workday* OR Worker* OR Labour* OR Labor* OR Occupation* OR job*)

3. (Cost OR Costs OR Economic* OR "Indirect Expenditure*" OR "Indirect Expense*")

4. 1 AND 2 AND 3

**ClinicalTrial.gov, 105 results**
1. (Obesity OR Overweight OR “Excess Weight” OR Overnutrition OR Adiposity OR "Body Mass Index" OR BMI OR "Skinfold Thickness" OR “Body Fat” OR "Waist Hip Ratio" OR "Waist Circumference")

2. ("Sick Leave" OR "Sickness Absence" OR "Sick Absence" OR "Sick Day" OR "Work Absence" OR "Work Leave" OR "Illness Day" OR "Illness absence" OR Absenteeism OR "Absence Day" OR "Absent Day" OR Presenteeism OR "Work Productivity" OR "Productivity Loss" OR "Work Ability" OR "Work Disability" OR "Disability Pension" OR "Early Retirement" OR "Premature Mortality" OR "Premature Death" OR Employment OR Employee OR Worker OR Workloss OR Workplace OR Workday OR Labour OR Labor OR Occupation OR job*) AND

3. (Cost OR Costs OR Economic OR "Indirect Expenditure" OR "Indirect Expense")

4. 1 AND 2 AND 3

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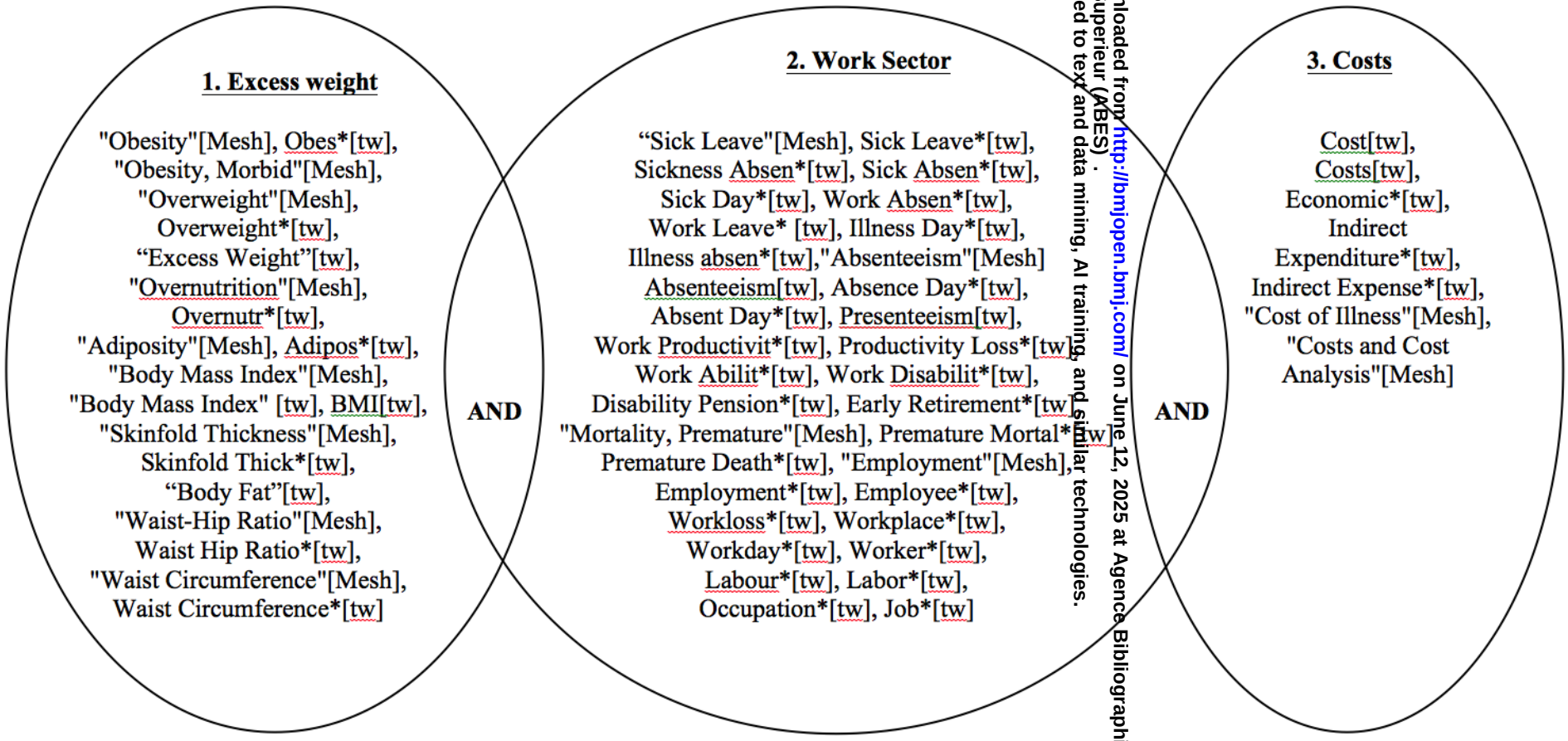
**Supporting Information 2: Search strategy (PubMed)**




All Keywords in the concepts are connected with the OR-operator (was removed for practicability reasons).

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## Supporting Information 3: Quality Scoring

| Author | Year | 1. Scope | | | 2. General economic characteristics | | 3. Calculation of costs | | | | | | 4. Study design and analysis | | | 5. Presentation of results | | | 6. Discussion | | | Quality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Study objective* | *Inclusion and exclusion criteria* | *Disease and diagnostic criteria* | *Cost-description* | *Nondiseased comparison group or disease-specific costs* | *Currency* | *Reference year* | *Perspective* | *Costs incorporated from more than one category* | *Data source* | *Valuation of costs* | *Discounting* | *Missing data, imputation method* | *Statistics appropriate* | *Sensitivity analysis* | *Sample size (subgroup)* | *Demographics* | *Arithmetic mean costs Standard deviations (errors)* | *Results discussed with respect to other studies* | *Limitations discussed* | *Conclusions appropriate regarding uncertainty in results* | % |
| Andreyeva et al.[26] | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a. | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Anis et al.[59] | 2010 | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | 80% |
| Asay et al.[66] | 2016 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 95% |
| Bhojani et al.[28] | 2014 | ✓ | | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | 62% |
| Blouin et al.[65] | 2017 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | | | | | | ✓ | ✓ | 71% |
| Borg et al.[29] | 2005 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 86% |
| Breitfelder et al.[22] | 2011 | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 95% |
| Cadilhac et al.[62] | 2011 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Cawley et al.[52] | 2007 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | n.a. | | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | 75% |
| Cawley et al.[42] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a. | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Chenoweth & Leutzinger[48] | 2006 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | n.a. | | ✓ | | | ✓ | | | ✓ | ✓ | 60% |
| Chenoweth et al.[23] | 2015 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | 75% |
| Dall et al.[51] | 2009 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | 75% |
| Dee et al.[61] | 2015 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | 80% |
| DiBonaventura et al.[40] | 2015 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a. | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | | 80% |
| Durden et al.[30] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a. | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Effertz et al.[64] | 2016 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | n.a. | | ✓ | | | | ✓ | ✓ | ✓ | ✓ | 71% |
| Ewing et al.[24] | 2011 | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | 67% |
| Finkelstein et al.[31] | 2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Finkelstein et al.[46] | 2012 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 90% |
| Finkelstein et al. [53] | 2005 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | | | ✓ | ✓ | 75% |
| Frezza et al. [25] | 2006 | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | 71% |

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| Author | Year | 1. Scope | | | 2. General economic characteristics | | 3. Calculation of costs | | | | | | 4. Study design and analysis | | | | 5. Presentation of results | | | 6. Discussion | | | Quality |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Study objective* | *Inclusion and exclusion criteria* | *Disease and diagnostic criteria* | *Cost-description* | *Nondiseased comparison group or disease-specific costs* | *Currency* | *Reference year* | *Perspective* | *Costs incorporated from more than one category* | *Data source* | *Valuation of costs* | *Discounting* | *Missing data, imputation method* | *Statistics appropriate* | *Sufficient sample size (ABES)* | *Sample size (subgroup)* | *Demographics* | *Arithmetic mean costs Standard deviations (errors)* | *Results discussed with respect to other studies* | *Limitations discussed* | *Conclusions appropriate regarding uncertainty in results* | % |
| Gates et al. [32] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | 80% |
| Goetzel et al. [33] | 2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 100% |
| Gupta et al. [41] | 2015 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Gussenhoven et al. [34] | 2013 | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Henke et al. [16] | 2010 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 100% |
| Kang et al. [17] | 2011 | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Katzmarzyk & Janssen [58] | 2004 | ✓ | | ✓ | | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a. | | ✓ | | | | | ✓ | ✓ | ✓ | 60% |
| Kirkham et al. [44] | 2015 | ✓ | | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 67% |
| Klarenbach et al. [63] | 2006 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a. | ✓ | ✓ | | | ✓ | | ✓ | ✓ | ✓ | 75% |
| Kleinman et al. [18] | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 85% |
| Knoll & Hauner[49] | 2008 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | ✓ | | | ✓ | ✓ | 71% |
| Konnopka et al. [57] | 2011 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | ✓ | 86% |
| Kyrolainen et al. [47] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | ✓ | n.a. | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | 65% |
| Lal et al. [19] | 2012 | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | 80% |
| Lehnert et al. [37] | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | 90% |
| Lehnert et al. [4] | 2014 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | 85% |
| Lightwood[45] | 2009 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | | ✓ | 95% |
| Moffatt et al. [60] | 2011 | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | n.a. | | ✓ | | | | | ✓ | ✓ | ✓ | 62% |
| Neovius et al. [21] | 2012 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 100% |
| Ostbye et al. [20] | 2007 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | ✓ | | | | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | 62% |
| Peake et al. [35] | 2012 | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 86% |
| Ricci & Chee[38] | 2005 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | n.a. | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 95% |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Study objective* | *Inclusion and exclusion criteria* | *Disease and diagnostic criteria* | *Cost-description* | *Nondiseased comparison group or disease-specific costs* | *Currency* | *Reference year* | *Perspective* | *Costs incorporated from more than one category* | *Data source* | *Valuation of costs* | *Discounting* | *Missing data, imputation method* | *Statistics appropriate* | *Sample size (subgroup)* | *Demographics* | *Arithmetic mean costs Standard deviations (errors)* | *Results discussed with respect to other studies* | *Limitations discussed* | *Conclusions appropriate regarding uncertainty in results* | % |
| Sander & Bergmann[50] | 2003 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | 85% |
| Su et al. [39] | 2015 | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | n.a. | | ✓ | ✓ | | | | ✓ | ✓ | ✓ | 75% |
| Sullivan et al. [43] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | n.a. | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | 80% |
| Tsai et al. [54] | 2008 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | 71% |
| Walden et al. [26] | 2013 | ✓ | ✓ | n.a. | ✓ | ✓ | ✓ | ✓ | | | ✓ | | | | ✓ | | | | | n.a. | ✓ | ✓ | 53% |
| Wolfenstetter[36] | 2012 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | 90% |

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## Supporting Information 4: Characteristics and costs of the 50 studies included in the review

| Study | Sample | Data source and year | Quality[1] | BMI categories[2] | Considered factors | Costs in 2016 PPP Dollar[3] |
|---|---|---|---|---|---|---|
| *Cross-sectional studies (Regression models, descriptive methods)* | | | | | | |
| Blouin et al. (2017)[65] | Quebec, NPHS: N=2,359, Canada | National Population Health Survey Household (NPHS) (1994-2011), National Health Expenditure Database (NHEX) (2011) | 71% | BMI (WHO): normal, overweight, obese | - | The economic burden in Quebec associated with obesity due to absence (in 2013) caused by disability and loss of productivity is $53.3 million. |
| Asay et al. (2016)[66] | MHR: N=356,758, n(obese)=92,910, civilian, noninstitutionalized, MEPS: N=24,006, n(obese)=7,190 USA | MarketScan Health Risk Assessment, Medical Expenditure Panel Survey (MEPS) (2008-2011) | 95% | BMI (WHO): obesity: >30 | - | The annual cost of absenteeism for US employers because of obesity (in 2015) was $272. The total US cost per year is $11.3 billion. In an alternative scenario where work lost work was taken up by a college costs amounted to $4.86- $18.1 billion. |
| Effertz et al. (2016)[64] | Nationally representative, TK: N=146,000, Germany | Techniker Krankenkasse (2008 - mid-2012) | 71% | BMI WHO): obesity grade I, II, III | - | The costs due to sick leave (in 2016) sum to $4.97 billion. The individual losses are $1.98 billion from lost productivity. The $2.99 billion is borne by the employer. |
| Chenoweth et al. (2015)[23] | Municipal employees in North Carolina, N=3,951 claims, USA | North Carolina League of Municipalities: Claims Management System (2000 – 2009) | 75% | BMI: normal: 18.5-24.9, overweight – class I: 25.0-27.0, overweight – class II: 27.1-29.9, obesity grade I, II, III | - | Average annual total lost workday income (in 2015) was between $4,891 and $5,132 for class I and II overweight. The total lost workday income for obesity classes I to III ranged from $6,402 to $6,839, the average cost in the normal weight group was $4,047. |
| DiBonaventura et al. (2015)[40] | Nationally representative, NHWS: N=71,530, n(overweight)=23,852 n(obese I)=13,037, n(obese II)=5,948, n(obese III)=4,683, USA | NHWS (2013) | 80% | BMI (WHO): normal, overweight, obesity grade I, II, III | Costs calculated with and without risk of physical comorbidities (diabetes). | The cost of overweight without pre-diabetes or type 2 diabetes for a combined measurement of absenteeism and presenteeism (in 2015) was $5,515 for overweight, $6,173 for obesity class I, $6,906 for obesity class II and $9,104 for obesity class III, the cost of normal weight was $4913 |
| Gupta et al. (2015)[41] | Nationally representative, NHWS: N=62,000, n(overweight)=20,135, n(obese I)=7,268, n(obese II)=2,360, n(obese III)=1,251, France, Germany, Italy, Spain, UK | EU5 NHWS (2013) | 85% | BMI (WHO): normal, overweight, obesity grade I, II, III | Generalized linear regression models controlled for obesity related comorbidities. | Estimated annual costs on average (in 2013): $3,624 or overweight (absenteeism 30.0%, presenteeism 70.0%), $3,751 for obese class I (absenteeism 28.0%, presenteeism 72.0%), $4,209 for obese class II (absenteeism 31.5%, presenteeism 68.5%), $5,480 for obese class III (absenteeism 32.0%, presenteeism 68.0%), $3,520 for normal weight (absenteeism 26.3%, presenteeism 73.3%). |
| Su et al. (2015)[39] | Nationally representative, N=11,755, n(normal)=6,534, n(obesity I, II, III)=5,221, USA | NHANES (2005-2012) | 75% | BMI: normal, obesity grade I, II, III | Sub cohorts for physical comorbidities | The cumulative outcome for the burden of obesity (in 2013) was $3,611 (over 5 years) and $7.732 (over 10 years). This leads to a excess costs of $1.134 (over 5 years) and $2.268 (over 10 years) when compared to the normal weight population. |
| Andreyeva et al. (2014)[26] | Nationally representative, NHANES: N=14,975, n(overweight)=5,116, n(obesity I,II, III)=4,747, BRFSS: N=182,227, n(overweight)=66,695, n(obesity I, II, III)=57,583, USA | NHANES (1998-2008), BRFSS (2012), Integrated Public UseMicrodata Series-Current Population Survey (2011) | 90% | BMI (WHO): normal, overweight, obesity grade I, II, III | - | The US total loss in productivity (in 2012) because of obesity-related absenteeism was estimated at $9.04 billion per year. The obesity-attributable fraction (%) in total absenteeism costs varied from 6.5% in District of Columbia to 12.6% in Arkansas, with the US average of 9.3%. |
| Kleinman et al. (2014)[18] | Communications, transportation, finance, healthcare, and retail | Human Capital Management Services Research Reference | 85% | BMI: normal weight: BMI<27, | Sub cohorts for physical | Adjusted annual costs (in 2014) were $1,081 for overweight (sick leave 80.2%, short-term disability 13.2%, long-term disability 0.9%, |



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| | employees, N = 1,700,000, n(overweight)=14,281, n(obesity)=18,801, USA | Database (2001–2012) | | overweight: BMI 27-30, obesity: BMI>30 | comorbidities | workers' compensation 5.6%), $1,350 for obese (sick leave 75.2%, short-term disability 15.4%, long-term disability 1.9%, workers' compensation 7.5%) and $966 for normal weight (sick leave 79.7%, short-term disability 14.0%, long-term disability 1.9%, workers' compensation 4.3%). |
| Lehnert et al. (2014)[37] | Nationally representative, N=7,990, n(overweight)=3,022, n(obese)=1,369, Germany | German Socio-Economic Panel (2009-2010) | 85% | BMI (WHO): Excess weight: BMI>25 | Adjusted model for physical and psychosocial comorbidities | The total population costs associated with overweight- and obesity-related excess sick leave days in Germany (in 2009) were $3 billion. |
| Finkelstein et al. (2010)[31] | Nationally representative, NHWS: N=24,140, n(overweight)=8,594, n(obese I)=4,683, n(obese II)=2,148, n(obese III)=1,569, MEPS: N=8,875, n(overweight)=3,373, n(obese I)=1,597, n(obese II)=612, n(obese III)=320, USA | NHWS (2008), MEPS (2006) | 90% | BMI (WHO): overweight, obesity grade I, II, III | - | Productivity losses (2010) due to excess weight compared to normal weight for men were $-517 for overweight (absenteeism $94, presenteeism -$611), $735 for grade I obese (absenteeism 41.5%, presenteeism 58.5%), $1,835 for grade II obese (absenteeism 39.4%, presenteeism 60.6%) and $5,305 for grade III obese (absenteeism 21.3%, presenteeism 78.7%). For women, the costs were $295 for overweight (absenteeism 54.9%, presenteeism 45.1%), $1,376 for grade I obese (absenteeism 32.6%, presenteeism 67.4%), $1,740 for grade II obese (absenteeism 4.2%, presenteeism 95.8%) and $4,733 for grade III obese (absenteeism 29.4%, presenteeism 70.6%). |
| Goetzel et al. (2010)[33] | Employees from multiple professions and worksites, N=10,026, n(overweight)= 3,180, n(obese)=3,834, USA | National Heart, Lung, and Blood Institute (2005-2007) | 100% | BMI (WHO): normal weight, overweight, obese: BMI>30 | - | Estimated annual costs per employee (in 2006): $2,764 for overweight (absenteeism 39.6%, presenteeism 60.4%), $3,090 for obese (absenteeism 45.5%, presenteeism 54.5%), $2,469 for normal weight (absenteeism 42.1%, presenteeism 57.9%). |
| Henke et al. (2010)[16] | Pepsi Bottling Group employees, N=11,217, n(overweight)=5,003, n(obese I)=2,344. n(obese II)=673, n(obese III)=269, USA | StayWell HealthPath HRA data from the Thomson Reuters MarketScan and Advantage Suite Databases (2004-2006) | 100% | BMI (WHO): normal weight, overweight, obesity grade I, II, III | Costs for physical and psychosocial comorbidities and behavioral factors. | Annual average additional costs (in 2008) of excess weight compared to normal weight ($958 for normal weight employees): Additional costs were $210 for overweight (workers' compensation 85.6%, short-term disability 14.4%), $640 for grade I obese (workers' compensation 81.4%, short-term disability 18.6%), $693 for grade II obese (workers' compensation 88.0%, short-term disability 12.0%) and $1,098 for grade III obese (workers' compensation 61.4%, short-term disability 38.6%) |
| Dall et al. (2009)[51] | Nationally representative, N=1,000,000, overweight 33%, obese I 17%, obese II or obese III 12%, USA | U.S. Census Bureau (2007), NHANES (1999-2004), National Health Interview survey (2006) | 75% | BMI (WHO): normal, overweight, obesity grade I and II, III combined | Including costs of physical comorbidities. | Excess productivity loss per person (in 2007) were $798 for overweight (absenteeism 6.8%, presenteeism 84.5%, disability 5.0%, premature mortality 3.6%), $1,051 for obese I (absenteeism 11.5%, presenteeism 66.5%, disability 2.0%, premature mortality 20.0%), $2,598 for obese II and III (absenteeism 11.8%, presenteeism 26.6%, disability 16.8%, premature mortality 44.8%). |
| Cawley (2008)[42] | Nationally representative, N(men)=14,187, obese 78.7%, morbidly obese 21.3% N(women)=19,402 women, obese 88.0%, morbidly obese 12.0%, USA | MEPS (2000 –2004) | 85% | BMI (WHO) obesity: BMI 30-40, morbid obesity: BMI>40 | Additional sample with physical comorbidities. | National aggregate annual costs of job absenteeism (in 2004) for obese nondiabetic were $2.8 billion ($731 million for men, $2,066 million for women). Costs for morbidly obese nondiabetic were $1.01 billion ($234 million for men, $777 million for women). Per-capita annual increases in absenteeism costs associated with obesity, as compared with healthy weight nondiabetics were $89 for men and $170 for women. For morbidly obese, the costs were $284 for men and $287 for women. |

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| Gates et al. (2008)[32] | Manufacturing employees, N=341, n(overweight)=143, n(mildly obese)=79, n(moderately/extremely obese)=43, USA | Survey in eight manufacturing countries in Kentucky (-) | 80% | BMI (WHO): normal weight, overweight, mild obesity: BMI 30-35, moderate or extreme obesity: BMI>35 | - | The annual per-person costs of moderately or extreme obese workers were $3,247 (absenteeism 46.9%, presenteeism 53.1%). The annual costs of all other workers were $2,700 (absenteeism 52.8%, presenteeism 47.2%). (Year of costing assumed: 2008)4 |
| Sullivan et al. (2008)[43] | Nationally representative, N= 43,221, n(obese)=10,970, USA | MEPS (2000–2002) | 80% | BMI (WHO) underweight, normal weight, overweight, obesity: BMI > 30 | Costs calculated with and without risk of physical comorbidities. | Annual costs of absenteeism (in 2007) per person without comorbidities were $94 for overweight and $402 for obese ($294 for normal weight). When controlling for chronic conditions, the costs were $83 for overweight and $288 for obese ($161 for normal weight). |
| Durden et al. (2008)[30] | Commercially insured employees, N=88,984, n(overweight)=34,259, n(severely obese)=8,780, n(obese)=14,826, USA | Self-reported data from MarketScan Research databases and MarketScan HRA Database (2003-2005) | 90% | BMI (WHO) underweight, normal weight, overweight, obese: BMI: 30-35 severely obese: BMI>35 | - | Estimated costs of workdays lost (in 2005) were $7,557 for overweight, $10,113 for obese, $10,362 for severely obese and $4,224 for normal weight. Marginal effects of the GLM of indirect costs due to absence, relative to the normal weight BMI group: $1,324 for overweight, $1,857 for obese and $1,738 for severely obese. |
| Cawley et al. (2007)[52] | Nationally representative, N= 54,970, overweight: 27% female, 42% male, obese: 21% female, 23% male, morbidly obese: 8% female 6% male, USA | MEPS (2000-2004) | 75% | BMI (WHO) healthy weight, overweight, obese: BMI 30-35 or 35-40 and no hypertension, hyperlipidemia, or diabetes, morbidly obese: BMI>40 or BMI 35-40 and hypertension, hyperlipidemia, or diabetes present | For obesity-diagnostic: physical comorbidities | Per capita increases in absenteeism costs associated with obesity (in 2004) were $89 for men and $181 for women compared with healthy weight nondiabetic subjects. Per capita increases in absenteeism costs associated with morbid obesity were $252 for men and $303 for women compared with healthy weight nondiabetic subjects. Estimated national aggregate costs of absenteeism were $5.5 billions for obesity in 2004. |
| Klarenbach et al. (2006)[63] | N= 58,289 (of all weight classes), estimated prevalence rate of obesity class III: 1%, Canada | Canadian Community Health Survey (2000 - 2001) | 75% | BMI (WHO) normal weight, obesity grade I, II, III | Physical and psychosocial comorbidities | Total lost productivity due to absenteeism (in 2004) for Class III obesity is estimated to be $171 million. |
| Ricci & Chee (2005)[38] | National population-based, N=6,894 employed adults, n(overweight)=2,490 , n(obese)=1,536, USA | The Caremark American Productivity Audit, The Caremark Work and Health Interview (2001-2003) | 95% | BMI (WHO) overweight, obese BMI>30 | Covariates in Logistic Regression Models: physical and psychosocial comorbidities and behavioral factors | Total cost of health-related lost productive time (in 2002) were $73 billion for overweight (absenteeism 30.7%, presenteeism 69.3%) and $56 billion for obese (absenteeism 32.2%, presenteeism 67.8%). |
| Finkelstein et al. (2005)[53] | Nationally representative, N= 25,427, n(overweight)=9,813*, n(obese)=5,736, USA | National Health Interview Survey (2001-2002) | 85% | BMI (WHO) overweight, obesity grade I, II, III | Regressions controlled any functional limitations not self-reported as obesity-related (e.g. difficulty walking, standing, sitting, stooping, reaching, or grasping) | Value of increased absenteeism in 2004 associated with overweight were $128, with grade-I obesity $476, with grade-II obesity $2,019, and with grade-III obesity $1,586. |



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| *Longitudinal studies* | | | | | | |
| Kirkham et al. (2015)[44] | Large computer manufacture employees, N = 17,089, obesity: 7-9%, USA | HRA survey data, human resources records, and employee insurance eligibility records (2006–2010) | 67% | BMI (WHO): obesity: BMI>35 | Health Risk levels of physical and psychosocial comorbidities and behavioral factors | Annual productivity costs (in 2014) of being at risk for BMI≥35: $3,608 (absenteeism 33.1%, presenteeism 66.9%). Costs of BMI<35: $3,086 (absenteeism 31.1%, presenteeism 68.9%). |
| Bhojani et al. (2014)[28] | Petrochemical workers (Shell), N=20,000 to 28,000, obesity 14%-42% from 1980-2009, USA | Physical examination records in the Shell Health Surveillance System (1980-2009) | 62% | BMI (WHO): obesity: BMI>30 | - Behavioral factors | At the end of 30 years, and assuming a workforce of 20,000 employees, the potential economic impact due to illness-absence from obesity would be $6.59 million/year. (Assumed year of costing: 2014) |
| Neovius (2012)[21] | Nationwide cohort of men, who performed mandatory military conscription tests at age 18 (follow-up after 38 years), N=45,920, n(overweight)=2,623, n(obese)=367, Sweden | Military Service Conscription Register, Social Insurance Register, Register of the Total Population, Population and Housing Censuses (1969/1970, 1986-2005) | 100% | BMI (WHO): underweight, normal weight, overweight, obese | Covariates: behavioral and environmental factors | Lifetime productivity losses (in 2010) according to the human capital approach: $87,264 for overweight (sick leave 20.7%, disability pension 35.6%, mortality 43.8%), $114,731 for obesity (sick leave 16.5%, disability pension 28.5%, mortality 54,6%), $66,864 for normal weight (sick leave 22.5%, disability pension 32.3%, mortality 45.2%). Friction cost method: $20,085 for overweight (sick leave 64.7%, disability pension 13.2%, mortality 21.6%), $23,092 for obesity (sick leave 62.0%, disability pension 13.5%, mortality 24.5%), $15,878 for normal weight (sick leave 70.2%, disability pension 11.5%, mortality 18.3%). |
| Wolfenstetter (2012)[36] | Population-representative, N=2,581, n(overweight)=786, n(obese)=406, n(healthy weight) = 679; n(healthy to overweight) = 299, n(healthy to obese)= 10, n(overweight to healthy)= 92, n(overweight to obese) = 257, n=(obese to healthy) = 2, n(obese to overweight)= 50, Germany | MONICA/KORA (Cooperative Health Research in the Region of Augsburg) survey-S3 (1994/95), KORA follow-up survey-F3 (2004/05) | 90% | BMI (WHO): normal weight, overweight, obese Changes in health status from 1994/1995 to 2004/2005 | - Healthcare utilization by physician visits and therapy | Costs of absenteeism per year per group (in 2005). Costs of participants who remained in the same weight group: $2,662 (healthy weight), $3,625 (overweight), $3,625 (obesity). Costs of participants who changed the weight group: $3,625 (Healthy to overweight), $607 (healthy to obese), $2,661 (overweight to healthy), $4,213 (overweight to obese), $284 (obese to healthy), $3,257 (obese to overweight). |
| Tsai et al. (2008)[54] | Shell Oil Company employees, 1994: N=4,153, n(overweight)=1,854, n(obese)=1,204, 2003: N=4,513, n(overweight)=1,719, n(obese)=1,732, USA | Shell Health Surveillance System (1994), follow-up 2003 | 71% | BMI (WHO) normal weight, overweight, obese: BMI >30 | Physical comorbidities | Costs of absences lasting 6 or more days per year: these excess workdays lost resulted in a loss of $2.18 million with $874,767 due to overweight employees ($471 per employee) and $1.31 million due to obese employees ($1,087 per employee). (Year of costing assumed: 2007)4 |
| Ostbye et al. (2007)[20] | Health care and university employees, N=11,728, 29.9% overweight, 14.2% obesity class I, 6.8% obesity class II, 4.9% obesity class III, USA | Duke University Health System and Duke University (1997-2004) | 62% | BMI (WHO) underweight, recommended weight, overweight, obesity grade I, II, III | - Behavioral factors | Indemnity claims costs (in 2005) for lost workdays from 1997-2004: $6.7 million; per 100 full-time equivalents $19,058. |
| Borg et al. (2005)[29] | Middle-aged subjects living in Malmö, N= 33,346, n(overweight)=10,775, n(obese)=2,450, Sweden | Malmö Prevention Project (1974-1984) and a mean follow-up of 17 years | 86% | BMI (WHO) overweight, obesity: BMI>30 | - | Average annual indirect cost (in 2003) due to death before retirement age, projected over 15 years were $4.73 million for overweight and $383 million for obesity. |



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| *Attributable risk studies (PAF)* | | | | | | |
| Dee et al. (2015)[61] | Nationally representative, N= -, Island of Ireland | Central Statistics Office (2007-2009), Department of Social Protection illness benefit data for (2009), Department of Social Development (Northern Ireland), Northern Ireland Statistics and Research Agency | 80% | BMI (WHO) overweight and obesity: BMI>30 | Overweight and physical comorbidities were included in the PAF analysis. | The estimated annual costs (in 2009) for the Republic of Ireland for absenteeism were $157 million (human capital approach) or $83 million (friction costs method). The costs of premature mortality were $684 million. The costs of absenteeism in Northern Ireland were $305 million (human capital approach) or $105 million (friction costs method). The cost of premature mortality was $189 million. |
| Lehnert et al. (2014)[4] | Nationally representative, N= -, overweight 37%, obese 23%, Germany | Prevalence data: German Health Interview, Examination Survey for Adults (DEGSI) (2008-2011), Population: population representative German Study (AgeCoDe) (2008) | 90% | BMI (WHO): Excess weight BMI>25 | Obesity and overweight attributable costs of physical comorbidities | The total indirect costs attributable to excess weight in 2008 in Germany were $9.5 billions. Indirect costs paid work: mortality (16.0%), early retirement (7.9%), sickness absences (10.5%). Indirect costs unpaid work: mortality (52.7%), early retirement (6.9%), sickness absence (5.2%) |
| Lal et al. (2012)[19] | Nationally representative, N= -, New Zealand | Burden of Disease Estimates Data Set (WHO), NZ Ministry of Health (2006) | 80% | BMI (WHO): overweight, obese: BMI>30 | Obesity and overweight attributable costs of physical comorbidities | Productivity losses in New Zealand (in 2006) according to the human capital approach: $180 million (premature death 64.4%, short-term absenteeism 35.6%). Costs according to the friction capital approach: $79 million (premature death 9.2%, recruitment and training costs 9.2%, short-term absenteeism 81.6%). |
| Kang et al. (2011)[17] | National representative, N=1,910,194, overweight men (women): 27.4% (22.0%), obese I men (women): 31.5% (24.6%), obese II men (women): 3.6% (3.4%), Korea | National Health Insurance Corporation, Korea National Health and Nutrition Examination Survey (2005) | 85% | BMI: normal weight: BMI: 18.5-22.9, overweight: BMI: 23-24.9, obesity I: BMI: 25-29.9, obesity II: BMI>30 | Obesity and overweight attributable costs of physical comorbidities | Total socioeconomic indirect costs (in 2005) were $873 million (loss of productivity due to premature deaths 62.8%, loss of productivity due to admission 62.8%, traffic costs 14%, nursing costs 9.9%, nursing fees 2.2%). Indirect costs were $260 million for overweight, $405 million for grade I obesity and $148 million for grade II obesity. |
| Konnopka et al. (2011)[57] | Nationally representative, N= -, Germany | Statistics from the German Federal Statistical Office, German Retirement Insurance Office (2002) | 86% | BMI (WHO): 4 risk classes: 0: BMI<25, 1: 25<BMI<30, 2: 30<BMI<35, 3: 35<BMI<40, 4: BMI>40 | Attributable costs of physical comorbidities. | Costs attributable to obesity and overweight (in 2002): $6.5 billion. (Costs unpaid work: mortality 48.8%, early retirement 7.9%, sickness absence 3.3%; costs paid work: mortality 18.5%, early retirement 11.8%, sickness absence 9.6%) |
| Moffat et al. (2011)[60] | N= -, Canada | Canadian Community Health Survey (2004-2005), Public Health Agency of Canada (Economic Burden of Illness in 2000) | 62% | BMI (WHO): excess weight: BMI>25 | Obesity and overweight attributable costs of physical comorbidities | Indirect costs (in 2005): $584 million (long-term disability 32.5%, short-term disability 9.8%, premature mortality 57.6%) in Alberta |
| Anis et al. (2010)[59] | N= -, overweight men: 42%-51%, obese men: 22%-27% overweight women: 30%-37%, obese women: 23%-29% (rates vary for different age groups), Canada | Canadian Heart Health Survey (1986-1992), Economic Burden of Illness in Canada (1998) | 62% | BMI (WHO): overweight, obesity | Obesity and overweight attributable costs of physical comorbidities | The cost attributable to excess weight in Canada (in 2006) is $4.4 billion ($1.5 billion for overweight and $2.7 billion for obesity). |
| Cadilhac et al. (2010)[62] | Population simulation for 2008, N about 17 million, Australia | Mainly: Australian Burden of Disease (BoD) study 2003 other input data: National Health Survey (2004-2005), Australian average weekly earnings (2008), Time Use Survey (2008), Disease | 90% | BMI (WHO): Excess weight: BMI>25, normal weight | Including costs of behavioral factors | Total potential attributable opportunity cost savings due to workforce participation and absenteeism (in 2008) for excess weight according to FCA: $638 million. |



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| | | Costs & Impact Study (200-2001) | | | | |
| Knoll & Hauner (2008)[49] | n(obese in 2003)=13,200,000, Germany | Federal Statistical Office, statements from insurance companies, German pension insurance, professional associations (1997-2004) | 71% | BMI (WHO) obesity: BMI > 30 | Physical and psychosocial comorbidities | Annual indirect costs (in 2003) with 4% discounting were $2.1 billion (disability 46%, incapacity for work 35%, mortality 19%). Costs with a 6% discounting rate were $1.8 billion (disability 42%, incapacity for work 41%, mortality 17%). In 2010 indirect costs were projected to be $2.4 billion, in 2015 $2.9 billion, in 2020 $3.6 billion. |
| Chenoweth & Leutzinger (2006)[48] | 7 U.S. states, N=77 Mio, state-specific prevalence rates for excess weight: 35%-60%, USA | Obtained from various health plans and state agencies in seven states and published studies | 65% | BMI (WHO) excess weight BMI>25 | Physical comorbidities | Productivity loss cost per year (in 2003) for excess weight (estimated lost hours used in one state-wide cost analyses) subtotal $25 billion (absenteeism 22.8%, short term disability 27.2%, presenteeism 50%). Productivity loss for California, North Carolina and Massachusetts were $41 billion. |
| Katzmarzyk & Janssen (2004)[58] | N= -, overweight: 33%, obese: 14.7%, Canada | Economic Burden of Illness in Canada (1998) and data taken from literature | 60% | BMI (WHO) Obesity: BMI>30 | Attributable costs of physical comorbidities. | Estimated indirect costs attributable to obesity in Canada (in 2001) (value of economic output lost due to illness, injury related work-disability or premature death): $2.7 billion. |
| Sander & Bergemann (2003)[50] | Representative population data from publications attributed to 12.24 million obese adults in Germany (of whom 2.9 million suffer from selected comorbidities), Germany | German National Survey (1998) and data taken from the literature and official German publications | 85% | BMI (WHO) Obesity: BMI>30 | 3 scenarios refer to the physical comorbidities (in the base case) | Annual Indirect costs of obesity (in 2001) due to mortality, work loss and disability: $282 million. |
| *Simulation studies (Markov model)* | | | | | | |
| Lightwood et al. (2009)[45] | Projected overweight adult prevalence (resulting from adolescent overweight) from n= 330,000 in 2020 to more than n= 9,700,000 in 2050, USA | NHANES (1971-2000) | 90% | BMI (WHO): Obesity: BMI>30 | Includes costs of physical comorbidities; Simulation designs on base case-, prevention- and treatment-settings | Projected excess costs attributable to current adolescent obesity to 2025 to 2050. Costs are expected to rise from $942 million in 2020 to $36 billion in 2050. |
| *Other studies* | | | | | | |
| Walden et al. (2013)[26] | Hospital staff, N > 800, lift team technicians for mobilizing the obese patient, USA | Hospital financial reports, non-validated staff satisfaction survey (2012) | 53% | Patient's weight>100kg, with a Braden Scale score<18 and/or the presence of pressure ulcers | - | Cost savings (in 2012) due to decreased injuries among staff from patient handling were $987,219. |
| Gussenhoven et al. (2013)[34] | Employees from seven Dutch companies, N = 460 (control group), only participants with excess weight were included, mean BMI=29, Netherlands | ALIFE@Work RCT (2004) | 85% | BMI (WHO): Excess weight: BMI>25 | - | Sick leave costs (in 2004) based on GLDP (= gross lost productivity days, total number of calendar days that workers were partially or fully sick listed) were $4,307, sick leave costs based on NLPD (= net lost productivity days; multiplying the number of sick leave days with the absenteeism percentage; for the assumption that partially sick listed employees were fully productive when at work) were $3,273. |
| Finkelstein et al. (2012)[46] | Full-time employees and eligible for LAGB, MEPS (N=134), mean BMI=44, NHWS (N=2,164), mean BMI=43, USA | MEPS (2005-2006), NHWS (2008) | 75% | BMI (WHO) eligible for bariatric surgery: BMI>40 or BMI 35-40 with a significant comorbidity | For obesity diagnostic: physiological comorbidities | Costs for the quarter before LAGB (in 2010) for bariatric surgery candidates were $67 for (absenteeism 83.3%, presenteeism 16.7%). |
| Peake (2012)[35] | Australian Defense Force personnel from army, navy and air force | Directorate of Workforce Information, ADF Central Medical | 86% | BMI (WHO): normal weight, | - Prevalence of injury | Mean productivity loss per person from each cohort (in 2009-10). For full days off work per calendar day (underestimated): $29 for |



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| | | | | | | |
|---|---|---|---|---|---|---|
| | service branches, N=679, n(overweight)=154, n(obese restricted body fat)=148, n(obese no restriction)=180, Australia | Records (2009-2010) | | overweight, obese with restricted body fat (≤28% for females, ≤24% for males), obese with no restriction | or illness | overweight, $57 for obese restricted body fat, $78 for obese no restriction on body fat and $12 for normal weight. For productivity loss from full days off work per workday (overestimated): $42 for overweight, $79 for obese restricted body fat, $110 for obese no restriction on body fat and $17 for normal weight. Productivity loss from restricted work days (50% limited activity) is $474 for overweight, $1129 for obese restricted body fat, $984 for obese no restriction on body fat and $695 for normal weight. |
| Breitfelder et al. (2011)[22] | Parents of children, N(children)=3,508, n(overweight)=216, n(obese children)=69, Germany | GINI-plus (German Infant Nutritional Intervention study), LISA plus (Influence of lifestyle factors on the development of the immune system and allergies in East and West Germany) | 85% | Age- and sex-specific percentile cut-off points for children: Normal weight (P10–P90), Overweight (>P90 to P97), Obese (>P97) according to Kromeyer-Hausschild | - Utilization of healthcare services by physician visits, therapy and other therapies | Indirect costs for parental work absence (in 2007) were $102 for overweight, $142 for obese and $120 for normal weight children. (For severely underweight, the costs were $153) |
| Ewing (2011)[24] | Patients undergoing laparoscopic gastric bypass or laparoscopic banding surgery, N=150, in relation to data from the Bureau of Labor Statistics, USA | LAGB Patients. The Bureau of Labor Statistics, Bureau of Economic Analysis (2006), Texas Tech University Health Sciences Center (TTUHSC) (2003-2005) | 67% | Obesity (no cut-off points stated) | - | Total per year economic impacts on South Plains from obesity (in 2003): $210 million. |
| Kyrolainen et al. (2008)[47] | Finnish male military personnel, N=7,179, overweight: 46%, obese: 10%, Finland | Male military personnel data from personnel administration (2004) | 65% | BMI (WHO) normal weight, overweight, obese: BMI >30 | Behavioral factors | Cost of sick leave per year per person (in 2004) were $915 for excess weight and $595 for normal weight. |
| Frezza et al. (2006)[25] | Bariatric patients, N=150, in relation to data from the bureau of Labor Statistics (2005, lost work time rate and employment and earnings data), USA | Patients from New Mexico who underwent laparoscopic gastric bypass and laparoscopic banding (2003-2005). Bureau of Labor Statistics (2005) | 71% | Bariatric patient sample: not described Prevalence data of New Mexico: obesity: BMI > 30 | - | Total per year economic impacts of obesity for New Mexico (in 2003): $1.79 billion from output lost and $265 million from labor income lost. Cost per year to New Mexico household: $2,229 from output lost, $329 from labor income lost. |

[1]BMI: Body mass index, WHO: World Health Organization, NHANES: National Health and Nutrition Examination Survey, BRFSS: Behavioral Risk Factor Surveillance System, LAGB: Laparoscopic adjustable gastric banding, MEPS: Medical Expenditure Panel Survey, NHWS: National Health and Wellness Survey

Percentage of criteria fulfilled of quality assessment by Stuhldreher et al.[15]

[2] Most studies used standard BMI classification as recommended by the World Health Organization: BMI (kg/m$^2$) normal weight: 18.5-24.99, overweight: 25.00-29.99, obese class I: 30.00-34.99, obese class II: 35.00-39.99, obese class III: ≥40.00. Excess weight was defined as overweight and obesity combined: BMI ≥25.00

[3] Costs were converted to 2016 PPP Dollar for comparison. The year of costing is given in parenthesethors who did not state the year of costing in their study were asked via email. If unable to reach, the date of submission or publication was assumed as the year of c



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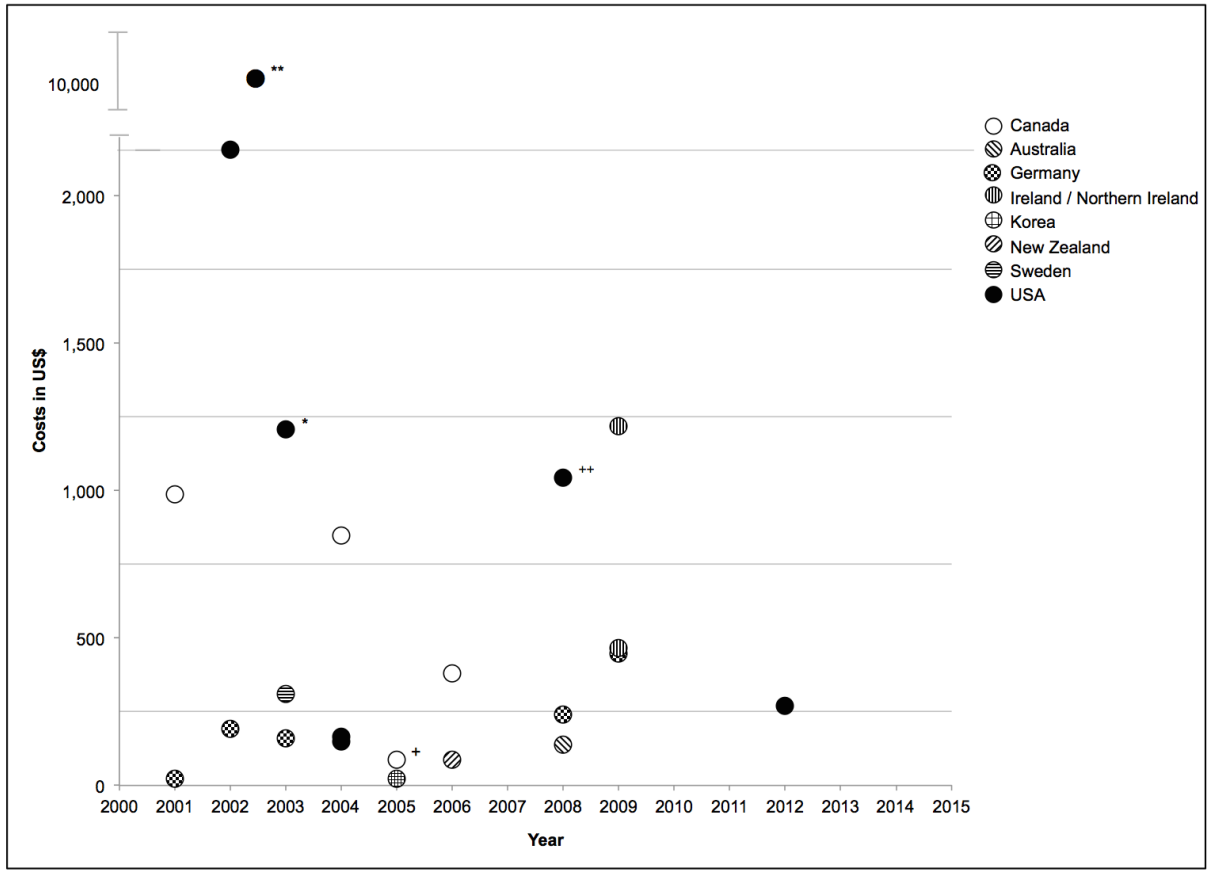
## Supporting Information 5: Excess costs per capita based on macroeconomic costs




* Costs of the three US states California, North Carolina, Massachusetts, + Costs of the province Alberta, ** Costs of the state of New Mexico, ++ Costs of South Plains of Texas

For better comparison, the per capita costs of the national costs studies are displayed. If not provided in the article, the per capita costs were calculated based on obese or overweight and obese adult population estimates in the year of costing.



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# PRISMA 2009 Checklist

| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | 1 |
| **ABSTRACT** | | | |
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number. | 2 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of what is already known. | 5-6 |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | 5-6 |
| **METHODS** | | | |
| Protocol and registration | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | - |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | 6-7 |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | 6 |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | 6-7 |
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | 6-7 |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | 7 |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | 6-7 |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | 7 |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | 7 |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., $I^2$) for each meta-analysis. | 7 |

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# PRISMA 2009 Checklist



| Section/topic | # | Checklist item | Reported on page # |
|---|---|---|---|
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | 19 |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | n.a. |
| **RESULTS** | | | |
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | 8 |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | 8-9 |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12). | - |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot. | 9, 13 |
| Synthesis of results | 21 | Present results of each meta-analysis done, including confidence intervals and measures of consistency. | n.a. |
| Risk of bias across studies | 22 | Present results of any assessment of risk of bias across studies (see Item 15). | - |
| Additional analysis | 23 | Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]). | 15 |
| **DISCUSSION** | | | |
| Summary of evidence | 24 | Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers). | 15-16 |
| Limitations | 25 | Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias). | 16-17 |
| Conclusions | 26 | Provide a general interpretation of the results in the context of other evidence, and implications for future research. | 17-18 |
| **FUNDING** | | | |
| Funding | 27 | Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review. | 1 |

*From:* Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

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