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SOCIAL COSTS OF OBESITY IN THE CZECH REPUBLIC

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Social Costs of Obesity in the Czech Republic

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Abstract:
Increasing prevalence of obesity is a pressing public health issue in the Czech Republic as well as world-wide, affecting up to 2.1 billion people. In the Czech Republic, 20-25% of adults and an increasing number of children are obese now. Given that obesity is a chronic disease which is associated with several serious comorbidities, it generates large social costs. The main aim of this study was to estimate both direct and indirect costs of obesity in the Czech Republic. Social costs of obesity are estimated using the cost-of-illness approach. Population attributable fractions (PAF) are computed based on prevalence of obesity in the Czech Republic and relative risks of 19 comorbidities. Direct costs (healthcare utilization costs and costs of pharmacotherapy) are estimated using the top-down approach, while indirect costs (absenteeism, presenteeism and premature mortality) are estimated using the human capital approach. In aggregate, the annual costs attributable to obesity in the Czech Republic in 2018 were 37.3 billion CZK (1.5 billion EUR). Direct costs were 13.1 billion CZK (0.5 billion EUR) and accounted for 3% of Czech healthcare expenditures. The highest healthcare utilization costs were attributable to type II diabetes (21.7%), ischemic heart disease (18.4%) and osteoarthritis (16.9%). The largest indirect costs were attributable to premature mortality (9.2 billion CZK/0.36 billion EUR), absenteeism (8.7 billion CZK/0.34 billion EUR) and presenteeism (6.3 billion CZK/0.25 billion EUR). This report demonstrates that obesity is a serious problem with considerable costs. Several preventive interventions should be applied in order to decrease the prevalence of obesity and achieve cost savings.

JEL: I12, I18
Keywords: obesity, social costs, cost-of-illness study, Czech Republic

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1 Introduction

Obesity is a serious global health problem which brings substantial economic burden to society. Worldwide rates of obesity have nearly tripled since 1975 and more than 2.1 billion people (30% of global population) suffer from overweight or obesity today. Importantly, obesity is a risk factor for cardiovascular diseases, type II diabetes and some types of cancers, which brings substantial healthcare costs, but also large indirect costs through lost productivity. The global economic impact of obesity is estimated to be $2 trillion (2.8% of global GDP), which is comparable to the impact of armed conflict, smoking or terrorism (Dobbs *et al.*, 2016). In OECD countries, 8.4% of healthcare budget is dedicated to treatment of overweight-related diseases (OECD, 2019a).

Obesity has become a pressing concern also with regard to the COVID-19 pandemic. Numerous studies have shown that overweight and obese individuals are more at risk for being COVID-19 positive. Obesity is also associated with much more severe symptoms of COVID-19, leading to significant increases in morbidity and mortality in COVID-19 patients (Popkin *et al.*, 2020). Moreover, due to many restrictions implemented in order to prevent the spread of COVID-19 (movement restrictions, social distancing, remote work/studies etc.), people lack physical activity which may aggravate current trends in the prevalence of obesity and put even larger strain on the healthcare system (Popkin *et al.*, 2020).

In the Czech Republic, the rates of obesity have been increasing since the 90's both in adults (Bruthans, 2019) and children (SZÚ, 2018). The goal of this study is to estimate the social costs of obesity in the Czech Republic. The cost-of-illness approach, which views the burden of specific illness as the sum of direct (medical) and indirect costs, is implemented. Direct costs (i.e. the costs of healthcare utilization and pharmacotherapy) are estimated using the top-down approach, while the indirect costs (presenteeism, absenteeism and premature mortality) are estimated using the human capital approach. The resulting social costs of obesity show us how much could be saved if the disease did not exist at all (Byford *et al.*, 2000). This is the most comprehensive study to estimate the social costs of obesity in the Czech Republic so far and it demonstrates what an extreme burden this disease brings to the society.

2 Literature Review

The estimates of social costs of obesity vary and depend on the underlying methodology and data, which is why we provide the literature review for different groups of costs separately. There exist other types of costs that we do not include in the present study - the intangible costs, which refer to pain and suffering, bullying, not being able to get a job because of obesity, prejudice in education and schooling etc. (Effertz *et al.*, 2016). These costs may be considerable, but are very difficult to monetize and thus are not typically included in cost-of-illness studies.

2.1 Direct costs

Numerous studies have found that obesity is associated with increased risk of cardiovascular diseases, type II diabetes and cancers (Guh *et al.*, 2009; Dobbins *et al.*, 2013). This leads to increased medical costs due to higher use of prescription drugs, outpatient care or longer hospital stays as a result of post-treatment complications (Effertz *et al.*, 2016; Cawley & Meyerhoefer, 2012; Konnopka *et al.*, 2011; Arterburn *et al.*, 2005). There are three approaches to estimate the direct costs of obesity: bottom-up, top-down and econometric approach (see section 3 for more detail). The latter two methods are most often used in literature. The main difference is that the top-down approach uses aggregate data and presents the results for the whole country, while

the econometric approach uses data on individual health expenditures and usually presents the results per capita.

Current literature indicates that the direct costs of obesity are substantial. For instance, Sturm (2002) estimates that obesity is associated with 36% increase in inpatient and outpatient spending and 77% increase in medication costs, while Kleinman *et al.* (2014) finds that direct costs are 50% larger for obese men and women. Several studies also show that medical costs increase proportionally with BMI (Wang *et al.*, 2006; Raebel *et al.*, 2004). Borg *et al.* (2005) points out the differences in the length of hospital stay of obese vs. normal weight individuals, which are shown to increase with both BMI and age.

Table A1 summarizes literature focusing on direct costs of obesity. The studies using the top-down approach vary in the amount of comorbidities included, which ranges from 4 to 18. The share of direct costs of obesity on total healthcare costs is estimated as 2.7% in the Republic of Ireland, 2.8% in Northern Ireland (Dee *et al.*, 2015), 3.7% in Korea (Kang *et al.*, 2011), 2.3% in Sweden (Borg *et al.*, 2005), 2.3-3.5% in Switzerland (Schmid *et al.*, 2005), 3.3% in Germany (Lehnert *et al.*, 2015) and 6.7% in Canada (Krueger *et al.*, 2015). In the Czech Republic, the direct costs of obesity were estimated as 7.6 billion CZK (excluding the costs of pharmacotherapy) in 2013, which accounted for 3.45% of total healthcare costs (Tuzarová, 2016). Earlier estimate from 2007 was 9.5 billion CZK (5.2% of healthcare costs), out of which 2.6 billion CZK were costs of pharmacotherapy (Hodycová, 2009). In general, the share of costs of overweight and obesity on total healthcare costs ranges between 2 and 8% (OECD, 2019a).

2.2 Indirect costs

2.2.1 Absenteeism

Absenteeism refers to absence from work due to illness. It is associated with substantial costs as an employee's absence reduces his own productivity as well as the productivity of coworkers, particularly when work relies on team production (Asay *et al.*, 2016). The rate of absenteeism due to illness varies across countries, but Czech Republic has one of the highest rates in Europe, reaching on average 16.3 days missed in 2018 (WHO, 2019). A study comparing costs of absenteeism across three risk factors (smoking, physical inactivity and obesity) and two chronic conditions (hypertension and diabetes) in the USA found that obesity was responsible for the largest costs which amounted to $11.2 billion (Asay *et al.*, 2016).

Table A2 summarizes literature which includes the costs of absenteeism associated with obesity. Almost all studies find that the costs of absenteeism are significantly larger for obese workers compared with normal-weight workers. However, the magnitude of the difference varies across studies, which can be caused by country differences, use of different data or different approaches. Usually, absenteeism is compared between obese and normal weight people (e.g. Effertz *et al.* (2016); Dall *et al.* (2009); Finkelstein *et al.* (2005)), but some studies compare BMI > 25 (thus including overweight) with normal weight (e.g. Dee *et al.* (2015); Lehnert *et al.* (2015); Kang *et al.* (2011); Konnopka *et al.* (2011)), which makes some results uncomparable. Several studies provide results separately for men and women which shows the difference in absenteeism across genders. In all of these studies, absenteeism costs are larger for women (Kleinman *et al.*, 2014; Lehnert *et al.*, 2014; Kang *et al.*, 2011; Finkelstein *et al.*, 2005). The results are usually given in monetary terms, but some studies also provide results in the number of days absent. Neovius *et al.* (2012) who concentrates on absenteeism in Swedish men provides productivity losses over lifetime. Studies which examine absenteeism across three obesity classes show that the rates of absenteeism increase with BMI (Andreyeva *et al.*, 2014; Dall *et al.*, 2009; Finkelstein *et al.*,

2005).

2.2.2 Presenteeism

Presenteeism refers to reduced productivity at work due to presence of mental or physical health complications (Johns, 2010). There is growing evidence that the costs of presenteeism associated with chronic conditions largely exceed the costs of absenteeism (Finkelstein *et al.*, 2010; Collins *et al.*, 2005; Goetzel *et al.*, 2004). Several productivity loss measures have been developed to quantify the costs of presenteeism. These surveys generally ask respondents to evaluate how much their health condiditon prevented them from working at full capacity. Some surveys are generic and focus on the overall health status, while others are more specific and focus on particular health conditions (e.g. allergies, depression, back pain etc.). The type of questions respondents answer vary across surveys (Johns, 2010). Respondents are for instance asked to show the degree of agreement with a statement such as "At work, I was able to focus on achieving my goals despite my (health problem)" (Koopman *et al.*, 2002). The surveys usually recall a period of 1 week to 1 month (Johns, 2010).

To the best of our knowledge, presenteeism related to obesity has not been measured in the Czech Republic thus far, therefore, our estimates are based on current literature. We search for studies that quantify the obesity-related presenteeism in the USA and Europe, which are summarized in Table A3. All the studies find that obesity is positively associated with presenteeism, but the extent differs across studies. Some studies compare obesity and overweight against normal weight (Boles *et al.*, 2004; Pelletier *et al.*, 2004), other studies focus purely on obesity vs. normal weight (Burton *et al.*, 2005; Goetzel *et al.*, 2010) and there are also studies which provide the result for each obesity class separately (Gupta *et al.*, 2015; Finkelstein *et al.*, 2010). These studies demonstarte that the rate of presenteeism increases with BMI, which is confirmed for different occupations (Kudel *et al.*, 2018). The studies usually provide results either in days lost or percent of productivity lost, which are converted to days lost, assuming there are 250 working days per year. The estimates range from 1.1 more days lost compared to normal weight (Goetzel *et al.*, 2010), over 3 or 4 days lost (Boles *et al.*, 2004; Burton *et al.*, 2005; Ricci & Chee, 2005) and up to 22.7-33 days lost for obesity class III (Finkelstein *et al.*, 2010; Gupta *et al.*, 2015). Based on these studies, we conservatively assume that the average rate of presenteeism for obese individuals in the Czech Republic is 1 day at minimum and 3 days at maximum, so the baseline value in this study is set at 2 days lost.

2.2.3 Premature mortality

Excess weight is associated with substantial increases in early mortality (Peeters *et al.*, 2003). Obesity and its related diseases are estimated to reduce life expectancy by 0.9 – 4.2 years (OECD, 2019a), which leads to large productivity losses. Around 92 million premature deaths from obesity-related diseases are projected in OECD, G20 and EU28 countries by 2050 (OECD, 2019a).

Current literature on the costs of premature mortality related to obesity is summarized in Table A4. The estimates of number of years lost due to obesity-related premature mortality vary across studies. Peeters *et al.* (2003) estimates that on average, 40-year-old obese women and men lose 7.1 and 5.8 years of life, respectively. Fontaine *et al.* (2003) makes his estimate for each point of the BMI scale starting from BMI = 25. He finds that years of life lost are larger for men than women and increase substantially with BMI, ranging from 3 to 13 years for men and from 3 to 8 years for women. In the Czech Republic, overweight-attributable reduction in life expectancy is estimated to be 3.5 years (OECD, 2019b). The obesity-related costs due to

premature mortality are evaluated as 395 million CZK for women and 800 million CZK for men in the Czech Republic in 2013 (Tuzarová, 2016). In general, the studies show that the costs are larger for men than women. This may have several explanations: men usually have higher wages, their retirement age is higher than women's or their prevalence of obesity may be higher.

2.3 Estimates from the Czech Republic

Only a few studies estimated the social costs of obesity in the Czech Republic. Hodycová (2009) focused purely on direct costs of obesity in 2007 which were estimated as 9.5 billion CZK, of which 2.6 billion CZK was pharmacotherapy. Roubík (2011) states the pharmaceutical costs of 3 main obesity-related comorbidities (DM type II, cardiovascular diseases and cancers) to be 8.3 billion CZK and total healthcare costs of these comorbidities to be 38.5 billion CZK (12.8% of healthcare budget in 2009)[1]. Nejedlá (2014) estimated direct and indirect costs of obesity to be 20.3-42.5 billion CZK and 17.2-37.8 billion CZK, respectively. However, these estimates are largely based on other (foreign) studies. Tuzarová (2016) described the direct and indirect costs of obesity in 2013, including 18 comorbidities, absenteeism and premature mortality. The overall costs are quantified as 12.1 billion CZK (7.6 billion CZK direct costs, corresponding to 3.45% of healthcare costs in 2013; 4.5 billion CZK indirect costs) and correspond to 0.3% of GDP in 2013.

3 Methodology

The economic burden of disease can be estimated using three approaches (Bloom *et al.*, 2012):

1. The cost-of-illness (COI) approach
2. The value of lost output approach (the economic growth approach)
3. The value of statistical life (VSL) approach

The COI approach views the economic burden of disease as the sum of several categories of direct and indirect costs. Direct costs are the visible costs related to the diagnosis and its treatment (e.g. medical care costs). Indirect costs are the invisible costs associated with the lost productivity due to morbidity and mortality. Pain and suffering (known as intangible costs) may also be included in this approach, although it is not very common. The economic growth approach predicts the burden of disease based on a macroeconomic model which estimates the relationship between the disease and GDP based on the effect of this disease on labour force, capital and other factors. The VSL approach estimates the burden of disease based on willingness to pay to reduce the risk of disability/death (Bloom *et al.*, 2012). As each of these approaches views the burden of disease from a different perspective, refers to a different time frame and relies on different data and assumptions, the results are not directly comparable (Bloom *et al.*, 2012). In this paper, we present the economic burden of obesity using the COI approach, as it is the most common approach used (WHO, 2009).

There are two types of approaches within the COI methodology:

1. The prevalence approach, which estimates the costs of all new and pre-existing cases in one year, including years lost due to premature death discounted to present value.
2. The incidence approach, which estimates lifetime costs of all new cases/deaths in given year.

[1] These are the total healthcare costs of the comorbidities, not the costs attributable to obesity.

The prevalence approach is used in our analysis as it is more useful when assessing the current economic burden of illness. The incidence approach is more suitable for assessing the expected impact of illness in the future (WHO, 2009).

3.1 Direct costs

Direct costs of illness include all resources related to its prevention, treatment and rehabilitation (WHO, 2009). These costs include both medical and non-medical costs (e.g. cost of transportation to health care provider, cost of special home equipment or nutrition).

There exist three methods to calculate the direct costs of a disease (Segel, 2006).

1. Top-down approach, which measures the proportion of a disease that is due to exposure to the disease or risk factor. For example, it attributes part of costs of diabetes to obesity. This approach thus uses aggregated data, along with PAF (population attributable fraction), which is used to determine the attributable costs.

2. Bottom-up approach, which estimates direct costs by calculating the average costs per patient and multiplying them by the prevalence of the illness.

3. Econometric approach, which estimates the difference between the costs for population with the disease as opposed to the costs for population without the disease, usually via regression analysis.

To the best of our knowledge, only data for the top-down approach are currently available in the Czech Republic. Due to further data constraints specific to the Czech Republic, the direct costs are computed separately for pharmaceuticals and healthcare utilization costs, as the pharmaceutical costs are not included in the healthcare utilization costs. The reason is that the healthcare utilization costs are documented with International Classification of Diseases (ICD) codes, whereas pharmaceutical costs are documented with ATC (Anatomical Therapeutic Chemical) classification codes, thus the pharmaceuticals are omitted from the healthcare utilization costs and need to be added separately.

3.1.1 Healthcare utilization costs

Healthcare utilization costs include the costs of in-patient and out-patient care, follow-up care, diagnostics, laboratories etc. To estimate these costs, we take the following steps:

1. Identify the comorbidities of obesity. These are the diseases that are more likely to occur if a person suffers from obesity.

2. Find the relative risk (RR) of each comorbidity. That is, how much more likely is a disease to occur in population with obesity as opposed to population with normal weight. $RR = \frac{r_1}{r_2}$, where r_1 is is the probability of disease at obese population and r_2 is the probability of disease at normal weight population.

3. Find prevalence (p) of obesity in the Czech Republic.

4. Compute PAF (population attributable fraction). PAF tells us what fraction of disease's costs is attributable to obesity:

$$PAF = \frac{p \cdot (RR - 1)}{p \cdot (RR - 1) + 1}$$

5. Find healthcare utilization costs associated with each comorbidity.

6. Compute the healthcare utilization costs attributable to obesity:

$$TC = \sum_d PAF_d \cdot C_d,$$

where TC are the healthcare utilization costs attributable to obesity and C are the healthcare utilization costs associated with diagnosis d.

3.1.2 Costs of pharmacotherapy

Since healthcare utilization costs do not contain the costs of pharmacotherapy[2], we include these separately. In the Czech Republic, data on costs of pharmacotherapy are classified by ATC cost groups. Therefore, it is crucial to identify the ATC groups which are related to obesity. As in the case of healthcare utilization costs, only part of the costs that is directly related to obesity will be counted towards the costs of pharmacotherapy. This is achieved by using the PAF.

3.2 Indirect costs

Indirect costs of illness are the value of lost production because of reduced working time due to morbidity or mortality. This lost time is then multiplied by age- and sex-specific average gross wage rates to calculate the indirect costs (WHO, 2009). Indirect costs are substantial for many diseases and may even exceed the direct costs (Segel, 2006).

Three primary approaches exist to estimate the indirect costs (Segel, 2006):

1. Human capital approach (HCA), which estimates the value of lost productivity due to illness per individual and then extrapolates it to the whole population. For mortality, the present value of future lost earnings is computed using a discount rate. The method also includes housework, which is valued as the opportunity cost of hiring a replacement from the labor market.

2. Friction cost approach (FCA), which also measures the value of lost productivity due to illness per individual, but only for the time it takes to replace the worker. It thus assumes that productivity losses only occur during the time the new employee is being hired and trained, known as the friction period.

3. Willingness to pay approach (WTP), which estimates the indirect costs by quantifying how much a person is willing to pay in order to reduce the risk of illness or mortality.

Human capital approach is most commonly used method in estimating indirect costs of illness (Segel, 2006). The other two methods are rarely used in COI studies as they require extensive surveys of preferences or data on length of friction period (for more detail, see the discussion). HCA will thus be used for estimation of indirect costs in this study.

We include three common components of indirect costs: absenteeism, presenteeism and premature mortality. We are interested in assessing all the lost productivity due to above mentioned components of indirect costs, which is why the productivity loss during "non-working" time must be included as well (Effertz *et al.*, 2016). The total lost productivity is the sum of paid and unpaid work. Paid work is valued by gender- and age-specific gross salary, whereas unpaid work is valued by the average salary of a household worker[3]:

$$P_{ag} = PW \cdot GS_{ag} + UW \cdot W_{HW},$$

[2] ICD-10 codes are not available for prescribed medicaments.

[3] We approximate this by average wage of cleaning services worker from ISPV (2020).

where P refers to age- (a) and gender- (g) specific productivity lost, PW stands for the amount of paid work, GS_{ag} refers to age and gender-specific gross salary, UW stands for the amount of unpaid work and W_{HW} stands for the wage of household worker. For simplicity, we assume that the wages of obese and non-obese individuals are the same. The productivity lost from paid work is considered until the retirement age (63.2 years for men and 62.7 years for women, OECD (2018)), whereas productivity from unpaid work is considered until the age of 76 for men and 82 for women (average life expectancy according to ČSÚ (2020a)).

3.2.1 Absenteeism

Absenteeism refers to absence from work due to illness. To calculate the number of days absent from work attributable to obesity, we need to know the terminated cases of incapacity for work for obesity-related comorbidities (defined by ICD-10 classification).

The number of days spent absent from work due to obesity are computed as:

$$DA\_obesity_{adg} = DA_{adg} \cdot PAF_{adg},$$

where DA_{adg} stands for age- (a), diagnosis- (d) and gender- (g) specific days absent. Total costs due to obesity-related absenteeism are monetarily valued as:

$$IC\_abs = \sum_{d} DA\_obesity_{adg} \cdot P_{ag},$$

where IC stands for indirect costs.

3.2.2 Presenteeism

Presenteeism refers to the lost productivity when present at work, because employees cannot work at full capacity due to health constraints related to obesity (for example fatigue or movement limitation). Measurement of presenteeism is more complicated compared to absenteeism and relies on surveys (e.g. EQ-5D, Work Productivity and Activity Impairment questionnaire).

To the best of our knowledge, no such survey has been conducted in the Czech Republic so far, which is why we use data from other studies based on literature review. Yearly lost productivity due to presenteeism will be valued as:

$$IC\_pres = \sum_{g} p_g \cdot E_g \cdot PL_g \cdot P_g$$

where $p_g \cdot E_g$ is the number of obese people in labour force (p is prevalence of obesity in working-age population, i.e. 25-64 years old), PL stands for productive days lost due to presenteeism and P_g is the gender-specific valuation of paid and unpaid work.

3.2.3 Premature mortality

As obese people have lower life expectancy, there are also costs associated with premature mortality. PAF are used to determine what amount of productive years lost due to each comorbidity is attributable to obesity. Many COI studies also compute the value of retirement years lost. Not including this would imply that the statistical life of retired people has no value (WHO, 2009). We follow the approach of Konnopka *et al.* (2011) and value the retirement years by a household worker wage.

In COI studies, costs are computed for one given year, but in case of premature mortality,

the net present value of future lost earnings is included (Segel, 2006). The value of productivity losses is discounted to present value using a discount rate:

$$NPV = \sum_{t=0}^{n} \frac{FV}{(1+i)^t},$$

where i is the discount rate, FV stands for future value and t is the amoun of years lost. The discount rate usually ranges between 0 and 10% (Segel, 2006). We use the discount rate of 3% as suggested by Segel (2006), but because the discount rate affects the results largely, we also perform sensitivity analysis with discount rate 1% and 5% (Hodgson & Meiners, 1982).

The obesity-attributable costs of premature mortality are computed as:

$$IC_{mort} = PAF_{adg} \cdot M_{adg} \cdot \left(0.5 \cdot P_{ag} + \sum_{t=1}^{n} \frac{P_{ag}}{(1+i)^t}\right),$$

where M_{adg} stands for age-, diagnosis- and gender- specific number of deaths. Only half of the productivity is accounted for in the first year ($A = 1$) to correct for different occurences of death during the year.

3.3 Sensitivity analysis

The robustness of our results is verified using sensitivity analysis, where we vary several essential parameters used in the evaluation of costs of obesity:

- PAF are recomputed using the 95% confidence interval of relative risks
- discount rate of 1% and 5% is used for computing the costs of premature mortality
- unpaid work is completely excluded from total costs
- presenteeism is computed for missing 1 day and 3 days of work (baseline value is 2 days)

4 Data

The data on prevalence of obesity in the Czech Republic are taken from the European Health Examination Survey (EHES) and the European Health Interview Survey (EHIS) from 2014, which are the latest results available[4]. These data have been collected by the Institute of Health Information and Statistics of the Czech Republic and the National Institute of Public Health in collaboration with the World Health Organization and Eurostat. The difference between EHIS and EHES is that EHIS contains self-reported data (collected via questionnaires) in population aged 15+ years, whereas EHES contains data measured by physicians in working population (25-64 years). These datasets were chosen because they are reported in 5-year cohorts which is convenient for precise computation of costs of obesity. We mainly use the data from EHES (these are considered most reliable since they are measured by physicians), which are completed with data from EHIS for the age cohorts 65+. The prevalence of obesity in population 15+ years is 25.3% for men and 22.9% for women (ÚZIS, 2014), while the prevalence in working population is 29.1 % for men and 24.7% for women (SZÚ, 2014).

The healthcare utilization costs and costs of pharmacotherapy in 2018 are obtained from the General Health Insurance Fund (GHIF), which is the largest insurance fund in the Czech Republic, covering majority of population. These costs are extrapolated to the whole population,

[4] A new survey started in 2019/2020, but the results have not been published yet.

assuming the GHIF has a representative sample of insured people in terms of the age, gender and costs. The extrapolation coefficient is equal to 1.79[5].

The data for computation of costs of absenteeism and premature mortality are obtained from the Institute of Health Information and Statistics of the Czech Republic. In particular, costs of absenteeism are computed based on data from the Information System Incapacity for Work, which provides the amount of days absent from work stratified by gender, 5-year age groups and diagnosis (ÚZIS, 2018b). Similarly, the costs of premature mortality are computed based on data from the Information System Deaths, which contains data about the number of deceased people due to each diagnosis, stratified by gender and 5-year age groups (ÚZIS, 2018a).

Paid work is valued by the average gross salary for each gender and age group in 2018, which is obtained from the Czech Statistical Office ČSÚ (2019). The value of unpaid work is approximated by the average wage of cleaning services workers, because the wage of household workers (which would be more convenient) is not available in the Czech Republic. The average hourly wage computed based on ISPV (2020) is 87 CZK/hour. The average amount of hours spent doing housework was estimated to be 3 hours for women and 2 hours for men (AVČR, 2016). The number of employed people aged 25-64 years in 2018 is obtained from the Eurostat (Eurostat, 2018).

5 Results

5.1 Direct costs

5.1.1 Healthcare utilization

Table A5 lists the relevant (i.e. significantly related) comorbidities of obesity along with the ICD-10 codes and PAF computed separately for men and women, based on the prevalence of obesity in the Czech Republic[6] and relative risks from Guh *et al.* (2009) and Dobbins *et al.* (2013). The largest PAF is in the case of Type II diabetes mellitus: 72.1% (64.6, 78.5) for women and 59.0% (53.3, 64.3) for men. This means that for women (men), 72% (59%) of healthcare utilization costs due to diabetes type II are attributable to obesity.

Total costs of healthcare utilization due to obesity are reported in Table 1 and amount to 10.3 billion CZK. The largest portion of these costs is due to type II diabetes mellitus (2.2 billion CZK, 21.7%), ischemic heart disease (1.9 billion CZK, 18.4%) and osteoarthritis (1.7 billion, 16.9%). The other significant parts of costs are due to dorsalgia, hypertension and congestive heart failure.

5.1.2 Costs of pharmacotherapy

Table 2 shows the ATC groups included in the study based on Hodycová (2009) and Dee *et al.* (2015), and the costs attributable to obesity. Drugs used in diabetes make up the largest part of pharmacotherapy costs (782 million CZK), followed by antithrombotic agents (603 million CZK) used for the cure of cardiovascular diseases and antineoplastic agents (599 million CZK) used for the cure of cancer. Total pharmacotherapy costs attributable to obesity are 2.8 billion CZK. The costs of pharmaceuticals used for the treatment of obesity is 0 because the insurance companies do not cover these drugs anymore and patients need to fully cover these medicaments.

[5] In 2018, there were 5.95 million people insured at GHIF; Czech population is 10.65 million.

[6] PAF are used in 5-year age groups when the data allows it.

Table 1: Healthcare utilization costs

Diagnosis	**Costs (95% CI)**	**% of total costs**
Type II diabetes mellitus	2 233.2 (2007.0, 2431.6)	21.66%
Ischemic heart disease	1 894.1 (1610.9, 2658.5)	18.37%
Osteoarthritis	1 737.4 (1315.8, 2134.2)	16.85%
Dorsalgia	1 240.8 (956.8, 1529.2)	12.04%
Hypertension	633.9 (351.3, 932.6)	6.15%
Congestive heart failure	482.8 (110.7, 905.1)	4.68%
Kidney cancer	376.6 (317.5, 434.5)	3.65%
Colon cancer	362.0 (263.0, 464.1)	3.51%
Obesity	246.9 (246.9, 246.9)	2.40%
Cholelithiasis and cholecystitis	233.6 (33.5, 457.1)	2.27%
Pulmonary embolism	200.4 (148.5, 251.9)	1.94%
Asthma	165.9 (73.3, 265.0)	1.61%
Stroke	113.5 (71.3, 157.7)	1.10%
Breast cancer	113.1 (44.3, 187.6)	1.10%
Pancreatic cancer	79.7 (38.8, 124.4)	0.77%
Endometrial cancer	72.5 (65.5, 79.6)	0.70%
Leukemia	53.3 (14.0, 94.4)	0.52%
Ovarian cancer	35.6 (25.9, 45.1)	0.35%
Gallbladder cancer	17.7 (7.3, 29.1)	0.17%
Malignant melanoma	15.6 (4.4, 27.4)	0.15%
Total	**10 308.7** (7 706.8, 13 455.9)	**100%**

Note: values are in millions CZK

Historically, the value of these particular costs has been declining as the insurance companies contributed less and less to cover these medicaments (Hodycová, 2009).

Table 2: Costs of pharmacotherapy

ATC classification	**ATC code**	**Costs (95% CI)**
For the cure of obesity		
Antiobesity preparations, excluding diet products	A08	0 (0, 0)
For the cure of diabetes mellitus		
Drugs used in diabetes	A10	781.6 (702.4, 851)
For the cure of cardiovascular diseases		
Antithrombotic agents	B01	524.5 (319, 812.2)
Cardiac therapy	C01	73.7 (44.8, 114.2)
Antihypertensives	C02	84.6 (46.9, 124.4)
Diuretics	C03	89.4 (49.5, 131.5)
Beta blocking agents	C07	113.3 (62.8, 166.7)
Calcium channel blockers	C08	76.3 (42.3, 112.2)
Agents acting on the reninangiotensin system	C09	505.7 (280.2, 744)
Lipid modifying agents	C10	379.3 (230.7, 587.4)
For the cure of cancer		
Antineoplastic agents	L01	39.9 (27.9, 52.4)
For the cure of arthrosis		
Anti-inflammatory and antirheumatic products	M01	111.2 (85.7, 137)
Total		**2 779** (1 892, 3 833)

ATC groups chosen based on Hodycová (2009) and Dee et al. *(2015); values are in millions CZK*

5.2 Indirect costs

5.2.1 Absenteeism

Out of 7.9 million days lost due to all obesity-related diseases in men in 2018, 2.8 million days were attributable to obesity. For women, 8.3 million days were lost due to all obesity-related diseases, out of which 2.3 million were attributable to obesity. These days are valued by age- and gender-specific gross wage. Total costs of absenteeism are 8.7 billion CZK (3.6 billion CZK for women and 5.1 billion CZK for men) and 7.6 billion CZK (3 billion CZK for women and 4.6 billion CZK for men) after excluding the value of unpaid work. The results are summarized in Table 3.

Table 3: Results - absenteeism

	days lost	INCLUDING UNPAID WORK	EXCLUDING UNPAID WORK
Women (25-64)	2 287 998	3 616	3 020
Men (25-64)	2 795 709	5 080	4 594
Total	**5 083 707**	**8 695**	**7 614**

Note: values are in millions CZK

5.2.2 Presenteeism

We calculate the costs of presenteeism based on the assumption that obese workers miss on average 1-3 days a year due to obesity-related presenteeism. The baseline value considered in our model is 2 days of work lost, which is associated with costs of 6.3 billion and 5.5 billion after excluding the value of unpaid work. The costs of presenteeism for 1 and 3 days amount to 3.2 and 9.5 billion CZK respectively (2.8 and 8.3 billion CZK, respectively, after excluding the value of unpaid work). The costs of presenteeism are summarized in Table 4.

Table 4: Results - presenteeism

	INCLUDING UNPAID WORK			EXCLUDING UNPAID WORK		
Days lost	1 day	2 days	3 days	1 day	2 days	3 days
Women	1 174	2 348	3 522	978	1 957	2 935
Men	1 984	3 969	5 953	1 793	3 586	5 379
Total	**3 158**	**6 316**	**9 475**	**2 771**	**5 542**	**8 314**

Note: values are in millions CZK

5.2.3 Premature mortality

Total number of deaths due to all obesity-related diseases in 2018 was 25 753 for women (6 923 were attributable to obesity) and 22 021 for men (3 793 were attributable to obesity). Most deaths were due to ischemic heart disease (almost 12 000 for both men and women). Overall, women lost 63 439 years due to obesity, from which 2 554 years were productive years (years that would have been spent working if they had not died prematurely) and 60 885 years were unproductive. Men lost in total 51 116 years due to obesity, from which 5 648 years were productive years

and 45 468 years were unproductive. The reason why the productive years make such a small part of total years lost due to obesity is that most people die due to obesity-related diseases after retirement. Using the discount rate of 3%, the costs of premature mortality due to obesity are 9.2 billion CZK, including unpaid work (4.9 billion CZK for women and 4.3 billion CZK for men). The costs are higher for women even though the amount of productive years lost is lower compared to men. This is because women lose more unproductive years than men - in fact, twice as many deaths due to obesity related diseases occur in women after retirement as opposed to men. After excluding the unpaid work, the costs are 3.5 billion CZK (0.9 billion for women and 2.6 billion CZK for men). In this case, the costs for women are lower because they lose fewer productive years than men. Table 5 shows the results for different discount rates.

Table 5: Results - premature mortality

	INCLUDING UNPAID WORK			EXCLUDING UNPAID WORK		
Discount rate	1%	3%	5%	1%	3%	5%
Women	5 472	4 917	4 477	1 041	916	817
Men	4 922	4 332	3 871	2 955	2 618	2 349
Total	**10 394**	**9 249**	**8 347**	**3 997**	**3 534**	**3 166**

Note: values are in millions CZK

5.3 Summary of results

Total costs of obesity in the Czech Republic for the year 2018 are summarized in Table 6 and amount to 37.3 billion CZK. In macroeconomic terms, this equals 0.7% of GDP in 2018 (ČSÚ, 2021). The indirect costs account for majority of the costs: 24.3 billion CZK (65%), whereas the direct costs are 13.1 billion CZK (35%), which accounts for 3% of total healthcare costs in 2018[7] (ČSÚ, 2020b).

Table 6: Summary of results

	CZK	**% of total costs**
Direct costs	**13 088.1**	**35.0%**
Healthcare utilization	10 308.7	27.6%
Pharmacotherapy	2 779.4	7.4%
Indirect costs	**24 260.7**	**65.0%**
Absenteeism	8 695.1	23.3%
Presenteeism	6 316.5	16.9%
Premature mortality	9 249.1	24.8%
TOTAL	**37 348.8**	**100.0%**

Note: values are in millions CZK

5.4 Sensitivity analysis

Table 7 shows the change in costs attributable to obesity as the key parameters are varied. Total costs range between 29.5 billion CZK (-21.1% from baseline values) and 47.3 billion CZK

[7] Total healthcare costs in the Czech Republic were 430.9 billion CZK in 2018 (ČSÚ, 2020b).

(+26.6% from baseline values). The largest changes result from using the low and high relative risks values (95% CI). These are also the only parameter changes which affect the direct costs. The largest negative change in indirect costs results from excluding the costs of unpaid work (-31.2%), while the largest positive change is due to high relative risks values (+23.6%).

Table 7: Sensitivity analysis

	Direct costs	% change	Indirect costs	% change	Total costs	% change
Baseline	13 088.1	–	24 260.7	–	37 348.8	–
Relative risks low values	9 598.9	-26.7%	19 853.4	-18.2%	29 452.3	-21.1%
Relative risks high values	17 288.9	32.1%	29 980.7	23.6%	47 269.6	26.6%
Discount rate 1%	13 088.1	0%	25 405.4	4.7%	38 493.5	3.1%
Discount rate 5%	13 088.1	0%	18 177.3	-25.1%	31 265.4	-16.3%
Excluding unpaid work	13 088.1	0%	16 690.6	-31.2%	29 778.7	-20.3%
Presenteeism 1 day	13 088.1	0%	21 102.5	-13%	34 190.6	-8.5%
Presenteeism 3 days	13 088.1	0%	27 418.9	13%	40 507.0	8.5%

Note: values are in millions CZK

6 Discussion

The goal of this study was to estimate the social costs of obesity in the Czech Republic in 2018. The resulting costs are equal to 37.3 billion CZK, which corresponds to 0.7% of GDP. This result is in accordance with existing studies which suggest that the impact of overweight and obesity is 0.45% to 1.62% of GDP (OECD, 2019a), although our study focuses purely on the costs of obesity, not including the costs of overweight.

The direct costs of overweight and obesity are estimated to be 13.1 billion CZK, corresponding to 3% of healthcare expenditures in 2018. International studies estimate the impact of overweight and obesity on health expenditures in the range of 2% to 7.9% (OECD, 2019a), but each study includes different amount of comorbidities and various components of direct costs. In the Czech Republic, direct costs of obesity have been previously estimated as 9.5 billion CZK in 2007 (Hodycová, 2009) and 7.6 billion CZK (excluding the costs of pharmacotherapy) in 2013 (Tuzarová, 2016). Our results correspond to these studies and the rising prevalence of obesity.

Concerning the indirect costs, the costs of absenteeism are equal to 8.7 billion CZK including unpaid work, which exceeds the previous estimate which was 3.2 billion CZK in 2013 (Tuzarová, 2016). This can be explained by exclusion of unpaid work, use of average net salaries and also increasing trend in number of days lost due to obesity-related absenteeism from 3.7 million days in 2013 to 5.1 million days in 2018. The costs of presenteeism amount to 6.3 billion CZK including unpaid work if we assume that on average, 2 productive days are lost annually due to obesity-related presenteeism. This assumption is based on current literature, because obesity attributable presenteeism has not been measured in the Czech Republic so far, so the result should be taken with caution. This is the reason why we include sensitivity analysis for presenteeism, evaluating the costs for 1 and 3 productive days lost. Typically, costs of presenteeism exceed the costs of absenteeism in many studies (Dee *et al.*, 2015; OECD, 2019a), so it is possible that the costs of presenteeism are underestimated. The costs of premature mortality are 9.2 billion CZK including unpaid work. These costs are higher for women than men, because women have higher life expectancy and most deaths in women occur after retirement (6 409 deaths in women

vs. 2 850 in men). When the unpaid work is excluded, the costs are much lower: 3.5 billion CZK. The reason is that most deaths occur after retirement (out of 10 716 deaths, 1 457 occured in productive age). When unpaid work is excluded, the value of years lost due to premature mortality after retirement is not accounted for at all. The costs are much lower for women than men, which is caused by lower wages and the fact that most deaths in women occur after retirement, so women lose fewer productive years due to premature mortality. In general, the indirect costs without unpaid work are higher for men than women because men have higher average salaries. When unpaid work is included, the difference between costs slightly decreases since women perform more daily unpaid work than men.

Cost-of-illness methodology is the most common measurement approach to estimate the burden of disease, but it has certain drawbacks. For instance, a variety of approaches within the COI methodology can be taken (HCA, FCA, WTP), which limits the comparability of results across studies. Additionally, it measures the value of individual's life only in terms of the production evaluated by average wage, ignoring other dimensions of illness and death, such as pain and suffering and lower quality of life (WHO, 2009). The COI approach shows how much money could be saved had the disease not existed and when performed with a clear explanation, COI studies represent an important analytic tool in public health policy (Segel, 2006).

In this study, human capital approach is used to estimate the indirect costs of obesity. This method has been mainly criticised for assuming full employment in the economy. This relates mainly to evaluation of costs of absenteeism where every day the worker misses is regarded as lost production. However, the approach disregards the fact that the work can be made up by the worker after his/her return, or it can be done by his/her colleagues, which would mitigate the costs to the employer (WHO, 2009). This drawback is solved by using the friction cost approach, which counts the productivity losses only for the time it takes to replace the absent worker. The FCA approach also has its limitations – for example, assuming that the sick worker is replaced by a previously unemployed person would imply that sickness and absence leads to lower unemployment, which is not supported empirically (WHO, 2009). Furthermore, it requires data on productivity losses in the friction period only, which are rarely available (Segel, 2006). The HCA approach is further criticised for evaluating the costs based on age- and gender-specific wages, implying that people earning lower wages are less valuable for the society. Willingness-to-pay approach mitigates this problem, however, it is not often employed as it requires extensive surveys of preferences and the results highly depend on the individuals' subjective responses to hypothetical questions (Segel, 2006).

There are several limitations in our study, mainly related to availability of relevant data. Firstly, we use the data on prevalence of obesity from 2014, even though we estimate the costs of obesity in 2018. The reason is that no more recent (and reliable) data are available in the Czech Republic currently. This should only have a marginal effect on our results, since based on recent trends, we assume that the prevalence of obesity either stayed the same or increased, which would imply even larger social costs (OECD, 2019a). Secondly, the relative risks used in computations of population attributable fractions (PAF) are based on studies from the USA, as these data have not been collected in the Czech Republic so far. The U.S. studies account for gender, age, race and smoking status in the estimations, but there is still some uncertainty involved in applying these relative risks in the Czech Republic. This is the reason why we also perform a sensitivity analysis and compute the social costs with 95% confidence interval values. The lower-bound estimate results in total costs of 29.5 billion CZK (-21.1% from the baseline estimation of costs), while the upper-bound estimate results in total costs of 47.3 billion CZK (+26.6% from baseline). Thirdly, there are no data available for estimation of costs of

presenteeism in the Czech Republic, which is why we do extensive literature review on studies examining obesity-related presenteeism in other countries. Based on these studies, we make an assumption that 2 working days are annually lost on average due to obesity. This is in our opinion rather conservative assumption, nevertheless, there is large uncertainty involved in the evalution of costs of presenteeism, which is why we perform sensitivity analysis where we compute the costs for 1 day lost and 3 days lost annually due to presenteeism. The effect on total costs is $\pm 8.5\%$. It is evident that foreign data have limited relevance in the Czech Republic. For further improvement of the analysis, it will be necessary to conduct a survey in the Czech Republic to obtain more relevant data.

Our study demonstrates that the costs of obesity are considerable in the Czech Republic and comparable to the costs of smoking and alcohol consumption, which are estimated as 14.5 billion CZK (0.8% of GDP) in 1999 (Ross, 2004) and 59.5 billion CZK (1.2% of GDP) in 2016 (Chadimova *et al.*, 2019), respectively. However, smoking and alcohol consumption have received more consistent attention in clinical practice and public health policy (Sturm, 2002). Similarly as alcohol consumption and smoking, early onset of obesity or overweight in childhood significantly increases the probability of being obese in adulthood (Whitaker *et al.*, 1997). This implies that obesity is a serious disease which should no longer be regarded as a lifestyle issue but needs to be recognised as a serious medical condition (Schmid *et al.*, 2005).

7 Conclusion

The rising prevalence of obesity has been putting an increasing preassure on the health care system and society, which will be further aggravated due to the COVID-19 pandemic. The goal of this study was to quantify the extent of this burden in the Czech Republic using data from 2018. The social costs of obesity are estimated using the cost-of-illness approach, which views the costs of an illness as the sum of direct and indirect costs. Total costs of obesity are estimated to be 37.3 billion CZK, which corresponds to 0.7% of GDP in 2018. Out of this, 35% (13.1 billion CZK) are attributable to direct costs and 65% (24.3 billion) are attributable to indirect costs. The direct costs account for 3% of total healthcare costs in 2018 with the largest part being attributable to type II diabetes mellitus. Within indirect costs, the largest part is attributable to premature mortality (9.2 billion CZK), absenteeism (8.7 billion CZK) and presenteeism (6.3 billion CZK).

Our study is the most comprehensive paper on the costs of obesity in the Czech Republic so far as it accounts for several groups of direct and indirect costs of obesity. These costs are substantial which is supported by the fact that they are comparable to the costs of smoking or alcohol consumption in the Czech Republic. Moreover, with rising prevalence of overweight and obesity in children and adults, these costs are likely to increase. A comprehensive, systemic program of multiple interventions should be implemented in order to increase awareness, reverse the trend of growing rates of obesity and save money in the long-term horizon.

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1 Appendix

Table A1: Literature review - direct costs

	n	country	method	number of comorbidities	population	normal weight	overweight	obesity	% of healthcare costs
Arterburn *et al.* (2005)	16 262	USA	econometric approach	N/A	18+	$2 424	$2 664	$2 984-4 399[1]	N/A
Finkelstein *et al.* (2005)	20 329	USA	econometric approach	N/A	18-64 women 18-64 men	0 (base)	$495 $169	$1 071-1 549[1] $392-1 591[1]	N/A
Cawley & Meyerhoefer (2012)	23 689	USA	econometric approach	NA	11-64	$1 763		$4 458	20.6%
Kleinman *et al.* (2014)[2]	72 778	USA	econometric approach	N/A	18+ women 18+ men	$4 142 $2 861	$4 583 $3 378	$6 328 $4 309	N/A
An (2015)	125 955	USA	econometric approach	N/A	18+ women 18+ men	0 (base)	N/A	$1 525 $1 160	N/A
Borg *et al.* (2005)	23 365	Sweden	econometric approach (total costs)	N/A	30-60 women 30-60 men	0 (base)	$101 million[3] $169 million		2.3%
Sander & Bergemann (2003)	N/A	Germany	top-down approach	4	25+	N/A	N/A	€2 billion	N/A
Konnopka *et al.* (2011)	N/A	Germany	top-down approach	16 (W), 17 (M)	18+	N/A	€4 854 million		2.1%
Lehnert *et al.* (2015)	N/A	Germany	top-down approach	16 (W), 17 (M)	18+	N/A	€8 647 million		3.27%
Schmid *et al.* (2005)	N/A	Switzerland	top-down approach	18	15+	N/A	CHF 1 077-1 615 million		2.3-3.5%
Kang *et al.* (2011)[4]	1.9 mil	Korea	top-down approach	7	20+	N/A	$270.5 million	$810.5 million	3.7%
Dee *et al.* (2015)	N/A N/A	Northern Ireland Republic of Ireland	top-down approach	16	N/A	N/A	€127 million €437 million		2.8% 2.7%
Krueger *et al.* (2015)	N/A	Canada	top-down aproach	16 13	12+ women 12+ men	N/A	$4.3 billion $4.8 billion	$7.6 billion $6.6 billion	6.7%
Hodycová (2009)	N/A	Czech Republic	top-down approach	7[5]	18+	N/A	N/A	9.5 billion CZK[6]	5.2%
Tuzarová (2016)	N/A	Czech Republic	top-down approach	18 (W), 16 (M)	18+	N/A	N/A	7.6 billion CZK	3.45%
Effertz *et al.* (2016)	146 000	Germany	bottom-up approach	NA	15+	N/A	N/A	29.39 billion	7.9%[7]

[1] *range for obesity class I-III;* [2] *normal weight is classified as BMI < 27, overweight: $27 \leq BMI < 30$, obesity: $BMI \geq 30$;* [3] *values are converted from SEK by a rate US$1 = SEK8*

[4] *In Korea, classification of obesity according to BMI is different than in Europe (Overweight: 23-24.9 kg/m^2; Obesity I: 25-29.9 kg/m^2; Obesity II: $\geq$ 30 kg/m^2)*

[5] *cardiovascular diseases are taken as 1 comorbidity;* [6] *6.7 billion healthcare utilization, 2.6 billion pharmacotherapy;* [7] *percentage of healthcare costs stated in OECD (2019a)*

Table A2: Literature review - absenteeism

	n	country	measurement unit	population	normal weight	overweight	obesity
Konnopka *et al.* (2011)	N/A	Germany	number of days/year total yearly costs	15+	0 (base)	5 875 022 days €646 million[1]	
Lehnert *et al.* (2014)	7 990	Germany	yearly costs per person (days absent/year) yearly costs per person (days absent/year) total yearly costs	18-65 women 18-65 men 18-65	0 (base)	€284 (3.64 days) N/A (N/A) €2.18 billion[2]	€405 (5.19 days) €367 (3.48 days)
Lehnert *et al.* (2015)	N/A	Germany	number of days/year total yearly costs	15+	0 (base)	11 478 208 days €1.28 billion[3]	
Effertz *et al.* (2016)	146 000	Germany	total yearly costs	15+	0 (base)	N/A	€3.87 billion
Finkelstein *et al.* (2005)	25 427	USA	yearly costs per person (days absent/year) yearly costs per person (days absent/year)	18-64 women 18-64 men	$0 (base)/(3.4 days) $0 (base)/(3 days)	$93 (3.9 days) $6 (3 days)	$302-805 (5.2-8.2 days)[4] $70-436 (3.5-5 days)
Finkelstein *et al.* (2010)	24 140	USA	yearly costs per person (days absent/year) yearly costs per person (days absent/year)	18+ women 18+ men	0 (base)	$147 (1.1 days) $85 (0.5 days)	$407-1262 (3.1-9.4 days)[4] $277-1026 (1.6-5.9 days)
Dall *et al.* (2009)	225 mil	USA	yearly costs per person total yearly costs	18+	0 (base)	$47 $3.5 billion	$104-264[4] $3.9-6.8 billion
Andreyeva *et al.* (2014)	14 975	USA	yearly cost per person (days absent/year) total yearly costs	18+	0 (base)/(4.25 days) 0 (base)	N/A (4.48 days) N/A	$216-348 (5.42-6.13 days)[4] $8.65 billion
Kleinman *et al.* (2014)[2]	72 778	USA	yearly costs per person (days absent/year) yearly costs per person (days absent/year)	18+ women 18+ men	$890 (4.09 days) $615 (2.66 days)	$1046 (5.02 days) $640 (2.81 days)	$1 175 (5.81 days) $792 (3.7 days)
Kang *et al.* (2011)	1.9 mil	Korea	total yearly costs	20+ women 20+ men	0 (base)	$29.5 million $44.4 million	
Dee *et al.* (2015)	N/A	Northern Ireland Republic of Ireland	total yearly costs total yearly costs	N/A	0 (base)	€215 million €136 million	
Neovius *et al.* (2012)	45 920	Sweden	**lifetime** productivity losses	19-65 men	€12 500	€15 000	€16 100
Tuzarová (2016)	N/A	Czech Republic	number of days/year total yearly costs	24-60 women & 25-64 men	0 (base)	N/A	3.7 million days 3.2 billion CZK

[1] *€481 million without unpaid work;* [2] *€1.37 billion women and €0.81 billion men;* [3] *€858 million without unpaid work;* [4] *range for obesity class I-III*

[5] *normal weight: BMI* < 27*; overweight: BMI* > 27 *and* < 30

Table A3: Literature review - presenteeism

	n	country	measurement unit	gender	normal weight	overweight	obesity		
							class I	class II	class III
Boles *et al.* (2004)[1]	2 264	USA	productivity loss (%)	both	5.6	7.1			
			productivity loss (days)		14.0	17.6			
Pelletier *et al.* (2004)[1]	500	USA	productivity loss (%)	both	4.7	7.9			
			productivity loss (days)		11.8	19.8			
Burton *et al.* (2005)	28 375	USA	productivity loss (%)	both	0 (base)	N/A	1.5		
			productivity loss (days)			N/A	3.8		
Ricci & Chee (2005)	7 000	USA	weekly hours lost	both	4.2	4.2	4.8		
			productivity loss (days)		26.3	26.3	30		
Gates *et al.* (2008)[2]	341	USA (KY)	productivity loss (%)	both	3.3	3.1	2.5	4.2	
			productivity loss (days)		8.1	7.8	6.1	10.4	
Finkelstein *et al.* (2010)	10 262	USA	productivity loss (days)	women	0 (base)	0.9	6.3	11.0	22.7
	13 878			men		-3.3	2.3	5.8	21.9
Goetzel *et al.* (2010)[3]	10 026	USA	productivity loss ($)	both	1200	1402	1416		
			productivity loss (days)		5.8	6.8	6.9		
Kirkham *et al.* (2015)	17 089	USA	productivity loss (days)	both	4.2	N/A	N/A	4.7	
Gupta *et al.* (2015)	31 653	FRA, DE, IT	productivity loss (%)	both	16	15.6	17.6	20.4	29.2
		ESP, UK	productivity loss (days)		40	39.1	44.0	50.9	73.0

Productivity loss in days is annual; conversion from productivity loss in percent to productivity loss in days is done assuming 250 working days per year

[1] *compares normal weight against BMI<18.5 or >24.9;* [2] *compares BMI categories with BMI<24.9 (normal weight + underweight);* [3] *the study uses average wage rate $25.67/hour*

Table A4: Literature review - premature mortality

	n	country	measurement unit	discount rate	population	normal weight	overweight	obesity
Konnopka *et al.* (2011)	N/A	Germany	annual number of deaths total productivity lost	5%	15+	0 (base)	36 653 €3 381 million	
Lehnert *et al.* (2014)	N/A	Germany	annual number of deaths total productivity lost	5%	15+	0 (base)	47 964 €5 669 million	
Effertz *et al.* (2016)	146 000	Germany	annual number of deaths amount of lost years total productivity lost	2%	15+	0 (base)	N/A	101 886 2 072 million €23.12 billion
Fontaine *et al.* (2003)	23 659	USA	years of life lost per person	N/A	15-75 women 15-75 men	N/A	<1 year <1 year	3-8 years[1] 3-13 years[1]
Dall *et al.* (2009)	225 million	USA	total productivity lost per capita productivity lost	3%	18+	0 (base)	$1.9 billion $25	$6.9-25.9 billion[2] $182-1006[2]
Borg *et al.* (2005)	23 365	Sweden	total productivity lost	3%	30-60 women 30-60 men	0 (base)	$1.15 million 3.3 million	$64.0 million 298.5 million
Neovius *et al.* (2012)	45 920	Sweden	per capita productivity losses	3%	18+ men	€25 100	€31 800	€52 100
Dee *et al.* (2015)	N/A	Northern Ireland Republic of Ireland	total productivity lost	4%	18-75 18-75	0 (base)	€147 million €593 million	
Kang *et al.* (2011)	1.9 million	Korea	total productivity lost	6%	20+ women 20+ men	0 (base)	$70 million $374 million	
Tuzarová (2016)	N/A	Czech Republic	amount of lost years total productivity lost amount of lost years ($) total productivity lost	1.5%	25-60 women 25-64 men	0 (base)	N/A	5 440 years 395 million CZK 2 290 years 800 million CZK

[1] *range for different BMI groups, BMI = 24 is used as reference category;* [2] *range for obesity class I-III*

Table A5: Comorbidities of obesity

Diagnosis	ICD-10 code	PAF (%) and 95% CI	
		women	men
Asthma	J45	15.0 (7.6, 23.0)	9.7 (3.4, 16.5)
Dorsalgia	M54	29.1 (22.4, 36.0)	31.2 (24.2, 38.3)
Type II diabetes mellitus	E11, E13, E14	72.1 (64.6, 78.5)	59.0 (53.3, 64.3)
Ischemic heart disease	I20 - I25	32.3 (29.1, 35.5)	15.3 (11.3, 31.2)
Leukemia	C91-95	6.8 (1.8, 12.0)	–
Malignant melanoma	C43, D03	–	6.1 (1.7, 10.7)
Stroke	I69.4, I64	10.0 (5.8, 14.4)	11.3 (7.6, 15.3)
Obesity	E65, E66.0, E66.2, E66.8-66.9	100	100
Cholelithiasis and cholecystitis	K81, K80	23.0 (3.7, 44.8)	9.7 (1, 19.4)
Osteoarthritis	M15 - M19	17.9 (16.6, 19.1)	44.5 (30.6, 57.6)
Pulmonary embolism	I26	36.3 (26.8, 45.8)	38.6 (28.8, 48.3)
Endometrial cancer	C54.1, C55, D07.0, D39.0	33.5 (30.2, 36.7)	–
Kidney cancer	C64, C65, C66, D30.0-30.2	27.1 (24.0, 30.1)	17.1 (13.3, 20.8)
Breast cancer	D05, D24, D48.6, C50	2.9 (1.1, 4.8)	–
Pancreatic cancer	C25, D01.7, D13.6, D13.7	12.0 (3.7, 21.4)	24.4 (14.0, 35.4)
Colon cancer	C18, D12.0-12.6	13.0 (10.6, 15.5)	19.2 (12.9, 25.8)
Ovarian cancer	C56, D27, D39.1	6.0 (4.3, 7.6)	–
Gallbladder cancer	C23, C24, D13.5	15.7 (6.8, 25.4)	10.5 (4.1, 17.6)
Congestive heart failure	I50	15.0 (1.6, 30.7)	16.5 (5.7, 28.5)
Hypertension	I10-15	24.4 (11.8, 37.7)	17.4 (11.3, 23.7)

Source: Guh et al. *(2009), Dobbins* et al. *(2013). ICD codes are taken from de Oliveira* et al. *(2015)*

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