THE ECONOMIC BURDEN OF OVERWEIGHT AND OBESITY IN SWEDISH CHILDREN
– A LIFETIME PERSPECTIVE

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Executive Summary

The World Health Organisation (WHO) reports that the global prevalence of overweight or obesity among children and adolescents aged 5-19 years rose from 4% to 18% over four decades between 1975 and 2016. In 2016, 340 million children lived with overweight and obesity. A similar trend of increasing prevalence of overweight and obesity among children and adolescents has been observed in Sweden. For instance, data from the Swedish Public Health Authority show a doubled prevalence of overweight and obesity among 11-15-year-olds since 1990. Recently, the BEST study following 3,650 men born 1946–1991 in western Sweden reported increases in childhood and pubertal body mass index, BMI, per decade of 0.23 kg/m^2 and 0.27 kg/m^2, respectively. Other Swedish data has shown that obesity and overweight in children remain in many cases also through adolescence and continues into adulthood. However, these studies also show that the correlation is not complete and that individuals switch between different groups as measured by BMI (underweight, normal weight, overweight, and obese).

Swelife Prevention Childhood Obesity is a national initiative aiming to prevent overweight and obesity in preschool children aged 0-6 in Sweden. Swelife Prevention Childhood Obesity involves stakeholders from the public and private sector and has set a common goal to reduce overweight and obesity among in preschool children aged 0-6 years in Sweden by 2030 with measurements at both regional and at municipality level. As part of the initiative, Innovation Skåne and the Pediatric unit at Sahlgrenska University Hospital/Västra Götalandsregionen has engaged the Swedish Institute for Health Economics to estimate the costs of overweight and obesity in Swedish children and adolescents over a life-time horizon using a societal perspective. To capture the life-time consequences of childhood obesity, the study uses the following examples

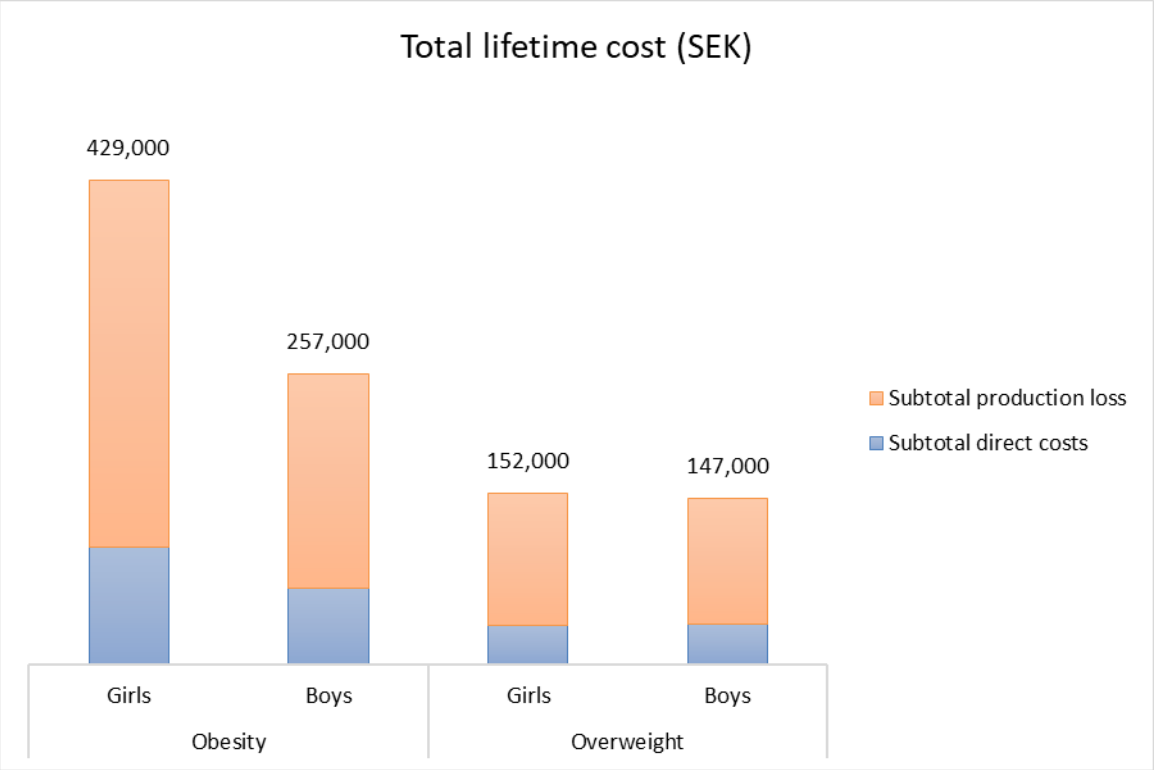
- The individual perspective following the child/adolescent over a life course
  - 6-year-old children with obesity and overweight, respectively. Results for boys and girls separately
  - 15-year-old adolescents with obesity and overweight, respectively. Results for boys and girls separately
- The national perspective following a birth cohort of 120,000 children over time. This analysis uses the data from the individual perspective and puts it into a broader perspective using the current observed prevalence of obesity and overweight among children and adolescents in Sweden.

- The municipality perspective reformulates the results for the municipality perspective using a middle-sized municipality with 50,000 inhabitants (presented in Appendix).

The study provides an estimation of the incremental lifetime cost of obesity or overweight at a specific age as compared to a person of the same sex and with normal weight at the same age. It is important to consider that the calculations take into account that weight status can change throughout life. This means that some overweight/obese children/adolescents will reach normal weight in adulthood and some normal weight children/adolescents will become overweight or obese later in life. Alternative assumptions regarding distribution of adult weight status were tested in sensitivity analyses.

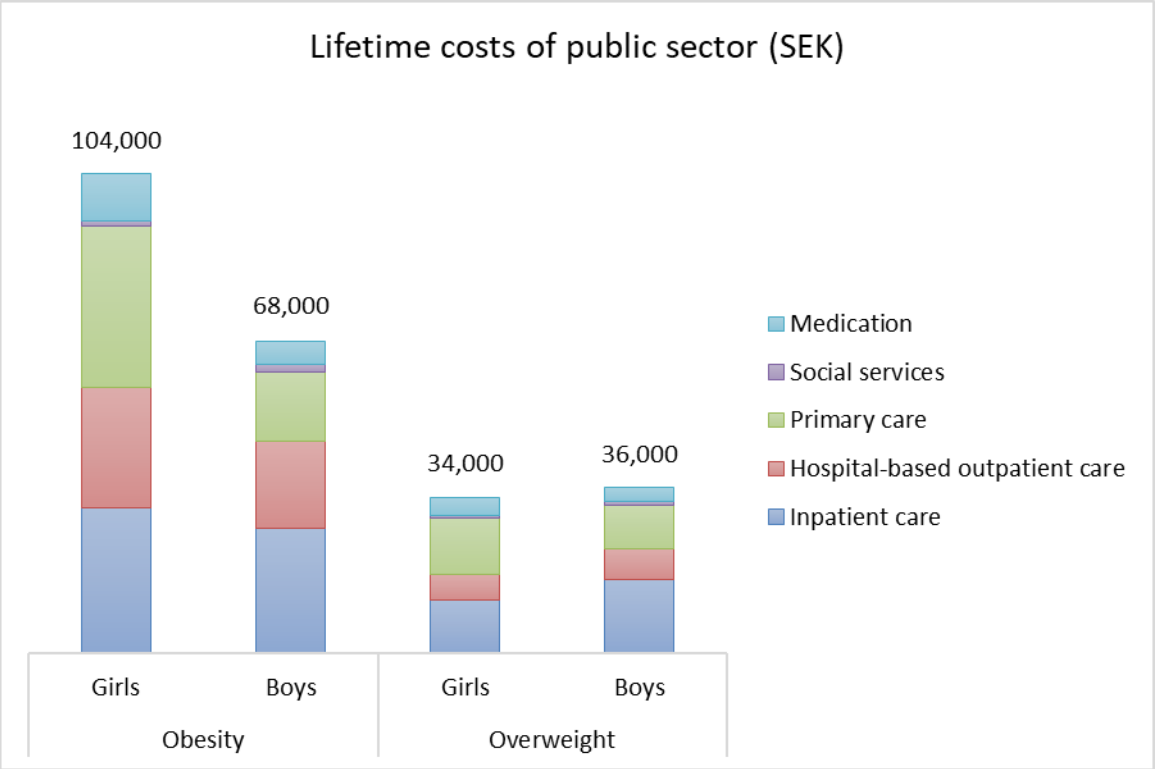
The study estimates costs of resource use in the health care sector and in social services from diseases that have been attributed to obesity and overweight in the literature. The study also estimates the cost burden resulting from production loss due to work absence related to health (i.e., sick leave). No data sources provide direct and complete links between obesity and overweight on the one hand and these outcomes (resource use, production loss) on the other. Instead, we have used established methods for calculating the attributable fraction of health care costs and work absence related to disease using data from The Swedish Association of Local Authorities and Regions and Försäkringskassan (the Swedish Social Insurance Agency) and risk increases from the epidemiological literature. A separate analysis explores the cost of lost production from higher risks of unemployment among people with obesity and overweight compared to normal weight. For these calculations, we rely on published data from a Swedish study using linked national register data which analyses the empirical evidence for an effect on educational level related to obesity and overweight.

The average incremental societal costs for a 6-year-old child with obesity, relative a 6-year-old child with normal weight, were estimated to approximately SEK 430,000 for girls and SEK 260,000 for boys. For an overweight 6-year-old, the incremental societal costs were considerably lower and more similar between girls and boys (~SEK 150,000). A major part of the costs (>75%) consisted of production losses from sick leave.



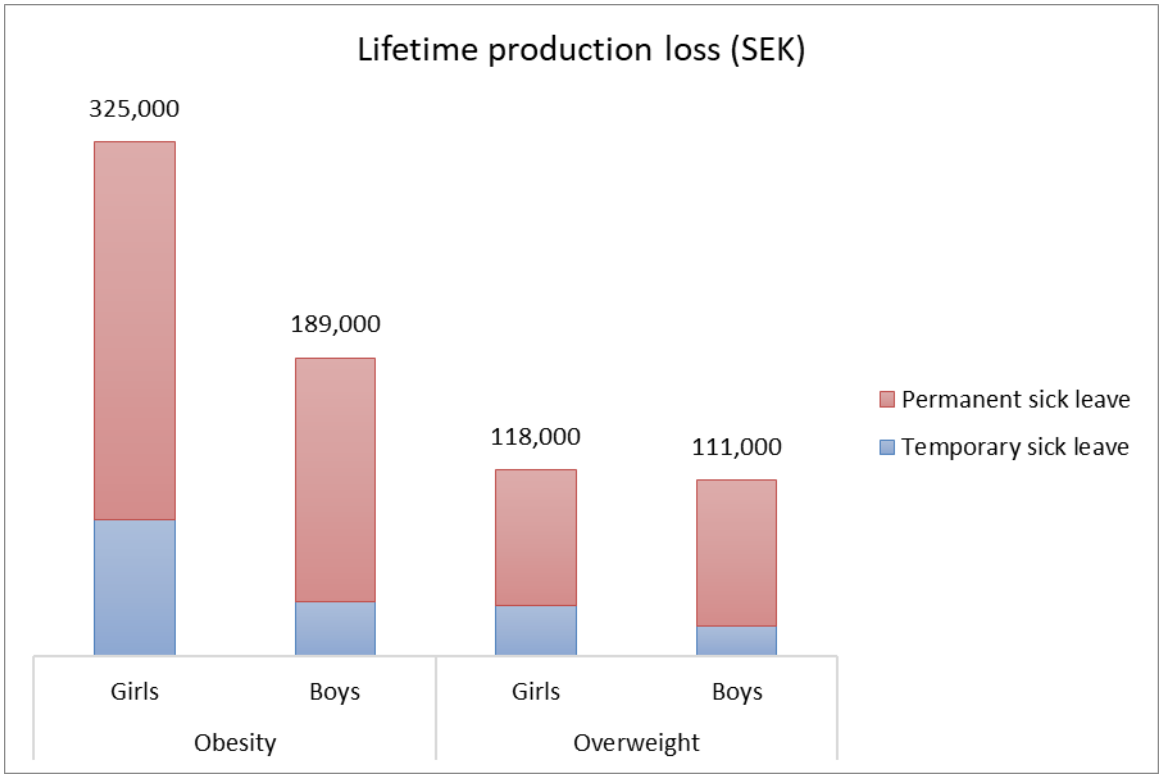
Average incremental total lifetime costs for a 6-year-old child with obesity or overweight. The costs are presented as the difference relative to the costs of a 6-year-old child of normal weight (Figure 3 in report)

The estimated average lifetime incremental direct costs of obesity for a 6-year-old child in terms of social services and health care were estimated to approximately SEK 100,000 for girls and SEK 70,000 for boys. Girls and boys with overweight had more similar estimated total public sector costs with an average of SEK 34,000 for girls and SEK 36,000 for boys.



Average incremental lifetime public sector costs (health care and social services) for a 6-year-old child with obesity or overweight. The costs are presented as the difference relative to the costs of a 6-year-old child of normal weight. (Figure 4 in the report)

The average incremental costs of production loss due to temporary and permanent sick leave were estimated to approximately SEK 330,000 and 190,000 among obese 6-year-old girls and boys, and approximately SEK 120,000 and 110,000 among overweight girls and boys. When including the costs of lost production due to unemployment linked to educational level, cost of production loss were in the range 90-100% larger (~SEK 650,000 and ~360,000 among obese girls and boys, and ~SEK 230,000 and ~220,000 among overweight girls and boys – results presented separately in Figure 19 in the report).



Average incremental lifetime costs of production losses for a 6-year-old child with obesity or overweight. The costs are presented as the difference relative to a 6-year-old child of normal weight. (Figure 5 in report)

The incremental cost for obesity/overweight of 6-year-old children in Sweden over a lifetime were estimated to SEK 1.8/2.1 billion (the results are presented in Figure 6 in the report). That the costs of overweight exceeded cost of obesity on a national level depend on a higher prevalence of overweight compared to obesity among Swedish children.

This study combines the growing literature on lifelong consequences of excess weight in childhood with data from surveys and population-based statistics with the aim of estimating the economic burden of excess weight in childhood and adolescence. The findings indicate that excess weight in childhood and adolescence can contribute to considerable societal costs over a lifetime. The calculations clearly demonstrate that, based on the current situation, healthcare costs contribute to a small proportion of total costs mainly represented by a higher disease burden in adulthood. Instead, the largest proportion of costs are attributed to different types of production losses. The study also

indicates that, although obesity is more costly than overweight for the individual child/adolescent, overweight in contribute to more costs on a national level due to the high prevalence.

Svensk sammanfattning

Svensk sammanfattning

Enligt världshälsoorganisationen (WHO) har den globala prevalensen för fetma eller övervikt hos barn och ungdomar i åldern 5 till 19 år ökat från 4% till 18% mellan åren 1975 och 2016. Under 2016 beräknades 340 miljoner barn i världen har övervikt eller fetma. En liknade trend med ökning av fetma och övervikt hos barn och ungdomar har även rapporterats i Sverige. Exempelvis visar data från Folkhälsomyndigheten att prevalensen för fetma och övervikt har dubblerats för åldersgruppen 11 till 15 år sedan 1990. Vidare har den så kallade BEST-studien, som följer 3 650 män födda i västsverige mellan 1946 och 1991, rapporterat att det för varje årtionde har skett en ökning i BMI med 0.23 kg/m^2 under barndomsåren och 0.27 kg/m^2 under ungdomsåren för männen i studien. Annan data från Sverige har visat att övervikt och fetma bland barn ofta bibehålls genom ungdomen och vidare in i vuxenlivet. Korrelationen mellan vikt i barndom/ungdomsår och vuxen ålder är dock inte absolut och individer kan växla mellan olika viktstatus (undervikt, normalvikt, övervikt och fetma) i olika stadier av livet.

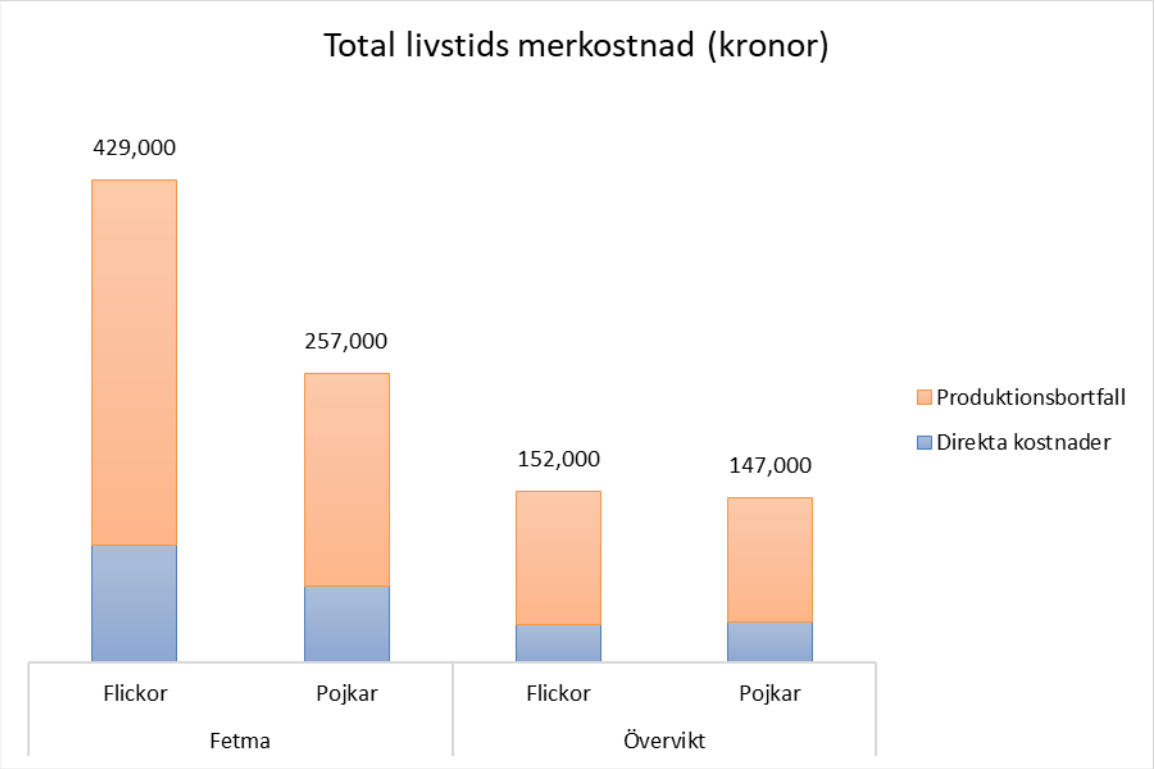
Swelifes projekt Prevention barnfetma är ett nationellt initiativ med målet att förebygga övervikt och fetma bland barn i förskoleåldern (0–6 år) i Sverige. Projektet, som består av partners från såväl offentlig som privat sektor, har satt det gemensamma målet att vid 2030 ha minskat övervikt och fetma bland 0–6-åringar i Sverige på både regional och kommunal nivå. Som en del av initiativet har Innovation Skåne och Avdelningen för pediatrik vid Sahlgrenska universitetssjukhuset/Västra Götalandsregionen gett Institutet för hälso- och sjukvårdsekonomi (IHE) i uppdrag att beräkna samhällskostnaderna för fetma och övervikt bland svenska barn och ungdomar över en livstid. För att fånga dessa kostnader har studien utgått från följande exempel:

1. Det individuella perspektivet som över en hel livstid följer:
    - 6-åriga barn med fetma eller övervikt; resultat för flickor och pojkar separat.
    - 15-åriga ungdomar med fetma eller övervikt; resultat för flickor och pojkar separat.
2. Det nationella perspektivet som följer en födelsekohort med barn över tid. I denna analys sätter man kostnader för individen i ett bredare perspektiv utifrån aktuella prevalensdata för fetma och övervikt bland barn och ungdomar i Sverige.
3. Det kommunala perspektivet som sätter kostnaderna i en kontext relevant för en medelstor kommun med 50 000 invånare (presenteras i Appendix).

Siffrorna från studien representerar en uppskattning av medelvärdet av merkostnader för barn/ungdomar med fetma eller övervikt vid en viss ålder jämfört med personer av samma kön med normalvikt vid samma ålder. Det är viktigt att ha i åtanke att beräkningarna tar hänsyn till växlingar mellan viktstatus över livet vilket innebär att en viss andel av barn med fetma eller övervikt kommer bli normalviktiga vid vuxen ålder. Likaså kommer en viss andel normalviktiga barn vid samma ålder få övervikt eller fetma senare i livet och därmed ackumulera högre kostnader.

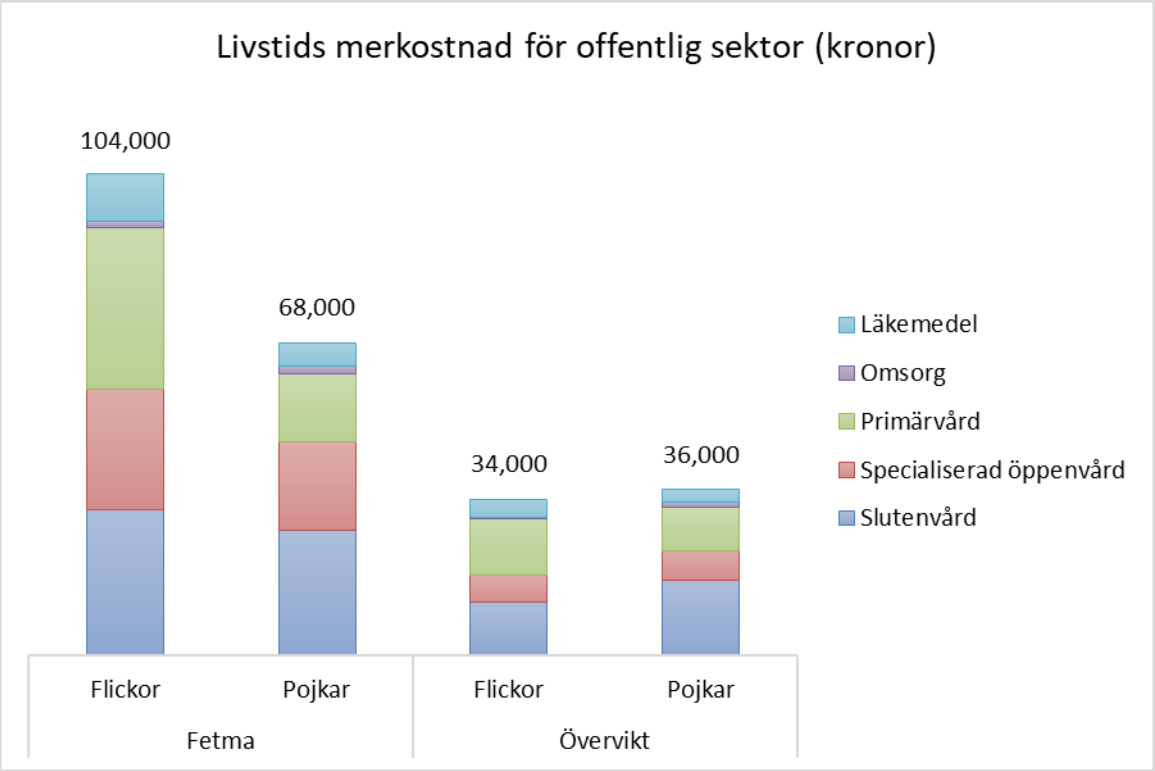
Beräkningarna summerar kostnader för resursanvändning i sjukvården och socialtjänst som i litteraturen har kopplats till fetma och övervikt. Dessutom beräknas kostnader av produktionsförluster relaterat till sjukfrånvaro. Det finns inga källor som ger en komplett och direkt koppling mellan dessa utfall (resursanvändning och produktionsförluster) och fetma/övervikt. I stället har vi i studien använt etablerade metoder för att beräkna tillskrivningsfaktorer genom att kombinera data från Sveriges Kommuner och Regioner och Försäkringskassan med riskökningar för sjukdomar i samband med fetma/övervikt från epidemiologiska studier. En separat analys undersöker även kostnader av produktionsbortfall från ökad risk för arbetslöshet kopplad till fetma/övervikt. För dessa beräkningar har vi använt data från en svensk studie baserad på nationella registerdata som analyserade empiriska evidens för en negativ effekt på utbildningsgrad relaterat till fetma och övervikt.

Den genomsnittliga merkostnaden för samhället över en livstid för ett 6-årigt barn med fetma relativt ett 6-årigt barn med normalvikt beräknades till ca 430 000 kronor för flickor och 260 000 kronor för pojkar. Samhällskostnader för en överviktig 6-åring var lägre och likartade för flickor och pojkar (ca 150 000 kronor). I samtliga fall utgjordes en stor del av kostnaderna (>75%) av produktionsförluster.



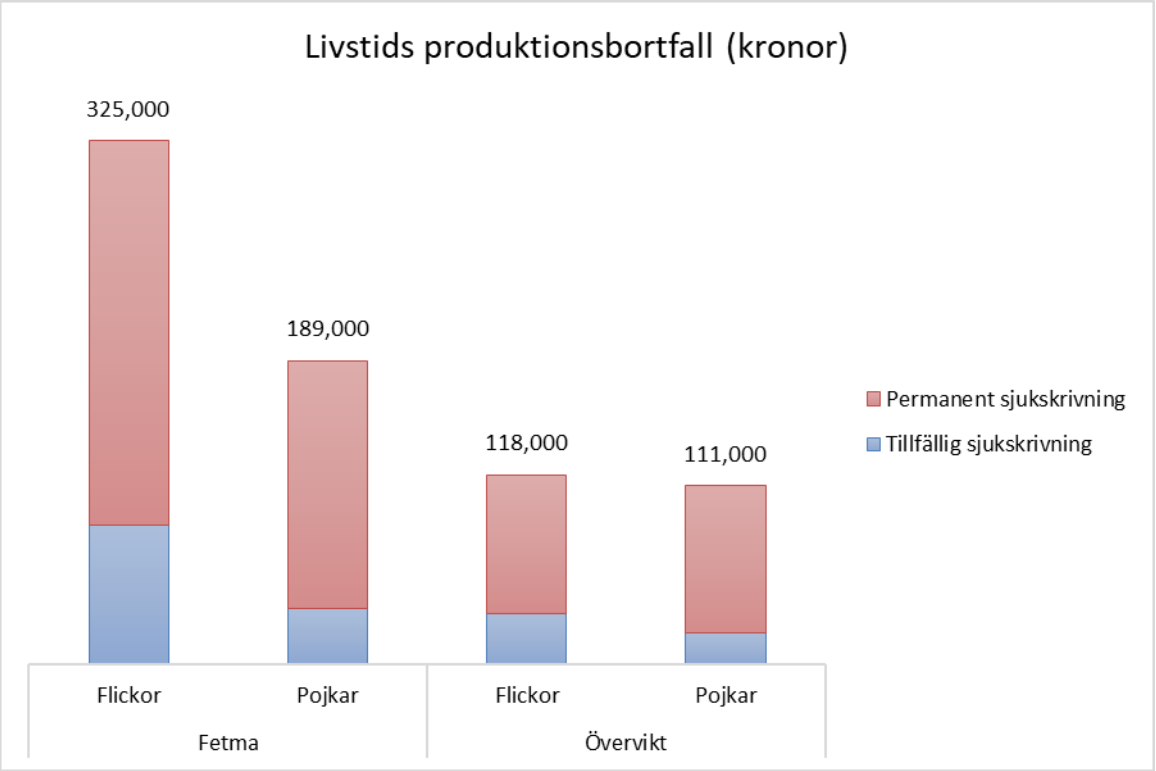
Genomsnittlig merkostnad för samhället över en livstid för en 6-åring med fetma eller övervikt. Kostnaderna är beräknade som skillnaden relativt kostnaderna för en normalviktig 6-åring av samma kön. (Figure 3 i rapporten)

Den genomsnittliga merkostnaden för den offentliga sektorn (sjukvård och socialtjänst) över en livstid för en 6-åring med fetma uppskattades till ca 100 000 kronor för flickor och 70 000 kronor för pojkar. Kostnaderna för flickor och pojkar med övervikt var 34 000 kronor respektive 36 000 kronor.



Genomsnittlig merkostnad för offentlig sektor (sjukvård och socialtjänst) för en 6-åring med fetma eller övervikt. Kostnaderna är beräknade som skillnaden relativt kostnaderna för en normalviktig 6-åring av samma kön. (Figur 4 i rapporten)

Den genomsnittliga merkostnaden för produktionsförlust kopplad till temporär eller permanent sjukskrivning uppskattades till ca 330 000/190 000 kronor för 6-åriga flickor/pojkar med fetma och 120 000/110 000 kronor för 6-åriga flickor/pojkar med övervikt. När även kostnader för förlorad produktion kopplad till arbetslöshet inkluderades i beräkningarna blev kostnaderna runt dubbelt så stora (650 000/360 000 kronor för flickor/pojkar med fetma och 230 000/220 000 kronor för flickor/pojkar med övervikt- dessa resultat presenteras separat i figur 29 i rapporten).



Genomsnittlig merkostnad av produktionsförlust för en 6-åring med fetma eller övervikt. Kostnaderna är beräknade som skillnaden relativt kostnaderna för en normalviktig 6-åring av samma kön. (Figure 5 in rapporten)

Merkostnaden för fetma/övervikt bland 6-åringar i Sverige över en livstid beräknades till 1,8/2,1 miljarder SEK (resultaten presenteras i figur 6 i rapporten). Att kostnaden för övervikt översteg kostnaden för fetma på nationell nivå berodde på att prevalensen är högre för övervikt än för fetma bland svenska barn.

Det blir alltmer tydligt från litteraturen att fetma och övervikt i barndomen kan ge livslånga konsekvenser på såväl hälsa som utbildning och arbetsliv. Denna studie kombinerar forskningsresultat från litteraturen med data från undersökningar och befolkningsstatistik, med målet att uppskatta den ekonomiska bördan av övervikt och fetma bland barn och ungdomar. Resultaten tyder på att fetma och övervikt i unga år kan bidra till betydelsefulla kostnader för samhället. Man kan se från beräkningarna, som är baserade på aktuella förhållanden, att kostnader för sjukvård bidrar till en liten del av de totala samhällskostnaderna och består i huvudsak av kostnader för en större sjukdomsbörda i vuxenlivet. I stället utgörs den största delen av samhällskostnaderna av olika typer

av produktionsförluster. Studien pekar också på att även om fetma är dyrare än övervikt på individnivå, bidrar övervikt till större samhällskostnader på grund av en högre prevalens.

Table of content

Foreword

To be added.

1. Background

Overweight and obesity have increased dramatically in many parts of the world over the last decades, particularly among children and adolescents[1], and is considered one of the most important issues in global health [2, 3]. The global prevalence of excess weight (i.e. overweight or obesity) among children and adolescents aged 5-19 rose from 4% to 18% between 1975 and 2016, resulting in a total of 340 million cases 2016. An increase has also been observed for younger children, and in 2019, 38.2 million children under the age of five were estimated to suffer from excess weight globally [4]. Further increases in weight gain among children and adolescents in recent years have been attributed to the COVID-19 pandemic as a consequence of decreased physical activity, increased screen time, changes in dietary intake, food insecurity, and stress [5].

1.1 Prevalence and trends of overweight and obesity among Swedish children/adolescents

In Sweden, a similar trend of increasing prevalence of overweight and obesity among children and adolescents has been observed [6]. For instance, the occurrence of overweight and obesity have more than doubled among 11-15-year-olds over the last three decades [7] and a recent Swedish study following 3650 men born in the period 1946–1991 reported a secular trend of increasing childhood and pubertal BMI per decade of 0.23 kg/m2 and 0.27 kg/m2, respectively [8]. However, a stabilization and even decline over the previous decade has been reported by some studies [9, 10]. Based on the latest data available from the Public Health Agency of Sweden [7, 11-13], proportions of children/adolescents with overweight or obesity in different age groups are 11% (9% overweight, 2% obesity) among 4-year-olds (2018 data), 21% among 6- to 9-year-olds (2018/19 data), 15% among 11- to 15-year-olds (2017/18 data) and 21% among 16- to 19-year-olds 2018/19. Among younger children (up to 9 years), overweight and obesity is more common in girls, whereas the opposite is observed for 11- to 15-year-olds. Among adolescents, overweight and obesity have in the previous decades been more common in boys, however, due to a strong increase among girls in recent years, the most current data show similar proportions between sexes. Results on occurrence of

[1] The World Health Organization (WHO) defines adolescents as people between 10 and 19 years of age. The majority of adolescents are, therefore, included in the age-based definition of “child”, adopted by the Convention on the Rights of the Child as a person under the age of 18 years.
Reference: 1. World Health Organization (WHO). *Recognizing adolescence*. [cited 2022 16 August]; Available from: https://apps.who.int/adolescent/second-decade/section2/page1/recognizing-adolescence.html.

overweight/obesity can differ between studies depending on the definition of overweight/obesity that is applied [2] and which growth curve that has been used as a reference [14]. The most commonly used international growth curves for overweight and obesity in children are those provided by the WHO [15] and the International Obesity Task Force (IOTF) [16, 17].

1.2 Causes of excess weight in Swedish children and adolescents

The aetiology of obesity is complex, and many factors can contribute to the disease besides a strong genetical component [18]. Important reasons for the increasing weight trend of the population are likely environmental and behavioural changes; diets high content of fat and energy density in combination with low physical activity and sedentary behaviour are considered to be contributing factors [3, 19]. A survey of habits of Swedish school children (age 11 to 15), based on self-reported data from 2017/18, demonstrated that Swedish children have better eating habits in comparison to the average of other European countries and Canada; a larger proportion eat fruit and vegetables, whereas consumption of sweets and fizzy drinks are less common than the average in Europe/Canada. However, the study also indicated a low degree of physical activity among Swedish school children; the proportion who reported that they were physically active for at least 1 h per day, as per recommendations by the WHO, were only 12% among girls and 17% among boys with the lowest proportion (9%) reported by 15-year-old girls and the highest (23%) by 11-year-old boys [20, 21]. A recent development that may have resulted in a reduction in physical activity among school-aged children is the increased use of internet, which in Sweden appear to coincide with the rise in child obesity [22].

1.3 Short term risk factors of excess weight in children and adolescents

Children and adolescents with excess weight are at increased risk of disease, both in childhood and later life. Risk factors that have been associated with obesity in children cover a range of physical

[2] The most commonly used BMI based definitions are for overweight: BMI ≥ 85th percentile to 95th percentile or BMI > one standard deviation above the average, and for obesity: BMI > 95th percentile or BMI > two standard deviations above the average Reference: 4. WHO, W.H.O. *Obesity and overweight*. [cited 2022 28 July]; Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight..

complications including neurological, endocrine (e.g. type 2 diabetes), cardiovascular problems (e.g. hypertension and dyslipidaemia), pulmonary (e.g. asthma), gastrointestinal (e.g. fatty liver disease), renal, dermatologic, musculoskeletal and psychosocial [2, 23]. A major consequence of the increase in obesity is likely the concomitant rise in type 2 diabetes among children observed in many parts of the world. Obesity is the most important risk factor for developing type 2 diabetes in children and adolescents which is linked to increased insulin resistance [24, 25]. A US study showed an increase in type 2 diabetes of 4.8% in youths (age 10-19) between 2002 and 2015 [26], and in the UK, the annual incidence of type 2 diabetes per 100,000 children increased from 6.4 to 33.2 between 1994 and 2013 with a fourfold higher risk among obese children compared to children with normal BMI [27]. In Sweden, the occurrence of type 2 diabetes among the younger population is still relatively low but a rising trend can be observed for some age groups, for instance, the prevalence of type 2 diabetes among 15-19 year old girls and boys increased 2- and 3-fold, respectively, between 2005 and 2015 [28].

Excess weight in children and adolescents can also have negative effects on their mental health in childhood/adolescence and lead to psychosocial problems, particularly among girls [29, 30]. A Swedish study for years 2005-2015 showed that obese children (n=12,500, age 6-17) had a higher risk (43% for girls and 33% for boys) of suffering from anxiety and depression compared to children from the general population [31]. Psychosocial problems among obese children/adolescents has further been suggested as a contributing factor to lower educational levels achieved by this group [32]. The large coexistence of unmedicated attention-deficit/hyperactivity disorder (ADHD) in obese teenagers may worsen the educational burden [33].

1.4 Long-term risk factors of excess weight in childhood

In addition to childhood complications, obesity and overweight in children/adolescents can also have long term effects and has been associated with considerably higher risks of morbidity from chronic disease such cardiovascular disease, diabetes and cancer in adulthood [34, 35]. For instance, obesity in adolescences has been estimated to account for a fifth of cardiovascular deaths and a quarter of deaths from coronary heart disease by the time the participants reach midlife [36] and cancer incidence in early adulthood has been positively associated with increasing BMI in adolescence [37]. In Sweden, the BMI Epidemiology Study (BEST) have investigated associations between childhood weight status and health in adult life. The study has used data for large cohort of men (~40,000) on weight and height from school health care records at 8 years and military conscription tests in young

adulthood, which has been linked to national hospital discharge and cause of death registers. Results from the study suggest that being or becoming overweight in puberty increases the risk cardiovascular disease and type 2 diabetes in adulthood [38-42]. In contrast, the risk of adult cancer and hematologic malignancies (i.e. non-Hodgkin lymphoma and diffuse large B-cell lymphoma) appear to be primarily linked to childhood BMI [43, 44].

Excess weight in childhood/adolescence has also been associated with increased mortality in adulthood. A recent Swedish study showed that children with obesity have a three times higher risk of mortality in early adulthood compared to those with normal weight. Although suicide and self-harm were found as the main causes of death for both obese and normal weight children, endogenous causes were significantly higher for children with obesity [45]. Moreover, high BMI in adolescence has been linked to increased mortality in early adulthood and midlife and related primarily to endogenous complications such as cardiovascular, endocrine and metabolic disease, and cancer [36, 46].

An important reason behind the associations between excess weight in childhood and adverse health in adult life is likely that overweight/obese children often maintain an unhealthy weight in adult life. It has been estimated that overall, children and adolescents with obesity have a five times higher risk of suffering from obesity in adulthood [47]. However, studies have indicated that even children in the upper range of normal weight are at risk of overweight/obesity in adulthoods and the risk increase with age and BMI [48, 49]. Thus, the highest risk of adulthood obesity is represented by obese adolescents of which approximately 80% have been predicted to maintain obesity into adulthood [47, 50]. A Swedish study presented odds ratios for overweight/obesity in adulthood (at 20 years of age) of 5.7 and 20.1 for children/adolescents with overweight or obesity at 5.5 and 15 years of age, respectively [50]. Another Swedish study estimated a growth chart relating childhood BMI to the probability of having BMI >23. A BMI of 18 (which translates to being overweight in accordance with IOTF cut-offs) at 4 years of age was associated with 0.70 probability of attaining a BMI > 23 kg at 18 years of age [51]. It is unclear whether excess weight in childhood also can have long-term health effects independent of adult weight status [52, 53]. There is little evidence in the literature to support the latter as associations between excess weight in childhood and adverse in health in adulthood generally appear to be lost after adjusting for adult BMI [52, 54]. Exceptions where associations between weight status in childhood or adolescence and health outcomes have been shown independent of weight status later in life include an Israeli study on coronary heart disease [55], and two studies from BEST on coronary atherosclerosis [42] and obesity-related cancer [44], respectively.

1.5 Risk factors and consequences of excess weight in adulthood

Maintaining excess weight from childhood increases the risk of adverse health in adulthood as overweight (BMI of ≥25 and <30 [4]) and obesity (BMI ≥30 [4]) in adults are associated with a range of conditions. A large study on global risk factors reported that BMI ≥ 25 kg/m2 was associated with 4million deaths and a loss of 120 disability-adjusted life years in 2015 [56]. The study also found an association between increase in BMI ≥ 25 kg/m2 and increased risk of 17 disease categories including cardiovascular disease, diabetes and cancer. Further, it showed that high BMI was one of the leading causes of premature death and lost life years in Sweden. A recent study using data from Finland and the UK showed that overweight and obesity in adults were associated with increased risks of complex multimorbidity (defined as four or more comorbid diseases) of approximately 3 and 12 times, respectively. The study also showed that obesity was significantly associated with increased risk of 21 non-overlapping diseases and with particularly strong associations (hazard ratios [HRs]> 3) for diabetes, sleep disorders, heart failure and gout [57]. Excess weight has also been associated with several cancers with some of the highest risks reported for oesophageal adenocarcinoma, endometrial cancer and kidney cancer [57-59]. Overall, the effects of excess weight on cancer risk appear modest (HRs below 2 for most cancer types) [57, 58], however, due to the high global prevalence of overweight and obesity, the contribution to the total cancer burden is considerable: in a study for 2012, excess weight was estimated to contribute to 544,300 cancer cases and 3.9 % of all cancers globally [60]. Consistent with the increased disease burden, excess weight among adults has been associated with higher sick-leave, mortality and production loss [61-64]. A Swedish study showed that overweight and obese young men identified from the Swedish Military Service Conscription Register, had a 20% and >30% increased risk, respectively, in future sick leave of medium (8-30 days) and long (>30 days) duration compared to those of normal weight [61]. Moreover, obesity and overweight were associated with a 100% and 30% increased risk, respectively, of death before the age of 56, and premature death was identified as the main cause of production loss related to excess weight [47].

1.6 The economic burden of childhood obesity- what is already known?

Excess weight has consequences both for the individual, in terms of reduced health, as well for society in terms of costs of healthcare (i.e. direct costs) and lost productivity (i.e. indirect costs). In

a previous study by IHE, the total societal costs of obesity in adults in Sweden was estimated to EUR 2.7 billion for 2016 of which 80% were represented by lost productivity. The study also estimated that by 2030 the costs could increase by 66%, provided that the trend of increasing obesity continued [65].

Estimating the societal costs of obesity and overweight in children requires a lifetime perspective as it needs to capture both the short-term consequences related to adverse health in childhood including costs of health care and social services and, as well as the long-term effects related to health complications in adulthood. In addition to costs of health care and social services, overweight and obesity in adulthood may also contribute to considerable productivity losses as a result of poor health (i.e. sick-leave) and mortality. Moreover, reduced employment/career prospects for people with obesity or overweight (e.g. as a result of poorer educational level and discrimination in employment situations) can result in both productivity loss and unemployment. Childhood obesity had an adverse effect on likelihood of completing 12 years of education in a Swedish study [32].

There are to our knowledge no Swedish studies to date which have estimated the lifetime cost of overweight and obesity in children. Among international studies, few have included both direct and indirect costs in calculations. In a meta-analysis from 2018, which combined data from 13 international studies (8 of direct costs only, 4 of indirect costs only, and 1 of both) published between 2006 to 2016, the mean lifetime cost of an obese child was estimated to approximately EUR 150,000 (2014 money value) of which nearly 90% was represented by indirect costs [66].

2. Aim

The aim of the study was to estimate the costs of overweight and obesity in Swedish children and adolescents in a life-time perspective. The costs included societal costs (i.e., health care/social services and production loss).

3. Method

Costs attributed to obesity and overweight were estimated in a lifetime perspective for children (6-year-olds) and adolescents (15-year-olds) with overweight or obesity. Using a link between childhood and adulthood weight status (described in section 3.3), the expected prevalence of adulthood obesity and overweight among children or adolescents with obesity and overweight was

estimated. This allowed for including costs of adulthood obesity and overweight. Mortality was accounted for using annual mortality risks and increased risk of mortality from obesity and overweight. Costs included health care costs of obesity-related disease and production loss due to obesity-related disease. Cost of lost production linked to educational level was also estimated (results presented in separate analysis). Yearly costs per person were applied to a hypothetical cohort using estimates of costs per person stratified by age and sex. The primary data sources for this study were public register data, online databases and national survey data from authorities as well as published scientific studies and reports. When register data were not available, we have primarily used published studies on resource use based on BMI level and, as a secondary alternative, published cost of illness studies. In those cases when no such sources were available, the cost could not be estimated.

3.1 Prevalence of overweight and obesity among children and adolescents in Sweden

In contrast to adults, body composition changes throughout childhood which affects the BMI. BMI is higher in infancy and adolescence than during preschool and the first school years. To determine weight status in children, it is therefore necessary to use age standardized BMI values. There are several challenges when developing BMI references with either standard deviation scores or cut-offs for overweight or obesity. The international growth curves provided by WHO and International Obesity Task Force (IOTF) are based on different data and criteria, and thus, generate somewhat different results. The cut-off values for obesity and overweight are generally higher for ITOF compared to WHO. Therefore, the ITOF curve generates smaller proportions of children with overweight/obesity [14].

For this study, information regarding prevalence of overweight and obesity among Swedish children and adolescents were largely sourced from statistical data from public health records and national surveys provided by the Public Health Agency of Sweden. Prevalence among four-year-olds was based on height and weight measurements for 2018 as part of the Swedish child health care system, with overweight and obesity classified according to IOTF cut-offs [11]. Prevalence among six to nine-year olds (one estimate for each year) were based on height and weight measurements for school year 2018/19 as a part of the Swedish school health system with overweight and obesity classified according to IOTF cut-offs [67]. Prevalence among 11- to 15-year-olds (average for the whole age group) was based on self-reported information for the school year 2017/18 as part of a national survey regarding school children's health behaviours with overweight and obesity classified according to

IOTF cut-offs [68]. Prevalence among 16- to 17-year-olds (one estimate for each year) was based on self-reported data collected in connection with a national health survey (Hälsa på lika villkor [in English: Health on similar terms]) conducted in 2020, with overweight and obesity classified according to WHO cut-offs. It should be noted that there may be underestimation of overweight/obesity prevalence based on self-reported data. Prevalence data for 5-year-olds and 10-year-olds were not available and were therefore assumed to be equal to the average of the preceding and subsequent year.

Table 1 shows a summary of the prevalence used when calculating costs of hypothetical cohorts. The distribution of overweight and obesity was based on prevalence of overweight and obesity among 6-year olds for children cohorts (results in section 4.1 and 4.3) and prevalence of overweight and obesity among 11- to 15-year-olds for adolescent cohorts (results in section 4.2). Prevalence of overweight and obesity in all childhood years are shown in figure Figure 23 and Figure 22 in the appendix.

Table 1 Prevalence of overweight and obesity among children (6-year olds) and adolescents (15-year olds)

	6-year olds	15-year olds
Overweight (girls/boys)	13.2%/10.7%	9%/13%
Obesity (girls/boys)	4.5%/4.3%	3%/5%

3.2 Increased risk of diseases in childhood/adolescence

The increased risk of asthma in children was sourced from a large meta-analysis including 18 articles and 73,252 children by Deng et al. 2019, which reported odds ratios due to overweight (OR = 1.22 [1.29 to 1.52]) and obesity (OR = 1.40 [1.14 to 1.31]).

The increased risks of anxiety and depression were sourced from the Swedish study by Lindberg et al. 2021. Subgroup analysis reported increased risk for anxiety (HR = 1.49 [1.22 to 1.82] among girls and HR = 1.88 [1.46 to 2.42] among boys) and depression (HR = 1.80 [1.41 to 2.29] among girls and HR = 2.68 [1.92 to 3.74] among boys) due to obesity despite exclusion of children with neuropsychiatric disorders and children with a family history of anxiety/depression.

The increased risk of fractures was sourced from a Spanish Longitudinal Cohort Study of 466,997 Children by Ce Lane et al. 2020. Overweight and obesity was associated with an excess risk of lower limb fracture (HR = 1.42 [1.26 to 1.59]; 1.74 [1.46 to 2.06], respectively) and upper limb fracture (adjusted HR = 1.10 [1.03 to 1.17]; 1.19 [1.07 to 1.31]).

3.3 Associations between overweight/obesity in childhood and adulthood

The distribution of adulthood weight status given the childhood or adolescence weight status were derived from Fåhraeus et al. 2012 [69] dissertation and is shown in Figure 1 and Figure 2. For example, among girls and boys that are not overweight or obese in preschool age, 5% and 2% become obese as adults, and 15% and 20% become overweight as adults. The calculations in the current analysis assumed the transition occurred gradually, and the prevalence was adjusted linearly each year from age 6 to age 18 for children and from age 15 to age 18 for adolescents. The base case analysis accounts for changes in weight status between different stages of life which means that normal weight children have a risk of becoming obese or overweight as adults and that obese/overweight children can reach normal weight in adulthood. The impacts of different assumptions regarding distribution of adult weight status are tested in sensitivity analyses (results presented in section 8.3-8.58.2 in the appendix).

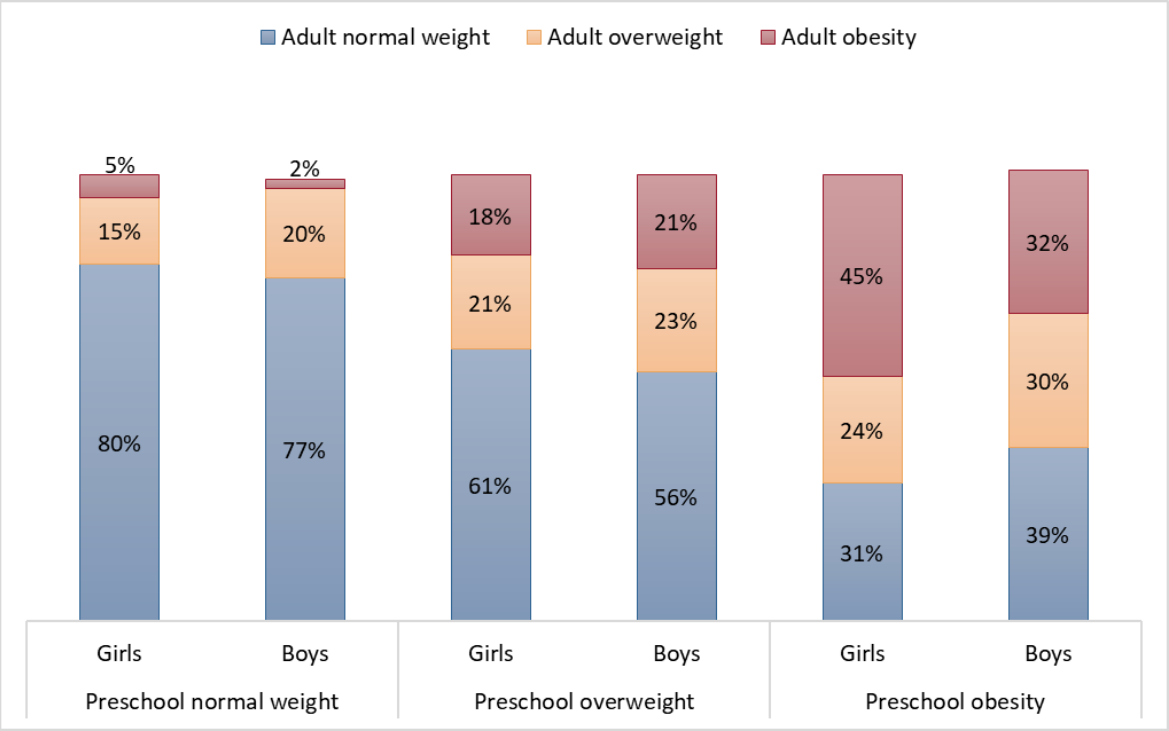


Figure 1 Distribution of adult weight status in relation to weight status in preschool age. The figure shows the proportion of children with normal weight, overweight and obesity, respectively, that will have normal weight, overweight or obese in adulthood. The numbers are based on data for 5.5-year-olds presented by Fåhraeus et al. [69].

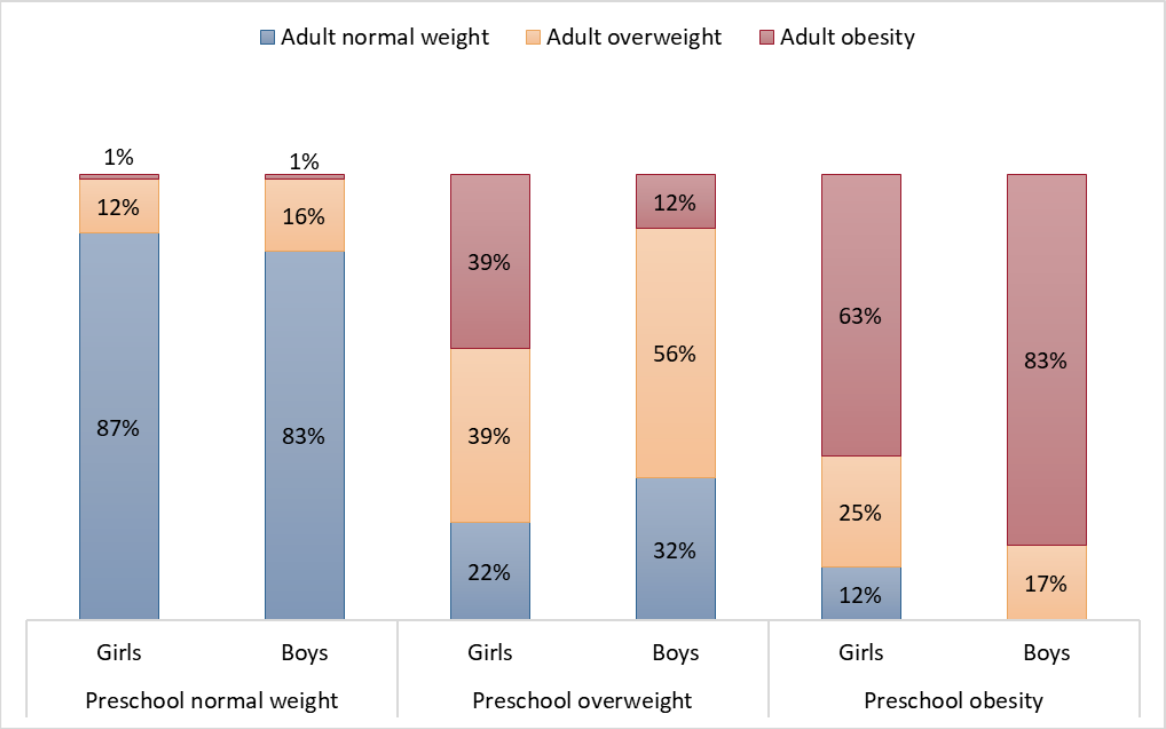


Figure 2 Distribution of adult weight status in relation to weight status in adolescence. The figure shows the proportion of adolescence with normal weight, overweight and obesity, respectively, that are likely to have normal weight, overweight or obese in adulthood. The numbers are based on data for 15-year-olds presented by Fåhraeus et al. [69].

3.4 Prevalence of overweight and obesity among adults

Prevalence of overweight and obesity among adults were sourced from national surveys provided by the Public Health Agency of Sweden 2020 and are shown in Figure 24 in appendix. Data for 85+year-olds were not available and was therefore assumed to be the same as for 65-84-year-olds. When calculating lifetime costs of obesity and overweight, it was assumed that an overweight or obese adult remained overweight or obese throughout the lifetime.

3.5 Increased risk of diseases in adulthood

Costs in adulthood were calculated based relative risks of a set of diseases which had been identified as related to obesity for a previous IHE report on the cost of obesity in Sweden. The diseases were sourced from a global report on risk factors of disease [56] and studies included in a published review of literature related to the economic burden of obesity [70]. The report listed a total of 17 disease with increased risks in association with obesity which included 10 cancer diagnoses, type 2 diabetes, four types of CVD, low back pain and chronic kidney disease. From the literature review, another 13 diseases were identified, including six cancer diagnoses, obesity as a diagnosis, gout, depression, pulmonary embolism asthma, cholelithiasis and arthrosis. The diseases including diagnostic codes according to the International Classification of Disease (ICD-10) and sources for relative risks are presented in Table 2.

Table 2 Diseases and ICD-10 codes associated with obesity and overweight, and their sources of excess risk.

Disease	ICD-10	Source
Cancer		
Oesophageal	C15	[56]
Stomach	C16	[71]
Colorectal	C18 – C21	[56]
Liver	C22	[71]
Gallbladder or biliary tract	C23 – C24	[56]
Pancreas	C25	[56]
Breast (post-menopausal)	C50	[56]
Cervix	C53	[71]
Uterus	C54 – C55	[56]
Ovarian	C56	[56]
Prostate	C61	[72]
Kidney	C64	[56]
Thyroid gland	C73	[56]
Non-Hodgkin's lymphoma	C82 – 85	[71]
Multiple myeloma	C90	[71]
Leukaemia	C91 – C95	[56]
Type 2 diabetes	E11, E14	[56]
Obesity	E66.8, E66.9	[73]
Gout	M10	[74]
Depression	F32.0-F32.3, F32.8, F32.9, F33.9	[75]
Cardiovascular disease		
Ischaemic heart disease	I20 – I25	[56]
Ischaemic stroke	I63 – I64	[56]
Haemorrhagic stroke	I61	[56]
Hypertensive heart disease	I11	[56]
Pulmonary embolism	I26.9, I26.0, I80.8	[72]
Asthma	J45	[72]
Cholelithiasis	K80	[72]
Arthrosis	M15-M19	[72]
Low back pain	M54.5	[56]
Chronic kidney disease	N18	[56]

3.6 Health care cost data and calculations

Costs of inpatient care and hospital-based outpatient care for obesity-related diseases were based on published statistics from The Swedish Association of Local Authorities and Regions' database of costs per patient. All costs were adjusted for inflation to 2021 price level. The database includes information on costs per health care visit, the number of visits and the number of days for each visit, and can be stratified by age, sex and main diagnoses. In 2020, the database included 94% of the total care visits in the inpatient care and 83% of the total care visits in hospital-based outpatient care. The costs were therefore adjusted to reflect 100% of care occasions. Total costs in 2019 stratified by sex and age were calculated for each disease using the reported ICD-10 code of the main diagnoses. For childhood asthma and obesity, the same ICD codes as for adults was used (Table 2). For childhood depression and anxiety, the same ICD codes as used in Lindberg et al. 2021 was used (anxiety: ICD-10 F40-42, depressive disorder: ICD-10 F32-F33). For childhood upper- and lower-limb fractures, ICD-10 codes S42, 52, 62, 72, 82, 92 were used. Average costs per person were then calculated by dividing total costs with total number of people stratified by sex and age using 2019 demographic data from Statistics Sweden. The portion of the costs attributed to obesity and overweight were calculated for each disease using relative risks and prevalence of obesity and overweight.

The national primary care data is less comprehensive than that of the specialised hospital care. The calculations of costs for primary care related to overweight and obesity were therefore based on a British study of women in the age interval of 55-79 years [76]. The study was selected due to, in addition to BMI, including information regarding socioeconomic status, education, number of children, smoking status, alcohol intake, which should improve the possibility to separate the effect of overweight and obesity. The costs of obesity-related primary care were thereby calculated directly based on BMI level and not linked to specific overweight/obesity-related diseases. The total cost of primary care in Sweden 2019 was sourced from Swedish Association of Local Authorities and Regions.

Usage of municipal care was based on the previous IHE report, in which such costs were calculated for ischemic heart diseases and stroke [65].

Resource use within palliative care is an important cost allocation for certain cancers. The cost of palliative care for 14 of the total 16 types of cancer that were included in the calculation of overweight/obesity in this study were sourced from a previous IHE report on the costs of cancer in

Sweden (Kostnaderna för cancer I Sverige idag och år 2020, [in English: the costs of cancer in Sweden today and year 2020] [77].

Costs of medications for 14 of the cancer types, ischaemic heart diseases, stroke and asthma were based on previous studies that have reported medication usage in Sweden [77-81]. For type 2 diabetes and obesity, costs were derived following the method used in the previous IHE report on the cost of obesity in Sweden [65].

3.7 Production loss data and calculations

Information on temporary sick leave (based on temporary sickness benefit, i.e. "sjukpenning") and permanent sick leave (based on sickness and activity compensation) in the general population was sourced from the Swedish Social Insurance Agency (Försäkringskassan).

The increased risk of temporary and permanent sick leave due to overweight and obesity was based on a Swedish study from 2013 [82] on sickness benefits and production losses related to overweight and obesity. The study, which was based on data from the Swedish Military Service Conscription Register, followed a cohort of men born in 1951-1976 and entered the Military Service Conscription in 1969 to 1994. Increased risks of sick leave per BMI class were calculated based on differences in sick benefit and sick and activity compensation obtained by people with healthy weight (BMI 18.5.24.9 kg/m^2 which was used as the reference group) and underweight (BMI <18,5 kg/m2) compared to those with overweight and obesity. Sick leave of 14 days or less is payed by the employer and therefore not registered by the Swedish Social Insurance Agency. Information on sick leave shorter than two weeks could not be acquired and is therefore not included in the calculations.

The cost of the lost market production was calculated by multiplying the time of lost production with the cost of one employed person (based on average Swedish salary) divided by age and sex [83] with the addition of social fees. The cost was weighted based on employment rate stratified by age and sex [84] and on percentage of full-time employment stratified by sex and job sector [85].

3.8 Production loss due to unemployment

The risk of not completing 12 years of schooling was based on Lindberg et al. [32]. The probability of completion of 12 years of schooling was 56.7% among obese children and 74.4% in the comparison group. When accounting for social factors, the adjusted odds ratio of success was 0.57.

Based on this, an adjusted probability of completion of 12 years of schooling among obese children was calculated (62.4%), resulting in 12% more children not completing 12 years of schooling among obese compared with the control group (74.4%-62.4%=12%). This was multiplied with the difference in employment rate for people with and without completion of 12 years of schooling (stratified by sex and age) reported by SCB 2018 to calculate the increased risk of unemployment due to childhood obesity. Due to lack of data, this estimation only includes impacts on the employment rate (i.e., proportion of people with full-time or part-time employment), not taking into account that childhood obesity also may result in higher risk of part-time unemployment. It was assumed that the missed education was not compensated for over time. The results of including estimated production loss due to unemployment were reported in the additional analysis in section 4.3.

3.9 Mortality

Age-specific risk of mortality was used to adjust the size of the hypothetical cohort over a lifetime. Mortality of the general population stratified by sex was sourced from Statistics Sweden. Increased mortality due to overweight and obesity, stratified by age and sex, was based on the previous IHE report [65].

3.10 Sensitivity analysis

Alternative assumptions on distribution of weight status in adulthood

In the base case analyses, it is accounted for that obese children may become overweight and normal-weight adults, overweight children may become obese or normal-weight adults, and normal-weight children have a risk of becoming overweight or obese adults. Obese and overweight children have a larger probability of having obesity and overweight as adults (see Figure 1), and this larger probability translates to the incremental costs of adult overweight/obesity attributed to childhood overweight/obesity. A sensitivity analysis where normal weight children remain normal weight to adulthood was performed to clarify the impact of the risk of adulthood overweight/obesity among normal-weight children in terms of estimated costs attributed to childhood obesity/overweight. The results of this analysis is presented in Appendix 8.3. An alternative scenario assuming that all children remain in their starting weight status is presented in Appendix 8.4. This may be interpretated as a subgroup analysis among children that maintain their weight status into adulthood. Finally, to further investigate uncertainty around the distribution of adult weight status given childhood

obesity/overweight, three different hypothetical scenarios with alternative distributions of adult weight status among overweight/obese children are presented in Appendix 8.5.

4. Results

4.1 Lifetime costs of obesity and overweight in 6-year-old children

Lifetime costs of obesity and overweight in 6-year-old children are presented as average incremental costs for a 6-year-old child with obesity/overweight relative a 6-year-old child with normal weight, and account for changes in weight status in different life stages (see section 3.3). The costs are divided into societal costs, which include public sector costs (i.e., costs of health care and social services), and production loss. The corresponding costs of obesity and overweight are also presented for a Swedish national cohort of 6-year-olds. Costs on a municipality level are presented in Appendix 8.2.1

4.1.1 Average incremental societal cost for a 6-year-old

Total societal costs

The average incremental societal costs for a 6-year-old child with obesity, relative a 6-year-old child of normal weight, was estimated to approximately SEK 429,000 for girls and SEK 257,000 for boys, (Figure 3). For an overweight 6-year-old, the incremental societal costs were considerably lower and more similar between girls (SEK 152,000) and boys (SEK 147,000). For both obese and overweight 6-year-old children, societal cost were to a large extent constituted by production losses (>75%).

As a comparison, in sensitivity analysis in which weight status was assumed to be maintained throughout life, the average incremental cost over a lifetime for a child with obesity/overweight at 6 years of age and throughout life was estimated to approximately SEK 970,000/410,000 for girls and SEK 750,000/320,000 for boys, compared to a child with normal weight throughout life (Appendix 8.4).

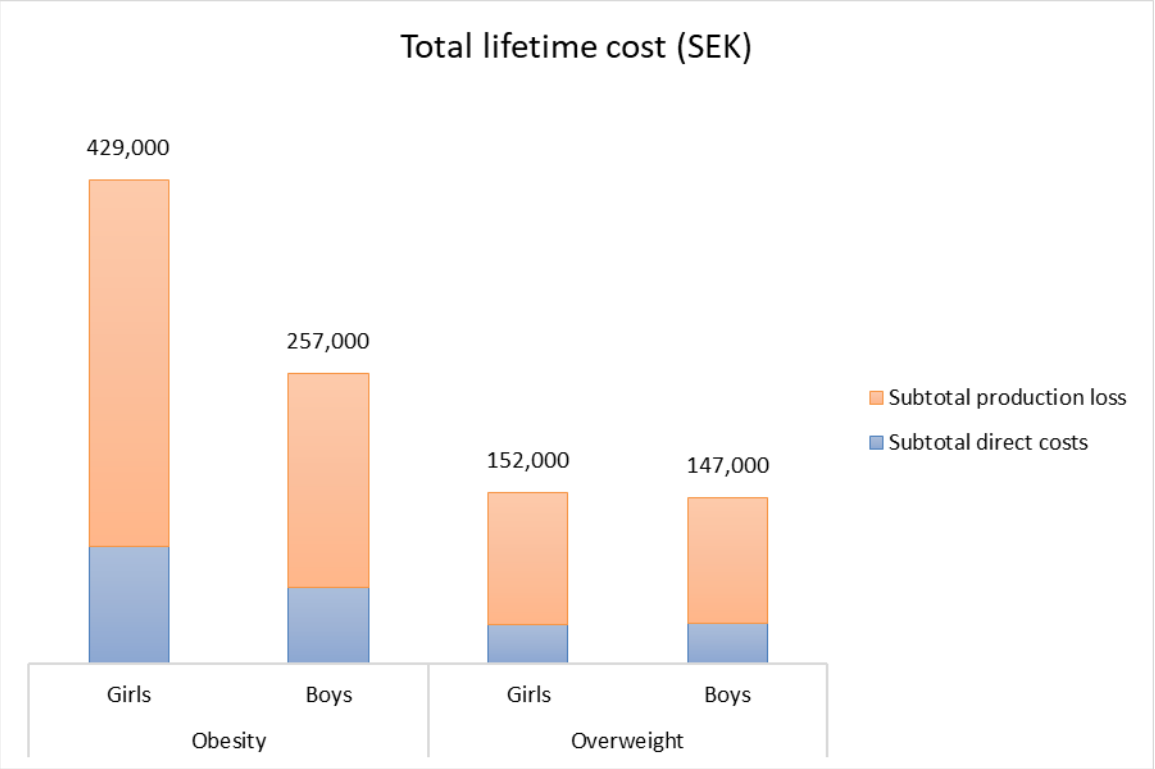


Figure 3 Average incremental total lifetime costs for a 6-year-old child with obesity or overweight. The costs are presented as the difference relative to the costs of a 6-year-old child of normal weight.

Public sector costs

The estimated average lifetime incremental costs of obesity or overweight for a 6-year-old child in terms of social services and health care are presented in Figure 4. Incremental public sector costs were approximately 50% higher for girls with obesity than for boys with obesity and the difference was largely represented by higher health care costs for girls, in particular costs related to primary care and medication. In contrast, girls and boys with overweight had similar total public sector costs, however, girls had more costs related to primary care whereas boys had more costs related to inpatient care.

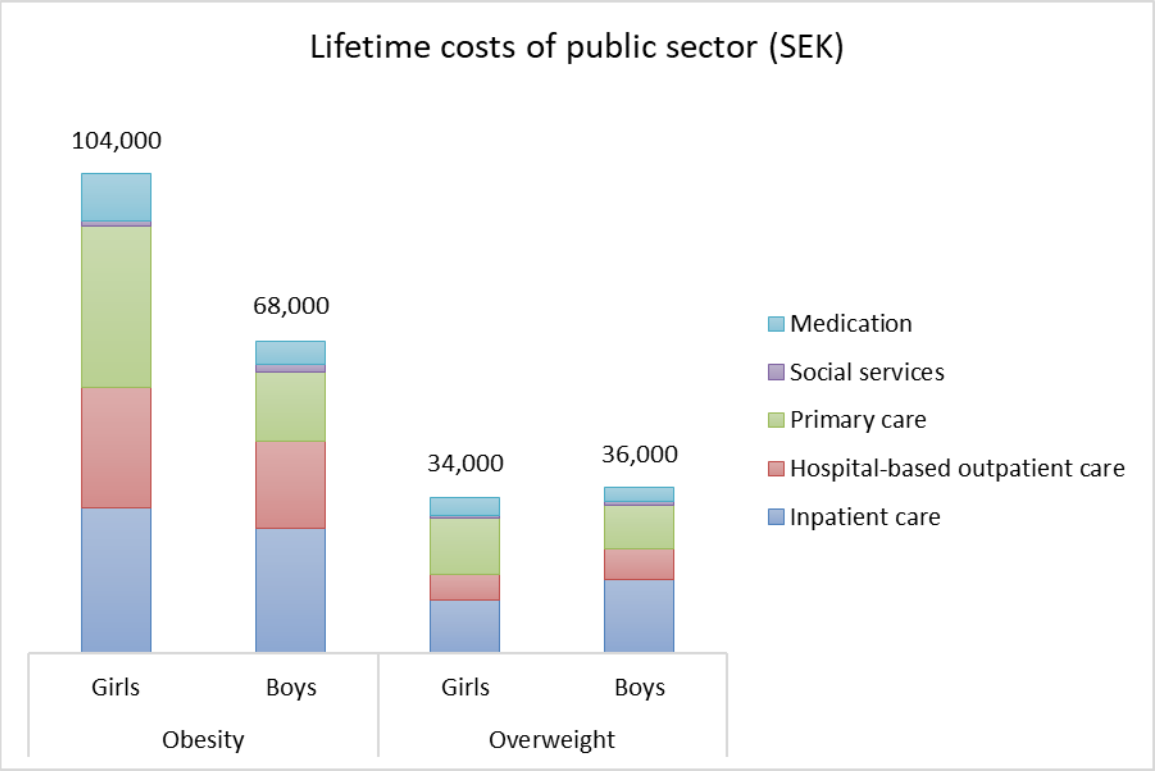


Figure 4 Average incremental lifetime public sector costs (health care and social services) for a 6-year-old child with obesity or overweight. The costs are presented as the difference relative to the costs of a 6-year-old child of normal weight.

Costs of production loss

The incremental cost of production loss was approximately 70% higher for obese 6-year-old girls compared to obese 6-year-old boys, and the difference was represented by a higher occurrence of both permanent and temporary sick leave for girls (Figure 5). Incremental cost of production loss was also somewhat higher for girls with overweight compared to boys with overweight, largely due to more temporary sick leave for the girls.

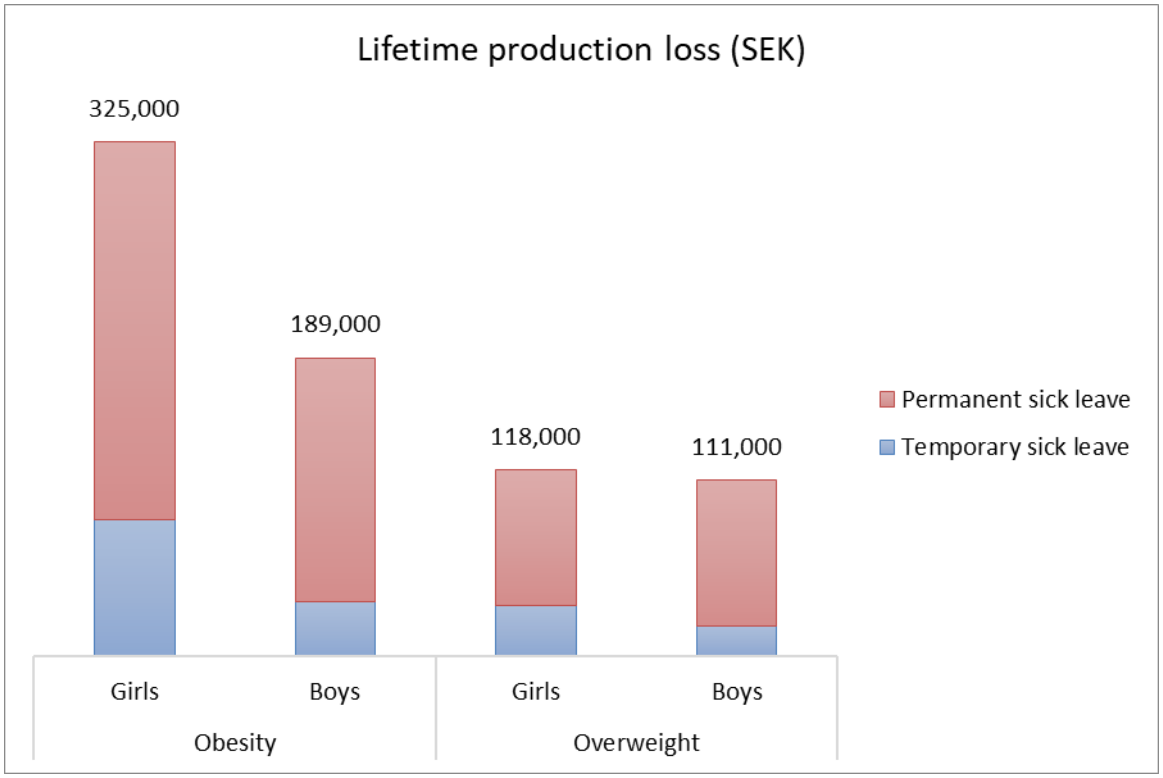


Figure 5 Average incremental lifetime costs of production losses for a 6-year-old child with obesity or overweight. The costs are presented as the difference relative to a 6-year-old child of normal weight.

4.1.2 Lifetime costs for a representative national cohort

To estimate costs of obesity and overweight in young children on a Swedish national level, lifetime costs of obesity and overweight was estimated for a cohort of 120,000 6-year-olds (60,000 boys, 60,000 girls). Based on the prevalence of obesity and overweight among 6-year-olds (Table 1), this translated to 2,700/2,580 girls/boys with obesity, and 7,920/6,420 girls/boys with overweight. In contrast to the costs presented for the individual child, on a national level, higher costs were estimated for overweight (approximately SEK 2.1 billion) compared to obesity approximately SEK 1.8 billion) (Figure 6) due to the higher prevalence of overweight among children. For both obesity and overweight, the greater proportions of costs (~75%) were represented by production loss. The distribution of costs between different categories of public sector costs and production losses for the cohort are presented in Figure 7 and Figure 8, respectively.

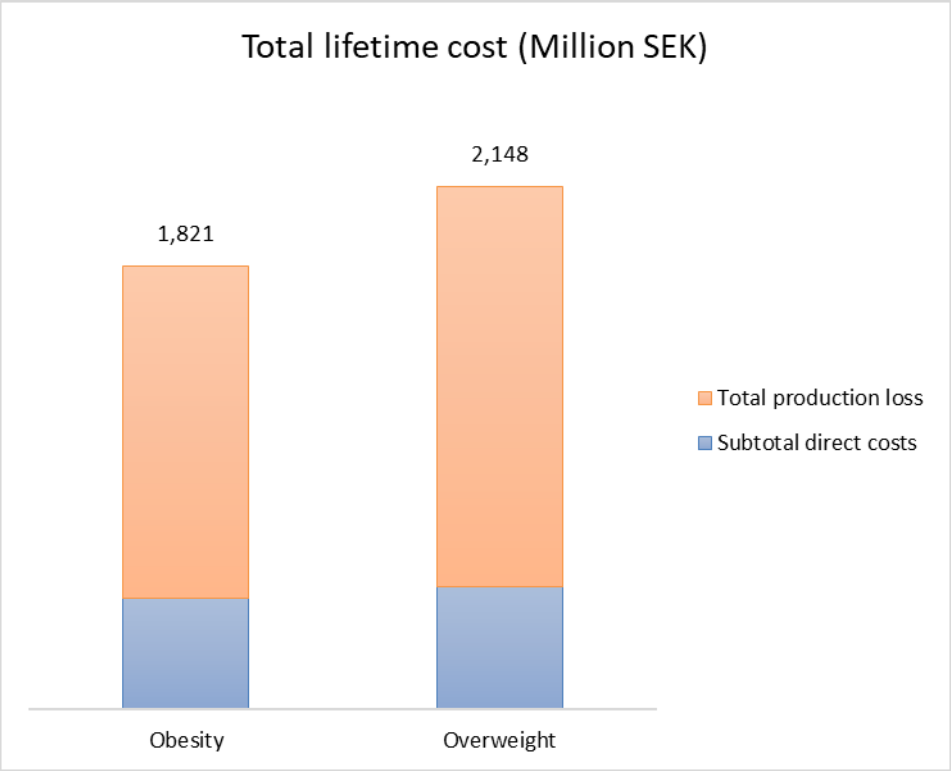


Figure 6 Total incremental lifetime costs for obesity and overweight in a cohort of 120,000 6-year-olds representing Swedish national numbers. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

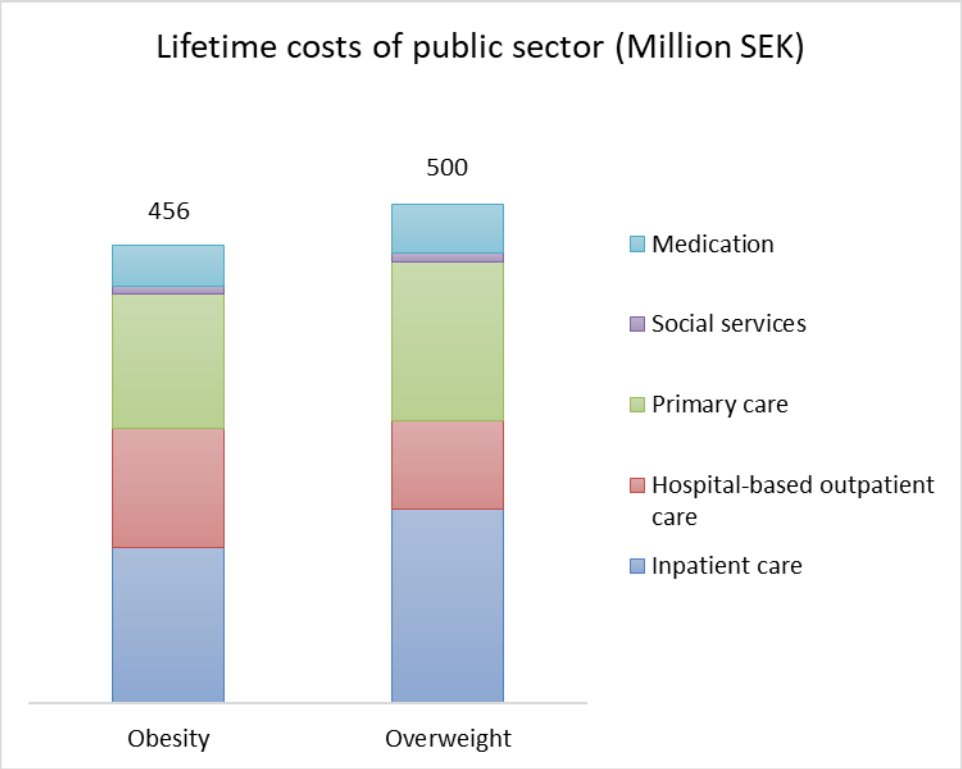


Figure 7 Incremental lifetime public sector costs for obesity and overweight in a cohort of 120,000 6-year-olds representing Swedish national numbers. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

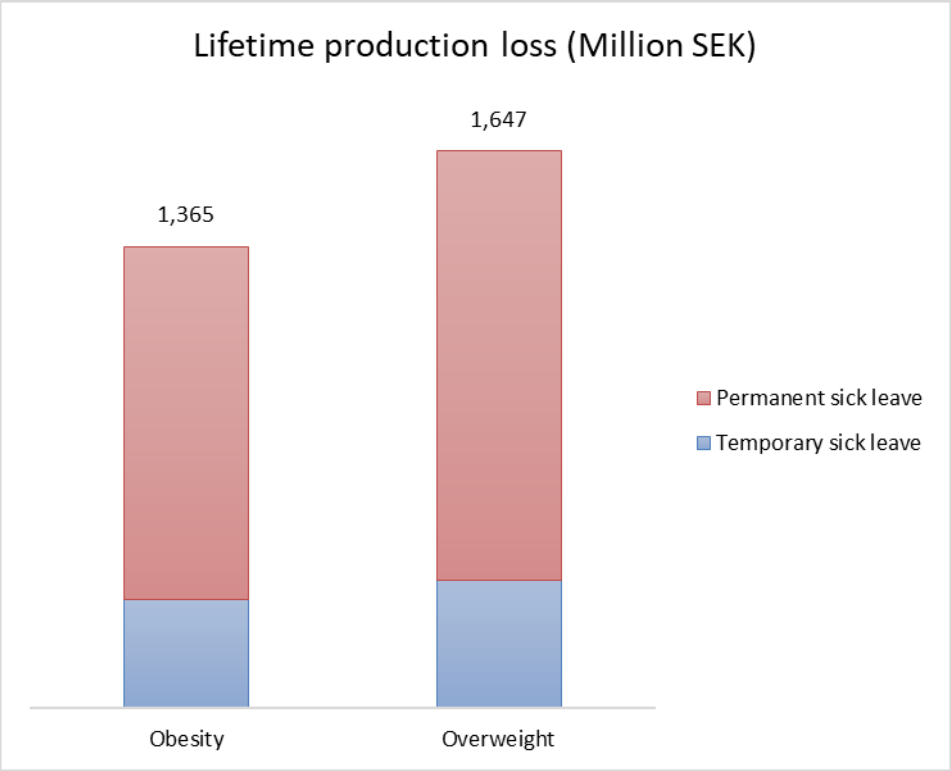


Figure 8 Incremental lifetime costs of production loss for obesity and overweight in a cohort of 120,000 6-year-olds representing Swedish national numbers. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

Figure 9 and Figure 10 shows the amount of costs incurred in different age intervals over the cohort's lifetime. Notice the stepwise increased burden for production loss with increasing age.

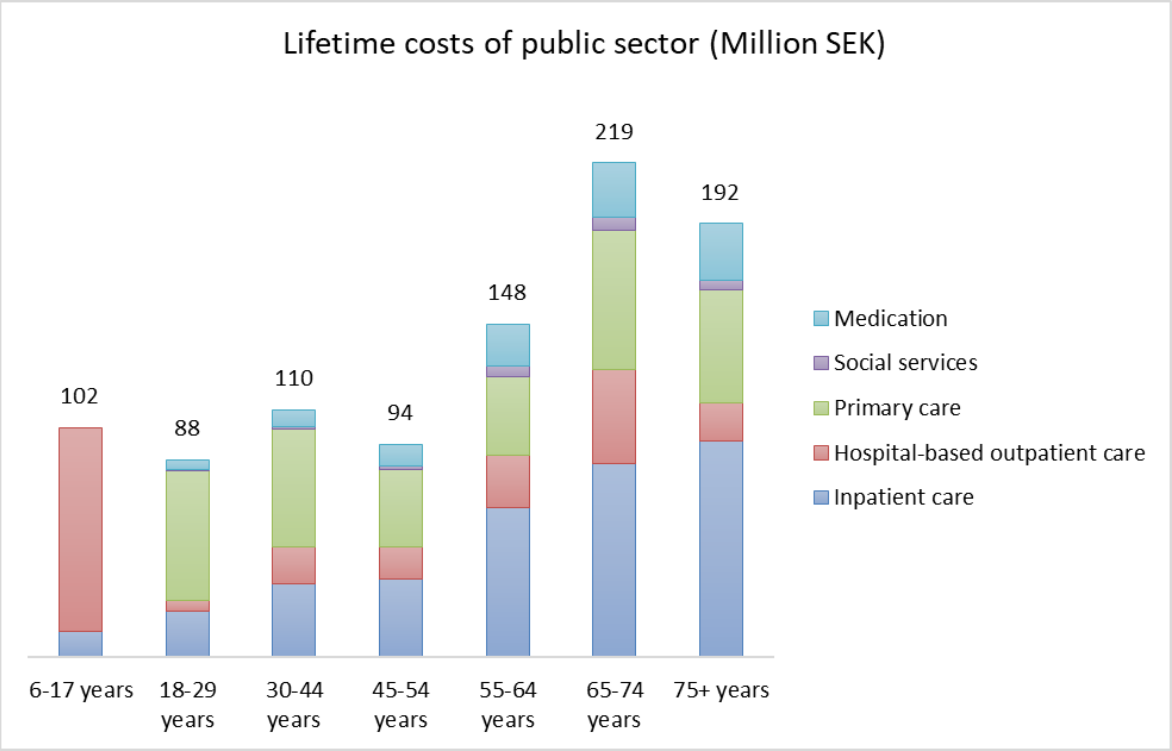


Figure 9 Incremental lifetime public sector costs for obesity and overweight in a cohort of 120,000 6-year-olds, stratified by age intervals. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

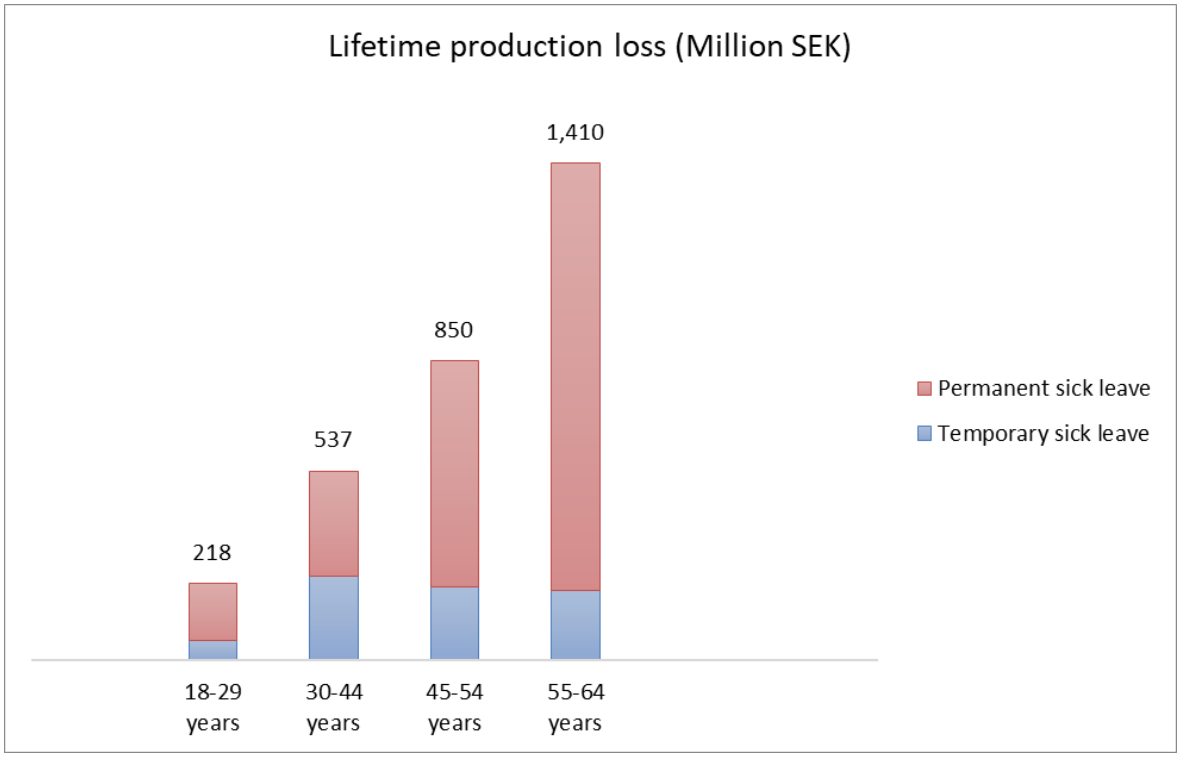


Figure 10 Incremental lifetime costs of production loss for obesity and overweight in a cohort of 120,000 6-year-olds, stratified by age intervals. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

4.2 Lifetime costs of obesity and overweight in adolescence

Costs of obesity and overweight in adolescence were calculated based on data for 15-year-olds. As for 6-year-olds, the costs are presented as incremental costs for an average adolescent with overweight or obesity relative to an average adolescent with normal weight and assuming potential changes in weight status in adulthood. The costs are divided into societal costs, which include public sector costs (i.e., costs of health care and social services) and production loss. The corresponding costs of obesity and overweight are also presented for a Swedish national cohort of 15-year-olds. Costs on a municipality level are presented in Appendix 8.2.2.

4.2.1 Average incremental societal cost for a 15-year-old

Total societal costs

Total average incremental societal cost over a lifetime for adolescents with obesity relative adolescents with normal weight were estimated to approximately SEK 641,000 for girls and SEK 604,000 for boys (Figure 11), which represented increases of approximately 1.5- and 2.4-fold, respectively, compared to the incremental costs calculated for obese 6-year-olds. Incremental societal costs for overweight adolescents were estimated to approximately SEK 469,000 for girls and SEK 210,000 for boys (Figure 11). For girls, this represented a 3-fold increase compared to the incremental societal costs estimated for overweight 6-year-old girls, whereas for the boys, the increase was only 1.4-fold compared to the cost of overweight 6-year-old boys. For both obese and overweight adolescents, production loss constituted more than 75% of total societal costs.

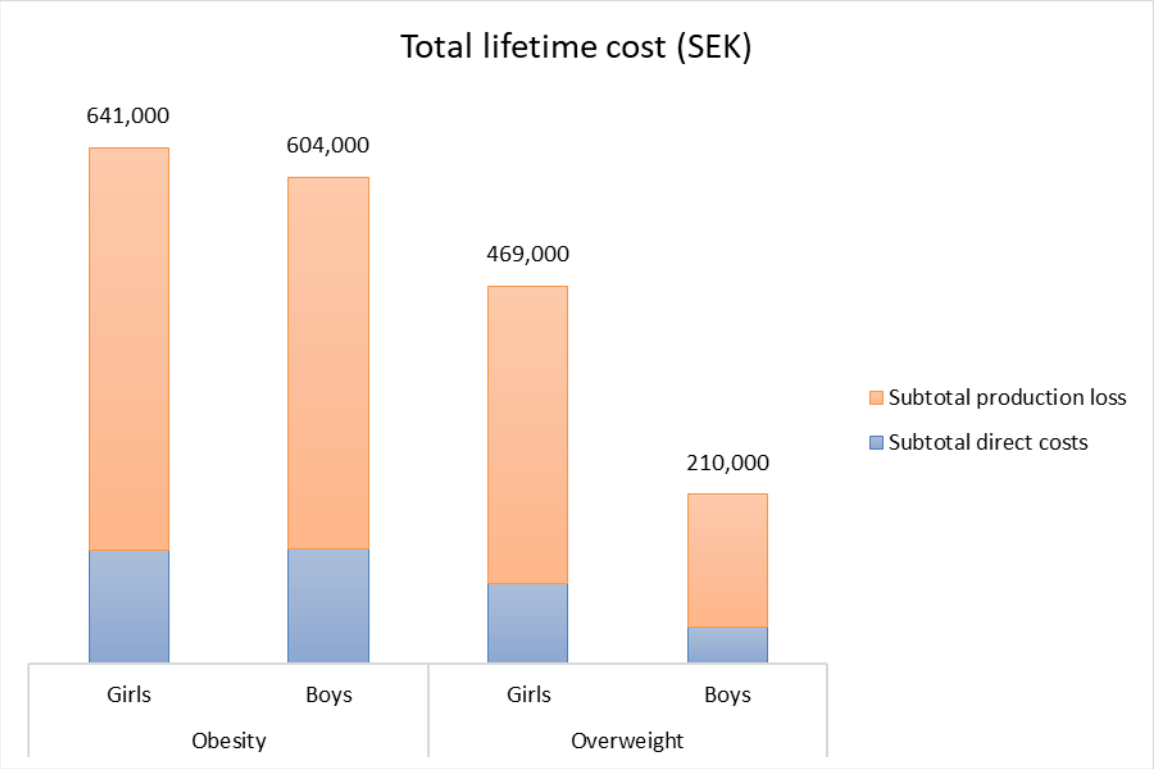


Figure 11 Average incremental total lifetime costs for a 15-year-old adolescent age with obesity or overweight. The costs are presented as the difference relative to the costs of a 15-year-old adolescent of normal weight

Public sector costs

Total incremental costs of healthcare and social services were relatively similar between adolescent girls and boys with obesity (Figure 12). However, the distribution of costs differed somewhat between sexes; girls had relatively more cost attributed to primary care, whereas the cost of inpatient care was higher for boys. For adolescents with overweight, larger differences were observed between sexes, with nearly twice as high incremental public sector costs for girls compared to boys, largely due to differences in costs of primary care and medication.

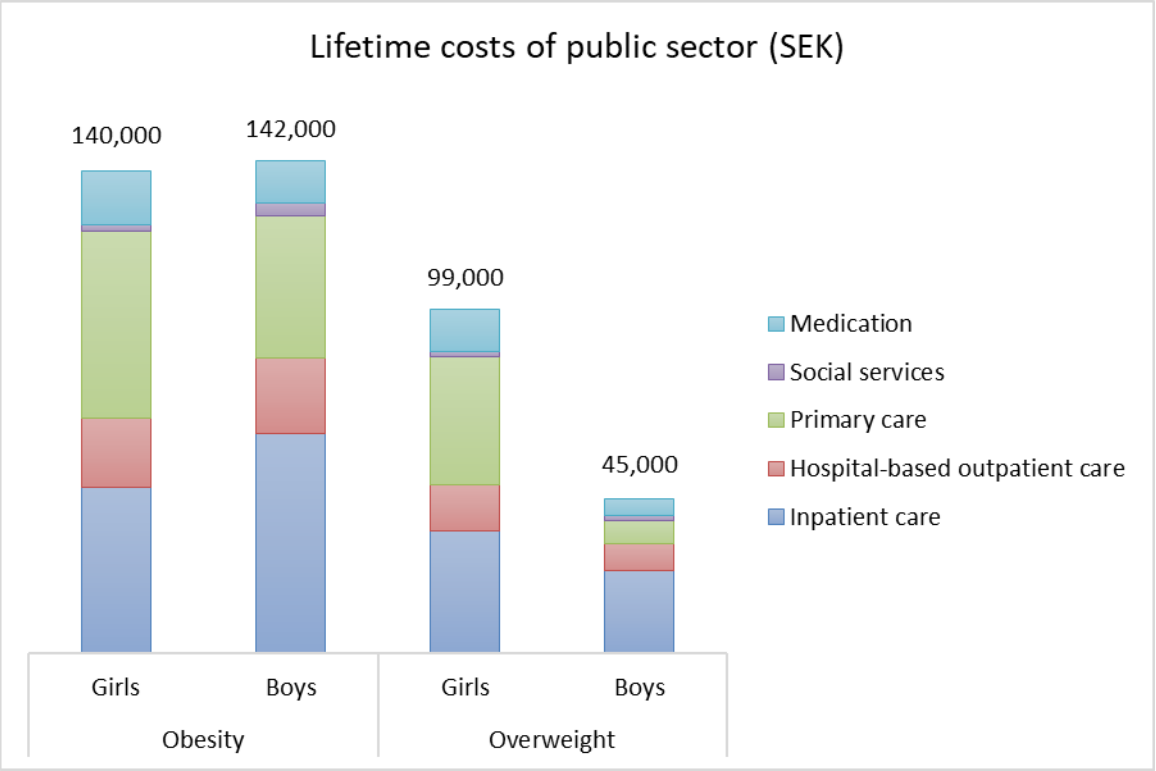


Figure 12 Average incremental lifetime costs of public services (health care and social services) for a 15-year-old adolescent with obesity or overweight. The costs are presented as the difference relative to a 15-year-old adolescent of normal weight.

Production losses

The average incremental cost of production loss was somewhat higher for obese girls compared to obese boys, mainly due to a higher cost of temporary sick-leave for girls (Figure 13). For overweight girls, incremental costs of production loss were roughly twice as high compared to overweight boys, and the difference was represented by higher costs of both permanent and temporary sick leave for girls.

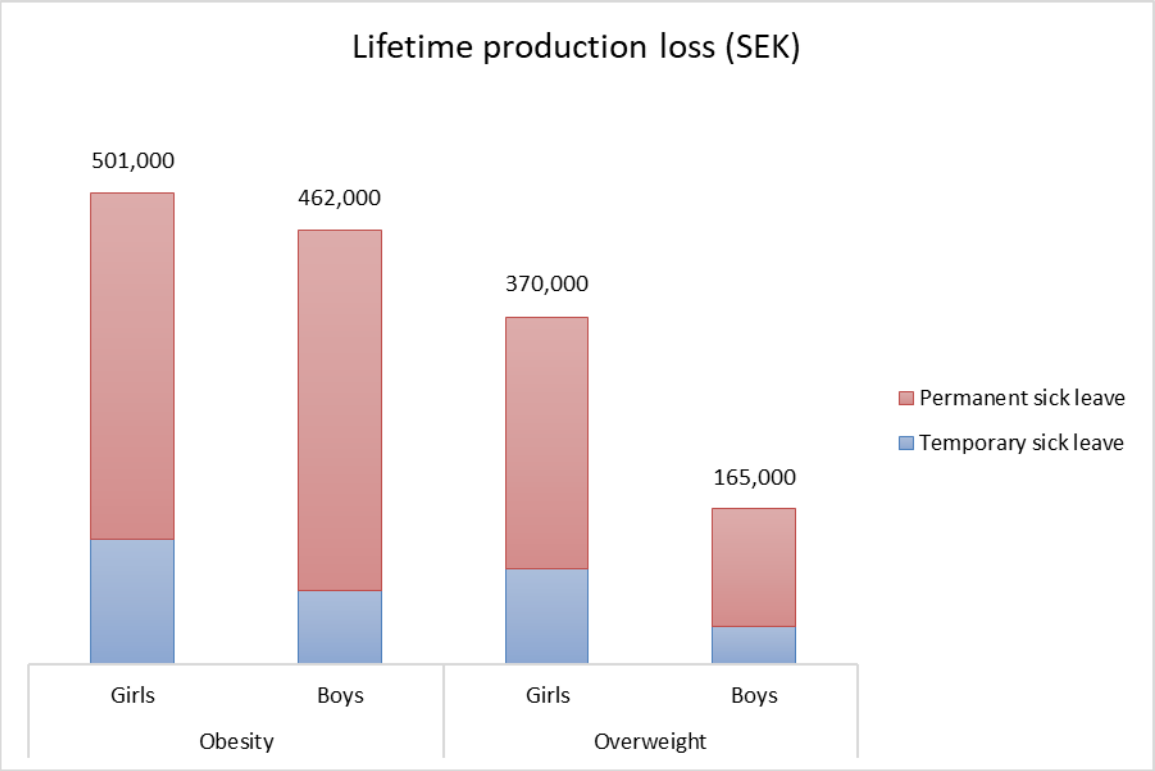


Figure 13 Average incremental lifetime costs of production loss (permanent and temporary sick-leave) for a 15-year-old adolescent with obesity or overweight. The costs are presented as the difference relative to a 15-year-old adolescent of normal weight.

4.2.2 Lifetime costs for a representative national cohort

To estimate costs of obesity and overweight in adolescents on a Swedish national level, lifetime costs of obesity and overweight was estimated for a cohort of 120,000 15-year-olds (60,000 boys, 60,000 girls). Based on the prevalence of obesity and overweight among 15-year-olds (Table 1), this translated to 1,800/3,000 girls/boys with obesity, and 5,400/7,800 girls/boys with overweight. Similar to the findings for the cohort of 6-year-olds, higher costs were estimated for overweight adolescents compared to obese adolescents (Figure 14), however, the costs were overall considerably higher, approximately 2-fold, compared to 6-year-olds. The total costs of overweight estimated for the cohort of adolescents (SEK 4.2 billion) was approximately 40% higher than costs of childhood obesity (SEK 3.0 billion). For both obesity and overweight, the greater proportions of costs (~80%) were represented by production loss. The distribution of costs between different categories of public

sector costs and production losses for the cohort are presented in Figure 15 and Figure 16, respectively.

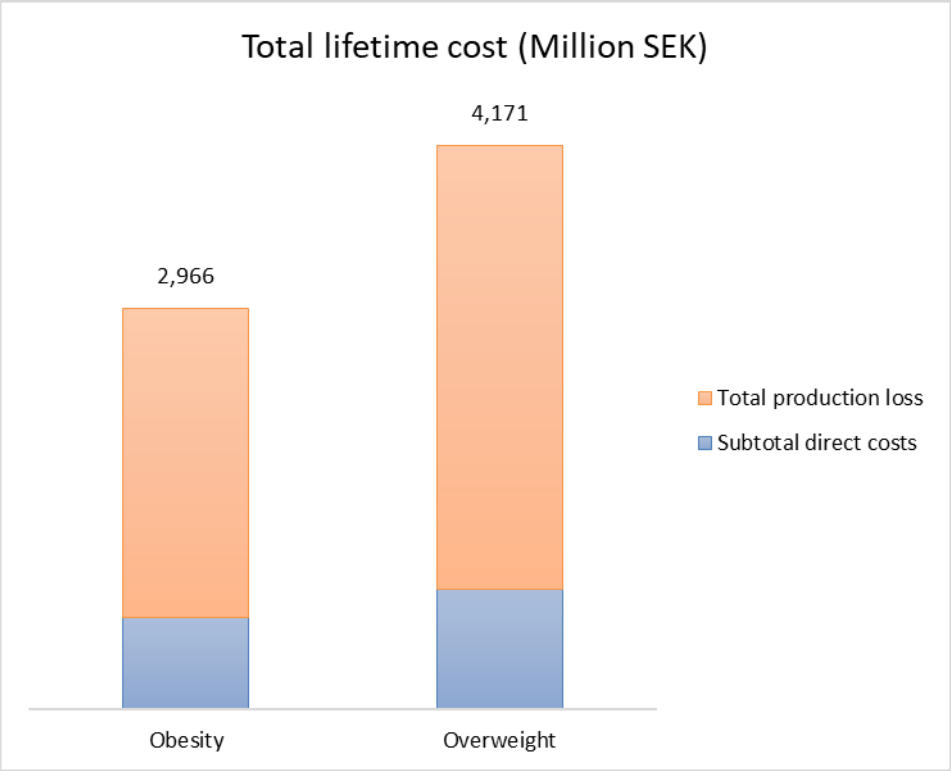


Figure 14 Total incremental lifetime costs for obesity and overweight in a cohort of 120,000 15-year-old adolescents representing Swedish national numbers. The costs are presented as the difference relative to costs of normal weight adolescents.

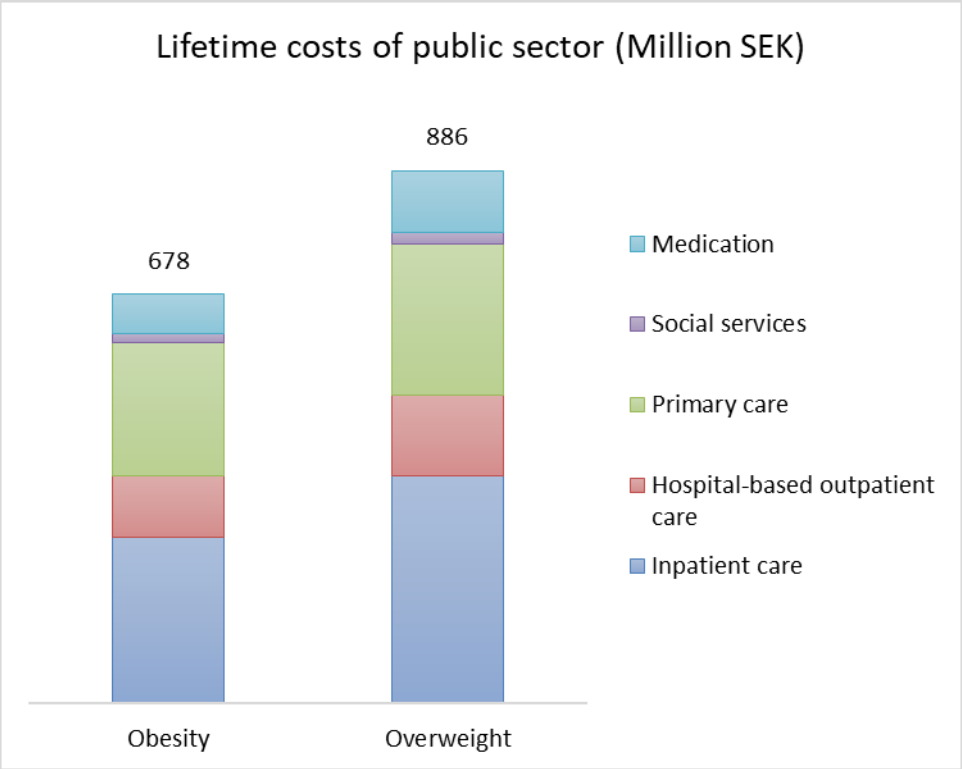


Figure 15 Incremental lifetime public sector costs for obesity and overweight in a cohort of 120,000 15-year-old adolescents representing Swedish national numbers. The costs are presented as the difference relative to costs of normal weight adolescents.

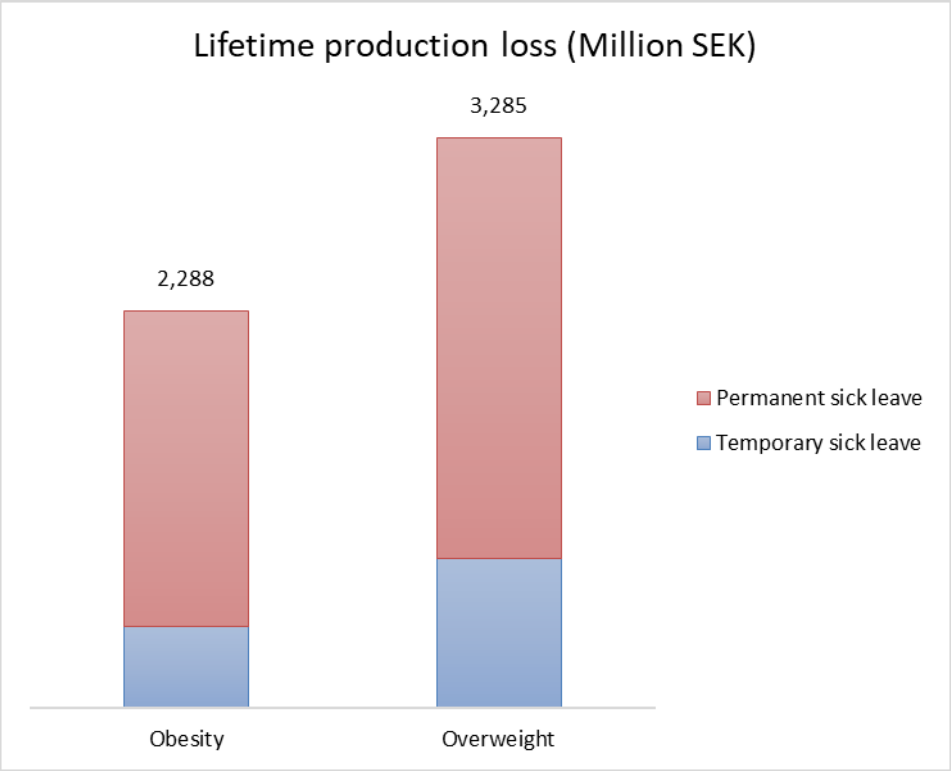


Figure 16 Incremental lifetime costs of production loss for obesity and overweight in a cohort of 120,000 15-year-old adolescents representing Swedish national numbers. The costs are presented as the difference relative to costs of normal weight adolescents.

Figure 17 and Figure 18 shows the amount of costs incurred in different age intervals over the cohort's lifetime. Notice the increased burden of costs after the age of 54 years.

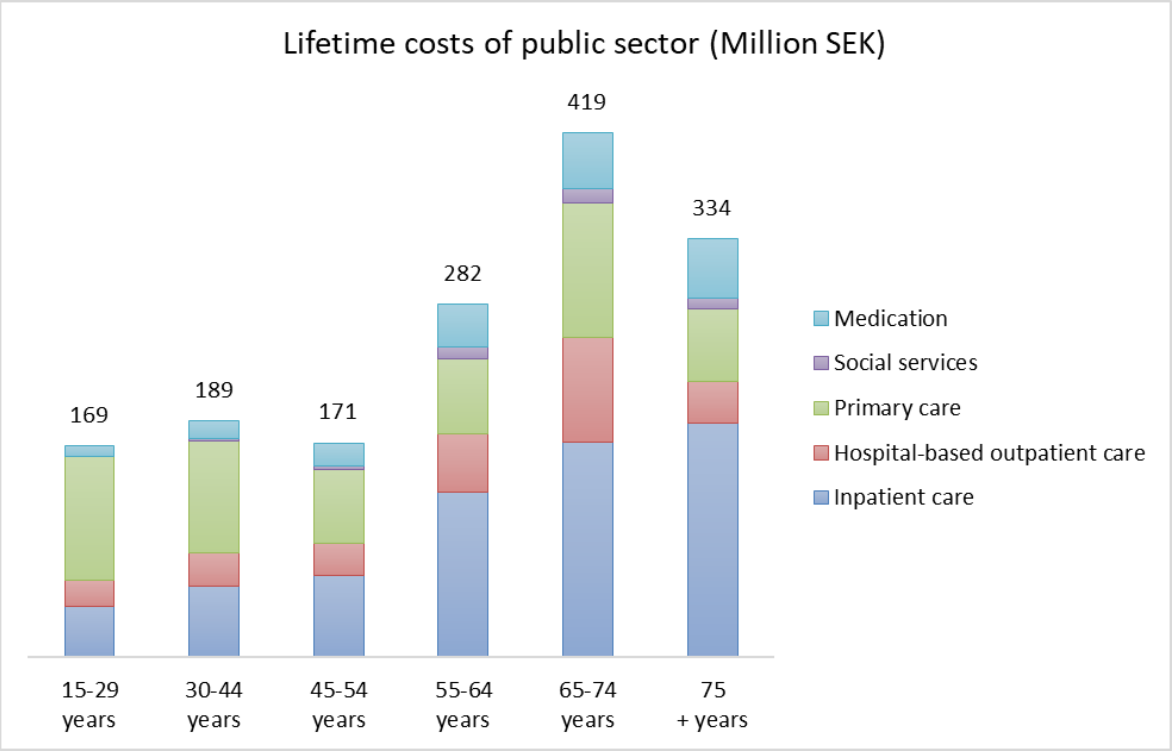


Figure 17 Incremental lifetime public sector costs for obesity and overweight in a cohort of 120,000 15-year-old adolescents, stratified by age intervals. The costs are presented as the difference relative to costs of normal weight adolescents.

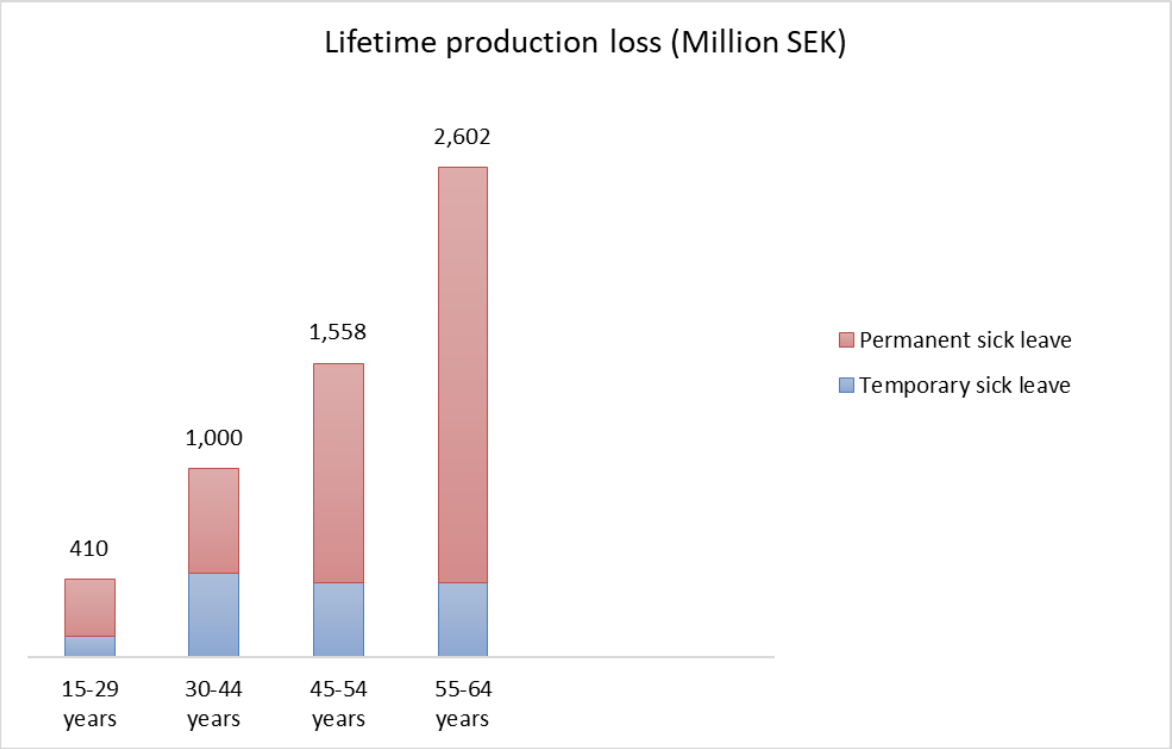


Figure 18 Incremental lifetime costs of production loss for obesity and overweight in a cohort of 120,000 adolescents, stratified by age intervals. The costs are presented as the difference relative to costs of normal weight adolescents.

4.3 Analysis including production loss due to unemployment linked to educational level (6-year-old children)

This section presents results including production loss due to employment linked to educational level. Lifetime costs of obesity and overweight in preschool children are presented as incremental costs for an average 6-year-old child with overweight/obesity relative an average 6-year-old child with normal weight. The costs of lost production are the same as in section 4.1 except in this section the production loss from unemployment is added to the analysis. The corresponding costs of overweight and obesity for a country-level cohort representing all 6-year-olds in Sweden is also presented.

4.3.1 Incremental cost of lost production for an average 6-year-old

Figure 19 shows the incremental cost of production loss over a lifetime for boys and girls with obesity and overweight. When including cost of lost production due to unemployment, the costs were approximately 651,000 and 363,000 among obese girls and boys, and 226,000 and 222,000 among overweight girls and boys. These estimates were in the range 90-100% larger than when not including cost of lost production due to unemployment (section 4.1).

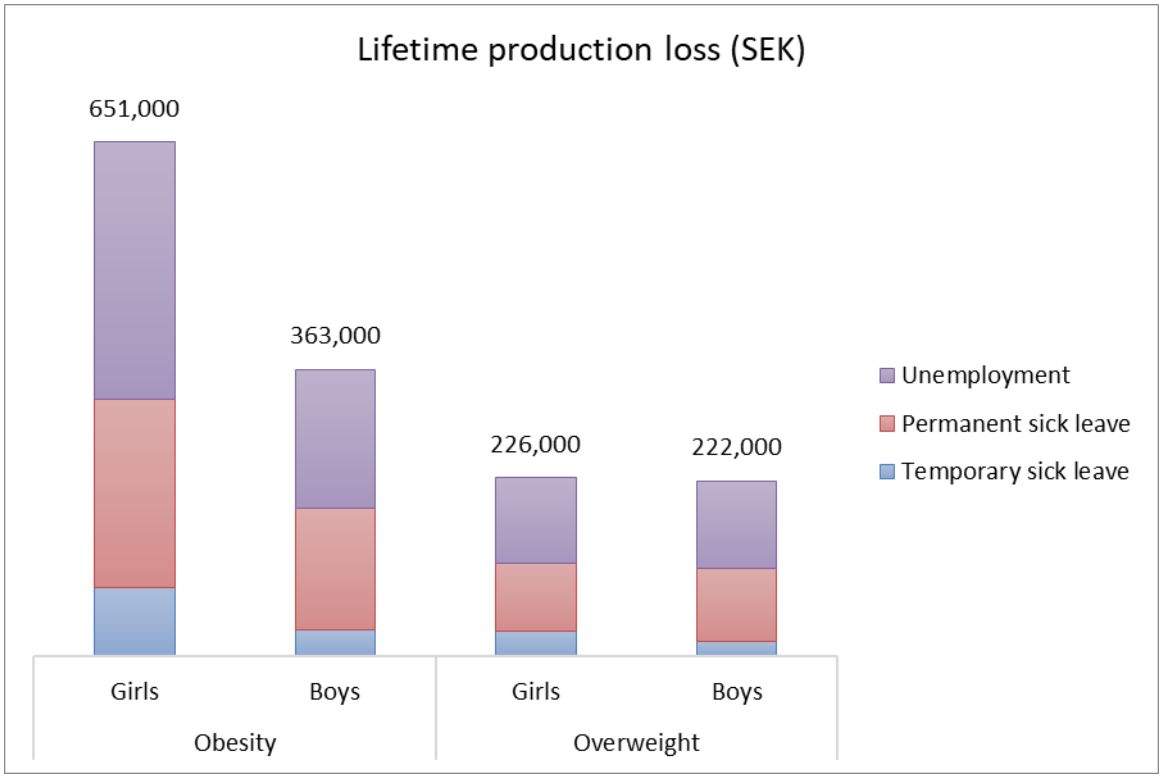


Figure 19 Average incremental lifetime costs of production losses including unemployment for a 6-year-old child with obesity or overweight. The costs are presented as the difference relative to a 6-year-old child of normal weight.

4.3.2 Lifetime costs for representative cohorts at city/national level

4.3.2.1 Country-level Swedish cohort of children

To estimate costs of obesity and overweight in young children on a Swedish national level, lifetime costs of obesity and overweight was estimated for a cohort of 120,000 6-year-olds (60,000 boys, 60,000 girls). Figure 20 shows the distribution of costs between the different categories of production losses for the cohort. Figure 21 shows the amount of costs incurred in different age intervals over the cohort's lifetime.

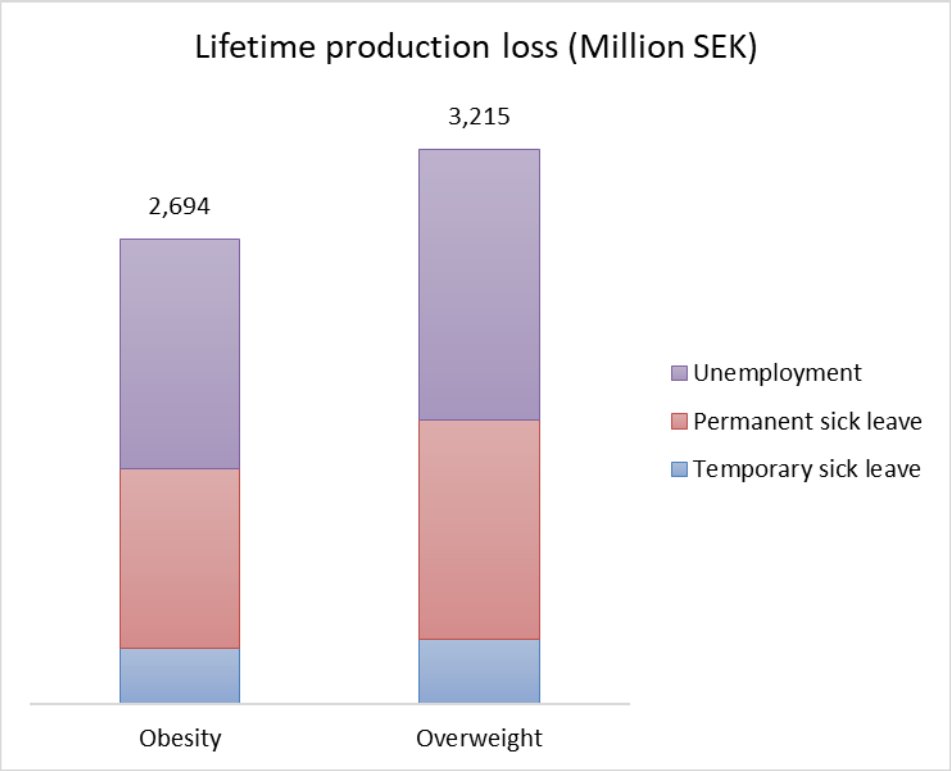


Figure 20 Incremental lifetime costs of production loss including unemployment for obesity and overweight in a cohort of 120,000 6-year-olds representing Swedish national numbers. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

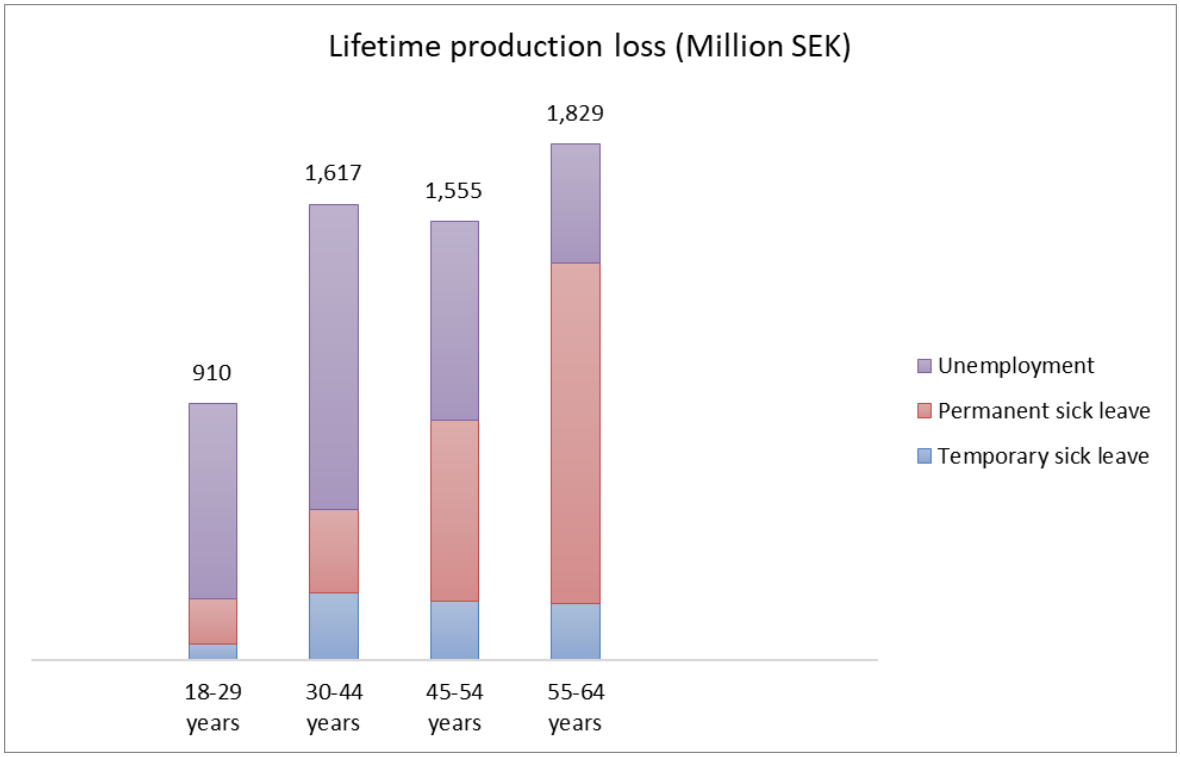


Figure 21 Incremental lifetime costs of production loss including unemployment for obesity and overweight in a cohort of 120,000 6-year-olds, stratified by age intervals. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

5. Discussion

The results from this study showed that both obesity and overweight in early childhood and adolescence will contribute to higher societal costs throughout life. On the individual level (i.e., estimated average costs per person), obesity contributed to more costs than overweight. This was partly due to the higher overall probability of maintaining unhealthy weight into adulthood for obesity compared to overweight, but also to the more severe health consequences related to obesity. Costs were much higher for excess weight in adolescence compared excess weight in early childhood, as a substantial minority of young children normalize weight from childhood to adolescence but not after entering puberty. Thus, the highest average incremental societal costs over a lifetime (SEK 641,000 for girls and SEK 604,000 for boys) was observed for an obese adolescent, which was approximately three times more than the costs estimated for an overweight 6-year-old

child (SEK 152,000 for girls and SEK 147,000 for boys). However, when the data was analysed on a national level, the costs of childhood overweight exceeded the costs of childhood obesity considerably due to the higher prevalence of overweight compared to obesity among both younger children and adolescents. The total lifetime cost of overweight for 6-year-olds/15-year-olds in Sweden were estimated to SEK 2.1/4.2 billion and of obesity to SEK 1.8 /2.9 billion.

It is important to keep in mind that the costs presented reflect lifetime costs for the two specific birth cohorts analysed (i.e. 6- and 15-year-olds) and their expected future costs over life. These age-cohorts were chosen to represent consequences of obesity before puberty and for mid-teenagers and to be straight forward to interpret. It was beyond the scope of this analysis to estimate the costs of obesity in all prevalent children, i.e. for the entire age span 0-17 years old. Nevertheless, results presented here indicate that the total lifetime costs of overweight and obesity for all Swedish children and adolescents would multiply and generate large numbers. Another important consideration is that the numbers presented from the base case analysis in this study reflect the difference in lifetime cost between children with obese/overweight at a certain age (i.e. age 6 and 15) compared to children with normal weight at the same age considering a “real life” scenario in which a persons’ weight status can change between childhood and adulthood. This means that we have accounted for the fact some children/adolescents with excess weight will have normal weight in adulthood, and vice versa. Sensitivity analyses investigated the impact on the results when 1) calculating the incremental life-time costs of childhood obesity/overweight compared with a child that maintains normal weight throughout life (Appendix 8.3), and 2) calculating the incremental life-time cost of a person with obesity/overweight from age 6 and throughout life compared to a person with normal weight from age 6 and throughout life (Appendix 8.4). The latter, which generated costs that were approximately double compared to the "real-life" scenario, fail to capture how excess weight in different stages of life can have different long-term impact.

When including unemployment linked to impaired educational level, the lifetime costs of lost production of overweight and obesity for 6-year-olds in Sweden were estimated to SEK 3.2 and 2.7 billion, respectively, compared with SEK 1.6 and 1.4 billion in when only production losses due to sick leave were included. While this is a substantial cost to the society, the impact of obesity on educational level may be a consequence of discrimination and bullying rather than of the medical condition, which motivate us to report these results in a separate analysis.

Although both obesity and overweight contributed to higher costs of health care and social services, production losses due to sick leave contributed to the largest proportion (≥75%) of total societal costs

over a lifetime. In cohorts of 6-year-old children, costs of outpatient care were highest during childhood years (6-17 years in Figure 9) and constituted a major part of the costs during those years. The largest contributor to these costs came from the ICD-10 codes for obesity (data not presented) which may reflect costs of initiation of childhood obesity treatment.

For both preschool children and adolescents, estimated societal costs of obesity and overweight were higher for girls than for boys largely due to consistently higher production losses for girls. The main factor that led to higher estimated costs of production loss for girls in this study was that women had more work absence than men in general, while the same relative risks of work absence were used for both women and men. Another difference between sexes was the higher cost of primary care observed for girls which partly can be explained by the same mechanism as the higher cost of production loss for girls – women had more primary care visits than men in general, while the same relative risks of primary care need was used for both women and men. The difference is also partly due to a higher mortality among men at the same time as a lot of the primary care costs were incurred in later ages.

The lifetime costs of overweight and obesity in childhood/adolescence presented in this study depend on the relationship between weight status in childhood/adolescence and adulthood. The calculations were based on a Swedish longitudinal study by Fåhraeus et al. which provided detailed information regarding the probabilities of retaining or changing weight status (i.e., normal weight, overweight, obesity) between different ages throughout childhood/adolescence and until early adulthood, for girls and boys separately [50, 84]. The study was based on a cohort of Swedish children (n~500) from the municipality of Jönköping which was found to provide the most comprehensive and representable data for predicting weight status developments among Swedish children. The results from the study, which showed that the association between weight status in childhood/adolescence increased with the age of the individual, were largely in line with similar international studies. For instance, Fåhraeus reported that 73% of obese adolescents (15-year-olds) retained obesity in early adulthood which is close to the 80% reported by a meta-analysis of 15 international cohorts [47, 84]. It should be noted that the cohort in Fåhreaus et al. were born in 1987, meaning that the transitions from childhood weight status to adulthood weight status reflects the interventions and treatments as well as incidence of overweight and obesity present in Sweden in the 90s. As such, the probabilities used to calculate transitions from childhood obesity to adulthood obesity and overweight used in the current analysis may not fully reflect future developments for todays's young children,the current clinical practice or societal organization. In a sensitivity analysis, we explored the impact of increasing the risk of

maintaining overweight/obesity in various degrees (Appendix 8.5) resulting in higher estimated costs.

The estimates of costs resulting from this study can be considered conservative for several reasons. For instance, although the literature describes a range of diseases that have been related to excess weight in childhood and adolescence [53], for the majority of these (e.g. neurological, cardiovascular, renal and dermatological disease), we could not find published studies reporting relative risks for these conditions in relation to childhood obesity or overweight that could be used in our calculations using the attributable fraction methodology. Therefore, although these diseases may contribute considerably to the overall costs and disease burden of a child/adolescent with excess weight, the associated costs could not be estimated and are therefore not included in the costs estimates.

The costs of medication are not prognostic in the sense of anticipating a higher future use of costly drugs for obesity such as GLP-1 receptor agonists – instead, costs reflect current clinical practice. Therefore, the lifetime costs attributed to medication could be larger as such drugs are gradually being adapted in clinical practice.

An implicit assumption in our calculations is also that normal-weight adults that were obese/overweight as children do not incur more costs than normal-weight adults that were not obese/overweight as children (i.e., we do not take fully into account legacy effects of childhood obesity). Costs of obesity- and overweight-related primary care in childhood years was not included due to lack of data. On a general note, while the national guidelines from the National Board of Health and Welfare regarding lifestyle interventions recommend weight reduction treatments in primary care, accessibility to these treatments is still limited. Moreover, cost estimates of production loss elated to sick leave, which was identified as the major contributing factor to total societal costs of excess weight in childhood/adolescence, covers only periods of leave longer than 14 days which is registered by Försäkringskassan. The analysis also did not include costs of presenteeism (i.e., reduced productivity at work). In the analysis where production loss due to unemployment linked to educational level was included (section 4.3), it was not taken into account that childhood obesity also may result in higher risk of part-time unemployment, therefore resulting in a conservative estimate. However, it was also assumed that the missed education was not compensated for over time, which is a non-conservative assumption. Furthermore, although several studies have indicated a negative effect of increasing weight on salary, particularly for women [65], such income penalty was not included in the costs estimates of this study due to being a loss for the individual rather than for the society.

The lifetime costs of childhood obesity have previously been estimated for other countries. A meta-analysis by Hamilton et al., using data from 13 studies (five from Europe and eight from the USA), calculated the life-time cost of childhood obesity and overweight to €150,000 (~SEK 1.5 million SEK, 2021 prices) and €58,000 (~SEK 575,000, 2021 prices), respectively [66]. For obesity, nearly 90% of costs were attributed to indirect costs. Healthcare costs of obesity ranged between €6,600 to €35,800 (~SEK 65,000 to 326,000, 2021 prices) for boys and €8,000 to €45,000 (~SEK 80,000 to 451,000, 2021 prices) for girls. In contrast, healthcare costs of overweight ranged between €-4,200 to €3,410 (~SEK -42,000 to 34,000, 2021 prices) for boys and -367 to 8,422 (~SEK -3,700 to 84,000, 2021 prices) for girls. The data from the different studies used in the analyses were heterogenous in terms of the ages covered by data of weight status and costs, study design (i.e., longitudinal cohort versus forecast modelling), and which costs that were included in the estimates (i.e., healthcare costs and/or production losses). The numbers on total lifetime costs presented by the meta-analysis are higher than what was reported here, which is largely related to differences in the cost categories represented by production losses; wage penalty, which contributed to more than 70% of the costs of production losses in the meta-analysis was not included in our estimates (although it is partly captured in the estimated production loss due to unemployment presented in separate analysis). However, there were also similarities between the findings from our study and the meta-analysis such as the predominance of costs related to production losses and the larger costs of obesity compared to overweight per average child.

The current analysis estimated lifetime costs of obesity/overweight attributed to childhood obesity/overweight specifically. It is important to remember that although the risk of becoming obese/overweight in adulthood is lower among normal-weight children compared with obese/overweight children, normal-weight children constitutes a larger group of people, and as such prevention of adulthood obesity/overweight among normal-weight children may also have an important role to play in reducing societal costs of obesity/overweight.

6. Conclusion

This study combines the growing literature on life-long consequences of excess weight in childhood with data from surveys and population-based statistics with the aim of estimating the economic burden of excess weight in childhood and adolescence. The findings indicate that excess weight in childhood and adolescence can contribute to considerable societal costs over a lifetime. The calculations clearly demonstrate that, based on the current situation, healthcare costs contribute to a

small proportion of total costs mainly represented by a higher disease burden in adulthood. Instead, the largest proportion of costs are attributed to different types of production losses. The study also indicates that, although obesity generates more costs than overweight at the individual level, overweight contribute to more costs on a national level due to the higher prevalence. If overweight and obesity would be prevented already before the age of 6 years and normal weight maintained during puberty, a substantial societal reduction of costs could be obtained.

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8. Appendix

8.1 Prevalence of overweight and obesity

Prevalence of overweight and obesity among children

Figure 22 Prevalence of obesity among children aged 4-17 years

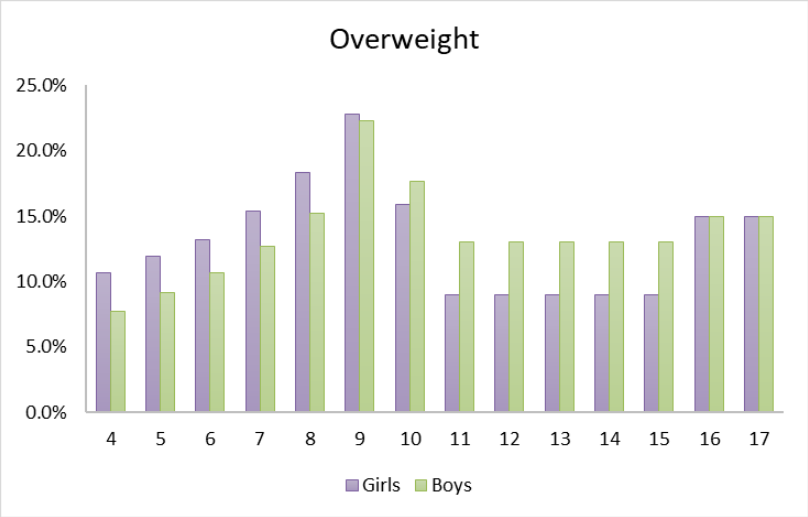

Figure 23 Prevalence of overweight among children aged 4-17 years

Prevalence of overweight and obesity among adults

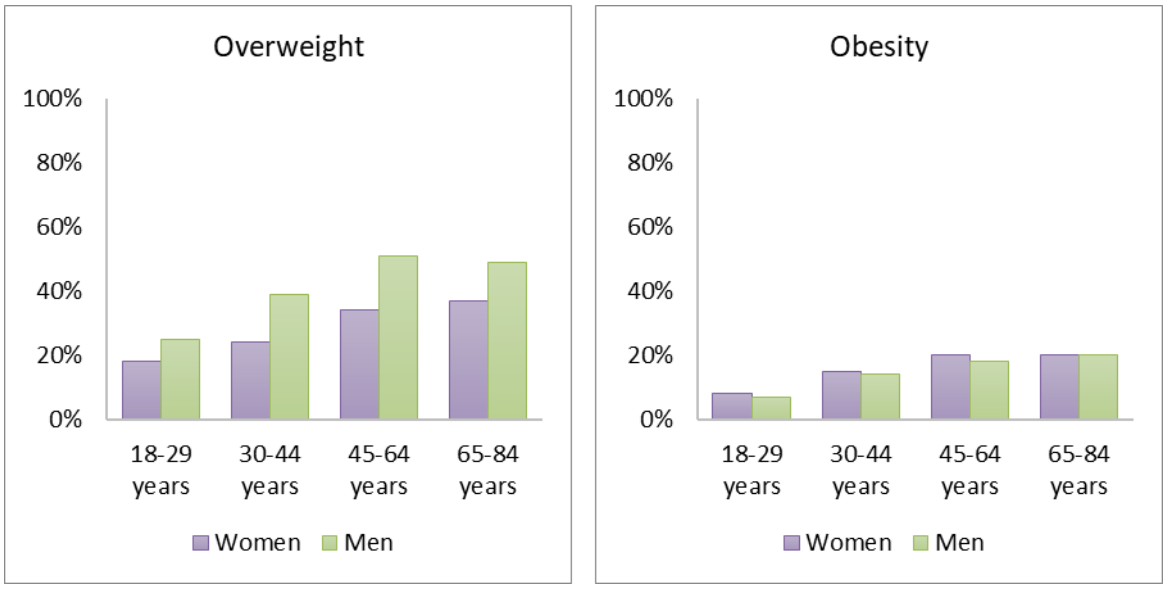

Figure 24 Prevalence of overweight and obesity in Swedish adults based on data from the Public Health Agency of Sweden.

8.2 Municipality-level Swedish cohorts

8.2.1 Municipality-level Swedish cohort of children

To estimate costs of obesity and overweight in young children in a Swedish municipality, lifetime costs of obesity and overweight was estimated for a cohort of 600 6-year-olds (300 boys, 300 girls), reflecting the approximate number of 6-year-olds in a medium-sized municipality of 50,000 inhabitants. Based on the prevalence of obesity and overweight among 6-year-olds (Table 1), this translated to 14/13 girls/boys with obesity, and 40/32 girls/boys with overweight. The results are similar to the results presented at the country level, with the only difference being that the cohort is smaller in numbers. Figure 25 shows the total lifetime costs due to the higher prevalence of overweight among children. For both obesity and overweight, the greater proportions of costs (~80%) were represented by production loss. The distribution of costs between different categories of public sector costs and production losses for the cohort are presented in Figure 26 and Figure 27, respectively.

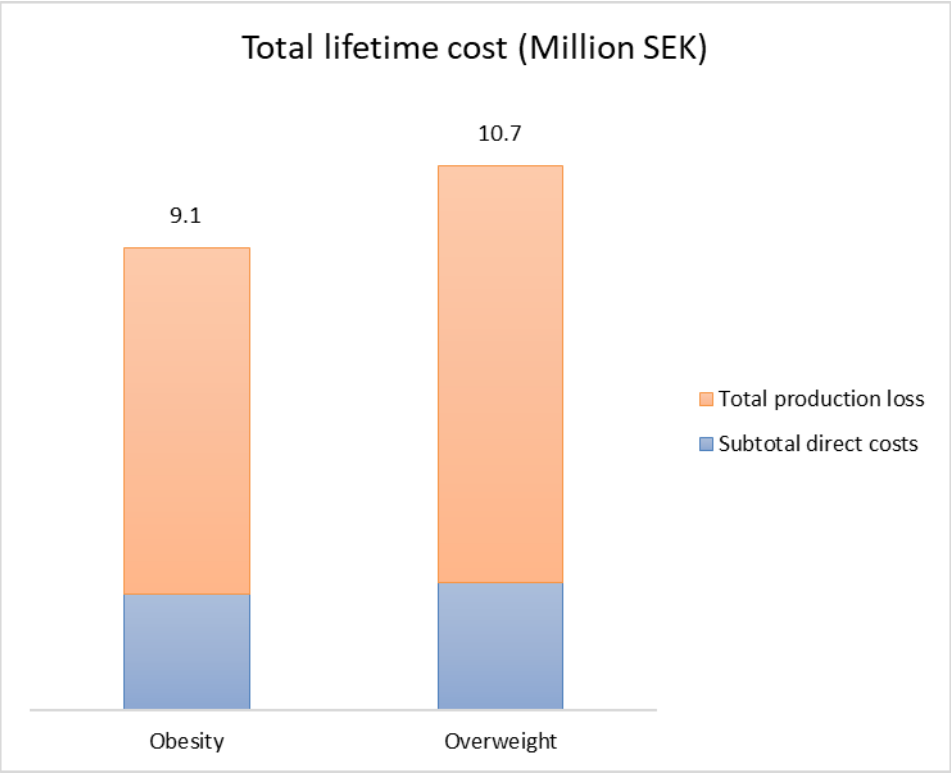

Figure 25 Total incremental lifetime costs for obesity and overweight in a cohort of 600 6-year-olds representing a medium-sized Swedish municipality. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

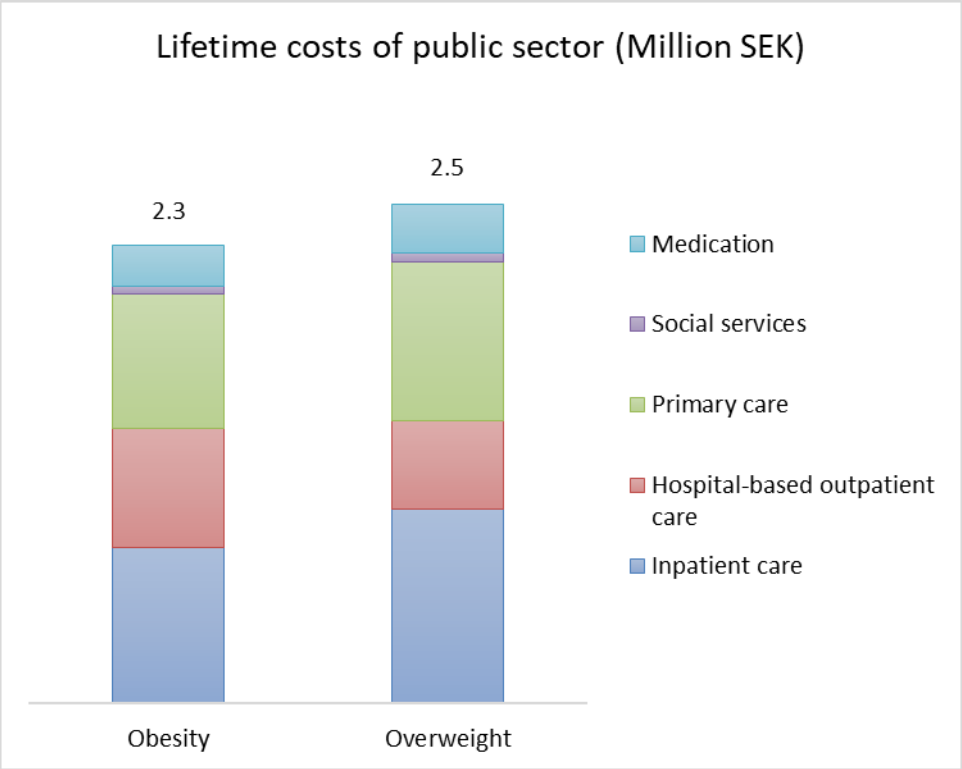

Figure 26 Incremental lifetime public sector costs for obesity and overweight in a cohort of 600 6-year-olds representing a medium-sized Swedish municipality. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

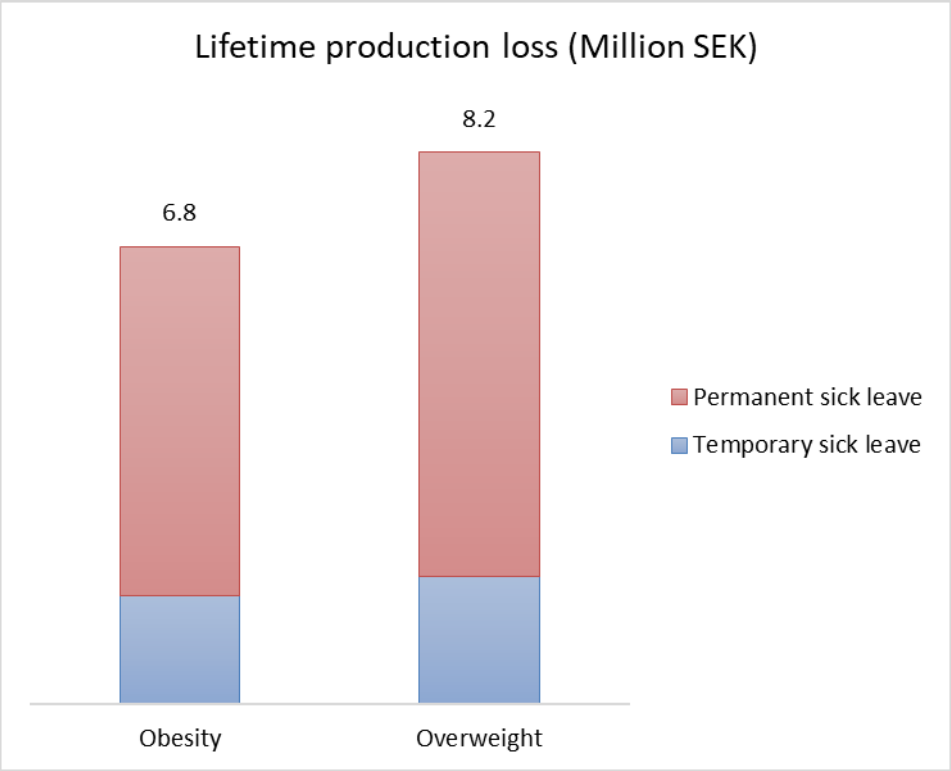

Figure 27 Incremental lifetime costs of production loss for obesity and overweight in a cohort of 600 6-year-olds representing a medium-sized Swedish municipality. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

Figure 28 and Figure 29 shows the amount of costs incurred in different age intervals over the cohort's lifetime.

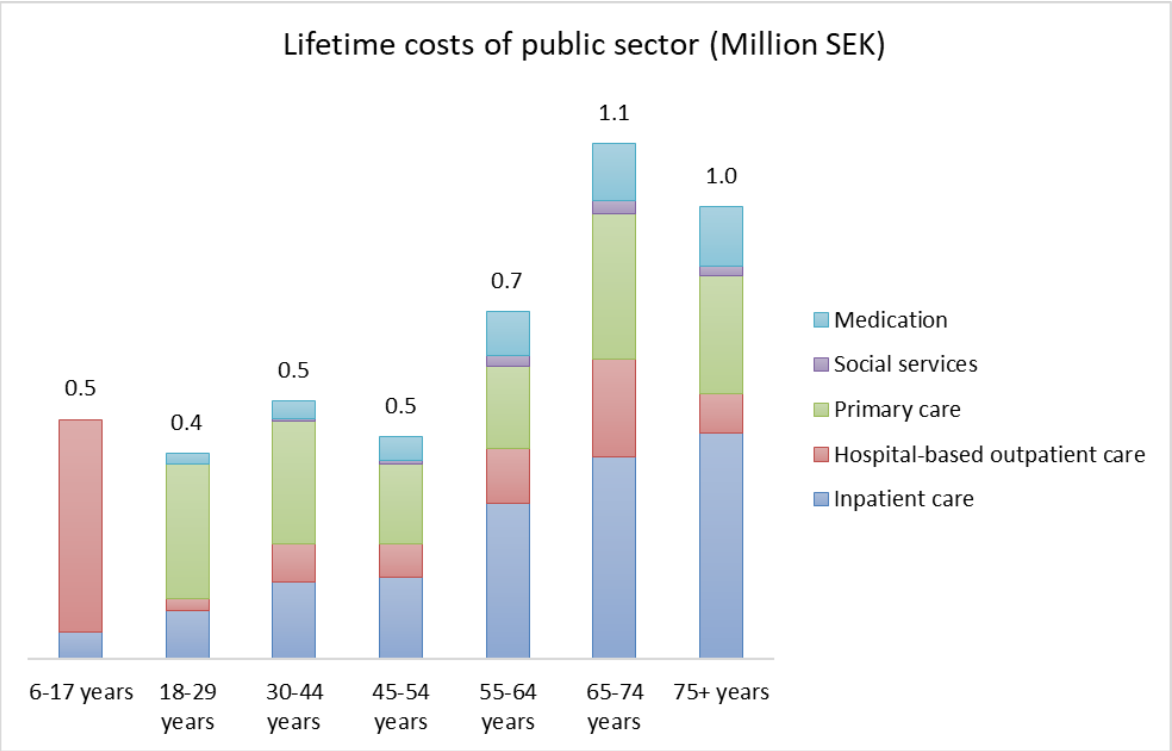

Figure 28 Incremental lifetime public sector costs for obesity and overweight in a cohort of 600 6-year-olds, stratified by age intervals. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

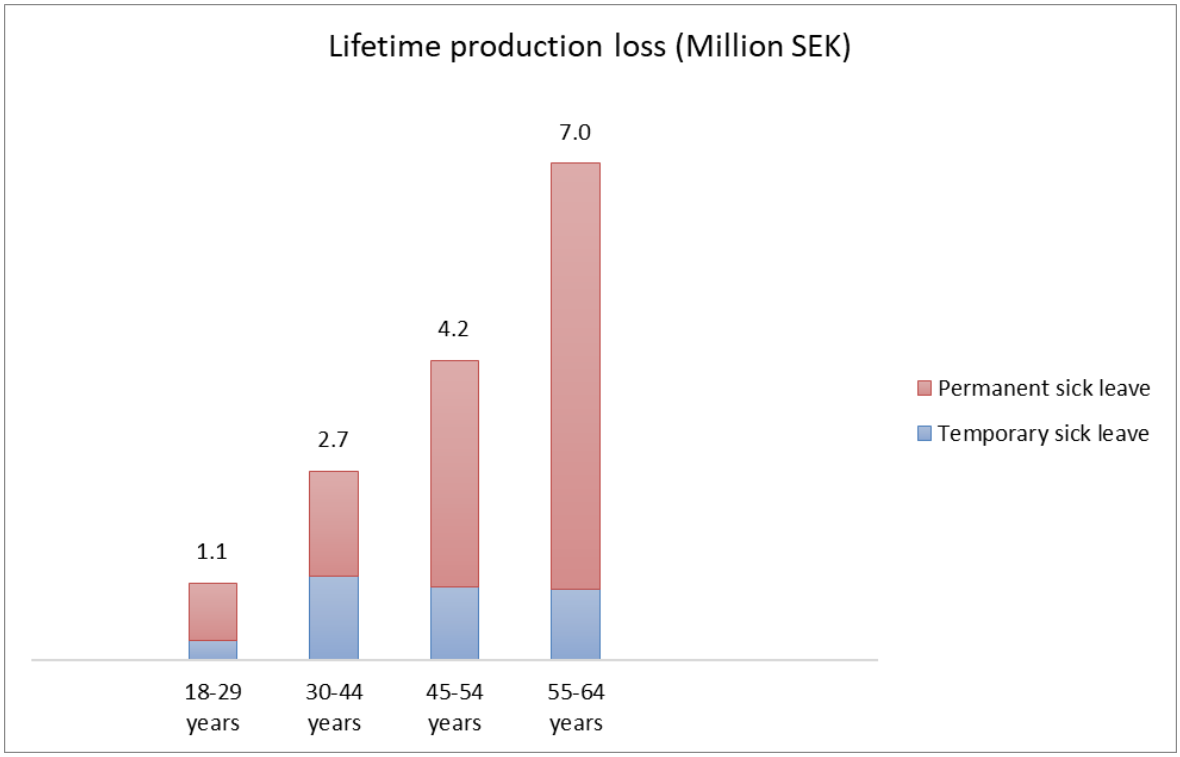

Figure 29 Incremental lifetime costs of production loss for obesity and overweight in a cohort of 600 6-year-olds, stratified by age intervals. The costs are presented as the difference relative to costs of normal weight 6-year-old children.

8.2.2 Municipality-level Swedish cohort of adolescents

To estimate costs of obesity and overweight in adolescents in a Swedish municipality, lifetime costs of obesity and overweight was estimated for a cohort of 600 15-year-olds (300 boys, 300 girls), reflecting the approximate number of 15-year olds in a medium-sized municipality of 50,000 inhabitants. Based on the prevalence of obesity and overweight among 15-year-olds (Table 1), this translated to 9/15 girls/boys with obesity, and 27/39 girls/boys with overweight. The results are similar to the results presented at the country level, with the only difference being that the cohort is smaller in numbers. Figure 30 shows the total lifetime costs due to the higher prevalence of overweight among children. For both obesity and overweight, the greater proportions of costs (~80%) were represented by production loss. The distribution of costs between different categories of public sector costs and production losses for the cohort are presented in Figure 31 and Figure 32, respectively.

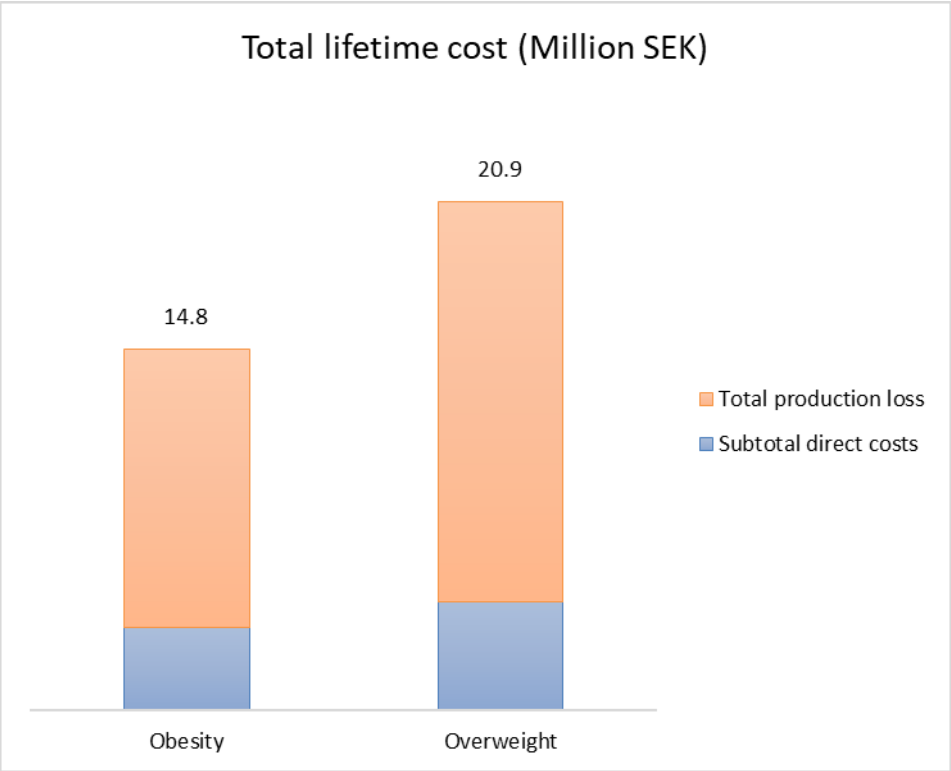

Figure 30 Total incremental lifetime costs for obesity and overweight in a cohort of 600 adolescents representing a medium-sized Swedish municipality. The costs are presented as the difference relative to costs of normal weight adolescents.

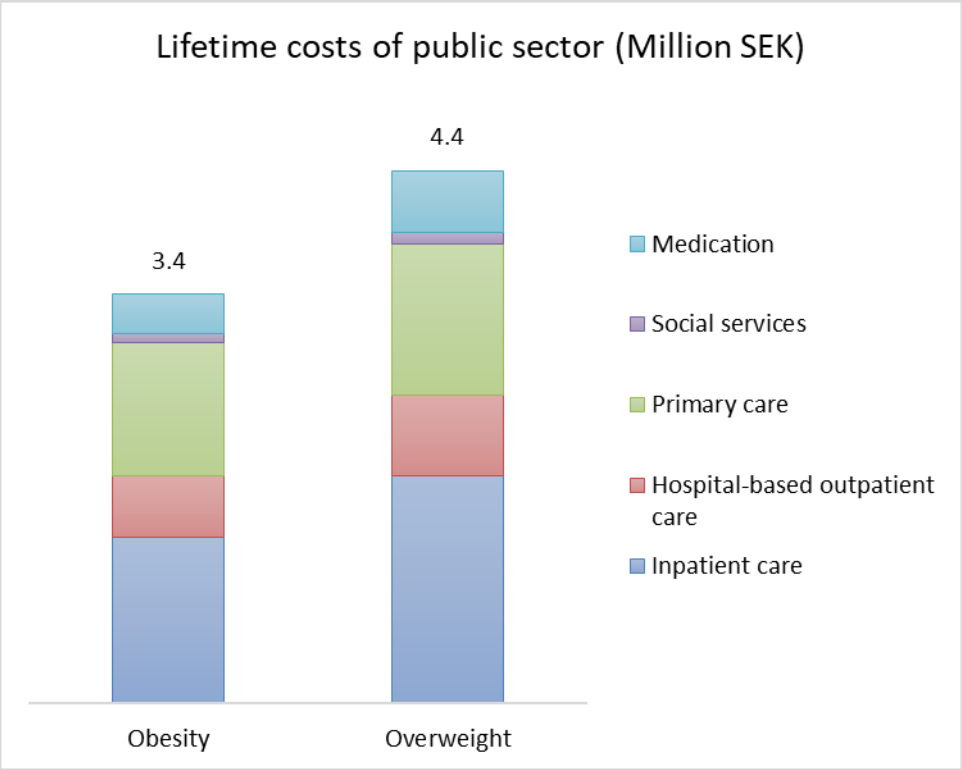

Figure 31 Incremental lifetime public sector costs for obesity and overweight in a cohort of 600 adolescents representing a medium-sized Swedish municipality. The costs are presented as the difference relative to costs of normal weight adolescents.

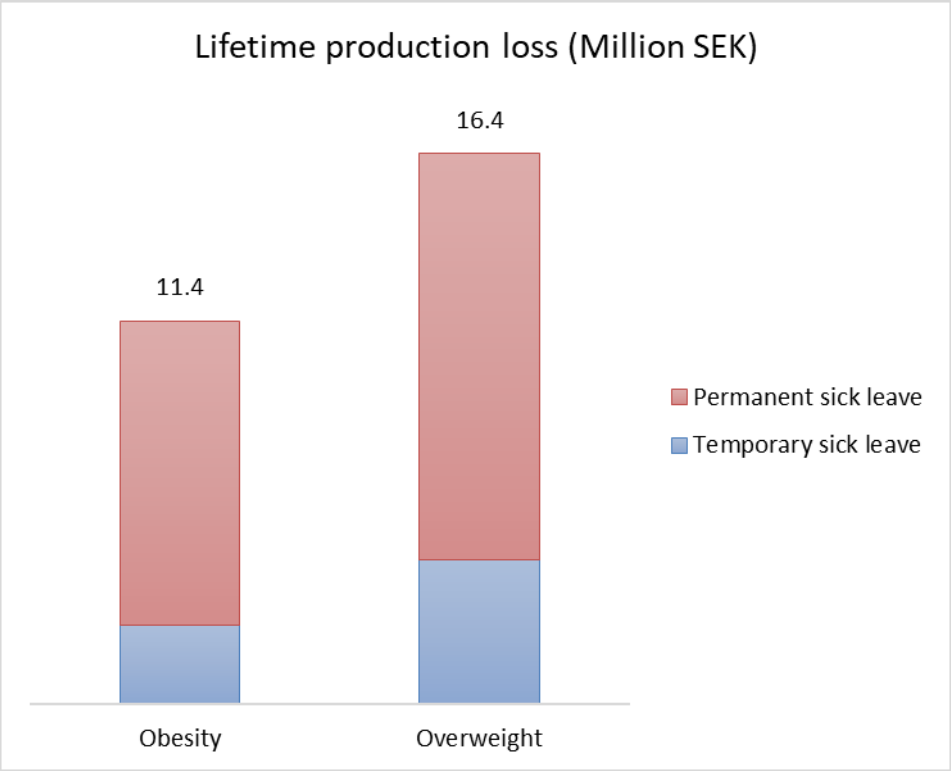

Figure 32 Incremental lifetime costs of production loss for obesity and overweight in a cohort of 600 adolescents representing a medium-sized Swedish municipality. The costs are presented as the difference relative to costs of normal weight adolescents.

Figure 33 and Figure 34 shows the amount of costs incurred in different age intervals over the cohort's lifetime.

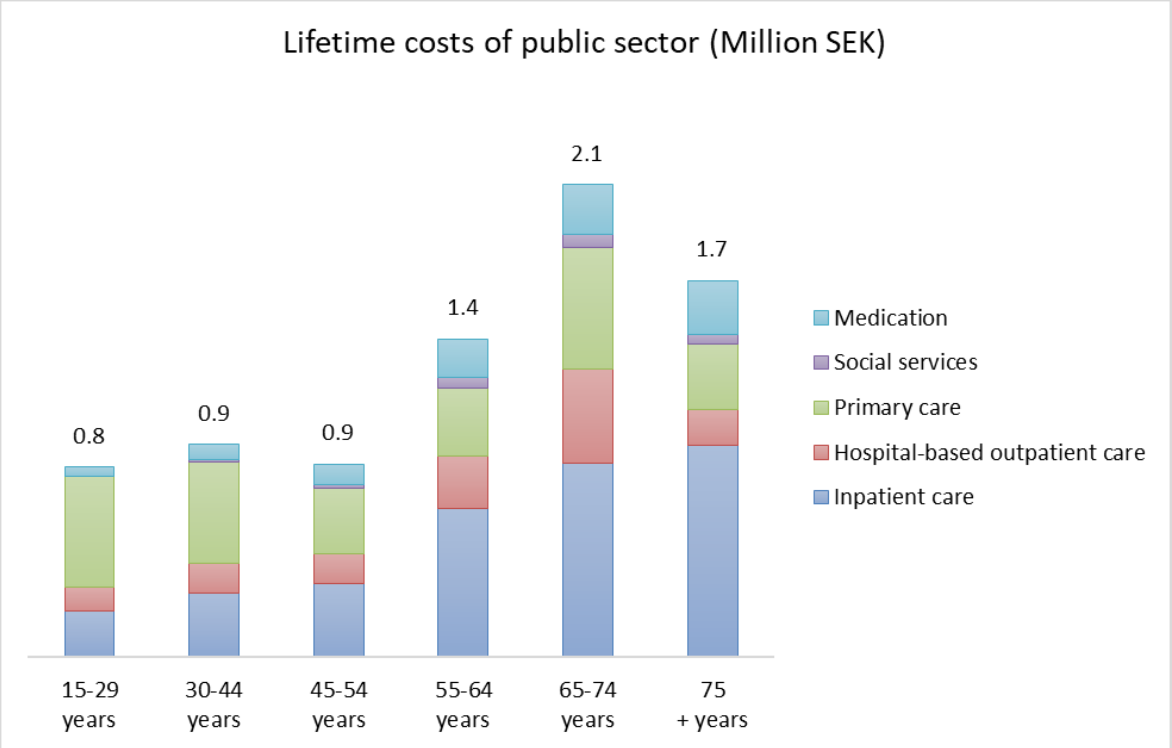

Figure 33 Incremental lifetime public sector costs for obesity and overweight in a cohort of 600 adolescents, stratified by age intervals. The costs are presented as the difference relative to costs of normal weight adolescents.

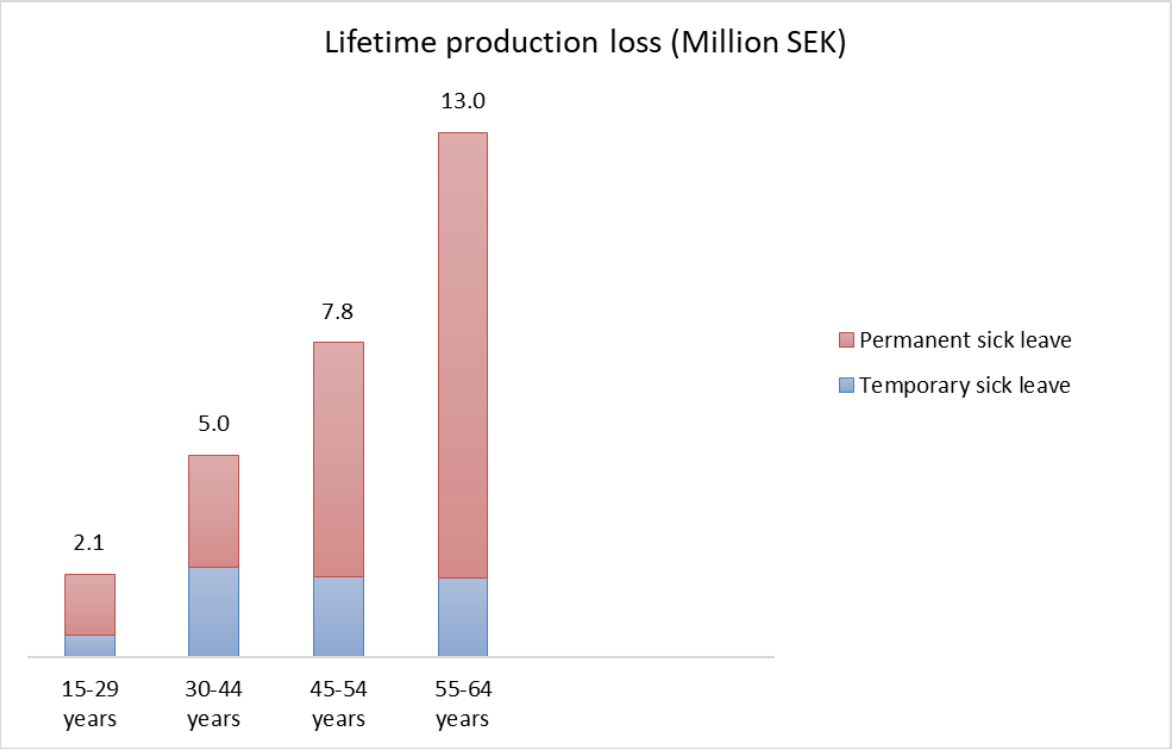

Figure 34 Incremental lifetime costs of production loss for obesity and overweight in a cohort of 600 adolescents, stratified by age intervals. The costs are presented as the difference relative to costs of normal weight adolescents.

8.3 Sensitivity analysis: incremental costs relative to children with normal weight maintained to adulthood

The sensitivity analysis presented below investigates how the results change if comparing overweight/obese children to children with normal weight and that maintain normal weight into adulthood. This scenario aims to clarify the impact of the risk of adulthood overweight/obesity among normal-weight children in terms of estimated costs attributed to childhood obesity/overweight. The incremental societal costs for an average 6-year-old child with obesity, relative a 6-year-old child of normal weight (maintaining normal weight to adulthood), was estimated to approximately SEK 536,000 for girls and SEK 339,000 for boys (compared with SEK 429,000 for girls and SEK 257,000 for boys in the base case analysis) (Table 3). For an overweight 6-year-old, the incremental societal costs were SEK 259,000 for girls and SEK 230,000 for boys (compared with SEK 152,000 for girls and SEK 147,000 for boys in the base case analysis).

Table 3. Alternative scenario where the costs are presented as the difference relative to a 6-year-old child of normal weight that stays normal weight during its lifetime.

		Lifetime costs of public sector		Lifetime production loss		Total lifetime costs	
		Girls	Boys	Girls	Boys	Girls	Boys
Base case	Obesity	104,000	68,000	325,000	189,000	429,000	257,000
	Overweight	34,000	36,000	118,000	111,000	152,000	147,000
Alternative scenario	Obesity	126,000	85,000	410,000	254,000	536,000	339,000
	Overweight	56,000	53,000	203,000	177,000	259,000	230,000

8.4 Sensitivity analysis: all children maintaining their weight status to adulthood

The sensitivity analysis presented below investigates how the results change when if all children remain in their starting weight status. This sensitivity analysis may be interpretated as a subgroup analysis among children that maintain their weight status into adulthood.

The incremental societal costs for an average 6-year-old child with obesity, relative a 6-year-old child of normal weight, was estimated to approximately SEK 965,000 for girls and SEK 748,000 for

boys (compared with SEK 429,000 for girls and SEK 257,000 for boys in the base case analysis) (Table 4). For an overweight 6-year-old, the incremental societal costs were SEK 406,000 for girls and SEK 324,000 for boys (compared with SEK 152,000 for girls and SEK 147,000 for boys in the base case analysis).

Table 4. Alternative scenario assuming all children maintain their weight status into adulthood. The costs are presented as the difference relative to a 6-year-old child of normal weight that stays normal weight during its lifetime.

		Lifetime costs of public sector		Lifetime production loss		Total lifetime costs	
		Girls	Boys	Girls	Boys	Girls	Boys
Base case	Obesity	104,000	68,000	325,000	189,000	429,000	257,000
	Overweight	34,000	36,000	118,000	111,000	152,000	147,000
Alternative scenario	Obesity	226,000	188,000	739,000	560,000	965,000	748,000
	Overweight	78,000	65,000	328,000	259,000	406,000	324,000

8.5 Sensitivity analysis: different assumptions on distribution of adult weight status among obese/overweight children

The sensitivity analysis presented below investigates how the results change when assuming larger probabilities of maintaining obesity/overweight from childhood to adulthood. Three alternative combinations of probabilities were tested in scenarios A-C (Table 5). For simplicity, the same probabilities were used for obese/overweight girls and boys.

Table 5. Alternative assumptions on distribution of adult weight status

		Adult weight status		
		Obesity	**Overweight**	**Normal weight**
Scenario A	Childhood obesity	60%	20%	20%
	Childhood overweight	20%	40%	40%
Scenario B	Childhood obesity	80%	20%	0%
	Childhood overweight	20%	60%	20%
Scenario C	Childhood obesity	80%	20%	0%
	Childhood overweight	20%	80%	0%

The incremental societal costs for an average 6-year-old child with obesity, relative a 6-year-old child of normal weight, was estimated to SEK 558,000-749,000 for girls and SEK 434,000-582,000 for boys in scenario A-C (compared with SEK 429,000 for girls and SEK 257,000 for boys in the base case analysis) (Table 4). For an overweight 6-year-old, the incremental societal costs were SEK 246,000-409,000 for girls and SEK 195,000-325,000 for boys in scenario A-C (compared with SEK 152,000 for girls and SEK 147,000 for boys in the base case analysis).

Table 6. Results under alternative assumptions on distribution of adult weight status

		Lifetime costs of public sector		**Lifetime production loss**		**Total lifetime costs**	
		Girls	Boys	Girls	Boys	Girls	Boys
Base case	Obesity	104,000	68,000	325,000	189,000	429,000	257,000
	Overweight	34,000	36,000	118,000	111,000	152,000	147,000
Scenario A	Obesity	134,000	112,000	424,000	322,000	558,000	434,000
	Overweight	52,000	45,000	194,000	150,000	246,000	195,000
Scenario B	Obesity	177,000	148,000	572,000	434,000	749,000	582,000
	Overweight	68,000	58,000	259,000	202,000	327,000	260,000
Scenario C	Obesity	177,000	148,000	572,000	434,000	749,000	582,000
	Overweight	84,000	71,000	325,000	254,000	409,000	325,000