Vesikansa *et al. BMC Public Health* (2025) 25:1739
https://doi.org/10.1186/s12889-025-22978-9

RESEARCH **Open Access**

Introduction

e worldwide prevalence of obesity has nearly tripled during the last 50 years, and approximately 2.6 billion people had overweight (body mass index, BMI, 25.0–29.9 kg/m^2) or obesity (BMI, ≥ 30.0 kg/m^2) in 2020 [1, 2].

years old, respectively, compared with the individuals in the NW group (18.5–24.9 kg/m^2), who were on average 38.4 years old. In the NW and OBII–III groups, over half of the individuals were female, whereas male sex was more common in the OW and OBI groups.

e prevalence of MetCs increased with the increase in BMI: the proportion of individuals without MetCs was 45.5% in NW, 26.7% in OW, 13.6% in OBI, and 14.0% in OBII–III groups (Table 1). All studied disease groups were more common in individuals with OB than individuals with NW: the highest di erences were observed for musculoskeletal disorders, metabolic and cardiovascular disorders, sleep apnea, and type 2 diabetes.

Sick leaves, disability pensions and rehabilitation periods

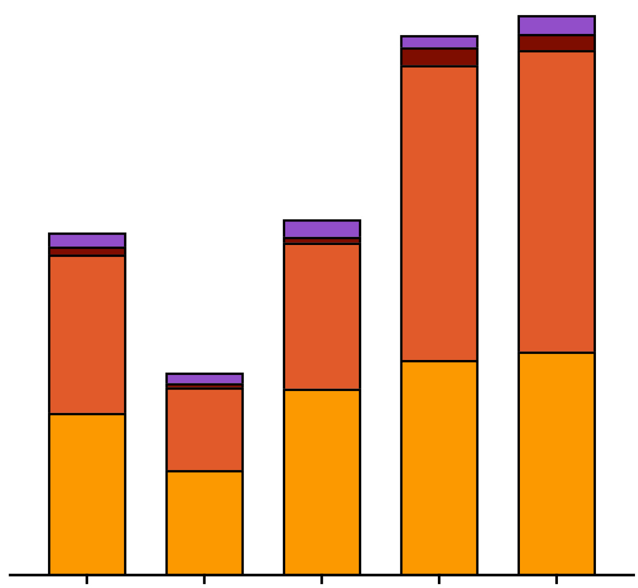
e proportion of individuals with long (> 10 days) sick leaves, disability pensions and rehabilitation periods increased with higher BMI (Table 2). In the NW group, 26.3% of the individuals had long sick leaves, whereas the corresponding proportions were 31.3% in the OW, 33.8% in the OBI and 33.4% in the OBII-III groups ($p = 0.024$). e mean annual length of a sick leave increased from

s.**ann_2 Acxtÿ t2 A [(26.9(yc.899999618(, antA)-24 stilit)-st6.9(ns and**

Table 2 Sick leaves, disability pensions, rehabilitation periods, and premature mortality in the working-age population. The number of individuals refer to a weighted number of in each group

BMI (kg/m^2)	Overall	NW (18.5–24.9 kg/m^2)	OW (25.0–29.9 kg/m^2)	OBI (30.0–34.9 kg/m^2)	OBII – III (35.0 + kg/m^2)	*p*
N	4,134	1,630	1,481	688	335	
Indirect costs, *n* (%)	1,397 (33.8)	470 (28.9)	518 (35.0)	272 (39.5)	137 (40.9)	< 0.001
Long sick leaves (> 10 days), *n* (%)	1,236 (29.9)	428 (26.3)	463 (31.3)	233 (33.8)	112 (33.4)	0.024
Total cohort, mean number of days (SD)	8.4 (23.0)	5.8 (17.8)	9.3 (24.7)	10.9 (26.1)	11.9 (28.4)	< 0.001
Individuals with sick leaves, mean number of days (SD)	28.1 (34.8)	21.9 (29.3)	29.6 (36.6)	32.3 (36.3)	35.4 (39.8)	< 0.001
Disability pensions, *n* (%)	146 (3.5)	31 (1.9)	51 (3.4)	42 (6.1)	23 (6.8)	< 0.001
Total cohort, mean number of (days) (SD)	11.3 (64.6)	6.0 (46.2)	10.4 (60.5)	20.5 (89.7)	22.1 (89.8)	< 0.001
Individuals with disability pensions, mean number of days (SD)	319.1 (140.3)	315.1 (120.8)	303.9 (132.8)	337.9 (158.6)	323.8 (141.8)	0.797
Rehabilitation periods, *n* (%)	164 (4.0)	44 (2.7)	52 (3.5)	50 (7.3)	18 (5.5)	< 0.001
Total cohort, mean number of days (SD)	0.7 (7.9)	0.3 (5.9)	0.5 (6.2)	1.4 (10.6)	1.6 (13.7)	0.420
Individuals with rehabilitation periods, mean number of days (SD)	17.1 (35.7)	12.7 (34.0)	14.6 (30.2)	19.7 (34.4)	29.3 (51.1)	0.723
Premature mortality						
Total cohort, mean number of days of life lost to due to premature mortality (SD)	0.9 (13.3)	0.7 (11.8)	1.1 (15.1)	0.9 (11.7)	1.4 (14.9)	0.793
Individuals with premature death, mean number of days of life lost to due to premature mortality (SD)	142.4 (82.1)	153.7 (85.4)	160.6 (83.2)	119.5 (66.6)	107.3 (72.3)	0.547

Abbreviations: *BMI* Body-mass index, *NW* Normal weight, *OBI* Class I obesity, *OBII – III* Class II – III obesity, *OW* Overweight, *SD* Standard deviation



main component of indirect costs was sick leaves (52%), whereas disability pensions contributed most to indirect costs in the OBI (54.6%) and OBII–III (53.8%) groups. Costs of rehabilitation periods and premature mortality represented 2.4% and 4.1%, respectively, of the total indirect costs across BMI groups. Mental (ICD-10, F-codes) and musculoskeletal disorders (M-codes) were the most common causes for sick leaves, disability pensions, and rehabilitation periods in all BMI groups, and no significant di erences were observed in the distribution of causes between the BMI groups.

Annual indirect costs by sex

For men, 23% in the NW, 31% in the OW, 37% in the OBI, and 28% in the OBII–III groups had indirect costs, whereas for women, the corresponding proportions were 33% (NW), 41% (OW), 43% (OBI), and 50% (OBII–III).

adjusted for age and sex. In the first model, with non-zero costs as an outcome (Fig. 3A), OBI was associated with 58% (odds ratio [OR], 1.58; 95% CI, 1.22–2.06; $p = 0.001$) and OBII–III with 64% (OR, 1.64; 95% CI, 1.15–2.35; $p = 0.006$) higher risk of having indirect costs compared with individuals with NW. Overweight was associated with 32% higher risk (OR, 1.32; 95% CI, 1.07–1.62; $p = 0.009$) of having indirect costs, whereas male sex was associated with a lower risk of having indirect costs (OR, 0.64; 95% CI, 0.53–0.76; $p < 0.001$). In the second model with positive costs as an outcome (Fig. 3B), OBI was associated with 53% (cost ratio [CR], 1.53; 95% CI, 1.19–1.97; $p = 0.001$) and OBII with 71% (CR, 1.71; 95% CI, 1.28–2.29; $p < 0.001$) higher costs compared with individuals with NW. In that model, male sex was associated with higher indirect costs (CR, 1.41; 95% CI, 1.18–1.68; $p < 0.001$).

Association between the BMI group and total costs

Compared with individuals with NW, OW was associated with 31% (CR, 1.31; 95% CI, 1.09–1.58; $p = 0.005$), OBI with 83% (CR, 1.83; 95% CI, 1.46–2.28; $p < 0.001$), and OBII–III with 95% (CR, 1.95; 95% CI, 1.48–2.55; $p < 0.001$) higher age- and sex-adjusted total costs (Fig. 4). Similarly, OW was associated with 19% (CR, 1.19; 95% CI, 1.00–1.41; $p = 0.050$), OBI with 56% (CR, 1.56; 95% CI, 1.25–1.93; $p < 0.001$), and OBII–III with 56% (CR, 1.56; 95% CI, 1.19–2.05; $p = 0.001$) higher direct costs when compared with individuals with NW (Supplementary Fig. 3). When adjusted for age and sex, the predicted total annual cost di erence was 1,124 per person with OW, 3,002 per person with OBI, and 3,443 per person with OBII–III compared with a person with NW (Supplementary Fig. 4). Overall, OB was associated with 3,146 higher costs than NW.

Total costs by the BMI group at the national level

At the national level, working-age individuals with OBI and OBII–III comprised 24.7% of the total population and were responsible for 33.0% (2.01bn), 39.5% (3.42bn), and 36.8% (5.43bn) of the direct, indirect, and total costs, respectively (Fig. 5). Individuals with OW comprised 35.8% of the population and 36.2% (5.35bn) of the total costs.

Based on the estimated number of working-age individuals in the Finnish population (n = 3,045,696), the extrapolated additional costs at the national-level were 1.23bn for OW (n = 1,091,447), 1.52bn for OBI (n = 506,794), and 0.85bn for OBII–III (n = 246,883) (Supplementary Fig. 5).

Direct, indirect, and total costs in the total adult Finnish population

A supplementary analysis was performed to estimate direct, indirect, and total costs of obesity in the total adult (≥ 18 years) population in Finland (n = 4,074,592). e mean annual total costs were 3,535 (SD, 7,935) per person in NW, 4,982 (9,736) in OW, 6,362 (11,597) in OBI, and 6,868 (11,858) in OBII–III groups

(Supplementary Fig. 6). When adjusted for age and sex, the predicted total annual total cost difference was €1,036 per person for OW, €2,221 per person for OBI, and €2,896 per person for OBII–III when compared with a person with NW (Supplementary Fig. 4). At the national level, the additional costs were €1.62bn for OW (n = 1,564,800), €1.62bn for OBI (n = 728,884), and €0.92bn for OBII–III (n = 317,615) (Supplementary Fig. 5).

Discussion

This nationally representative, population-based study utilized individual-level data from the biobank and health and social care registers to assess indirect, direct, and total costs of overweight and obesity in Finland. The results indicated that in working-age individuals, indirect costs were 1.5-fold and 1.7-fold higher than direct costs in OW and OB, respectively; in contrast to individuals with NW, who had almost equal direct and indirect costs. Compared with individuals with NW, age- and sex-adjusted annual total (direct + indirect) costs were 31% (€1,124), 83% (€3,002), and 95% (€3,443) higher for individuals with OW, OBI, and OBII–III, respectively.

At the national level, total additional costs associated with adult overweight and obesity were €1.6bn and €2.5bn, respectively. This corresponds to 1.5% of the gross domestic product (GDP), exceeding the estimated costs of alcohol (€1.4bn annually) and tobacco (€1.3bn in 2020) consumption. The proportion of GDP is lower than the estimated average economic impact (2.2% of global GDP) of OW and OB across 161 countries in the world [29]. However, the numbers are not directly comparable due to different methodologies, data sources, and cost components included [30, 31].

Sick leaves and disability pensions were the main components (94% across the BMI groups) of indirect costs in all BMI groups, but their contribution was different in individuals with NW and OW compared with individuals with OB. The rise in indirect costs in OB was mainly driven by the significantly higher proportion of individuals with OB having disability pensions (OBI, 6.1%; OBII–III, 6.8%) compared with individuals with NW (1.9%), whereas the mean length of a disability pension was similar in all BMI groups. Correspondingly, the mean annual costs of disability pensions were approximately 3.6-fold and 3.7-fold higher for individuals with OBI (2,450€) and OBII–III (2,506€), compared with individuals with NW (687€).

e importance of this finding is highlighted by the fact that return to work after temporary disability pension has been reported to be relatively uncommon, meaning that cumulative costs over time will be considerable [32]. us, preventing permanent disability should be of high costs was more common in women, but the mean indirect costs were higher for men than women. That was mainly due to fact that disability pensions, which are rare but costly, dominated indirect costs in men, whereas sick leaves were the main cost contributor in women. When total costs were assessed, no significant association was observed between the sexes.

Our results showed that, not only OB, but also OW was associated with significantly higher total costs compared with NW in working-age individuals, in contrast to our previous findings which only assessed direct costs in the adult population [9, 25]. In addition, the effect size in direct costs between individuals with OB and the NW was bigger in the working-age population than in our previous study. This suggests that the direct healthcare burden of OW and OB is higher in the working-age population compared with elderly. Indeed, obesity in older adults has been proposed to be more complex than in young and middle-aged adults, and an ideal BMI range may be different [36, 37].

One of the possible explanations for a different association between OB and direct costs in the working-age and total adult population could be that in the aging population, individuals with highly prevalent multimorbidity, incurring the highest costs, have passed away. Overall, multimorbidity has been shown to cause a heavy burden on Finnish healthcare [38]. Previously, we showed that the attributable direct costs of obesity were mainly driven by the increased prevalence of metabolic comorbidities in individuals with OB [9, 25]. Only approximately 10% of individuals with OB were metabolically healthy, and individuals with OB had higher HCRU and medication use in all disease groups. Here, the main contributors (mental and musculoskeletal diseases) to indirect costs were similar in all BMI groups, suggesting that the increase in indirect costs with OB is expected to be largely due to significantly increased overall morbidity.

The main strengths of this study are the nationally representative sample of Finnish adults, and comprehensive data collected from several national health and social care registers, which allowed a detailed and reliable estimation of both indirect and direct costs at the population level. The BMIs for the study individuals were measured in clinical examination, in contrast to self-reporting which has the tendency of underreporting weight and overreporting height [39]. Limitations include the lack of information on short sick leaves and presenteeism in indirect costs, and the lack of private and occupational healthcare in national registers before the year 2019. In addition, longitudinal data on unemployment or shortfall in labour force participation were not available in the registers used. Overall, estimating exact indirect costs and the true value of lost work productivity is challenging, as the percentage of labor force participation can vary between age groups for different reasons including, e.g., studies or parental leaves.

Variation in costs was high even within the BMI group, and the relatively small number of individuals especially in the OBII–III group caused wide confidence intervals. It should also be noted that individuals with a weak physical condition are more likely to opt-out of health examinations and thus the study population, which may cause bias especially in high BMI classes. In addition, modelling results can somewhat depend on the approach used. For the result of predicted total annual cost difference per person, we tested different types of models (Gamma, inverse Gaussian) in sensitivity analyses. The original Poisson result for excess cost was €3,443 for OBII–III compared with a person with NW. With different models, the corresponding result was quite stable (€3,370–€3,448). There was more variation in the predicted absolute value in those with OBII-III (€6,868–€7,183). This gives insight that the excess costs are quite stable, whereas the predicted absolute values are more prone to the cost burden go along with improved health status and quality of life. e burden associated with obesity is not restricted to individuals with severe obesity (OBII–III), but anific6(t)anveralth h obesity is