ORIGINAL ARTICLE

Influence of obesity and physical workload on disability benefits among construction workers followed up for 37 years

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ABSTRACT
Objectives The objectives of this study are to investigate the relation between obesity and labour force exit via diagnosis-specific disability benefits, and whether physical workload modifies this association.
Methods A longitudinal analysis was performed among 3 28 743 Swedish construction workers in the age of 15–65 years. Body weight and height were measured at a health examination and enriched with register information on disability benefits up to 37 years later. Diagnoses of disability benefits were categorised into cardiovascular diseases (CVDs), musculoskeletal diseases (MSDs), mental disorders and others. A job exposure matrix, based on self-reported lifting of heavy loads and working in bent forward or twisted position, was applied as a measure of physical workload. Cox proportional hazards regression analyses were performed, and the relative excess risk due to interaction (RERI) between obesity and physical workload was calculated.
Results Obese construction workers were at increased risk of receiving disability benefits (HR 1.70, 95% CI 1.65 to 2.76), mainly through CVD (HR 2.30) and MSD (HR 1.71). Construction workers with a high physical workload were also more likely to receive a disability benefit (HR 2.28, 95% CI 2.21 to 2.34), particularly via MSD (HR 3.02). Obesity in combination with a higher physical workload increased the risk of disability benefits (RERI 0.28) more than the sum of the risks of obesity and higher physical workload, particularly for MSD (RERI 0.44).
Conclusions Obesity and a high physical workload are risk factors for disability benefit. Furthermore, these factors are synergistic risk factors for labour force exit via disability benefit through MSD. Comprehensive programmes that target health promotion to prevent obesity and ergonomic interventions to reduce physical workload are important to facilitate sustained employment.

What this paper adds

- ► Increased risks of disability benefits have been documented among workers with obesity and among workers with a high physical workload. However, whether physical workload moderates the relation between obesity and disability benefits is unknown.
- ► This study found that obese construction workers were at increased risk of receiving disability benefits, mainly through cardiovascular diseases and musculoskeletal diseases. Construction workers with a high physical workload were also more likely to receive a disability benefit, particularly for musculoskeletal diseases.
- ► Obesity and high physical workload were found to be synergistic risk factors. Obesity in combination with a higher physical workload increased the risk of disability benefits more than the sum of the risks of obesity and higher physical workload, particularly for musculoskeletal diseases.
- ► Further research needs to address the effectiveness of comprehensive programmes that target health promotion to prevent obesity and ergonomic interventions to reduce physical workload.

INTRODUCTION
Obesity is a risk factor for long-term sickness absence and premature labour force exit through disability benefits.[1–3] The increasing prevalence of obesity in combination with an ageing workforce might contribute to a growing burden of disease in workplaces and in society.

In a meta-analysis including 17 longitudinal studies, an increased risk of disability benefits (pooled relative risk (RR) of 1.53) was found among obese individuals.[2] Although a relation between obesity and disability benefits has been consistently reported, only few studies have provided insight into the underlying diseases. A prospective study with 10 years of follow-up among Finnish employees showed that, after adjustment for age and gender, obesity (severe) was associated with all-cause disability benefits as well as with disability benefits due to musculoskeletal diseases (MSDs).[4] In another Finnish study, a higher body mass index (BMI) was also related to an increased risk of disability due to MSD and due to cardiovascular diseases (CVDs) but not due to mental disorders.[5] An 11-year follow-up study among male construction workers in Germany showed positive associations between BMI and work disability due to osteoarthritis and CVD.[6] In a Swedish study, BMI was measured at military conscription, and information on disability benefits was extracted from national registers until up

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to 25 years later. The study showed that obese individuals had a higher risk of disability benefits due to circulatory causes, musculoskeletal causes and psychiatric causes.[7] Kark *et al* [8] also found an increased risk of disability benefits among men with mental disorders. Another Swedish study among 7697 male residents reported an RR of 2.8 of obesity for all-cause risk of disability benefits after adjustment for smoking. The incidence of disability benefits via MSD, CVD and mental disorders was more than twice as high among obese individuals than among individuals with a BMI between 20 and 25 kg/m^2.[9]

A requirement for a disability benefit is that the individual has a disease that incapacitates for work. To understand the relation between obesity and disability benefits, more insight into the underlying diseases to be granted a disability benefit is crucial. Among the most common diagnoses for disability benefits in Sweden are MSD, CVD and mental disorders.[10] We hypothesise that obese workers, and to a smaller extent overweight workers, have a higher risk of disability benefits—particularly through diseases related to the metabolic syndrome (primarily CVD and diabetes)[11] and MSD such as osteoarthritis,[12] sciatica,[13] knee pain[14] and low back pain.[15]

An important consideration is whether the type of work will influence the risk of premature labour force exit through disability benefits among obese workers. A high physical workload is an important risk factor for disability benefits.[16] With regard to MSD, obesity and a high physical workload (eg, heavy lifting) may share a common mechanical pathway, that is, high compressive and shear forces on the lumbar spine. Hence, we hypothesise that the combination of obesity and high biomechanical physical workload increases the risk of disability benefits, in particular due to MSD. Such synergistic effects may have consequences for designing successful interventions to reduce premature labour force exit among obese individuals. The construction industry is an appropriate setting to study the risk of a high BMI in combination with a high physical workload. This study aimed to obtain better insight into the relation between obesity and disability benefits, by investigating (1) specific causes of disability benefits among obese workers in the construction industry and (2) whether physical workload moderated the relation between obesity and disability benefits.

METHODS

Study design and study population

The risk of exit through disability benefits was studied in a longitudinal study among Swedish construction workers in the period 1980–2008. According to an agreement between employers and unions, Swedish construction workers were affiliated with the national occupational health service (*Bygghälsan*) from the mid-1960s until 1 January 1993. All workers were offered free health examinations on a regular basis, and the cumulative participation in health examinations among workers in the Swedish construction industry was estimated to be about 80%.[17]

From 1971, the examination results were stored in a data register. This historical cohort includes 389 132 individuals employed in the construction industry, who participated in one or more health examination between 1971 and January 1993. Construction workers without information on BMI (n=3231) were excluded as well as construction workers who were examined before reaching 15 years of age or after 64 years of age (n=1853). Because the retirement age was changed from 67 to 65 years in 1976, all analyses were restricted to 1980 or later. Men who were born in 1915 or earlier (n=15 202), had died (n=4347), emigrated (n=3294) or had full disability benefit (n=9315) before 1980 were excluded. Persons on full disability benefit before they were examined the first time were also excluded (n=25). The current study was restricted to men, as the proportion of women was too small for a meaningful analysis (5.2%; n=18 164). Because the focus of this study was on the role of overweight and obesity, men who are underweight (BMI <18.5 kg/m^2) were excluded from the analyses (1.5%, n=4958). The final sample included 328 743 men.

Information on job, year of birth, body weight and height, and smoking was used from the first health examination. The Regional Ethical Review Board in Umeå approved the study (2011-367-32M).

Disability benefits

Individuals in the working age who have limitations in their working capacity due to disease might receive a disability benefit. The Social Insurance Office in Sweden decides whether an individual is eligible to receive a disability benefit. The date of disability benefit decisions in the construction worker cohort was available through a linkage with the disability benefit register in the Swedish Social Insurance Office. The date of disability benefit in our analysis was the date the person first received *full* (100%) benefit. A small proportion received partial disability benefits.[18] Because the legislation for disability benefit was changed in 2008 making eligibility for disability benefits much more restrictive, the analyses investigate disability benefits between 1 January 1980 through 31 December 2008. As only a minority returns to work after receiving disability benefits, the disability benefits is, for most individuals, a disability pension. The register of disability benefit includes primary and secondary diagnoses classified according to International Classification of Diseases, Ninth Revision (ICD 9) or ICD, 10th Revision (ICD 10). In the analysis, we used the primary diagnosis. We categorised the diagnosis as MSD (ICD 9: 710–739, ICD 10: M00–M99), CVD (ICD 9: 390–459, ICD 10: I00–I99), mental disorders (ICD 9: 290–319, ICD 10: F00–F99) and other diagnoses (eg, containing respiratory (ICD 9: 460–519, ICD 10:J00–J99), neurological (ICD 9: 320.359, ICD 10: G00–G99) and injuries (ICD 9: 800–959, ICD 10: S00–S99 T00–T32)).

Body mass index

Body weight and height were measured at the first examination. BMI (kg/m^2) was calculated and used to categorise individuals as healthy weight ($18.5 \leq BMI < 25$ kg/m^2), overweight ($25 \leq BMI < 30$ kg/m^2) or obese ($BMI \geq 30$ kg/m^2).

Physical workload

To assess exposure to physical workload of construction workers within a certain occupational group, a job exposure matrix (JEM) was developed. The exposure assessment was based on a survey among a subset of construction workers conducted between 1989 and 1992. In total, 77 803 male construction workers indicated on a five-point scale, ranging from rarely (1) to often (5), how often they worked with lifting heavy loads and how often they worked in bent forward/twisted working postures. First, for each individual, the mean score was calculated over the answers on these two questions. Second, occupational group scores were calculated by averaging these individual mean scores among all workers within the same occupational group. Third, each construction worker within an occupational group was assigned this group score. Finally, three exposure categories were obtained: a group score between 1 and 2.5 was considered as low physical workload, a score between 2.5 and 3.5 as intermediate physical workload and a score of 3.5 or higher as a high physical workload. Hence, in this approach, construction workers within an occupational group have by definition the same exposure to physical workload (online supplementary appendix A).

Covariates

Covariates included age and smoking status. Age was defined as the calendar age at the first examination.

Smoking status was divided into non-smokers, ex-smokers, current smokers and unknown smoking habits according to the first examination, and, if no information was available, data from the second or third examination were used.

Statistical analysis

Descriptive statistics were used to present baseline information on BMI, physical workload, diagnoses of disability benefits and the covariates. The relation between obesity, physical workload and all-cause disability benefits was analysed by performing Cox proportional hazards regression analysis. Construction workers were censored in case they reached the age of 65 years, the statutory retirement age between 1976 and 2001 (after 2001, individuals could choose to have governmental pension between 61 and 67 years of age). The follow-up started at the time of first examination and ended in case of disability benefits, death or emigration, or at the end of the follow-up period in 2008. Univariate analyses were performed as well as analyses with adjustment for age and smoking. Then, the relation between BMI status and specific causes of disability benefits was assessed. For each diagnosis of disability benefits, the event was compared with the total study population, censoring construction workers with a disability benefit due to another cause and those who reached the retirement age during follow-up. To obtain insight into the role of physical workload in the relation between obesity and disability benefits, the analyses were stratified by BMI category. The proportional hazards assumption was evaluated by inspecting the log(-log(survival) versus log of survival time graph, which showed parallel curves for BMI categories, categories of physical workload and age groups. Population attributable fractions (PAFs) were calculated using the formula $PAF=\Sigma p_i\ (HR_i-1)/(1+\Sigma p_i(HR_i-1))$, in which p_i is the proportion of the population in the *i*th BMI status category, HR_i is the adjusted HR comparing the *i*th BMI status category with those having a normal body weight.[19]

To study to what extent physical workload modified the influence of overweight and obesity on disability benefits, additive interaction was analysed by calculating the relative excess risk due to interaction (RERI) and the corresponding 95% CI.[20] To construct a 2×2 table, low and intermediate physical workloads were combined into one category. The RERI was calculated as $RERI = HR_{\text{(obesity + high physical workload)}} - HR_{\text{(obesity + low /intermediate physical workload)}} - HR_{\text{(healthy weight + high physical workload)}} + 1$. A RERI greater than zero indicated synergy (more than additivity), and a RERI lower than zero indicated negative interaction (less than additivity). The tables present the results of analyses performed using complete data. In addition, missing values in covariates were handled by multiple imputations by generating five independent datasets for all analyses. Statistical analyses were carried out using IBM SPSS Statistics V.22.

RESULTS

The study population consisted of 3 28 743 men, with a mean age of 32.4 year (SD 11.4 years) at baseline. The mean follow-up time was 22.5 years (SD 8.5 years), ranging from 0 to 37 years. The mean BMI was 24.1 kg/m^2 (SD 3.1 kg/m^2); 29.3% was overweight and 4.4% was obese (table 1). BMI increased with age (β=0.10, 95% CI 0.09 to 0.10). In total, 14.7% of the construction workers had a low physical workload, 28.0% an intermediate and 57.4% a high **physical** workload. Construction workers in the highest physical workload group were younger than those with a low physical workload (mean age 32.1 and 36.4 years, respectively).

Table 1 Baseline characteristics of the study population (n=328 743)

	n	%
Age (years)		
15–34	206 875	62.9
35–49	84 867	25.8
50–64	37 001	11.3
BMI category		
Healthy weight (18.5–24.9 kg/m^2)	217 972	66.3
Overweight (25.0–29.9 kg/m^2)	96 452	29.3
Obesity (≥30.0 kg/m^2)	14 319	4.4
Smoking*		
Never smoker at enrolment	134 426	43.7
Former smoker at enrolment	48 106	15.6
Smoker at enrolment	124 891	40.6
Physical workload		
Low	48 267	14.7
Intermediate	91 888	28.0
High	188 588	57.4
Disability benefits during follow-up	61 176	18.6
Diagnosis: CVD within total disability	8472	13.8
Diagnosis: MSD within total disability	30 675	50.1
Diagnosis: mental disorder within total disability	6136	10.0
Diagnosis: other within total disability	15 893	26.0

*n=21 320 had no information on smoking status at baseline.
BMI, body mass index; CVD, cardiovascular disease; MSD, musculoskeletal diseases.

There were 61 176 cases (18.6%) with disability benefits granted in the period between 1980 and 2008. Most cases of disability benefits were due to MSD (n=30 675; 50.1%), followed by CVD (n=8472; 13.8%) and mental disorders (n=6136; 10.0%). Other diagnoses accounted for 15 893 of the cases (26.0%). During follow-up, 13 811 construction workers (4.2%) died before ageing 65 years and 7285 construction workers (2.2%) emigrated.

The mean BMI at examination was higher among construction workers receiving a disability benefit during follow-up (25.1, SD 3.3) than among those not receiving a disability benefit (23.9, SD 3.0). The prevalence of overweight and obesity is higher among construction workers receiving a disability benefit due to CVD compared with those not receiving a disability benefit during follow-up (44.5% overweight and 10.4% obese among those with disability benefits due to CVD, vs 27.0% overweight and 3.6% obese among those without a disability benefit). This was also found, to a smaller extent, for construction workers receiving a disability benefit due to MSD (overweight 41.1%, obese 7.7%) or other diagnoses (38.6% overweight, 7.8% obese).

Figure 1A,B show the proportion of construction workers without disability benefits relative to the time since examination for healthy weight, overweight and obesity (figure 1A), and

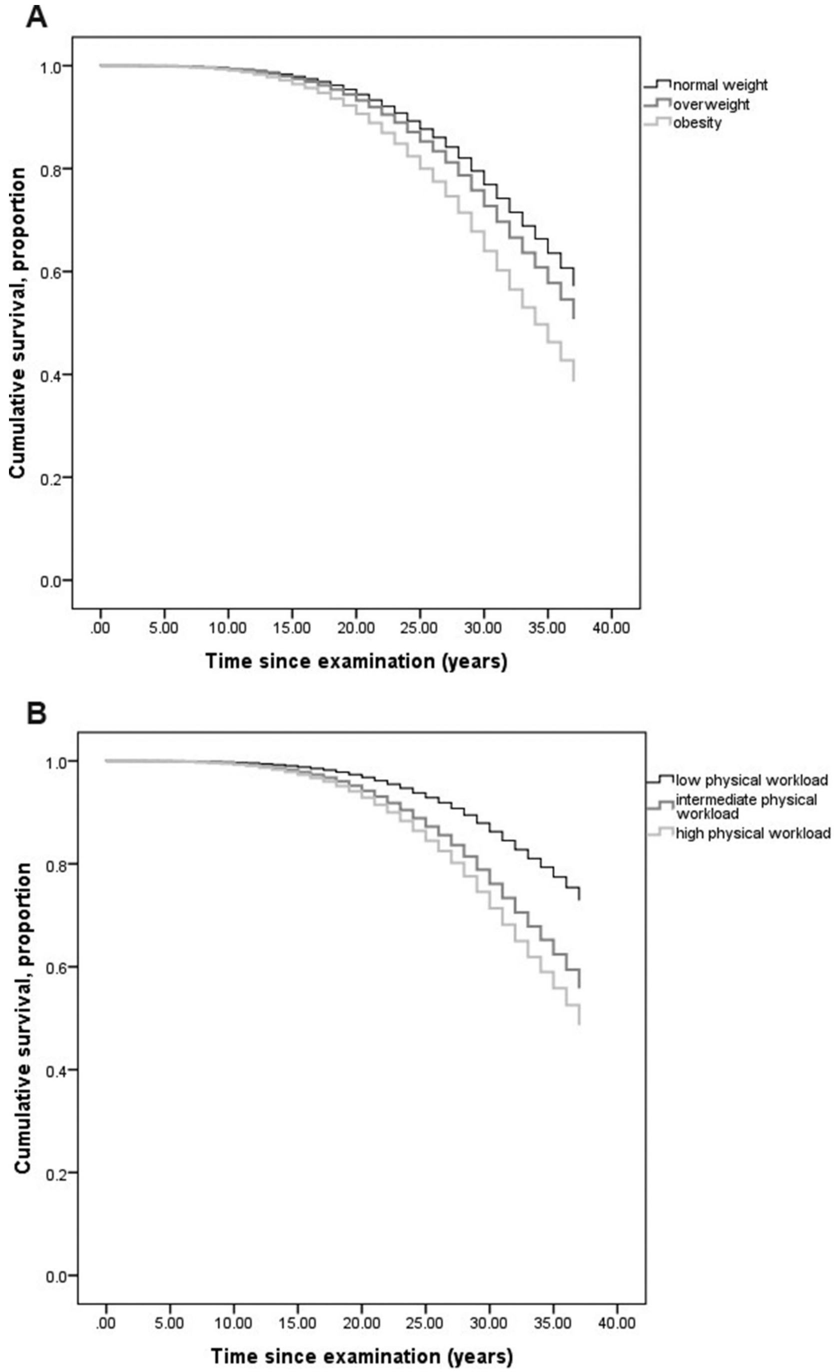

Figure 1 (A) Survival time to receiving full (100%) disability benefits among male construction workers, stratified by body mass index status. (B) Survial time to receiving full (100%) disability benefits among male construction workers, stratified by physical workload.

for low, intermediate and high physical workload (figure 1B). The figures show the highest proportion of workers receiving a disability benefit among obese individuals and among those with a high physical workload.

A higher BMI status was related to an increased risk of disability benefit (table 2). After adjustment for age and smoking, obese construction workers had an increased risk of receiving a disability benefit (HR 1.65, 95% CI 1.59 to 1.70, not in table). Additional adjustment for physical workload did not further attenuate the relation between obesity and disability benefit (HR 1.70, 95% CI 1.65 to 1.76; table 2). The PAF was 0.09. A higher BMI was most strongly related to disability benefits due to CVD but was also a risk factor for MSD and the other diagnoses. Diagnoses-specific PAFs ranged between 0 (mental disorders) and 0.18 (CVD).

A higher physical workload was also related to all-cause disability benefits. After adjustment for age and smoking, the risk of receiving a disability benefit was increased among construction workers with the highest physical workload compared with those with a low physical workload (HR 2.25, 95% CI 2.19 to 2.31, not in table). Additional adjustment for BMI status did not further attenuate the relation between high physical workload and disability benefit (HR 2.28, 95% CI 2.21 to 2.34, table 2). Those having a higher physical workload were more likely to receive disability benefits, irrespective of age at examination. The PAF for physical workload was 0.69. A higher physical workload

Table 2 Relation between obesity and diagnoses of disability benefits in a cohort study among construction workers (n=3 28 743)

	Disability benefits				
	All, n=61 176, HR (95% CI)	CVD, n=8472, HR (95% CI)	MSD, n=30 675, HR (95% CI)	Mental disorders, n=6136, HR (95% CI)	Other, n=15 893, HR (95% CI)
BMI continuous*	1.05 (1.05 to 1.05)	1.09 (1.09 to 1.10)	1.06 (1.05 to 1.06)	0.99 (0.98 to 1.00)	1.04 (1.03 to 1.04)
BMI: healthy weight	1.00	1.00	1.00	1.00	1.00
BMI: overweight	1.21 (1.19 to 1.23)	1.47 (1.40 to 1.54)	1.26 (1.23 to 1.29)	0.91 (0.86 to 0.97)	1.13 (1.09 to 1.17)
BMI: obesity	1.70 (1.65 to 1.76)	2.30 (2.13 to 2.50)	1.71 (1.63 to 1.79)	1.21 (1.06 to 1.38)	1.60 (1.50 to 1.70)
Physical workload: low	1.00	1.00	1.00	1.00	1.00
Physical workload: intermediate	1.84 (1.79 to 1.90)	1.28 (1.19 to 1.38)	2.13 (2.04 to 2.23)	2.07 (1.87 to 2.28)	1.68 (1.59 to 1.78)
Physical workload: high	2.28 (2.21 to 2.34)	1.48 (1.39 to 1.57)	3.02 (2.90 to 3.15)	1.82 (1.66 to 1.99)	1.90 (1.81 to 2.00)

Fully adjusted model (age, smoking, BMI, physical workload).
*BMI as a continuous variable not in same multivariate model as BMI as categorical variable.
BMI, body mass index; CVD, cardiovascular disease; MSD, musculoskeletal diseases.

was most strongly related to disability benefits due to MSD but also a risk factor for the other diagnoses. Diagnoses-specific PAFs ranged between 0.32 (CVD) and 0.86 (MSD). Analyses based on the multiple imputations dataset showed similar results, marginally different from the results presented above.

Table 3 shows that obesity in combination with a high physical workload increased the risk of receiving all-cause disability benefits and the diagnoses of MSD more than the combined independent risks of obesity and physical workload (RERI=0.44; 95% CI 0.23 to 0.66). This synergy was less apparent for the other diagnoses and for the combination of overweight and physical workload (table 3).

DISCUSSION

Obese men, and to a lesser extent overweight men, working in the Swedish construction industry were at increased risk of receiving disability benefits—mainly through CVD and MSD. Construction workers with a high physical workload were also more likely to receive a disability benefit—particularly via MSD. The combination of obesity and high physical workload increased the risk of receiving disability benefits more than the sum of the risks of obesity and higher physical workload, showing synergy between these risk factors for labour force exit via disability benefit.

The finding that obesity (HR 1.70), and to a smaller extent overweight (HR 1.21), was related to future disability benefit is in line with previous findings. Our results show somewhat higher risks than those in our recent meta-analysis,[2] which might be explained by differences in study populations, follow-up duration and type of measurements. The present study elaborates on the studies included in the meta-analysis by focusing on specific diagnoses for disability benefits and on workers with high physical workload. A high BMI in itself is not a disease that entitles a disability benefit. The diagnoses-specific analyses showed that obesity was particularly related to disability benefits via CVD (HR 2.30) and MSD (HR 1.71), and to a smaller extent via mental disorders. These results are in line with our hypotheses, since obesity is a well-known risk factor for both CVD and MSD.[10–14] Mutual adjustment for BMI and physical workload attenuated the HRs with less than 10%, showing its independent effects on the specific diagnoses of disability benefits.

Independent of a high BMI, a high physical workload was also related to a disability benefit (HR 2.28), in particular via MSD (HR 3.02). Our physical workload questions mainly focused on biomechanical exposures. Both a high BMI and a high biomechanical workload might increase the stress on weight-bearing joints such as knees, ankles and hips,[21] increasing the risk of MSD and eventually disability benefits via an MSD diagnosis. Therefore, it is not surprising that MSD was the most frequent diagnosis for disability benefits in the construction industry—an industry with a relatively high physical workload. For MSD, also a synergistic effect was found, suggesting interaction between BMI and physical workload. It is plausible that the stress on weight-bearing joints and the low back is already high among construction workers with a high body weight, making them more sensitive for the high physical workload than construction workers with a lower BMI—leading to increased strain that

Table 3 Analysis of the synergistic effect of obesity and physical work load on disability benefit among construction workers with a normal body weight or obesity (n=2 32 291) and among construction workers with a normal body weight or overweight (n=314 424).

	Disability benefit diagnosis				
	All, HR (95% CI)	CVD, HR (95% CI)	MSD, HR (95% CI)	Mental disorders, HR (95% CI)	Other, HR (95% CI)
Healthy weight: low/intermediate physical workload	1.00	1.00	1.00	1.00	1.00
Healthy weight:high physical workload	1.59 (1.55 to 1.63)	1.28 (1.19 to 1.37)	1.93 (1.86 to 2.00)	1.11 (1.04 to 1.19)	1.45 (1.38 to 1.52)
Overweight: low/intermediate physical workload	1.22 (1.19 to 1.26)	1.44 (1.34 to 1.56)	1.29 (1.23 to 1.34)	0.93 (0.85 to 1.03)	1.18 (1.11 to 1.25)
Overweight: high physical workload	1.91 (1.86 to 1.96)	1.89 (1.76 to 2.03)	2.40 (2.31 to 2.50)	1.00 (0.92 to 1.10)	1.59 (1.51 to 1.67)
Obesity: low/ intermediate physical workload	1.78 (1.69 to 1.88)	2.35 (2.09 to 2.65)	1.81 (1.68 to 1.95)	1.19 (0.98 to 1.46)	1.71 (1.55 to 1.88)
Obesity: high physical workload	2.65 (2.53 to 2.77)	2.89 (2.58 to 3.23)	3.19 (3.00 to 3.39)	1.41 (1.18 to 1.68)	2.23 (2.04 to 2.43)
RERI: overweight and physical workload (95% CI)	0.10 (0.05 to 0.15)	0.16 (0.03 to 0.30)	0.18 (0.10 to 0.26)	−0.04 (−0.16 to 0.08)	−0.04 (−0.13 to 0.05)
RERI: obesity and physical workload (95% CI)	0.28 (0.14 to 0.41)	0.26 (−0.12 to 0.63)	0.44 (0.23 to 0.66)	0.10 (−0.24 to 0.43)	0.08 (−0.16 to 0.32)

Adjusted for age and smoking.
CVD, cardiovascular disease; MSD, musculoskeletal diseases; RERI, relative excess risk due to interaction.

could trigger inflammatory processes.[22] A high physical workload is also related to the other diagnoses for disability, but no synergistic effects were found for CVD and mental disorders. For these diseases, other mechanisms might lead to disability benefits.

The physical workload measure was derived from a JEM based on self-reported information on lifting and twisting/bending from a subset of individuals working in the Swedish construction industry. Hence, our measure of physical workload contains two important components of biomechanical workload. In another dimension of physical workload, 'energetic workload' or 'occupational physical activity', the focus is on work demands that increase the cardiovascular load. A physical workload measure, mainly paying attention to energetic workload or occupational physical activity, might lead to different results. It might be hypothesised that a high occupational physical activity in combination with a high BMI also increases the risk of disability benefits through both CVD and MSD. Although leisure time physical activity has been shown to be protective for sickness absence or disability benefits,[23 24] high occupational physical activity has actually been found to be a risk factor.[25] Furthermore, the type of work might change over time and multiple measurements on the physical workload would provide more insight into the accumulation of physical workload over time, the timing of the physical workload, the increase or reduction of physical workload and the influence on premature labour force exit.

The current study showed adverse effects of high BMI and high physical workload on premature labour force exit through disability benefits among construction workers. In this specific occupational setting, the PAFs for body weight status were lower than for physical workload. This can largely be explained by the high prevalence of physical workload in the construction industry. Still, 9% of the cases of disability benefits might be attributed to overweight and obesity; for CVD, this was 18%.

Strengths and limitations

The current study elaborates on previous studies by investigating a specific occupational group, different diagnoses of disability benefits and synergistic effects between BMI and physical workload. Strengths of the study are the large number of participants, the objective measurement of body weight and height, the long duration of the follow-up period and the use of register data for diagnosis-specific disability benefits. Furthermore, most of the men had similar socioeconomic status and they worked in the same industry.

Although the use of register data for diagnosis-specific disability benefits is a strength of this study, the diagnosis categories were broadly defined. MSD contains a whole range of musculoskeletal diseases (ICD 9: 710–739, ICD 10: M00–M99), CVD (ICD 9: 390–459, ICD 10: I00–I99), including both upper and lower extremity disorders. The influence of BMI on disability benefits via such a broad range of MSD diagnoses as well as the synergistic effect might be underestimated in comparison with diagnoses specifically focused on the lower extremities or lower back.

The outcome measure in this study, disability benefits, is based on national legislation, and therefore the results cannot simply be generalised to countries with different legislation regarding disability benefits. Furthermore, eligibility criteria within countries change over time and have become more restrictive in the past decade. This might also influence the risk estimates reported in the current study.

The results of this study cannot simply be generalised to other occupational groups or to women. The study was focused on a particular occupational group with relatively high physical work demands, and the analyses were restricted to the male population. However, previous studies also showed that a high BMI and a high physical workload are related to disability benefit in general. Concerning gender, another study reported somewhat lower risks of obesity among men than women.[4]

Although BMI was measured objectively, BMI might not be the optimal measure. The measure does not distinguish between muscle mass and fat mass. The construction industry might also be an industry in which men with a high muscle mass are employed—who might be misclassified as being overweight or even obese. If the categories 'overweight' and 'obesity' are a combination of men with a high muscle mass and men with a high fat mass, then the risk of disability benefits might be underestimated. For future research it would be interesting to get insight into the patterns of BMI over the life course and the influence on sickness absence and labour force transitions. In the current study, BMI was measured during enrolment in the study, most often before 1980.

The results show a relation between obesity, physical workload and disability benefits, although the influence of unmeasured confounding cannot be completely ruled out. The study focused on obesity and physical workload, taking into account age and smoking. Other sociodemographic, work-related and health-related characteristics might influence the relation. However, due to the selection of construction workers, we have quite a homogeneous group, ruling out some confounding due to such characteristics.

The results of our study imply that interventions are needed to prevent obesity and to reduce the physical workload, and to lower the risks of receiving disability benefits. In general, participation in health promotion programmes is higher in comprehensive interventions, consisting of multiple components aimed at multiple health behaviours.[26] However, the effects of workplace health promotion programmes on body weight reduction are modest in general,[27–29] and also in construction workers.[30] A recent study among construction workers showed that an intervention with individual face-to-face and telephone counselling aimed at improving both a healthy lifestyle and reducing musculoskeletal symptoms reported positive changes in vigorous physical activity, dietary behaviour and body weight-related outcomes after 6 months. However, the intervention did not result in improvements in musculoskeletal symptoms and did not prove to be cost-effective after 12 months of follow-up.[31] Hence, there is still an urgent need for (cost-)effective interventions for reducing obesity and preventing MSDs. The variety of physical work tasks asks for more insight into suitable preventative measures. Empirical evidence of ergonomic interventions showed no clear reduction in physical workload among construction workers.[32 33] Technical measures might reduce the physical workload of construction workers.[34]

The increasing prevalence of overweight and obesity in most Western countries is concerning, both with respect to an increasing prevalence of associated chronic diseases as well as with respect to the influence of a sustainable employable workforce. Obesity and a high physical workload are both risk factors for disability benefit, particularly due to CVD and MSD. Furthermore, obesity and physical workload are synergistic risk factors for labour force exit via disability benefit. Therefore, both worksite health promotion programmes and preventive ergonomic interventions are important among construction workers with physically heavy jobs to facilitate sustained employment.

Contributors SJWR contributed to the study design and performed the data analysis and the drafting of the manuscript. BJ contributed to the study design, discussed the data analyses and contributed to the drafting of the manuscript. A JvdB contributed to the study design and the drafting of the manuscript. KIP contributed to the study and the drafting of the manuscript. JW contributed to the study design and the drafting of the manuscript. AB contributed to the study design, discussed the data analyses and contributed to the drafting of the manuscript.

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Competing interests None declared.

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REFERENCES

1 Claessen H, Brenner H, Drath C, *et al*. Repeated measures of body mass index and risk of health related outcomes. *Eur J Epidemiol* 2012;27:215–24.
2 Robroek SJ, Reeuwijk KG, Hillier FC, *et al*. The contribution of overweight, obesity, and lack of physical activity to exit from paid employment: a meta-analysis. *Scand J Work Environ Health* 2013;39:233–40.
3 van Duijvenbode DC, Hoozemans MJ, van Poppel MN, *et al*. The relationship between overweight and obesity, and sick leave: a systematic review. *Int J Obes* 2009;33:807–16.
4 Roos E, Laaksonen M, Rahkonen O, *et al*. Relative weight and disability retirement: a prospective cohort study. *Scand J Work Environ Health* 2013;39:259–67.
5 Rissanen A, Heliövaara M, Knekt P, *et al*. Risk of disability and mortality due to overweight in a Finnish population. *BMJ* 1990;301:835–7.
6 Claessen H, Arndt V, Drath C, *et al*. Overweight, obesity and risk of work disability: a cohort study of construction workers in Germany. *Occup Environ Med* 2009;66:402–9.
7 Neovius M, Kark M, Rasmussen F. Association between obesity status in young adulthood and disability pension. *Int J Obes* 2008;32:1319–26.
8 Kark M, Neovius M, Rasmussen F, status O. Obesity status and risk of disability pension due to psychiatric disorders. *Int J Obes* 2010;34:726–32.
9 Månsson NO, Eriksson KF, Israelsson B, *et al*. Body mass index and disability pension in middle-aged men--non-linear relations. *Int J Epidemiol* 1996;25:80–5.
10 The National Social Insurance Board. *Social insurance in Sweden*. Stockholm, Sweden: National Social Insurance Board, 2004.
11 Abdullah A, Amin FA, Stoelwinder J, *et al*. Estimating the risk of cardiovascular disease using an obese-years metric. *BMJ Open* 2014;4:e005629.
12 Reyes C, Leyland KM, Peat G, *et al*. Association between overweight and obesity and risk of clinically diagnosed knee, hip, and hand osteoarthritis: a population-based cohort study. *Arthritis Rheumatol* 2016;68:1869–75.
13 Shiri R, Lallukka T, Karppinen J, *et al*. Obesity as a risk factor for sciatica: a meta-analysis. *Am J Epidemiol* 2014;179:929–37.
14 Frilander H, Viikari-Juntura E, Heliövaara M, *et al*. Obesity in early adulthood predicts knee pain and walking difficulties among men: a life course study. *Eur J Pain* 2016;20:1278–87.
15 Shiri R, Karppinen J, Leino-Arjas P, *et al*. The association between obesity and low back pain: a meta-analysis. *Am J Epidemiol* 2010;171:135–54.
16 Järvholm B, Stattin M, Robroek SJ, *et al*. Heavy work and disability pension - a long term follow-up of Swedish construction workers. *Scand J Work Environ Health* 2014;40:335–42.
17 Stattin M, Järvholm B. Occupation, work environment, and disability pension: a prospective study of construction workers. *Scand J Public Health* 2005;33:84–90.
18 Hult C, Stattin M, Janlert U, *et al*. Timing of retirement and mortality--a cohort study of Swedish construction workers. *Soc Sci Med* 2010;70:1480–6.
19 Hoffmann R, Eikemo TA, Kulhánová I, *et al*. Obesity and the potential reduction of social inequalities in mortality: evidence from 21 European populations. *Eur J Public Health* 2015;25:849–56.
20 Knol MJ, VanderWeele TJ. Recommendations for presenting analyses of effect modification and interaction. *Int J Epidemiol* 2012;41:514–20.
21 Runhaar J, Koes BW, Clockaerts S, *et al*. A systematic review on changed biomechanics of lower extremities in obese individuals: a possible role in development of osteoarthritis. *Obes Rev* 2011;12:1071–82.
22 Wahlström J, Burström L, Nilsson T, *et al*. Risk factors for hospitalization due to lumbar disc disease. *Spine* 2012;37:1334–9.
23 Lahti J, Rahkonen O, Lahelma E, *et al*. Leisure-time physical activity and disability retirement: a prospective cohort study. *J Phys Act Health* 2013;10:669–75.
24 Robroek SJ, Schuring M, Croezen S, *et al*. Poor health, unhealthy behaviors, and unfavorable work characteristics influence pathways of exit from paid employment among older workers in Europe: a four year follow-up study. *Scand J Work Environ Health* 2013;39:125–33.
25 Holtermann A, Hansen JV, Burr H, *et al*. The health paradox of occupational and leisure-time physical activity. *Br J Sports Med* 2012;46:291–5.
26 Robroek SJ, van Lenthe FJ, van Empelen P, *et al*. Determinants of participation in worksite health promotion programmes: a systematic review. *Int J Behav Nutr Phys Act* 2009;6:26.
27 Anderson LM, Quinn TA, Glanz K, *et al*; Task Force on Community Preventive Services. The effectiveness of worksite nutrition and physical activity interventions for controlling employee overweight and obesity: a systematic review. *Am J Prev Med* 2009;37:340–57.
28 Rongen A, Robroek SJ, van Lenthe FJ, *et al*. Workplace health promotion: a meta-analysis of effectiveness. *Am J Prev Med* 2013;44:406–15.
29 Verweij LM, Coffeng J, van Mechelen W, *et al*. Meta-analyses of workplace physical activity and dietary behaviour interventions on weight outcomes. *Obes Rev* 2011;12:406–29.
30 Groeneveld IF, Proper KI, van der Beek AJ, *et al*. Sustained body weight reduction by an individual-based lifestyle intervention for workers in the construction industry at risk for cardiovascular disease: results of a randomized controlled trial. *Prev Med* 2010;51:240–6.
31 Viester L, Verhagen EA, Bongers PM, *et al*. The effect of a health promotion intervention for construction workers on work-related outcomes: results from a randomized controlled trial. *Int Arch Occup Environ Health* 2015;88:789–98.
32 van der Molen HF, Sluiter JK, Hulshof CT, *et al*. Implementation of participatory ergonomics intervention in construction companies. *Scand J Work Environ Health* 2005;31:191–204.
33 van der Molen HF, Frings-Dresen MH, Sluiter JK. The longitudinal relationship between the use of ergonomic measures and the incidence of low back complaints. *Am J Ind Med* 2010;53:n/a–40.
34 Visser S, van der Molen HF, Kuijer PP, *et al*. Stand up: comparison of two electrical screed levelling machines to reduce the work demands for the knees and low back among floor layers. *Ergonomics* 2016;59:1224–31.