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Original article - JIM-11-0394.R1

August 2011

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Sources of Funding

The IPD work consortium is supported by the EU New OSH ERA research programme (funded by the Finnish Work Environment Fund, the Swedish Research Council for Working Life and Social Research, the German Social Accident Insurance, the Danish National Research Centre for the Working Environment), the Academy of Finland (grant #132944), the BUPA Foundation (grant #22094477), and the Ministry of Social Affairs and Employment, the Netherlands. The HNR is funded by the Heinz Nixdorf Foundation, Germany, German Ministry of Education and Science (BMBF), and the German Research Foundation (DFG). The German National Accident Insurance (DGUV) supports analyses in the frame of the OSH ERA project. The Dutch contribution (POLS) was funded by the Ministry of Social Affairs and Employment, the Netherlands. David Batty is a Wellcome Trust Fellow. Funding bodies for participating cohort studies are listed in their web-pages.

Abstract. The Individual-participant-data meta-analysis in working populations (IPD-Work) consortium (Belgium, Denmark, Finland, France, Germany, the Netherlands, Sweden, and the UK) Job strain in relation to body mass index: pooled analysis of 160,000 adults from 13 cohort studies. *J Intern Med* 2011; doi:xxxx.

Background. Evidence of an association between job strain and obesity is mixed, mostly limited to small-scale studies, and does not distinguish between categories of underweight or obesity sub-classes.

Objectives. To examine the association between job strain and body mass index (BMI) in a large adult population.

Methods. We performed a pooled cross-sectional analysis based on individual-level data from 13 European studies resulting in a total of 161,746 participants (49% men, mean age 43.7 years). Longitudinal analysis with a median follow-up of 4 years was possible in 4 cohort studies (N=42,222).

Results. Of the participants, 86,429 were normal weight (BMI 18.5 - 24.9 kg/m^2), 2149 underweight (BMI < 18.5 kg/m^2), 56,572 overweight (BMI 25.0 - 29.9 kg/m^2), and 13,523 class I (BMI 30 - 34.9 kg/m^2) and 3073 classes II-III (BMI $\geq$ 35 kg/m^2) obese. In all, 27,010 (17%) participants reported job strain. In cross-sectional analyses, we found increased odds of job strain among underweight (odds ratio 1.12, 95% confidence interval 1.00 to 1.25), obese class I (1.07, 95% confidence interval 1.02 to 1.12) and classes II-III participants (1.14, 95% confidence interval 1.01 to 1.28) as compared with normalweight participants. In longitudinal analysis, both weight gain and weight loss were related to the onset of job strain during follow-up.

Conclusions. In an analysis of European data, we found both weight gain and weight loss to be associated with the onset of job strain, a finding which is consistent with the 'U'-shaped cross-sectional association between job strain and BMI.

[247 words]

Keywords: Body mass index, cohort studies, job strain, obesity, thinness, work stress.

INTRODUCTION

Obesity and job strain (i.e., stress at work) are major public health issues in modern societies, potentially contributing to a range of health-related outcomes, such as reduced quality of life, disability, cardio- and cerebro-vascular diseases, and depression.[1-3] According to recent European Union estimates, stress is cited as a factor in half of all lost working days and thus represents a substantial cost in terms of human distress and impaired economic performance.[4] There may be a link between job strain and body mass index (BMI)[5-12] – the most commonly utilised measure of adiposity – as stress might contribute to an unhealthy life style,[5] such as physical inactivity[6] and unfavourable diet[7] which in turn could induce weight gain. Other mechanisms are also plausible. Conversely, psychosocial stress may reduce appetite leading to weight loss.[8-10] In addition to stress being a risk factor for weight change, there is a suggestion that this relationship might be bi-directional. Obesity, for instance, may reduce work capacity[11] so increasing the risk of feelings of stress (the reversed causation hypothesis). Finally, given its link with both overweight and exposure to stressful work conditions,[12] it is also likely that socioeconomic disadvantage may have an important role in generating these relationships (the common cause hypothesis).

To date, empirical evidence for an association between job strain (or other forms of work stress) and BMI has been inconsistent, revealing positive (more stress, higher BMI),[8, 13-17] null,[18,19] and inverse (more stress, lower BMI) [20,21] findings. Small sample sizes in most of these studies may have contributed to the mixed results. This low study power has also led to an inability to distinguish between categories of underweight or different classes of obesity. To enable more precise characterisation of the association between job strain and BMI than in previous studies, we pooled data from 13 independent cohort studies, resulting in an individual-level meta-analysis of 161,746 men and women.

SUBJECTS AND METHODS

Study population and study design

This study is part of the IPD-Work ("Individual-participant-data meta-analysis in working populations") consortium of European cohort studies. A collaboration of 5 studies was established at a workshop in London, UK, on November 8, 2008 since when a further 8 cohort studies joined the collaboration.

In this study, we pooled data from 13 prospective cohort studies (see **table 1** for full names): from Belgium (Belstress), Denmark (DWECS, IPAW, PUMA), Finland (FPS, HeSSup), France (Gazel), Germany (HNR), the Netherlands (POLS), Sweden (SLOSH, WOLF N, WOLF S), and the UK (Whitehall II). Details of the design, recruitment, measurements and ethical approval of the participating studies are presented in **Supplementary Information Appendix**. Participants with complete data on BMI, job strain, sex, and age were included in these analyses, yielding an analytic sample of 78,487 employed men and 83,259 employed women (mean age 43.7 years at study entry). Characteristics of these studies and the study members are presented in **Table 1**.

Assessment of body mass index

BMI was calculated using the usual formulae (weight in kilograms divided by height in meters squared). Participants with missing values for weight or height were excluded (N=2220, 1.3% of all participants). To avoid a few potentially unreliable measurements unduly affecting the results, participants with BMI values <15 or >50 were excluded from the analysis (100 participants; 0.1%). We classified BMI into five categories according to the World Health Organization (WHO) recommendations.[22] Thus, participants whose BMI was less than 18.5 kg/m^2 were categorised as underweight, those with a BMI between 18.5 and <25 were categorised as normal weight, and those with a BMI between 25 and <30 were categorised as overweight. Following the International

Classification of adult obesity,[22] we used two sub-categories of obesity: obese class I (BMI 30 to <35) and class II and III combined (BMI ≥35).

Definition of job strain

According to the job strain model – the most widely tested work stress model – job strain arises when an employee simultaneously has high psychological job demand and low control over work.[23] In the included studies, job strain was assessed using participant-completed questionnaires. All questions in the job demand scale and job control scale required responses in Likert-type formats. Mean response score for job demand items and mean response score for job control items were calculated for each participant. An unfavourable (high) level of *job demand* was denoted by a score *above* the study-specific median; while an unfavourable (low) level of *job control* was defined as a score *below* the study-specific median score. We defined *job strain* as the combination of these two categories. All other combinations of job demand and control, including the values equal to the median value, were assigned to the non-job strain category. Participants with missing data on more than half of the items of job demand or job control were excluded (N=1714, 1% of all participants).

Covariates

Covariates were age, sex, socioeconomic status (SES: high, intermediate, low) and smoking status (current smoker versus non-smoker). Participants with missing values for either age or sex were excluded from all analyses (n=367; 0.2%). More detailed description of the variables is presented in **Supplementary Information Appendix.**

Statistical analyses

We examined individual-level data from nine studies. For a further four whose investigators chose to carry out their own analyses, we provided syntax and instructions for statistical analysis. One-

stage and two-stage meta-analyses of individual participant data [24-26] approaches were used. In the cross-sectional analysis, we used two-stage meta-analysis to include all cohort studies irrespective of whether individual-level or aggregate data were available from the study.
For each study, effect estimates and their standard errors were estimated using logistic regression (the first stage); these study-specific results were then pooled using random-effects meta-analysis (the second stage).[27] We calculated summary odds ratios and their 95% confidence intervals (CI) for job strain in individuals who were categorised as underweight, overweight or obese (classes I and II-III), comparing them to normal weight individuals. We adjusted the odds ratios for sex, age, SES, and smoking. To test the association of BMI with job demand and job control, we computed summary mean difference in demand and control scores between BMI-categories using linear regression. Heterogeneity among study-specific estimates was assessed using the I^2 statistic.[28] In a sensitivity analysis, we ran the analyses separately for studies from which individual-level data were available for pooled analysis. Additionally, to examine measurement method as a source of heterogeneity, we ran these analyses separately for studies with measured height and weight and those based on self-reported height and weight.

In order to examine sub-group differences and longitudinal associations, we used a one-stage meta-analysis pooling all available individual-level data into one dataset. We tested for possible interactions of BMI category, sex and age group (> vs $\leq$50 years) by including an interaction term (BMI*covariate) in the model using a mixed effects logistic regression model with study as the random effect. In four studies (Belstress, FPS, HeSSup, and Whitehall II), BMI and job strain components had been re-measured approximately four years apart so allowing us to examine the longitudinal associations between job strain and BMI-categories in this sub-group of cohorts. To define job strain at follow-up, we used the same study-specific cut-off points that were used at baseline. These studies allowed us to examine a series of subsidiary questions: (1) Does exposure to job strain predict obesity among non-obese participants and is this association stronger for those with repeated exposure to job strain (test of a dose-response association)?; (2) Are both weigh gain (change from non-obese to obese between baseline and follow-up) and weight loss (change from obese to non-obese) related to the onset of job strain at follow-up?; (3) Does obesity at baseline predict the onset of job strain at follow-up (test of reverse causation)?; and (4) Does SES at baseline predict obesity and job strain at follow-up and do the associations between job strain and obesity attenuate in a stratified analysis within three strata of SES (test of the common cause hypothesis)?

Models were fitted with PROC GENMOD, PROC GLIMMIX, and PROC MIXED in SAS 9 or SPSS 17. Meta-analysis was conducted using R (version 2.11, library Meta, www.r-project.org). More details about statistical analysis can be found from **Supplementary Information Appendix.**

RESULTS

Of the participants, 86,429 (53.4%) were normal weight (BMI 18.5-24.9), 2149 (1.3%) underweight (BMI<18.5), 56,572 (35.0%) overweight (BMI 25.0-29.9), 13,523 (8.4%) obese class I (BMI 30-34.9), and 3073 (1.9%) obese classes II and III combined. A total of 27,010 (17%) participants reported job strain. Study-specific results are provided in **Table 1**.

Job demand, job control and obesity

Supplementary Figure S1 presents a forest plot of mean differences in job demand score in each BMI-category relative to the normal weight group. In an age- and sex-adjusted model (model 1), no association was observed between BMI-category and job demand score. After further control for SES (model 2), there was some suggestion of a dose-related link such that higher job demand was associated with a higher risk of obesity, although all point estimates included zero. This positive relation was also seen in the longitudinal analysis of incident obesity (age-, sex- and SES-adjusted odds ratio for top versus bottom quintile 1.14, 95% CI 0.99 to 1.32, **Table S1**).

Supplementary Figure S2 shows a corresponding forest plot for job control and BMI categories. In age- and sex-adjusted analyses (model 1), job control was slightly lower among underweight, overweight and obese participants compared with their normal weight counterparts. However, after adding SES to the multivariable model, with the exception of underweight, all these differences were statistically non-significant (model 2).

Job strain and obesity

Figure 1 presents a forest plot of the random-effect summary odds ratios for job strain in each BMI-category (study-specific results are provided in **Supplementary Figures S3** to **S5**). In an age- and sex-adjusted model (model 1), there was a suggestion of a 'U'-shaped relation such that, the greatest risk of job strain was apparent in the underweight and obese groups, while the risks was lowest in the normal weight group. Thus, the odds ratio for job strain was 1.12 (95% CI 1.01 to 1.25) for underweight participants compared to those who were normal weight. The corresponding odds ratio was 1.07 (1.01 to 1.12) for overweight participants, 1.19 (1.13 to 1.25) for class I obese participants, and 1.30 (1.16 to 1.46) for combined class II and class III obese. Adjustment for SES attenuated the odds ratios for overweight and obesity (model 2), but they remained statistically significant at conventional levels for the two obesity categories. Further adjustment for smoking had essentially no effect on these estimates.

Longitudinal associations

Among the participants who were non-obese at baseline, low versus high SES at baseline was related to the risk of subsequent obesity, with an age- and sex-adjusted odds ratio of 1.54 (95% 1.35 to 1.76). **Table 2** shows longitudinal associations between job strain and obesity at follow-up in this population. These analyses are based on four cohort studies with a median (interquartile range) follow-up of 4 (4-5) years. Job strain at baseline only or at both baseline and follow-up was not associated with obesity at follow-up. Similarly, in analyses not depicted in the table, change in BMI during the follow-up did not differ between initially non-obese participants with and without job strain at baseline (age-, sex- and SES-adjusted mean difference in BMI change -0.02, 95% CI -0.06 to 0.02 kg/m^2, P=0.46), or between those with and without job strain at baseline and follow-up (mean difference -0.04, 95% CI -0.10 to 0.02 kg/m^2, P=0.22). However, new exposure to job strain at follow-up was associated with becoming obese at follow-up (odds ratio compared to no job strain at baseline and follow-up 1.18, 95% CI 1.02 to 1.36)(table 2). When we examined this relationship within three strata of SES, the conclusions were essentially unchanged.

Table 3 shows the converse longitudinal analysis whereby we relate BMI with job strain at follow-up among participants without job strain at baseline. Low SES at baseline was a strong predictor of job strain at follow-up (odds ratio 2.93, 95% CI 2.64 to 3.24), but baseline BMI categories were not associated with subsequent job strain (no support for the reverse causation hypothesis). Becoming obese was associated with a raised risk of job strain at follow-up (odds ratio 1.18, 95 % CI 1.02 - 1.36). This was also evident within all strata of SES although all confidence intervals included unity. In addition, contradictorily, change from obese to non-obese was associated with an increased odds of job strain at follow-up (odds ratio 1.31, 95% CI 1.03 to 1.68 compared to non-obese at baseline and follow-up), a finding replicated at low and intermediate levels of SES, although these analyses were hampered by low numbers (only 5 incident job strain cases in high-SES group).

Sensitivity analyses

We found no statistical evidence to suggest that the cross-sectional association between job strain and obesity varied between participants younger and older than 50 (P for interaction = 0.36) or between men and women (P for interaction = 0.35). Furthermore, the afore-described results remained largely unchanged after exclusion of the 4 studies that did not share individual-level data or when the analyses were performed separately for clinically measured vs. self-reported BMI.

Adjustment for the length of follow-up had practically no effect on the longitudinal association estimates.

DISCUSSION

This analysis of pooled data from up to 160,000 adults in 13 European studies sought to describe the association between job strain and BMI in greater detail than has previously been possible. The results show a ‘U’-shaped association between the two factors such that the proportion of employees with job strain was highest in the underweight and obese groups, with the lowest risk seen in the normal weight. Two recent reviews, which were narrative and based on studies with smaller numbers, found no consistent cross-sectional association between work stress and BMI.[29, 30] However, in those analyses the stressed and non-stressed participants were compared in terms of mean BMI, making it difficult to detect higher levels of stress among both underweight and obese individuals.

Our longitudinal analysis shows that changes in job strain and BMI category tend to co-occur. First, we found that change from no job strain at study baseline to job strain at follow-up is correlated with change from non-obese at baseline to obese at follow-up, a finding also apparent when we stratified analysis for each socioeconomic group. Second, we found that reduction in weight (from obese to non-obese) predicted subsequent job strain, again largely independently of socioeconomic status. Thus, both weight gain and weight loss were associated with the onset of job strain, a finding which is consistent with the 'U'-shaped cross-sectional association between job strain and BMI-category.

We found little direct evidence to suggest that job strain is an independent causal risk factor for weight gain. First, the association was substantially reduced after adjustment for socioeconomic status; second, baseline job strain did not predict change in BMI nor the risk for obesity in longitudinal analysis; and third, repeated measurements of job strain provided no evidence of dose-response associations between job strain and BMI or obesity. These findings are in agreement with the previous evidence. In a study-based meta-analysis of 8514 participants, Wardle and colleagues found no clear evidence for a longitudinal association between job strain and BMI (correlation coefficient 0.014, 95% CI: −0.002 to 0.031, P=0.09).[31] This is concordant with data from Japanese,[32] Swiss,[33] Swedish,[34] and Finnish[35] studies which reported no association between job strain/work stress and change in adiposity. It has been suggested that the effect of job strain on BMI change might differ between subgroups of individuals [10, 34] or be limited to waist circumference instead of BMI.[32] However, BMI and waist circumference are strongly correlated [36] implying that if job strain was a strong predictor of waist circumference a predictive association should also be seen for BMI. Some studies have examined associations between other indicators of work stress (e.g., job insecurity or iso-strain) and weight change but with inconsistent findings.[8, 15, 16, 33, 37]

Considering the reversed causation hypothesis, there was no evidence to suggest that obesity confers an increased risk of job strain. The fact that neither a direct causal effect nor the reverse causation hypothesis obtained support in our longitudinal analyses raises the possibility that common causes might underline the apparent association between the onset of job strain and weight change. In cross-sectional age- and sex-adjusted analyses, the excess odds of job strain was approximately 20% in obese class I and 30% in obese classes II-III, but adjustment for socioeconomic status attenuated these estimates to 7% and 14%, respectively. This attenuation suggests that socioeconomic adversity is likely to at least partially explain the association between job strain and obesity. In the longitudinal analysis, similar associations between the onset of job strain and weight change were observed *within* socioeconomic groups which means that these associations are unlikely to be solely explained by socioeconomic status, but other, yet unknown, factors may also be involved. Further research is needed to confirm this. It may be that adverse life events and the onset of psychiatric disorder, particularly depressive symptoms, contribute to the association between the onset of job strain and weight gain, as these factors are known to affect weight control and reporting of job strain.[38] Previous research suggests a robust association between non-intentional weight loss, underweight and increased mortality,[39, 40] which is largely attributable to a pre-existing physical illness. This explanation might also apply in the present study with pre-existing physical morbidity potentially generating the associations between weight loss, underweight and job strain.

Our study has several important strengths, but also some limitations. First, to our knowledge this is the first study in which the association between BMI and job strain was studied across the entire BMI distribution, that is, including underweight individuals and two sub-categories of obese individuals. Second, the analysis covers multiple study populations from several countries, increasing the generalisability of the findings. Given that the sample size was larger than in any prior study, the likelihood of random error influencing our results is also lower than in the previous investigations. Third, we defined work stress based on the job strain model, which is the most widely used though not the only conceptualization in this area of research. However, apart from socioeconomic status and smoking, we did not examine the role of potential mediating or confounding factors. Despite data harmonization, variation in the assessment of job strain and socioeconomic status between studies may have contributed to imprecision in the estimates. Data harmonization also meant that the measures of job strain and socioeconomic status used in this study might not be optimally adjusted for the specific contexts of each participating study, potentially contributing to underestimation of the associations. On the other hand, using study-specific measurements, as in previous reviews, may introduce information bias and overestimate the associations.

In summary, data from up to 13 European cohort studies show a cross-sectional 'U'-shaped association of job strain with obesity and underweight and corresponding longitudinal associations of both weight gain and weight loss with the onset of job strain. As these associations were relatively modest in terms of absolute effect size and not necessarily causal, our data do not suggest that interventions reducing job strain would be effective in combating obesity at a population level. However, early screening for job strain and obesity in workplaces may inform appropriate treatment strategies or lifestyle changes to prevent adverse health outcomes associated with these conditions, such as work disability and depressive disorders.

[3161 words]

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Detailed description: Study design, recruitment of participants and measurements in the 13 participating studies

Table S1: Longitudinal associations of job demand and job control quintiles and incident obesity in 4 studies with repeat data

Figure S1: Summary estimates for the association between BMI categories and job demand score

Figure S2: Summary estimates for the association between BMI categories and job control score

Figure S3: Study-specific meta-analysis of job strain among underweight versus normal weight adults.

Figure S4: Study-specific meta-analysis of job strain among overweight versus normal weight adults.

Figure S5: Study-specific meta-analysis of job strain among obese versus normal weight adults.

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Table 1. ***Characteristics of participants in 13 European cohort studies***

Study[a] and country	Study years	Number of participants[b]	Number (%) of women	Mean age (range)	Mean (SD) BMI	Number (%) of job strain cases
Belstress, Belgium	1994-1998	20,983	4928 (23%)	45.5 (33-61)	26.1 (3.8)	3948 (19%)
DWECS, Denmark	2000	5523	2567 (46%)	41.8 (18-69)	24.6 (3.7)	1224 (22%)
FPS, Finland	2000-2002	46,933	37,844 (81%)	44.6 (17-65)	25.0 (4.1)	7641 (16%)
Gazel, France	1997	11,259	3101 (28%)	50.3 (43-58)	25.4 (3.5)	1630 (14%)
HeSSup, Finland	1998	16,355	9067 (55%)	39.6 (20-54)	24.9 (3.9)	2857 (17%)
HNR, Germany	2000-2003	1823	742 (41%)	53.4 (45-73)	27.4 (4.4)	221 (12%)
IPAW, Denmark	1996-1997	1965	1305 (66%)	41.3 (18-68)	24.2 (3.8)	339 (17%)
POLS, Netherlands	1997-2002	23,836	9891 (41%)	38.3 (15-85)	24.4 (3.7)	3829 (16%)
PUMA, Denmark	1999-2000	1774	1456 (82%)	42.6 (18-69)	24.5 (3.9)	266 (15%)
SLOSH, Sweden	2006, 2008	10,730	5749 (54%)	47.6 (19-68)	25.4 (3.9)	2098 (20%)
Whitehall II, UK	1985-1988	10,262	3397 (33%)	44.4 (34-56)	24.6 (3.5)	1440 (14%)
WOLF N, Sweden	1996-1998	4692	772 (16%)	44.1 (19-65)	26.2 (3.6)	599 (13%)
WOLF S, Sweden	1992-1995	5643	2427 (43%)	41.5 (19-70)	24.6 (3.6)	913 (16%)
Total	1985-2008	161,746	83,259 (51%)	43.7 (15-85)	25.1 (3.8)	27,010 (17%)

[a]Study acronyms: DWECS: Danish Work Environment Cohort Study; FPS: Finnish Public Sector Study; HeSSup: Health and Social Support; HNR: Heinz Nixdorf Recall Study, IPAW: Intervention Project on Absence and Well-being; POLS: Permanent Onderzoek Leefsituatie; PUMA: Burnout, Motivation and Job Satisfaction study; SLOSH: Swedish Longitudinal Occupational Survey of Health, WOLF: Work, Lipids, Fibrinogen (N=Norrland, S=Stockholm).
[b]Individuals with complete data on job strain, age, sex and body mass index.

Figure 1. ***Summary estimates for the association between BMI categories and high job strain—Model 1: adjusted for sex and age, Model 2: additionally adjusted for socioeconomic status (N = 161,746)***

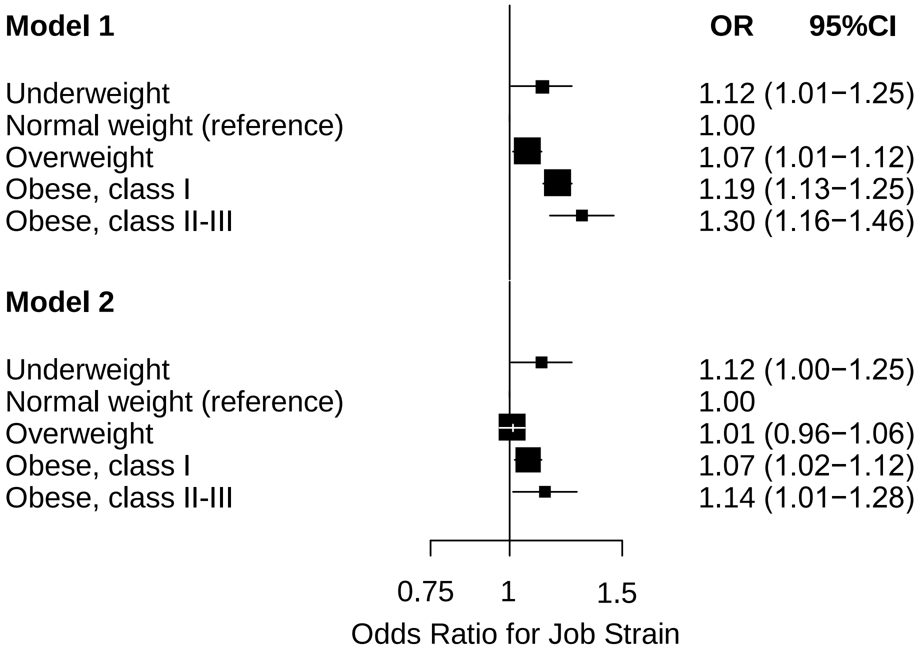

Table 2. ***Longitudinal association between job strain and incident obesity among non-obese participants in 4 studies with repeat data (n = 42,222)[a]***

	Number of participants[b]	Number (%)of new obesity cases	Obesity at follow-up OR (95% CI)[c]
Job strain at baseline			
No	35,715	1748 (5.2)	1.00 (reference)
Yes	6507	336 (4.9)	0.99 (0.88 - 1.12)
Job strain at baseline and at follow-up			
No and no	31,768	1518 (4.8)	1.00 (reference)
No and yes	3947	230 (5.8)	1.18 (1.02 - 1.36)[d]
Yes and no	3796	204 (5.4)	1.06 (0.92 - 1.24)
Yes and yes	2711	132 (4.9)	0.95 (0.79 - 1.14)

[a] Belstress, FPS, HeSSup and Whitehall II. Median follow-up 4 years.
[b] Participants who were normal or overweight at baseline.
[c] Odds ratios are adjusted for age, sex and SES.
[d] The corresponding age- and sex-adjusted odds ratio 1.16 (0.89 - 1.53) in low-SES group (n = 7923), 1.18 (0.97 - 1.43) in intermediate SES group (n = 23,151) and 1.25 (0.86 - 1.83) in high-SES group (n = 11,148).

Table 3. ***Longitudinal associations between BMI categories and job strain at follow-up among participants without job strain at baseline in 4 studies with repeat data (n = 39,970).[a]***

	Number of participants[b]	Number (%) of new job strain cases	Job strain at follow-up OR (95% CI)[c]
BMI category at baseline			
Underweight	446	54 (12.1)	1.05 (0.79 - 1.41)
Normal weight	22,701	2488 (11.0)	1.00 (reference)
Overweight	13,014	1459 (11.2)	1.04 (0.97 - 1.12)
Obese	3809	458 (12.0)	1.08 (0.96 - 1.20)
Obesity at baseline and at follow-up			
No and no	34,412	3771 (11.0)	1.00 (reference)
No and yes	1749	230 (13.2)	1.18 (1.02 - 1.36)
Yes and no	551	77 (14.0)	1.31 (1.03 - 1.68)[d]
Yes and yes	3258	381 (11.7)	1.03 (0.92 - 1.15)

[a] Belstress, FPS, HeSSup and Whitehall II. Median follow-up 4 years.
[b] Participants with no job strain at baseline.
[c] Odds ratios for BMI and obesity are adjusted for age, sex and SES.
[d] The corresponding age- and sex-adjusted odds ratio 1.34 (0.86 - 2.10) in low-SES group (n = 7192) and 1.47 (1.07 - 2.02) in intermediate SES group (n = 21,402). There were only 5 new job strain cases among the high-SES participants who were obese at baseline but non-obese at follow-up.

ONLINE APPENDIX: Supporting information

Study design, recruitment of participants and measurements in the 13 European studies included in the individual-participant meta-analyses of body mass index and job strain

Details of the design, recruitment of the participants and measurements in the studies included in the meta-analyses are presented below. Participants were eligible for the meta-analyses if they were in employment and had available data on job strain.

BELSTRESS

Belstress is a prospective cohort study set up to investigate the associations between work-related stress and health outcomes. Between 1994 and 1998, a total of 21,419 people aged 35-59 were recruited into the study from the payroll records of 25 large companies or public administrations. [1, 2] Of these, 21,024 men and women had data on job strain and were eligible for our meta-analyses. The ethics committees of the University Hospital of Ghent and the Faculty of Medicine of the Université Libre de Bruxelles approved the Belstress study.

DANISH WORK ENVIRONMENT COHORT STUDY (DWECS)

DWECS is a split panel survey of working aged Danish people. The cohort was established in 1990, when a simple random sample of men and women, aged 18-59, was drawn from the Danish population register. The participants have been followed up at five year intervals and data from the year 2000 was used for the IPD-Work. That year 11,437 individuals were invited to participate and 8583 agreed to do so. [3, 4] Of the 5606 individuals who were employed, 5574 had data on job strain and were eligible for our meta-analyses. In Denmark, questionnaire- and register-based studies do not require ethics committee approval. DWECS was approved by and registered with the Danish Data protection agency (registration number: 2007-54-0059).

FINNISH PUBLIC SECTOR STUDY (FPS)

The Finnish Public Sector study is a prospective cohort study comprising the entire public sector personnel of 10 towns (municipalities) and 21 hospitals in the same geographical areas. Participants, who were recruited from employers' records in 2000-2002, were individuals who had been employed in the study organisations for at least six months prior to data collection. [5] 48,598 individuals responded to the questionnaire. Of these, 48,034 had data on job strain and were eligible for our meta-analyses. Ethical approval was obtained from the ethics committee of the Finnish Institute of Occupational Health.

GAZEL

Gazel is a prospective cohort study of 20,625 employees (15,011 men and 5,614 women) of France's national gas and electricity company, Electricité de France-Gaz de France (EDF-GDF). [6, 7] Since the study baseline in 1989, when the participants were aged 35–50 years, they have been posted an annual follow-up questionnaire to collect data on health, lifestyle, individual, familial, social, and occupational factors. Job strain was measured in Gazel in 1997, which we treated as a baseline year for our analyses. The 11,448 individuals who participated at that time and had data on job strain were eligible for our meta-analysis. The GAZEL study received approval from the national commission overseeing ethical data collection in France (Commission Nationale Informatique et Liberté).

HEALTH AND SOCIAL SUPPORT (HESSUP)

The Health and Social Support (HeSSup) study is a prospective cohort study of a stratified random sample of the Finnish population in the following four age groups: 20–24, 30–34, 40–44, and 50–54. The participants were identified from the Finnish population register and posted an invitation to participate, along with a baseline questionnaire, in 1998. A follow-up questionnaire was sent to all participants still living in Finland in 2003. [8] Job strain was measured in 1998 and of the 19,629 individuals who responded to the follow-up questionnaire, 17,102 had data on job strain and were eligible for our meta-analyses. The Turku University Central Hospital Ethics Committee approved the study.

HEINZ NIXDORF RECALL STUDY (HNR)

The Heinz Nixdorf Recall study is a prospective population-based cohort study of individuals randomly selected from the mandatory lists of residence in the metropolitan Ruhr-Area in Germany in Germany. Details of the study methods have been described previously. [9, 10] Briefly, 4814 participants aged 45-75 years were enrolled at study baseline in 2000-2003. Job stress measures and comprehensive medical data were collected during the baseline examination. For the present analyses baseline job strain measures were available for 1841 employed men and women. The HNR study had been approved by the institutional local ethical committees and a quality management system according to European industrial norms (DIN EN ISO 9001:2000) was applied

INTERVENTION PROJECT ON ABSENCE AND WELL-BEING (IPAW)

IPAW is a 5-year psychosocial work environment intervention study including 22 intervention and 30 control work places in three organisations (a large pharmaceutical company, municipal technical services and municipal nursing homes) in Copenhagen, Denmark. [11, 12] The baseline questionnaire was posted to all the employees at the selected work-sites between 1996 and 1997. Of the 2721 employees who worked at the 52 IPAW sites, 2068 men and women completed the baseline questionnaire. Psychological, social support and other interventions took place at 22 workplaces during 1996-98 at the organisational and interpersonal level. Job strain was measured in 1996-1997 and the 2031 participants, who had data on job strain, were eligible for our meta-analysis. IPAW was approved by and registered with the Danish Data Protection Agency (registration number: 2000-54-0066).

PERMANENT ONDERZOEK LEEFSITUATIE (POLS)

Permanent Onderzoek Leefsituatie (POLS) is a series of annual cross-sectional health and lifestyle surveys of Dutch men and women.[13] The participants are a representative sample of the Dutch population, drawn form the Municipal Population Register (Gemeentelijke Basis Administratie, GBA). Only those living in a private household were included. Most of the data collection is done using computer assisted personal interviewing. At study baseline in 1997- 2002, a total of 59,441 men and women participated in the surveys. Of these, 24,761 were in paid employment, aged 15-85 and had job strain measure available and were eligible for our meta-analyses. POLS was approved by the medical ethics committee of the Netherlands Organisation for Applied Scientific Research.

BURNOUT, MOTIVATION AND JOB SATISFACTION STUDY (PUMA)

Burnout, Motivation and Job Satisfaction study (Danish acronym: PUMA) is an intervention study of burn-out among employees in the human service sector.[14] Selection criteria for the participating organisations was that they had between 200 and 500 employees, that occupational groups within each organisation were willing to participate and that the organisations would commit to the entire five-year study period. At study baseline in 1999-2000, a total of 1914 participants agreed to take part. Of these, 1847 individuals had data on job strain and were eligible for our meta-analyses. PUMA was approved by the Scientific Ethical Committees (Videnskabsetisk Komiteer) in the counties in which the study was conducted and approved by and registered with the Danish Data Protection Agency (registration number: 2000-54-0048).

SWEDISH LONGITUDINAL OCCUPATIONAL SURVEY OF HEALTH (SLOSH)

Swedish Longitudinal Occupational Survey of Health (SLOSH) is a follow-up study of individuals who participated in the Swedish Work Environment Survey (SWES) in 2003 or 2005. SWES, conducted biennially by Statistics Sweden (SCB), is based on a sample of gainfully employed people aged 16-64 years drawn from the Labour Force Survey (LFS). These individuals were first sampled into LFS through stratification by county, sex, citizenship and inferred employment status.

Data from the 2006 and 2008 data collection waves of SLOSH were used in the IPD-Work analyses. In both years, data were collected using postal self-completion questionnaires. In 2006, 5,985 individuals responded to the questionnaire. Of these, 5141 people worked at least 12 hours a week and 5104 had data on job strain and were thus eligible for our meta-analyses. [15] In 2008, a further 6751 individuals responded to the questionnaire. [16] Of these, 5895 men and women worked at least 12 hours a week and 5866 had data on job strain and were thus eligible for our meta-analyses. SLOSH has been approved by the Regional Research Ethics Board in Stockholm.

WHITEHALL II

The Whitehall II study is a prospective cohort study set up to investigate socioeconomic determinants of health. At study baseline in 1985-1988, a total of 10,308 civil service employees (6895 men and 3413 women) aged 35-55 and working at 20 civil service departments in London were invited to participate in the study.[17] Job strain was measured at study baseline and 10,285 men and women had data on job strain and were eligible for our meta-analyses. The Whitehall II study protocol was approved by the University College London Medical School committee on the ethics of human research. Written informed consent was obtained at each data collection wave.

WOLF (WORK, LIPIDS, AND FIBRINOGEN) STOCKHOLM AND WOLF NORRLAND STUDIES

The WOLF (Work, Lipids, and Fibrinogen) Stockholm study is a prospective cohort study of 5698 people (3239 men and 2459 women) aged 19–70 and working in companies in Stockholm county. [18] WOLF Norrland is a prospective cohort of 4718 participants aged 19-65 working in companies in Jämtland and Västernorrland counties.[19] At study baseline the participants underwent a clinical examination and completed a set of health questionnaires. For WOLF Stockholm, the baseline assessment was undertaken at 20 occupational health service units between November 1992 and June 1995 and for WOLF Norrland at 13 occupational health service units in 1996-98. The Regional Research Ethics Board in Stockholm, and the ethics committee at Karolinska Institutet, Stockholm, Sweden approved the study.

ASSESSMENT OF BODY MASS INDEX

BMI (weight in kilograms divided by height in meters squared) was calculated from weight and height that were clinically measured in five studies (Belstress, HNR, Whitehall II, WOLF-N, WOLF-S) and self-reported in eight studies (DWECS, FPS, Gazel, HeSSup, IPAW, POLS, PUMA, SLOSH). POLS was the only study in which weight and height were coded in categories; we used the category mean for calculating BMI in that cohort study.

Participants with missing value for weight or height were excluded (N=2220, 1.3% of all participants). To avoid a few potentially unreliable measurements unduly affecting the results, participants with BMI values less than 15 or greater than 50 were excluded from the analysis (100 participants; 0.1%).

ASSESSMENT OF COVARIATES

Sex and age were either obtained from registers or recorded in a medical examination (DWECS, FPS, Gazel, HNR, IPAW, PUMA, SLOSH, WOLF N, and WOLF S) or from a questionnaire (Belstress, HeSSup, POLS, and Whitehall II). In addition, we assessed socio-economic status (SES) and smoking as these factors may be related to both BMI and stress. SES was obtained from recorded occupation in DWECS, FPS, Gazel, IPAW, and PUMA, self-reported occupation in Belstress, HNR, POLS, SLOSH, WOLF N, WOLF S, Whitehall II, and education in HeSSup, and was classified as low (e.g., cleaners, maintenance workers), intermediate (registered nurses, technicians), or high (teachers, physicians). Self-employed participants or participants with missing data on SES (n=4342, 2.7%) were categorised in a separate group "others" (rather than excluded from the analysis) in order to keep the numbers identical for analyses with and without socioeconomic status. Smoking status was self-reported in all studies and categorised as "current smoker" versus "non-smoker". Participants with missing value for sex or age were excluded from the analysis (n=367; 0.2%).

STATISTICAL ANALYSIS

We examined individual-level data from the following nine studies: Belstress, FPS, Gazel, HeSSup, HNR, SLOSH, Whitehall II, WOLF N, and WOLF S. For a further four studies (DWECS, IPAW, POLS, and PUMA) whose investigators chose to carry out their own analyses, we provided syntax and instructions for statistical analysis.

One-stage and two-stage meta-analyses of individual participant data [20-22] approaches were used. In the main cross-sectional analysis we used two-stage meta-analysis to include all cohort studies irrespective of whether individual-level or aggregate data were available. In one-stage meta-analyses for examining sub-group differences and longitudinal associations, we pooled all available individual-level data (from the above-mentioned nine studies) into one dataset.

For each study, effect estimates and their standard errors were estimated using logistic regression analysis (the first stage); these study-specific results were then pooled using random-effects meta-analysis (the second stage) [23]. We calculated summary odds ratios and their 95% confidence intervals (CI) for job strain in individuals who were categorised as underweight, overweight or obese (classes I and II-III), comparing them to normal weight individuals. We adjusted the odds ratios for sex, age, SES, and smoking. To test the association of BMI with job demand and job control, we computed summary mean difference in demand and control scores between BMI-categories using linear regression. Heterogeneity among study-specific estimates was assessed using the I2 statistic.[24] In a sensitivity analysis, we ran the analyses separately for studies from which individual-level data were available for pooled analysis. Additionally, to examine measurement method as a source of heterogeneity, we ran these analyses separately for studies with measured height and weight (Belstress, HNR, Whitehall II, WOLF-N, and WOLF-S) and those based on self-reported height and weight (DWECS, FPS, Gazel, HeSSup, IPAW, POLS, PUMA, SLOSH). In order to examine sub-group differences, we tested for possible interactions of BMI category, sex and age group(> vs <50 years) by including an interaction term (BMI*covariate) in the model, using a mixed effects logistic regression model with study as the random effect.

In four studies (Belstress, FPS, HeSSup, and Whitehall II), BMI and job strain components had been re-measured approximately four years apart so allowing us to examine the longitudinal associations between job strain and BMI-categories in this sub-group of cohorts. To define job strain at follow-up, we used the same study-specific cut-off points that were used at baseline. These studies allowed us to examine a series of subsidiary questions: (1) Does exposure to job strain predict obesity among non-obese participants and is this association stronger for those with repeated exposure to job strain (test of a dose-response association)?; (2) Are both weigh gain (change from non-obese to obese between baseline and follow-up) and weight loss (change from obese to non-obese) related to the onset of job strain at follow-up?; (3) Does obesity at baseline predict the onset of job strain at follow-up (test of reverse causation)?; and (4) Does SES at baseline predict obesity and job strain at follow-up and do the association between job strain and obesity disappear in a stratified analysis within three strata of SES (test of the common cause hypothesis)?

Study-specific linear and logistic regression analysis models were fitted with PROC GENMOD in SAS 9 (Belstress, DWECS, FPS, Gazel, HeSSuP, HNR, IPAW, PUMA, SLOSH, Whitehall II, WOLF N, and WOLF S) or SPSS 17 (POLS).

Mixed models based on pooled data were fitted with PROC GLIMMIX and PROC MIXED in SAS 9. Meta-analysis was conducted using R (version 2.11, library Meta, www.r-project.org).

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Table S1. Longitudinal associations of job demand and job control quintiles and incident obesity in 4 studies with repeat data[a]

		Number of participants[b] (Number of cases[c])	Model 1	Model 2
Job demand				
	Q1	9528 (458)	1.00 (reference)	1.00 (reference)
	Q2	10,353 (526)	1.05 (0.92 - 1.20)	1.07 (0.94 - 1.22)
	Q3	7287 (349)	0.99 (0.86 - 1.15)	1.03 (0.90 - 1.19)
	Q4	8133 (398)	1.02 (0.89 - 1.17)	1.08 (0.94 - 1.24)
	Q5	7145 (367)	1.07 (0.93 - 1.24)	1.14 (0.99 - 1.32)
Job control				
	Q5	10,744 (502)	1.00 (reference)	1.00 (reference)
	Q4	8751 (401)	0.98 (0.85 - 1.12)	0.93 (0.81 - 1.06)
	Q3	8819 (433)	1.04 (0.92 - 1.19)	0.95 (0.83 - 1.09)
	Q2	6416 (336)	1.13 (0.98 - 1.31)	0.99 (0.86 - 1.16)
	Q1	7716 (426)	1.18 (1.03 - 1.35)	0.99 (0.85 - 1.14)

Model 1 is adjusted for age and sex and Model 2 additionally for socioeconomic status.
[a] Belstress, FPS, HeSSup and Whitehall II. Median follow-up 4 years.
[b] Normal and overweight participants at baseline
[c] Obese participants at follow-up

Figure S1. ***Summary estimates for the association between BMI categories and job demand score (Model 1: adjusted for sex and age, Model 2: additionally adjusted for socioeconomic status) (N = 161,746)***

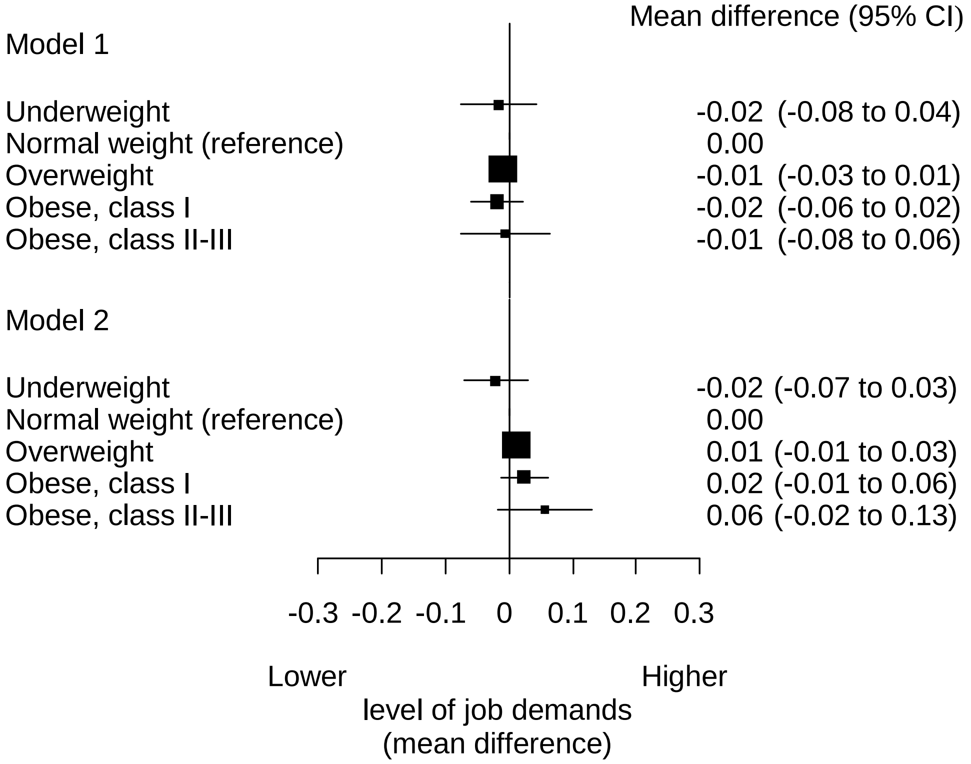


Figure S2. ***Summary estimates for the association between BMI categories and job control score (Model 1: adjusted for sex and age, Model 2: additionally adjusted for socioeconomic status) (N = 161,746)***

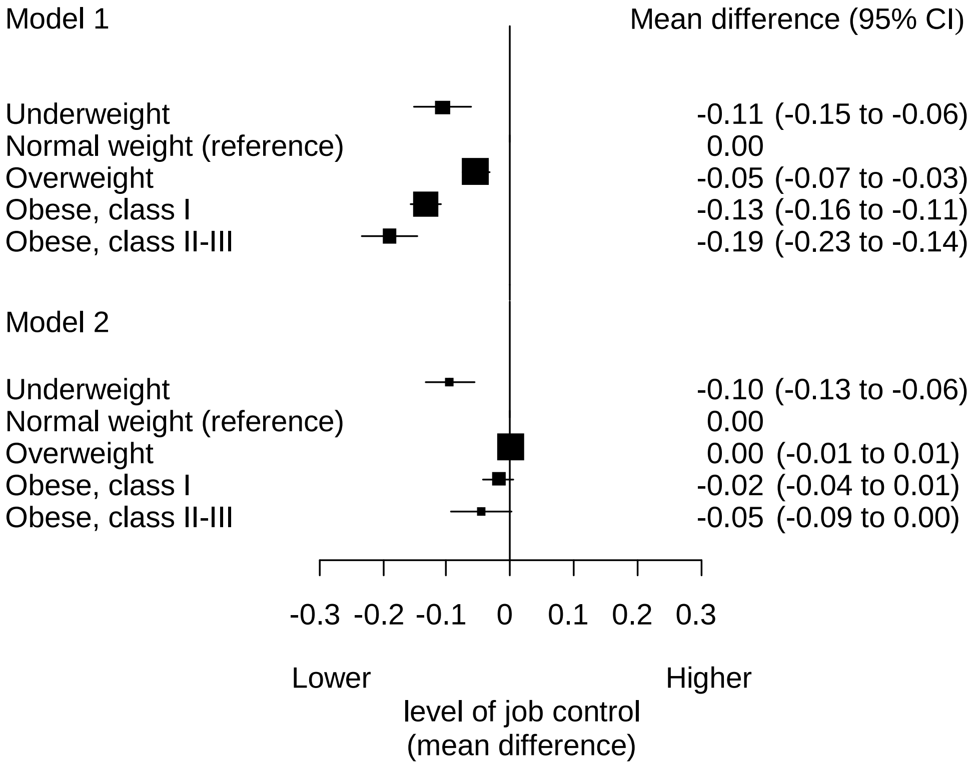


Figure S3. Random-effects meta-analysis: age- and sex-adjusted odds ratio for job strain among underweight (BMI<18.5) versus normal weight (BMI 18.5-24.9) adults.

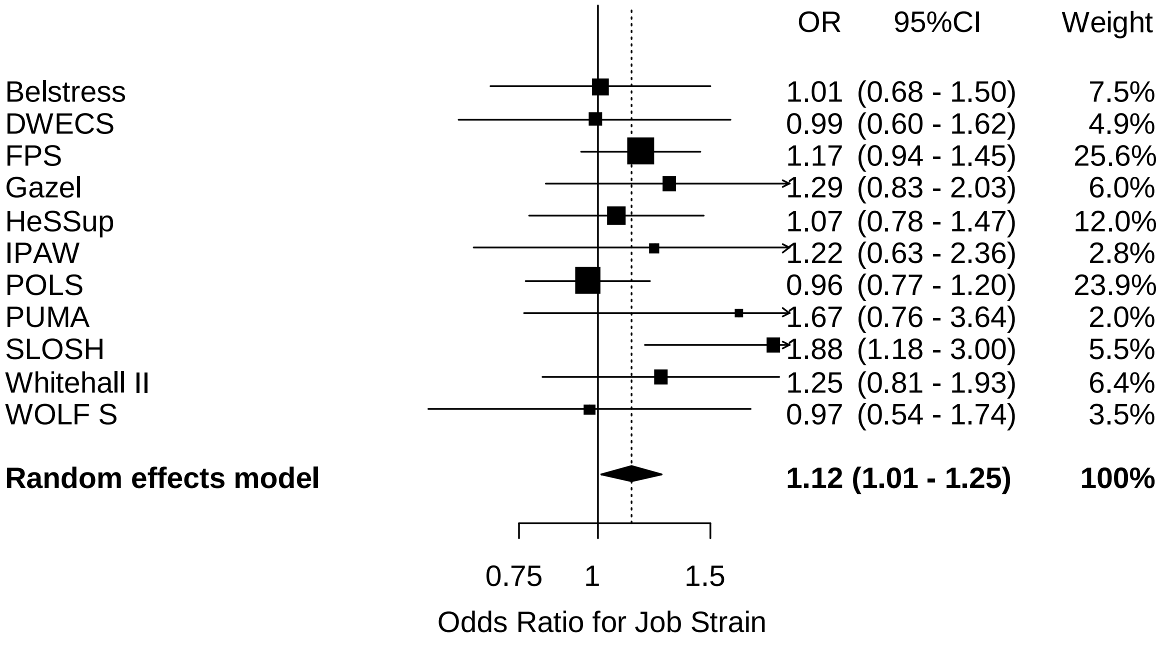
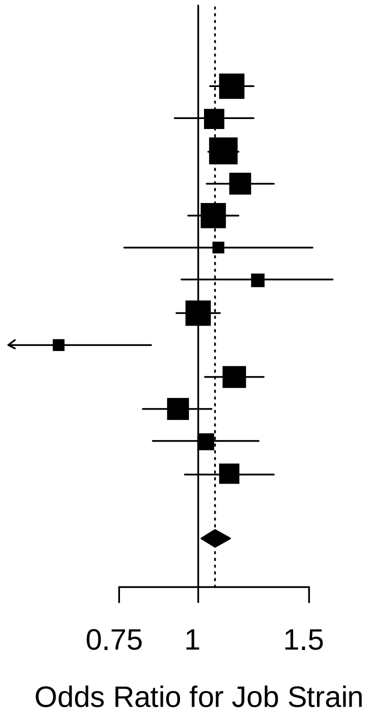


Figure S4. Random-effects meta-analysis: age- and sex-adjusted odds ratio for job strain among overweight (BMI 25.0-29.9) versus normal weight (BMI 18.5-24.9) adults.



	OR	95% CI	Weight
Belstress	1.13	(1.04 - 1.22)	11.9%
DWECS	1.06	(0.92 - 1.23)	7.1%
FPS	1.10	(1.04 - 1.16)	14.0%
Gazel	1.17	(1.03 - 1.32)	8.6%
HeSSup	1.06	(0.96 - 1.16)	10.7%
HNR	1.08	(0.76 - 1.51)	2.0%
IPAW	1.24	(0.94 - 1.63)	2.8%
POLS	1.00	(0.92 - 1.08)	11.8%
PUMA	0.60	(0.43 - 0.84)	2.0%
SLOSH	1.14	(1.02 - 1.27)	9.6%
Whitehall II	0.93	(0.82 - 1.05)	8.3%
WOLF N	1.03	(0.85 - 1.24)	5.0%
WOLF S	1.12	(0.95 - 1.32)	6.2%
Random effects model	**1.07**	**(1.01 - 1.12)**	**100%**

Figure S5. Random-effects meta-analysis: age- and sex-adjusted odds ratio for job strain among obese (BMI≥30) versus normal weight (BMI 18.5-24.9) adults.