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Physical work exposure, chronic musculoskeletal pain and risk of insomnia: Longitudinal data from the HUNT Study, Norway

Running head: Physical work exposure, chronic pain and insomnia

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AUTHORS' CONTRIBUTIONS

Study concept and design: All authors. Drafting of the manuscript: All authors. Critical revision of the manuscript: All authors. Statistical analysis: All authors. Analysis and interpretation of data: All authors. Critical revision: All authors. Final approval: All authors.

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What this paper adds:

1. **What is already known about this subject?**
    - Previous studies have shown that physical work demands may be positively associated with insomnia symptoms. However, work-related fatigue has been suggested as an important factor on the causal pathway between high work demands and various health problems. Still, no studies have investigated the prospective association between work-related fatigue and insomnia, and if pain aggravates this association.
2. **What are the new findings?**
    - Work-related physical fatigue is strongly associated with increased risk of insomnia in vocationally active women and men.
    - The risk is especially high among workers who always experience work-related physical fatigue and who also suffer from chronic musculoskeletal pain.
3. **How might this impact on policy or clinical practice in the foreseeable future?**
    - These findings provides important knowledge for policy makers and employers by showing that work-related physical fatigue and chronic pain are important targets to reduce incidence of insomnia symptoms in workers.

ABSTRACT

Objectives To prospectively investigate (i) the association of physical work demands and work-related physical fatigue with risk of insomnia symptoms and (ii) if these associations are influenced by chronic musculoskeletal pain.

Methods Prospective study on a working population of 8,563 women and 7,598 men participating in the Nord-Trøndelag Health Study (Norway) who reported no insomnia at baseline in 1995-1997. Occurrence of insomnia symptoms was assessed at follow-up in 2006-2008. A Poisson regression model was used to calculate adjusted risk ratios (RRs) for insomnia symptoms with 95% confidence interval (CI).

Results Compared to workers without work related physical fatigue, women and men who reported that they were always fatigued had RRs of insomnia of 2.34 (95% CI 1.72-3.18) and 2.47 (95% CI 1.59-3.83), respectively. Overall, physical work demands was not associated with risk of insomnia, although men who reported heavy physical work had a RR of 0.67 (95% CI 0.47-0.97) compared to men with mostly sedentary work. Compared to the reference group of workers without work-related physical fatigue and no chronic pain, analyses of joint effects showed that women with excessive work-related fatigue had a RR of 4.20 (95% CI 2.95-5.98) if they reported chronic pain and a RR of 1.67 (95% CI 0.87-3.18) if they did not. Corresponding RRs in men were 3.55 (95% CI 2.11-5.98) and 2.13 (95% CI 1.07-4.25).

Conclusion These findings suggest that there is an interplay between work-related physical fatigue and musculoskeletal pain that should receive particular attention in the prevention of insomnia in working populations.

Key words: job demands, occupational load, musculoskeletal complaints, sleep problems, physical work

INTRODUCTION

Approximately eight percent of the working population suffers from insomnia while about one third reports insomnia symptoms.[1-3] Sleep problems and insomnia are associated with increased risk of adverse health outcomes, such as type 2 diabetes,[4] chronic musculoskeletal pain,[5] and cardiovascular disease.[6] Furthermore, insomnia may impair work performance and productivity as well as increase the risk of adverse safety outcomes, sickness absence and work disability.[7-11] The unfavorable consequences for both individuals, workplaces, and society puts insomnia as an important public health concern, and underscore the importance of identifying modifiable risk factors for prevention.

Several cross-sectional studies have shown that physical work demands are associated with sleep problems and insomnia.[12-16] For instance, repeated and monotonous movements, twisted work positions, breaking into sweat each day, shaking and vibration, and moving or lifting heavy loads are associated with disturbed sleep.[12 13] Likewise, much walking at work, lifting and/or heavy manual labour [15] as well as prolonged periods with hard physical exertion at work are associated with poor sleep.[14] However, a recent prospective study found no association between long-term exposure to physically demanding work tasks and risk of insomnia symptoms.[17] These inconsistent results warrant further exploration of the association between work demands and insomnia, and differences in physical capacity between workers may be of particular importance. It is conceivable that long-term exposure to similar physical work demands may elicit different effects depending on the physical capacity of the individual worker. Perceived work-related physical fatigue may therefore capture the relative load imposed by physical work exposure better than classifications based on work type and physical work demands. Work-related fatigue has been suggested as an important factor on the causal pathway

between high work demands and various health problems.[18] Still, no previous study has prospectively examined if work-related physical fatigue increase the risk of insomnia.

Furthermore, high physical work demands is strongly associated with both musculoskeletal pain [19] and increased risk of insomnia. [20] Thus, it is conceivable that chronic musculoskeletal pain further amplifies any adverse effects that heavy workload and work-related physical fatigue might have on insomnia risk. Knowledge on such as interplay between physical work demands, work-related physical fatigue and musculoskeletal pain would be valuable for improved prevention of insomnia in an occupational setting.

The aim of this population-based study was therefore twofold. First, to prospectively examine the association of physical work demands and work-related physical fatigue with risk of insomnia symptoms. Second, we explored if chronic musculoskeletal pain amplified any adverse effects of high work demands or physical fatigue on risk of insomnia.

METHODS

Study population

All inhabitants aged 20 years or older receding in Nord-Trøndelag County in Norway have been invited to participate in The Nord-Trøndelag Health Study (The HUNT Study). The first survey was conducted in 1984-1986 (HUNT1), the second in 1995-1997 (HUNT2) and the most recent in 2006-2008 (HUNT3). The current study is based on data from HUNT2 and HUNT3. In HUNT2, 93,898 people were invited to participate, and 65,237 (69.5%) accepted the invitation. In HUNT3, 93,860 people were invited and 50,839 (54.1%) accepted the invitation. More detailed information about the HUNT Study can be found at http://www.ntnu.edu/hunt.

In the current study, we used data from the 36,984 people who participated at both HUNT2 and HUNT3. First, we excluded 8,984 who did not report to be vocationally active (paid work or self-employed) at HUNT2, and 2,120 persons who were ≥60 years at HUNT2. Further, we excluded 2,170 persons who reported insomnia symptoms and 925 persons who reported use of sedatives and/or sleeping medicine at HUNT2. Further, we excluded persons with incomplete information about physical work demands (n=3892), work-related physical fatigue (n=742) and chronic musculoskeletal pain (n=19). Of the remaining 18,132 persons, 16,161 persons answered relevant insomnia questions in both surveys. Thus, the prospective analysis was based on information from 8,563 women and 7,598 men aged 20-60 years. In supplementary analysis, the responders were compared with (i) workers who were excluded due to missing information on central variables at baseline, and (ii) workers with complete baseline information but no information about insomnia at HUNT3.

All participants signed a written consent, and the study was approved by the Regional Committee for Ethics in Medical Research (project no. 2014/612 REK midt, Norway). The study was carried out according to the Declaration of Helsinki.

Physical work demands

Physical work demands were assessed by the question: "How would you describe your work?", with four possible response options: "Mostly sedentary work (e.g., at a desk, on an assembly line)", "Much walking at work (e.g., delivery work, light industrial work, teaching)", "Much walking or lifting at work (e.g., postman, nurse, construction work)", and "Heavy physical work (e.g., forestry work, heavy agricultural work, heavy construction)".

Work-related physical fatigue

Work-related physical fatigue was assessed by the question "Is your work so physically demanding that you are often physically worn out after a day's work?", with the response options: "Yes, nearly always", "Quite often", "Seldom" and "Never, or almost never". Based on these answers we constructed a new variable to categorize participants into three categories: Never/seldom fatigued (never or almost never/seldom), often fatigued (quite often) and always fatigued (yes, nearly always).

Chronic musculoskeletal pain

Chronic musculoskeletal pain was assessed by the question: "During the last year, have you had pain and/or stiffness in your muscles and limbs that has lasted for at least 3 consecutive months?" with response options "Yes" and "No".

Insomnia symptoms

Insomnia symptoms in HUNT2 was assessed by two questions: “Have you had problems falling asleep during the last month?” and “During the last month, did you ever wake up to early, not being able to fall asleep again?” with four responses options on each question: “Never”, “Occasionally”, “Often”, and “Almost every night”. Participants who reported “Never” or “Occasionally” on both questions were considered unlikely to have insomnia at baseline and were included in the study. Participants who reported “Often” or “Almost every night” were excluded from the study.

In HUNT3, classification of insomnia was based on four questions to approximates the diagnose of insomnia according to the DSM-V criteria.[21]: 1) “How often during the last three months have you had difficulty falling asleep at night?”, 2) “How often during the last three months have you woken up repeatedly during the night?”, 3) “How often during the last three months have you woken to early and couldn’t get back to sleep?”, and 4) “How often during the last three months have you felt sleepy during the day” with three response options on each question: “Never/seldom”, “Sometimes” and “Several times a week”. Participants were classified with insomnia if they answered “Several times a week” on at least one of the questions 1-3 and ‘Several times a week’ on question 4.

Other variables

Height (to the nearest centimeter) and weight (to the nearest half kilogram) measured at the clinical examination were used to calculate BMI as mass divided by the square of height (kg/m2). Participants were classified into one of three BMI groups according to the cut-points

suggested by the World Health Organization:[22] normal weight (BMI 18.5-24.9 kg/m2), overweight (BMI 25.0-29.9 kg/m2), or obese (BMI≥30.0 kg/m2). Leisure time physical activity was assessed by the question: “How much of your leisure time have you been physically active during the last year? (Think of a weekly average for the year. Your commute to work counts as leisure time)”. The participants were then asked to specify number of hours per week of light (no sweating or heavy breathing) and/or hard (sweating and heavy breathing) physical activity with the response options: “None”, “Less than 1 hour”, “1-2 hours” and “3 or more hours” for both light and hard activity. Based on this information, we constructed a new variable with four categories combining information on light and hard activity: inactive (none light or none hard activity), low activity (<3 h light and none hard activity), moderate activity (≥3 h light and/or <1 h hard activity), and high activity (any light and ≥1 h hard activity). Education was assessed by the question: “What is your highest level of education?”, and were divided into: “primary school”, “high school” “college ≤4 years” and “college >4 years”. Shift work was assessed by the question: ‘Do you work shifts, at night, or on call?’, with two response options: ‘no’ and ‘yes’. Participants were asked to indicate number of working hours based on the question: ‘How many hours of paid work do you have a week?’, and then dichotomized into ‘<45 hours’, ‘≥45 hours’ and ‘unknown’. Smoking was assessed by questions about past or present use of cigarettes, and then divided into three categories: ‘never smoked’, ‘previous smoker’ and ‘current smoker’. Job satisfaction was assessed by the question: ‘All things considered, how much do you enjoy your work?’, with four response options: ‘a great deal’, ‘a fair amount’, ‘not much’, ‘not at all’. Scoring ‘not much’ or ‘not at all’ was considered as low job satisfaction.

Statistical analysis

A modified Poisson regression was used to estimate risk ratios (RRs) of insomnia symptoms associated with work-related physical fatigue, physical work demands and chronic musculoskeletal pain. Participants who reported work-related physical fatigue "often" and "always" were compared to the reference group who reported to experience fatigue "never/seldom". Participants who reported "much walking", "much walking and lifting" and "heavy physical work demands" were compared to the reference group with "mostly sedentary work". The precision of the RRs was assessed by 95% confidence intervals (CIs) using robust variance estimation. All associations were stratified by sex and adjusted for age (20-29, 30-39, 40-49, 50-59 years) and education ("primary school", "high school" "college ≤4 years", "college >4 years" and "unknown"). Work-related physical fatigue was additionally adjusted for physical work demands (mostly sedentary, much walking at work, much walking or lifting at work, heavy physical work).

We estimated the joint effect of physical work demands and chronic musculoskeletal pain on risk of insomnia symptoms, using workers without pain and mostly sedentary work as the reference group. In analysis of the joint effect of work-related physical fatigue and chronic musculoskeletal pain on risk of insomnia, participants without pain who seldom/never experienced fatigue served as the reference group. The analyses of joint effects were adjusted for age, education and physical work demands as described above, and also for BMI (18.5-24.9 kg/m2, 25.0-29.9 kg/m2, ≥30 kg/m2, and unknown), smoking (no, yes, unknown), and leisure time physical activity (inactive, low activity, moderate activity, high activity, unknown). Potential effect modification between the variables was assessed as departure from additive effects calculating the relative excess risk due to interaction (RERI). We calculated RERI estimates with 95% CIs from the following equation: $RERI = RR_{\text{any chronic musculoskeletal pain and always}}$

physical fatigue-$RR_{\text{no chronic musculoskeletal pain and always physical fatigue}}$ -$RR_{\text{any chronic musculoskeletal pain and never/seldom physical fatigue}}$ + 1,[23] i.e., RERI>0 indicate a synergistic effect beyond an additive effect. The same RERI calculation was performed for the joint effect of any chronic musculoskeletal pain and physical work demands.

Supplementary analyses were conducted to assess the robustness of the results. First, we included potential confounders associated with physical capacity as covariates in the multi-adjusted models, such as BMI, smoking and leisure-time physical activity. Second, shift work and working hours are two known risk factors of sleep problems. [24 25] We excluded therefore workers with shift work and/or and long working hours (≥45 h per week) and assessed possible interaction with long working hours and/or shift work (this latter analysis was conducted on a pooled sample adjusting for sex). Moreover, because of potentially socioeconomic differences within the categories of physical work demands and fatigue, we excluded workers with higher education (≥13 years). Further, because 65.5 % of men who report heavy physical work were farmers or forest owners, we repeated the main analyses excluding these workers. Since high physical work demands can cause a shift in occupation towards less physically demanding jobs in older workers, we also stratified the analyses by age (20-39 years vs 40-60 years). Finally, we investigated the effect of work-related physical fatigue within strata of physical work demands and excluded workers who reported low job satisfaction.

All statistical analyses were performed using Stata for Windows, version 13.1 (StataCorp LP, College Station, Texas).

RESULTS

Table 1 presents the baseline characteristics of the study population stratified by sex and physical work demands. A total of 475 (5.5%) women and 286 (3.8%) men reported insomnia at follow-up (HUNT3). Compared with workers who were excluded due to missing information on central variables at baseline, the responders tended to be older (mean age, 42.7 vs. 38.9), experience more musculoskeletal pain (41.7% vs. 37.6%), have higher education (28.5% vs. 24.6%) and smoke less (15.2% vs. 21.3%). The differences were less evident when we compared the responders with workers with complete baseline information but no information about insomnia at HUNT3.

Physical work demands was not associated with risk of insomnia symptoms among women, but men who reported heavy physical work had a RR of 0.67 (95% CI 0.47-0.97) compared to men with mostly sedentary work (Table 2). Women and men who reported to always be physically fatigued after work had increased risk of insomnia, with RRs of 2.34 (95% CI 1.72-3.18) and 2.47 (95% CI 1.59-3.83), respectively.

Table 3 shows the joint effect of physical work demands and chronic musculoskeletal pain on risk of insomnia symptoms. Overall, there was no clear evidence of interaction, i.e., the RERI estimates between physical work demands and pain were 0.38 (95% CI -1.47-2.24) in women and -0.53 (95% CI -1.25-0.20) in men.

Table 4 shows the joint effect of work-related physical fatigue and chronic musculoskeletal pain on risk of insomnia symptoms. Compared to the reference group of workers without pain and who never/seldom experienced work-related fatigue, women who always experienced work-related fatigue had a RR of 4.20 (95% CI 2.95-5.98) if they also reported chronic musculoskeletal pain, whereas the RR was 1.67 (95% CI 0.87-3.18) among

those without chronic pain. The corresponding RRs among men were 3.55 (95% CI 2.11-5.98) and 2.13 (95% CI 1.07-4.25). The RERI estimates between work-related fatigue and pain on risk of insomnia symptoms were 1.17 (95% CI -0.15-2.49) for women and 0.77 (95% CI -1.29-2.83) for men.

Supplementary analyses

The inclusion of BMI, smoking, and physical activity as covariates in the multi-adjusted model had negligible influence on the results. Further, exclusion of farmers and forest owners, workers with higher education (≥13 years), and workers who reported to be dissatisfied with their work had minor influences on the results. When excluding workers with shift work and long working hours, the RRs for insomnia symptoms became somewhat weaker among women (2.02, 95% CI 1.26-3.24) and men (1.95, 95% CI 0.99-3.88) who experienced to always be fatigued in relation to their work. Further, a weak additive interaction of work-related physical fatigue and shift work or/and long working hours were observed (RERI: 0.82, 95% CI -0.07-1.71). Analyses stratified by age ±40 years showed a stronger reduced risk of insomnia among men with heavy physical work demands in the youngest age group (RR 0.45; 95% CI 0.24-0.85) than in the oldest (RR 0.83; 95% CI 0.48-1.43).

DISCUSSION

The main finding of the current study was the strong positive association between work-related physical fatigue and risk of insomnia symptoms in both women and men. Workers who always experienced to be physically fatigued after work had more than twofold higher risk of insomnia symptoms compared to workers who never or seldom experienced work-related physical fatigue. Chronic musculoskeletal pain seems to amplify this association. Physical work demands were not clearly associated with risk of insomnia symptoms in these data. Thus, the current findings suggest that initiatives aimed at reducing work-related physical fatigue and chronic musculoskeletal pain are of particular importance to reduce incidence of insomnia in vocationally active women and men.

We are not aware of any previous study that have investigated work-related physical fatigue as an independent risk factor for insomnia symptoms. Sluiter and colleagues showed that work-related physical fatigue may serve as an intermediate factor for the association between work demands and subjective health complaints, where the latter was defined as a combination of psychosomatic complaints, sleep quality, emotional exhaustion, and fatigue.[18] Thus, the current study expands one these findings by prospectively studying the independent effect of physical work demands, work-related physical fatigue and risk of insomnia symptoms. We found that work-related physical fatigue increased risk of insomnia symptoms in both women and men, also after adjusting physical work demands, suggesting that physical fatigue induces sleep problems irrespective of work demands. The underlying mechanisms for such an effect is unclear, but lack of proper rest and recovery could be a stressor that in turn has a negative influence on sleep.[26 27]

Further, our results suggest that chronic musculoskeletal pain amplify the adverse association between work-related physical fatigue and risk of insomnia. Although the confidence intervals in the analyses of additive interaction were wide, they indicate additive interaction of work-related physical fatigue and pain with insomnia. However, it should be noted that physical work exposures and chronic musculoskeletal pain was measured at the same time. It is therefore possible that people with chronic musculoskeletal pain experiences an exacerbation of work-related physical fatigue, which in turn increase the risk of insomnia symptoms. However, the exact mechanisms and temporal association between fatigue and chronic pain are poorly understood,[28] especially in relation to insomnia symptoms. Thus, these findings suggests that the risk of insomnia is especially high in pain-afflicted workers with excessive work-related physical fatigue, and provide novel insight into the interplay between physical work exposure and musculoskeletal pain.

The finding that heavy physical work demands reduced the risk of insomnia among men is somewhat surprising considering the results in other studies.[12 15 17] Cross-sectional studies have found a positive association between physical work demands and prevalence of sleep problems [12] or disturbed sleep, [15] but this was not replicated in a prospective study by Åkerstedt and colleagues.[17] The results from the cross-sectional studies may be prone to bias, particularly due to confounding by socioeconomic status or selection into occupations with high physical work demands that also are positively associated with sleep problems. To pursue some alternative explanations we performed a set of supplementary sensitivity analyses. However, the protective effect of heavy physical work among men remained after exclusion of farmers and forest owners, men with high education, low job satisfaction, shift work or long working hours. Further, the analyses of joint effects between musculoskeletal pain and physical work demands showed no

interaction. However, it should be noted that chronic pain increased the risk of insomnia within all strata of physical work demands.

Strengths of the current study include the large population, the prospective design, and the available information on several potential confounders. Importantly, we excluded workers at baseline with insomnia symptoms and persons who used sedative and/or sleep medication. The insomnia questions in HUNT3 have been found to have acceptable reliability with kappa-values between 0.35-0.44.[29] The questionnaire on chronic musculoskeletal pain in HUNT2 was adopted from the Standardized Nordic Questionnaire, which has been shown to have acceptable reliability and validity.[30-32]

Some limitations should be considered when interpreting the results. First, the classification of insomnia in HUNT2 was less specific than in HUNT3 in terms of approximating the DSM-V criteria. Second, the question on work-related fatigue has not been validated, and we cannot exclude the possibility that the reporting of fatigue is influenced by psychosocial work stressors. Further, the classification scheme of physical work demands have shown to perform well,[33] but subjective interpretations of the exposure categories could have influenced the results. It should be noted that few women in our study reported heavy physical work demands, and we do not know whether our classification of physical work demands includes the same type of activity or occupation in women and men. In view of the long follow-up period (10-11 years) and the prerequisite that the workers who were included in the analysis should have participated at both HUNT2 and HUNT3, we cannot exclude the possibility that these findings are influenced by selection into the workforce, resulting in the healthiest workers accruing the most exposure over their lifetime. Unfortunately, we could not address short-term effects of the exposures nor if workers with high physical work exposures are more prone to change job. Thus, we do not have

data on continuity of work, changes in employment status, exposure variation or the progression of insomnia during the follow-up period. Finally, it should be noted that there were only minor differences between workers included in the current study compared to those with missing information on central variables.

In conclusion, work-related physical fatigue is associated with increased risk of insomnia in vocationally active women and men, especially among workers who also reported chronic musculoskeletal pain. Physical work demands were not associated with risk of insomnia symptoms in women, but men with heavy physical work had a lower risk of insomnia. These findings suggest that there is an interplay between work-related physical fatigue and musculoskeletal pain that should receive particular attention in the prevention of insomnia in working populations.

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TABLES

Table 1. Baseline characteristics of the study population stratified by sex and physical work demands.

	Women				Men			
	Mostly sedentary	Much walking	Much walking or lifting	Heavy physical work	Mostly sedentary	Much walking	Much walking or lifting	Heavy physical work
No. of persons	2,384	3,166	2,772	241	2,443	1,847	1,577	1,731
Age, mean (SD)	42.2 (8.9)	42.4 (9.7)	41.2 (9.4)	43.9 (9.4)	44.7 (8.5)	44.4 (9.1)	41.4 (9.9)	42.7 (10.1)
Body mass index, mean (SD)	25.2 (3.8)	25.3 (4.0)	25.6 (4.1)	26.4 (4.5)	26.5 (3.1)	26.2 (3.2)	26.3 (3.3)	26.4 (3.2)
Obese, % (no.)	10.9 (259)	11.7 (369)	13.0 (362)	18.7 (45)	12.3 (300)	11.0 (203)	12.1 (192)	13.1 (226)
Physically inactive, % (no.)	2.4 (56)	2.8 (87)	3.6 (101)	7.9 (19)	3.6 (89)	3.8 (71)	6.0 (95)	9.5 (164)
Current smokers, % (no.)	15.3 (365)	15.8 (500)	17.9 (495)	16.2 (39)	12.7 (311)	13.1 (241)	15.4 (243)	14.7 (254)
Not satisfied with work, % (no.)	102 (4.3)	80 (2.5)	93 (3.4)	16 (6.6)	118 (4.8)	101 (5.5)	78 (4.9)	83 (4.8)
Higher education, % (no.)[a]	32.2 (768)	34.6 (1,096)	24.6 (683)	9.1 (22)	49.9 (1,220)	31.6 (583)	7.4 (116)	6.3 (109)
Any chronic pain, % (no.)	41.7 (993)	40.6 (1,286)	45.9 (1,273)	55.2 (133)	35.0 (854)	39.3 (726)	41.4 (653)	46.5 (805)
Shift work, % (no.)	7.3 (175)	16.2 (513)	52.0 (1,441)	11.6 (28)	16.0 (390)	24.5 (453)	22.8 (359)	7.3 (113)
Working hours, mean (SD)	32.3 (8.7)	28.9 (10.4)	28.6 (9.9)	30.3 (16.9)	39.0 (7.1)	38.1 (7.7)	38.7 (9.0)	38.7 (16.1)
Physical fatigue, % (no.)								
Never/seldom	89.4 (2,037)	63.3 (1,919)	32.1 (864)	17.2 (41)	89.8 (2,115)	74.6 (1,325)	37.6 (572)	18.5 (307)
Often	9.7 (221)	31.8 (962)	54.5 (1,467)	61.8 (147)	9.2 (217)	23.2 (412)	54.1 (822)	63.7 (1,056)
Always	1.0 (22)	4.9 (148)	13.4 (360)	21.0 (50)	1.0 (24)	2.2 (39)	8.3 (126)	17.8 (296)

Abbreviations: SD, standard deviation

[a] College or higher

Table 2. Risk of insomnia at 11-year follow-up associated with physical work demands and work-related physical fatigue.

	Women				Men			
Physical work exposure	No. of persons	No. of cases	Age-adjusted, RR[a]	Multi-adjusted, RR (95% CI)[b]	No. of persons	No. of cases	Age-adjusted, RR[a]	Multi-adjusted, RR (95% CI)[b]
Physical work demands								
Mostly sedentary	2,384	129	1.00	1.00 (reference)	2,443	95	1.00	1.00 (reference)
Much walking	3,166	162	0.95	0.96 (0.76-1.20)	1,847	71	1.00	0.98 (0.73-1.33)
Much walking or lifting	2,772	169	1.12	1.10 (0.88-1.38)	1,577	73	1.16	1.12 (0.81-1.54)
Heavy physical work	241	15	1.17	1.20 (0.71-2.03)	1,731	47	0.70	0.67 (0.47-0.97)
Work-related fatigue								
Never/seldom fatigued	4,867	233	1.00	1.00 (reference)	4,315	154	1.00	1.00 (reference)
Often fatigued	2,794	165	1.27	1.33 (1.07-1.67)	2,506	89	0.98	1.19 (0.87-1.62)
Always fatigued	579	58	2.21	2.34 (1.72-3.18)	485	32	1.82	2.47 (1.59-3.83)

Abbreviations: CI, confidence interval; RR, risk ratio

[a]Adjusted for age (20-29 years, 30-39 years, 40-49 years, 50-59 years).

[b]Adjusted for age (20-29 years, 30-39 years, 40-49 years, 50-59 years) and education (primary school, high school, college ≤4 years, college >4 years, unknown). The analysis of work-related fatigue was additionally adjusted for physical work demands (mostly sedentary, much walking, much walking or lifting, heavy physical work).

Table 3. The joint effect of physical work demands and chronic musculoskeletal pain on risk of insomnia.

	No pain			Any pain		
Physical work demands	No. of persons	No. of cases	Multi-adjusted, RR[a] (95% CI)	No. of persons	No. of cases	Multi-adjusted, RR[a] (95% CI)
Women						
Mostly sedentary	1,391	48	1.00 (reference)	993	81	2.57 (1.82-3.64)
Much walking	1,880	66	1.01 (0.70-1.46)	1,286	96	2.38 (1.70-3.34)
Much walking or lifting	1,499	62	1.12 (0.78-1.63)	1,273	107	2.49 (1.78-3.48)
Heavy physical work	108	3	0.82 (0.26-2.61)	133	12	2.77 (1.48-5.20)
Men						
Mostly sedentary	1,589	45	1.00 (reference)	854	50	2.10 (1.41-3.13)
Much walking	1,121	33	1.06 (0.68-1.67)	726	38	1.91 (1.24-2.93)
Much walking or lifting	924	34	1.23 (0.76-1.97)	653	39	2.06 (1.32-3.22)
Heavy physical work	926	19	0.71 (0.41-1.23)	805	28	1.28 (0.79-2.09)

Abbreviations: CI, confidence interval; RR, risk ratio

[a] Adjusted for age (20-29 years, 30-39 years, 40-49 years, 50-59 years), education (primary school, high school, college ≤4 years, college >4 years, unknown), body mass index (18.5-24.9 kg/m^2, 25.0-29.9 kg/m^2, ≥30 kg/m^2, unknown), smoking (no, yes, unknown), and leisure time physical activity (high activity, moderate activity, low activity, inactive, unknown).

Table 4. The joint effect of work-related physical fatigue and chronic musculoskeletal pain on risk of insomnia.

	No pain			Any pain		
Work-related physical fatigue	No. of persons	No. of cases	Multi-adjusted, RR[a] (95% CI)	No. of persons	No. of cases	Multi-adjusted, RR[a] (95% CI)
Women						
Never/seldom fatigued	3,077	103	1.00 (reference)	1,790	130	2.37 (1.84-3.05)
Often fatigued	1,409	55	1.23 (0.88-1.73)	1,385	110	2.71 (2.04-3.60)
Always fatigued	192	10	1.67 (0.87-3.18)	387	48	4.20 (2.95-5.98)
Men						
Never/seldom fatigued	2,848	84	1.00 (reference)	1,467	70	1.65 (1.20-2.27)
Often fatigued	1,337	33	0.97 (0.63-1.51)	1,169	56	1.99 (1.35-2.94)
Always fatigued	200	10	2.13 (1.07-4.25)	285	22	3.55 (2.11-5.98)

Abbreviations: CI, confidence interval; RR, risk ratio

[a] Adjusted for age (20-29 years, 30-39 years, 40-49 years, 50-59 years), education (primary school, high school, college ≤4 years, college >4 years, unknown), physical work demands (mostly sedentary, much walking, much walking or lifting, heavy physical work), body mass index (18.5-24.9 kg/m^2, 25.0-29.9 kg/m^2, ≥30 kg/m^2, unknown), smoking (no, yes, unknown), and leisure time physical activity (high activity, moderate activity, low activity, inactive, unknown).