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Physical workload and increased frequency of musculoskeletal pain: a cohort study of employed men and women with baseline occasional pain

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ABSTRACT

Objectives Musculoskeletal pain (MSP) is prevalent among the workforce. This study investigates the long-term association between physical workload (PWL) and increased frequency of MSP among male and female employees with pre-existing occasional MSP.

Methods This study uses the Stockholm Public Health cohort survey data from the baseline 2006. The sample includes 5715 employees with baseline occasional MSP (no more than a few days per month). Eight PWL exposures and overall PWL were estimated using a job-exposure matrix (JEM). The JEM was assigned to occupational titles from a national register in 2006. Follow-up survey data on frequent MSP (a few or more times a week) were collected from 2010. Logistic regressions produced sex-specific ORs with 95% CIs and were adjusted for education, health conditions, psychological distress, smoking, BMI, leisure-time physical activity and decision authority.

Results Associations were observed between several aspects of heavy PWL and frequent MSP for men (eg, OR 1.57, 95% CI 1.13 to 2.20, among those in the highest exposure quartile compared with those in the lowest quartile for heavy lifting) and women (eg, OR 1.76, 95% CI 1.35 to 2.29, among those in the highest exposure quartile compared with those in the the lowest quartile for physically strenuous work). Small changes were observed in the OR after adjustment, but most of the ORs for PWL exposures among the men were no longer statistically significantly increased.

Conclusion A high level of exposure to heavy PWL was associated with increased frequency of MSP 4 years later for men and women with baseline occasional pain.

Key messages

What is already known about this subject?

- Heavy physical workload (PWL) is a well-recognised risk factor for the occurrence of musculoskeletal pain (MSP) and has been linked to sick leave and labour market exit.
- MSP is prevalent among the workforce; whether exposure to a heavy PWL is a risk factor for worsening MSP for workers with pre-existing pain remains undetermined.

What are the new findings?

- Many specific PWL exposures and overall heavy PWL were associated with increased frequency of MSP for male and female workers in the highest exposure quartile in comparison to those in the lowest exposure quartile.
- After full adjustment, many ORs for the male workers lost significance; conversely, many of the associations for female workers remained statistically significant.

How might this impact on policy or clinical practice in the foreseeable future?

- Reducing exposure to heavy PWL among workers with milder MSP may help prevent a transition to more severe MSP; however, evidence for the effectiveness of workplace interventions for the management of less severe MSP is scarce, and most occupational guidelines focus on the prevention of MSP or the reduction of chronic pain; more studies are needed to corroborate our findings and to explore whether changes in exposure could have protective effects.

INTRODUCTION

Musculoskeletal pain (MSP) is a condition that is prevalent among the workforce.[1 2] Many workers with MSP will recover without too much disruption in daily life, but some will experience continuous or reoccurring pain,[3 4] reduced work ability[5 6] or work absence.[5 7–9] Most existing studies have explored risk factors associated with MSP incidence, but factors associated with worsening MSP among workers with pre-existing MSP are scarce.

Heavy physical workload (PWL) is a well-recognised risk factor for the occurrence of MSP[10 11] and has been linked to sick leave[12 13] and premature exit from working life.[14 15] However, whether a heavy PWL is a risk factor for worsening MSP among workers with established MSP remains undetermined.

Only a few studies exploring the relationship between PWL and worsening MSP among workers with pre-existing pain have been found. A cohort study from New Zealand explored the association between self-reported PWL and the transition from acute to chronic back pain.[16] It used a sample of 840 workers with first-time compensation claims due to work-related back injury. The results suggested that exposure to frequent heavy lifting was associated with increased odds of continuing to receive compensation 3 months later. A Danish cohort study[17] explored

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exposure to PWL and increased number of pain sites. Exposure to PWL was measured in two ways: self-reported data and a job-exposure matrix (JEM), and for both measures, an overall index score was constructed. Separate analyses were conducted for men and women. The results suggested an association between exposure to heavy PWL and an increase in the number of pain sites for both sexes. Another two studies found no association between heavy PWL and worsening pain. A UK-based study[18] explored 786 subjects in the general population with neck pain. The study found no association between self-reported exposure to heavy lifting at work and persistent neck pain 1 year later. Also, a Swedish cohort study that explored 6820 workers with occasional baseline neck pain found no association between perceived overall heavy PWL and long-duration troublesome neck pain 5 years later.[19]

A few shortcomings in the aforementioned studies should be noted. First, the studies use self-reported data to estimate PWL,[16 18 19] which potentially results in differential misclassification.[20] Second, they explore either an aggregate measure of PWL[17 19] or only one exposure. PWL encompasses several exposures; therefore, the studies might have overlooked associations between specific risk factors and MSP. Finally, the effects from exposure to PWL on the musculoskeletal system may vary between sexes,[21 22] yet only two studies conducted sex-specific analysis.[17 19]

This study investigates the long-term association between heavy PWL and increased frequency of MSP in a sample of male and female workers with pre-existing occasional pain. It explores several PWL exposures that are objectively measured using a sex-specific JEM with separate analyses conducted for men and women.

METHODS

Participants and study design

This study uses data from the Stockholm Public Health Cohort (SPHC). The SPHC is a randomly selected sample of residents in Stockholm County who responded to repeated questionnaires. The sampling methods, cohort demographics, attrition and ethics have been previously described in detail.[23] This study uses a sample of workers that responded to the baseline 2006 and follow-up 2010 questionnaires. Of the 56 634 net sample, 34 707 participants completed the baseline questionnaire (response rate 61%) and 25 167 responded to the follow-up (response rate 77%).

The selected workers include those who had not reached statutory retirement age by 2010 (≤59 year old at baseline) and were employed or self-employed (question from the SPHC) at the baseline (figure 1). To investigate an increase in pain, the sample included only people with baseline occasional MSP. Occasional MSP was determined based on participants' responses to two questions in the baseline questionnaire: 'Have you had any pain in the neck, arms or shoulder in the past 6 months?' and 'Have you had any pain in the lower back in the past 6 months?' with five response options: 'no', 'yes, a few times in the past 6 months', 'yes, a few times in the past month', 'yes, a few times in the past week' and 'yes, every day'. Workers with pain no less than a few times in the past 6 months and no more than a few times per month for at least one of the locations were eligible for the study (figure 1). Of the 6100 eligible participants, 5715 (2573 men and 3142 women) had no missing values for all included variables.

Exposure: PWL

Exposure to heavy PWL was estimated using a recently developed Swedish JEM for PWL. The JEM is constructed from a sample of responders to eight questions from the repeated Swedish Work Environment Surveys (SWES) conducted between 1997 and 2013 (n=90 062). The eight questions (online supplemental appendix 1) cover occupationally related activities that yield increased physical load on the musculoskeletal system and include heavy lifting (≥15 kg), physically strenuous work, fast breathing due to PWL, forward bent position, twisted position, working with hands above shoulder level, repetitive work and frequent bending and twisting. Each response option was assigned a score from 1 (lowest) to 5 or 6 (highest), depending on the response categories (online supplemental appendix 1). Subsequently, gender-specific arithmetic mean values for each of the eight exposures were calculated for 355 different occupations coded with the Swedish Standard Classification of Occupation (SSYK) 96 coding system—the higher the mean value, the higher the exposure. An index score (overall PWL) was created by summing the scores and calculating a mean value. The SSYK 96 codes were obtained from the Longitudinal Integration Database for Health Insurance and Labour Market Studies (LISA) for the 2006 baseline. Most participants (81%) had an SSYK at a four-digit level; when missing, a three-digit code was used.

The mean JEM values for all JEM exposures were assigned to the SSYK codes of all participants with an SSYK code, 18–64 years old and employed/self-employed at the baseline, before the exclusion of workers older than 59 years, non-responders to the follow-up questionnaire, and those with no or frequent pain (n=17 234) (figure 1). This sample was deemed the best representation of the Swedish workforce. Subsequently, the mean JEM values for each sex were separately grouped into quartiles, based on the sample of n=17 234 workers, thus creating four sex-specific exposure groups: *low (reference group)*, *medium–low*, *medium–high and high* level of PWL. A selective dropout of subjects in the higher exposed categories was observed when selecting our final sample (n=5715). The largest dropouts occurred with the exclusion of non-responders to the follow-up questionnaire or workers with frequent MSP. The loss was more obvious among women.

Outcome: frequent MSP

Two questions in the 2010 SPHC questionnaire determined frequent MSP: 'Have you had pain in the past 6 months in the shoulder or arms?' and 'Have you had pain in the past 6 months in the lower back?' with the response options: 'no', 'yes, a few times a month or more' or 'yes, a few times a week or more'. An incident case was identified via the response 'yes, a few times a week or more' for one or both questions.

Covariates

Potential confounders were identified from the literature. Data on completed level of education were obtained from the LISA database and transformed into three groups: (1) primary school (1–9 years), (2) secondary school (10–12 years) and (3) tertiary education (12+ years). The following variables were obtained from the baseline SPHC questionnaire. Long-term health condition was measured by a yes or no response option for the question: 'Do you suffer from a long-term illness, health problems following an accident, disability or other persistent health problems?' Psychological distress was estimated by using the 12-Item General Health Questionnaire (GHQ12). The scores for the GHQ12 range from 0 to 12. A binary variable was created using a score of 3 or more to indicate psychological distress.[24] The GHQ12 has been shown to be a reliable and valid single scale scoring measure for common mental illnesses in epidemiological

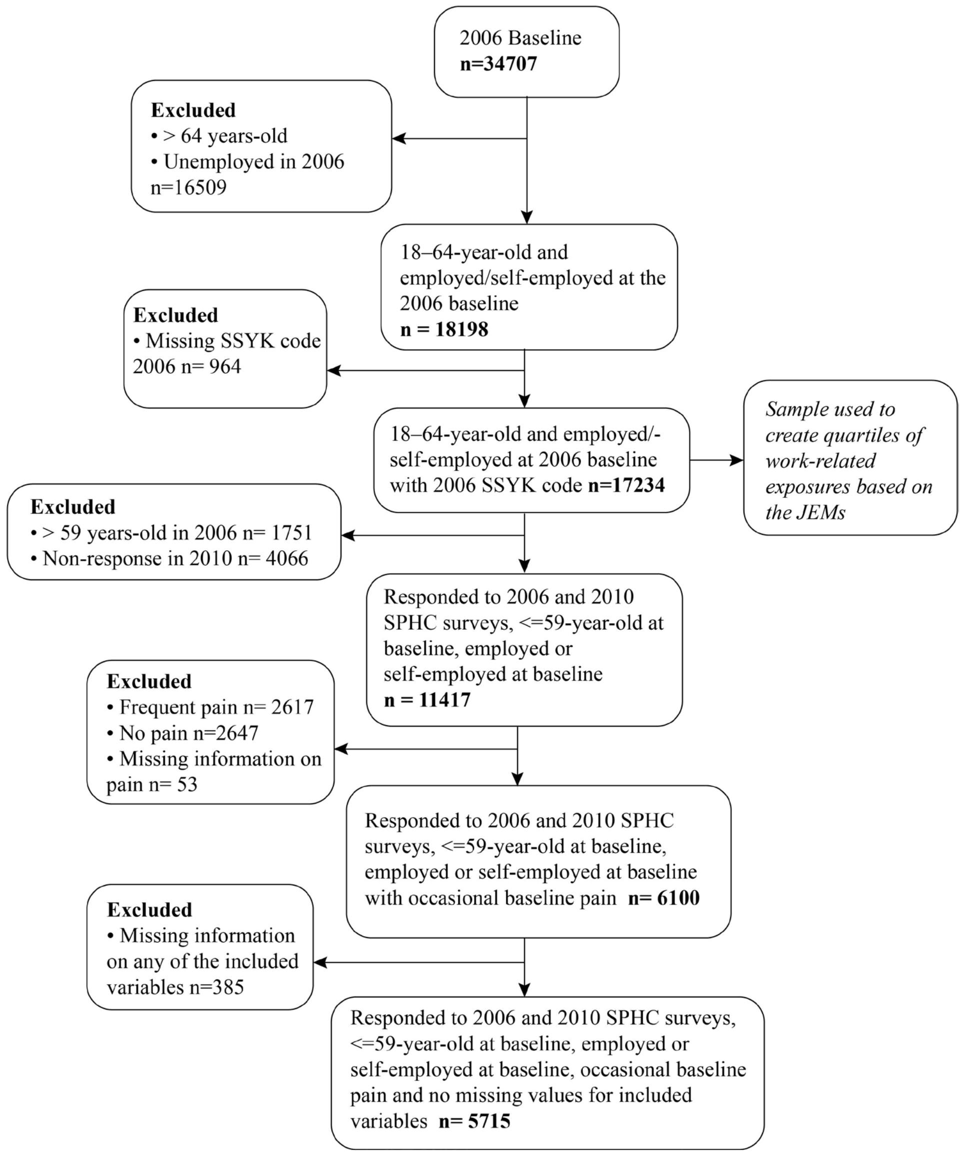

Figure 1 Sample selection. JEM, job-exposure matrix; SPHC, Stockholm Public Health Cohort; SSYK, Swedish Standard Classification of Occupation.

studies.[24 25] Body mass index (BMI) (weight (kg)/(height×height) (m^2)) was calculated using self-reported data and classified: underweight (BMI≤18) or normal (BMI>18 and ≤24), overweight (BMI>24 and ≤30) and obese (BMI>30). Leisure-time physical activity was determined via the question, 'How much have you exercised and exerted yourself physically in the past 12 months?' The response options included 'sedentary leisure time', 'moderate leisure-time exercise', 'moderate regular leisure-time exercise' and 'regular leisure-time exercise and training' and used as a categorical variable. Finally, being a smoker was determined by a response of 'yes' to the question 'Do you smoke daily?'.

Data on decision authority at work were obtained from a recently developed Swedish JEM for psychosocial workload. The psychosocial JEM was constructed using the same procedure used for the physical JEM as noted previously. Responses to four questions from the SWES 1989–2013 were combined to create an index score for decision authority. The questions cover workers' level of autonomy concerning when tasks are conducted, work pace, work breaks and work structure (online supplemental appendix 1). The response scale was recoded into a scale of 0–10, and a gender-specific mean index score was fixed to each SSYK code. Every participant was assigned a mean value using their SSYK code (LISA database). A binary variable (high/low decision authority) was created using the median cut-off based on the same sample of 17 234 workers used for the PWL exposure. All confounders were tested for multicollinearity and all VIF values were between 1 and 2.4, thus indicating no concern[26] and were entered into the final analysis.

Statistical analysis

Statistical analysis was conducted using SPSS V.25.0. The distribution of the covariates across the quartiles of PWL was calculated separately for men and women. Separate logistic regression analyses were conducted for all potential covariates to test for a statistically significant association with frequent MSP (95% CI). We explored the association between heavy PWL and risk of frequent MSP with the addition of the confounding variables.

The final model included confounders based on their theoretical and clinically meaningful associations with PWL and MSP. Logistic-regression models were used to explore the association between level of heavy PWL and frequent MSP 4 years later.

Table 1 Prevalence of covariates in different levels of PWL measured by the JEM index score

	Male workers with occasional MSP										Female workers with occasional MSP									
	Low n=661		Medium–low n=671		Medium–high n=634		High n=607		Total n=2573		Low n=930		Medium–low n=780		Medium–high n=749		High n=683		Total n=3142	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Age (years)																				
18–29	35	5.3	60	8.9	86	13.6	95	15.7	276	10.7	66	7.1	86	11.0	138	18.4	157	23.0	447	14.2
30–39	227	34.3	214	31.9	158	24.9	161	26.5	760	29.5	287	30.9	236	30.3	202	27.0	179	26.2	904	28.8
40–49	213	32.2	208	31.0	200	31.5	184	30.3	805	31.3	352	37.8	223	28.6	205	27.4	172	25.2	952	30.3
50–59	186	28.1	189	28.2	190	30.0	167	27.5	732	28.4	225	24.2	235	30.1	204	27.2	175	25.6	839	26.7
Completed education																				
Primary (1–9 years)	12	1.8	36	5.4	83	13.1	133	21.9	264	10.3	18	1.9	52	6.7	48	6.4	117	17.1	235	7.5
Secondary (12 years)	136	20.6	272	40.5	327	51.6	390	64.3	1125	43.7	218	23.4	332	42.6	278	37.1	438	64.1	1266	40.3
Tertiary (12+ years)	513	77.6	363	54.1	224	35.3	84	13.8	1184	46.0	694	74.6	396	50.8	423	56.5	128	18.7	1641	52.2
Long-term health condition																				
No	559	84.6	541	80.6	504	79.5	487	80.2	2091	81.3	759	81.6	650	83.3	605	80.8	565	82.7	2579	82.1
Yes	102	15.4	130	19.4	130	20.5	120	19.8	482	18.7	171	18.4	130	16.7	144	19.2	118	17.3	563	17.9
Psychological distress (GHQ12 score>3)																				
No	564	85.3	579	86.3	534	84.2	544	89.6	2221	86.3	736	79.1	635	81.4	601	80.2	548	80.2	2520	80.2
Yes	97	14.7	92	13.7	100	15.8	63	10.4	352	13.7	194	20.9	145	18.6	148	19.8	135	19.8	622	19.8
Smoking																				
No	633	95.8	625	93.1	559	88.2	516	85.0	2333	90.7	848	91.2	695	89.1	644	86.0	538	78.8	2725	86.7
Yes	28	4.2	46	6.9	75	11.8	91	15.0	240	9.3	82	8.8	85	10.9	105	14.0	145	21.2	417	13.3
Leisure-time physical activity																				
Sedentary	46	7.0	59	8.8	73	11.5	92	15.2	270	10.5	68	7.3	63	8.1	50	6.7	81	11.9	262	8.3
Moderate	468	70.8	477	71.1	420	66.2	413	68.0	1778	69.1	692	74.4	561	71.9	563	75.2	499	73.1	2315	73.7
Regular	147	22.2	135	20.1	141	22.2	102	16.8	525	20.4	170	18.3	156	20.0	136	18.2	103	15.1	565	18.0
BMI																				
Underweight/ normal	236	35.7	237	35.3	208	32.8	186	30.6	867	33.7	605	65.1	473	60.6	429	57.3	374	54.8	1881	59.9
Overweight	372	56.3	372	55.4	359	56.6	346	57.0	1449	56.3	263	28.3	243	31.2	260	34.7	241	35.3	1007	32.0
Obese	53	8.0	62	9.2	67	10.6	75	12.4	257	10.0	62	6.7	64	8.2	60	8.0	68	10.0	254	8.1
Decision authority																				
High	635	96.1	526	78.4	154	24.3	47	7.7	1362	52.9	894	96.1	506	64.9	163	21.8	87	12.7	1650	52.5
Low	26	3.9	145	21.6	480	75.7	560	92.3	1211	47.1	36	3.9	274	35.1	586	78.2	596	87.3	1492	47.5

BMI, body mass index; GHQ-12, 12-Item General Health Questionnaire.JEM, job-exposure matrix; MSP, musculoskeletal pain; PWL, physical workload.

Crude (OR) and adjusted ORs were computed for both sexes, with associated 95% CIs. All regressions were adjusted for age.

Two sensitivity analyses replicated the the final step of analysis previously mentioned using (1) workers without baseline MSP (n=2510) and (2) workers that maintained exposure throughout the follow-up (n=4356).

RESULTS

Distribution of covariates in levels of heavy PWL

After the 4-year follow-up, 356 cases of frequent MSP were found for men and 545 for women. Table 1 displays the prevalence of the covariates across the levels of heavy PWL, measured by the JEM index. Between both sexes with the highest level of PWL, the proportions of younger workers and workers with only primary education were larger than among those with lower levels of workload. Smoking and low decision authority were more prevalent in higher levels of PWL for both sexes. We observed a similar distribution of the risk factors across the levels of PWL among the larger sample of workers used to create the JEM exposures (online supplemental appendix 2).

Associations between each covariate and frequent MSP

In the univariate analyses to assess for potential confounders (table 2), educational attainment at a secondary school level was weakly associated with frequent MSP, but a primary school level was not. Having a long-term health condition, psychological distress (GHQ12) or being a smoker were associated with increased pain. Low decision authority was associated with the outcome for women only. BMI and leisure-time physical activity were not associated with frequent MSP for either sex.

Associations between aspects of heavy PWL and frequent MSP

Table 3 displays the deviations from the crude estimate when adjusting for the included confounders. In this table, only information concerning the index variable is shown. Slight deviations for PWL when controlling for the confounding of health and lifestyle factors were observed. Adjusting for education or decision authority had the largest effect on the crude estimate for PWL for men, but only small variations in the estimates were observed for women.

Statistically significant associations were observed between several aspects of heavy PWL (heavy lifting, physically strenuous work, work tasks causing fast breathing, forward bent position, twisted position, repetitive work, frequent bending or twisting or overall PWL (JEM index)) and frequent MSP for male workers in the highest exposure quartile in comparison to those in the lowest exposure quartile (table 4). Associations were also observed between several PWL exposures and frequent MSP for male workers in the medium–high exposure quartile compared with the lowest exposure quartile. After adjusting for completed level of education, long-term health conditions, psychological distress, smoking, BMI, leisure-time physical activity and decision authority, statistically significant increased ORs only

Table 2 Univariate association between confounding variables and risk of frequent MSP among workers with baseline occasional MSP (crude ORs with 95% CIs)

	Men n=2573	Women n=3142
	OR (95% CI)	OR (95% CI)
Completed education		
Primary (1–9 years)	1.36 (0.93 to 1.98)	1.01 (0.69 to 1.46)
Secondary (12 years)	1.26 (0.99 to 1.61)	1.23 (1.02 to 1.49)
Tertiary (12+ years)	1	1
Long-term health condition		
No	1	1
Yes	1.37 (1.05 to 1.79)	1.50 (1.20 to 1.87)
Psychological distress (GHQ)		
No	1	1
Yes	1.42 (1.05 to 1.93)	1.40 (1.12 to 1.74)
Do you smoke?		
No	1	1
Yes	1.46 (1.04 to 2.05)	1.33 (1.03 to 1.71)
Leisure-time physical activity		
Sedentary	1	1
Moderate	0.89 (0.62 to 1.28)	0.86 (0.63 to 1.19)
Regular	0.91 (0.60 to 1.38)	0.90 (0.62 to 1.31)
BMI		
Underweight/normal	1	1
Overweight	1.22 (0.95 to 1.57)	1.13 (0.93 to 1.39)
Obese	1.0 (0.74 to 1.69)	1.10 (0.78 to 1.55)
Decision authority		
High	1	1
Low	1.12 (0.89 to 1.40)	1.29 (1.07 to 1.25)

All analyses are adjusted for age.
BMI, body mass index; GHQ, General Health Questionnaire.MSP, musculoskeletal pain.

remained for a medium–high and a high level of heavy lifting and medium–high exposure to physically strenuous work. The results of an additional analysis when excluding education as a confounder showed higher-risk estimates than the fully adjusted model among men (table 4, model indicated by *).

Among women, associations were observed between all the PWL exposures, except repetitive work, and more frequent MSP for women in the highest exposure quartile compared with those in the lowest exposure quartile (table 4). Associations were also observed between several PWL exposures and frequent MSP for female workers in the medium–high exposure quartile compared with the lowest exposure quartile. Most statistically significant increased relative risks remained after adjusting for the aforementioned confounders.

Two sensitivity analyses were conducted. The first showed that heavy PWL was not associated with an increased risk of frequent MSP among a sample of pain-free workers (online supplemental appendix 3). The second showed statistically significant associations between a high level of overall PWL and frequent MSP among workers who maintained the same exposure throughout the follow-up (online supplemental appendix 4). After full adjustment, the results were attenuated for both sexes and became non statistically significant for the men.

DISCUSSION

Summary of the findings

This is one of the first prospective studies to investigate the association between a range of PWL exposures, measured using a JEM, and increased frequency of MSP separately for male and female workers with pre-existing baseline occasional pain.

Associations were observed between a higher, compared with a lower, level of exposure to overall PWL and frequent MSP among workers with occasional MSP. In addition, most of the specific PWL exposures were associated with frequent MSP. After full adjustment, statistically significant relative risks remained for exposure to medium–high or high level of heavy lifting and a medium–high level of physically strenuous work among the men. Conversely, many of the associations for female workers remained statistically significant after adjustment.

Table 3 Association between heavy PWL and risk of frequent MSP with the addition of the chosen confounding variables among workers with baseline occasional MSP (crude ORs and AORs with 95% CIs)

	Men n=2573				Women n=3142			
	PWL index				PWL index			
	Low	Medium–low	Medium–high	High	Low	Medium–low	Medium–high	High
Model 1								
OR (95% CI)	1	1.08 (0.78 to 1.50)	1.38 (1.00 to 1.89)	1.40 (1.02 to 1.93)	1	1.24 (0.95 to 1.61)	1.45 (1.11 to 1.88)	1.74 (1.34 to 2.27)
Model 2								
AOR (95% CI)	1	1.06 (0.76 to 1.48)	1.30 (0.94 to 1.80)	1.34 (0.96 to 1.86)	1	1.25 (0.96 to 1.63)	1.43 (1.10 to 1.87)	1.71 (1.31 to 2.25)
Model 3								
AOR (95% CI)	1	1.04 (0.75 to 1.45)	1.29 (0.92 to 1.80)	1.26 (0.88 to 1.82)	1	1.22 (0.93 to 1.60)	1.41 (1.10 to 1.86)	1.71 (1.29 to 2.28)
Model 4								
AOR (95% CI)	1	1.12 (0.80 to 1.56)	1.59 (1.08 to 2.34)	1.66 (1.09 to 2.56)	1	1.24 (0.94 to 1.63)	1.46 (1.06 to 2.01)	1.76 (1.26 to 2.46)
Model 5								
AOR (95% CI)	1	1.10 (0.78 to 1.53)	1.50 (1.01 to 2.22)	1.59 (1.03 to 2.46)	1	1.26 (0.95 to 1.66)	1.45 (1.04 to 2.01)	1.74 (1.24 to 2.45)
Model 6								
AOR (95% CI)	1	1.05 (0.75 to 1.48)	1.39 (0.92 to 2.10)	1.42 (0.89 to 2.28)	1	1.25 (0.94 to 1.66)	1.45 (1.04 to 2.02)	1.74 (1.20 to 2.50)

Model 1—adjusted for age.
Model 2—model 1+health and lifestyle factors (smoking, long-term illness, psychological distress, BMI and leisure-time physical activity).
Model 3—model 1+education.
Model 4—model 1+decision authority.
Model 5—model 2+decision authority.
Model 6—model 2+education and decision authority.
AOR, adjusted OR; BMI, body mass index; MSP, musculoskeletal pain; PWL, physical workload.

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Table 4 Association between heavy PWL and risk of frequent MSP among workers with baseline occasional MSP (crude ORs and AORs with 95% CIs)

	Male workers with occasional pain n=2573				Female workers with occasional pain n=3142			
	Low	**Medium–low**	**Medium–high**	**High**	**Low**	**Medium–low**	**Medium–high**	**High**
Physical Load Index								
Cases with frequent pain/n	79/661	85/671	98/634	94/607	129/930	129/780	140/749	147/683
OR (95% CI)	1	1.08 (0.78 to 1.50)	1.38 (1.00 to 1.89)	1.40 (1.02 to 1.93)	1	1.24 (0.95 to 1.61)	1.45 (1.11 to 1.88)	1.74 (1.34 to 2.27)
AOR* (95% CI)	1	1.10 (0.78 to 1.53)	1.50 (1.01 to 2.22)	1.59 (1.03 to 2.46)	1	1.26 (0.95 to 1.66)	1.45 (1.04 to 2.01)	1.74 (1.24 to 2.45)
AOR† (95% CI)	1	1.05 (0.75 to 1.48)	1.39 (0.92 to 2.10)	1.42 (0.89 to 2.28)	1	1.25 (0.94 to 1.66)	1.45 (1.04 to 2.02)	1.74 (1.20 to 2.50)
Heavy lifting (at least 15 kg)								
Cases with frequent pain/n	72/653	86/645	104/682	94/593	123/816	115/811	145/751	162/764
OR (95% CI)	1	1.25 (0.89 to 1.75)	1.49 (1.08 to 2.05)	1.57 (1.13 to 2.20)	1	0.93 (0.71 to 1.23)	1.38 (1.05 to 1.80)	1.53 (1.18 to 1.98)
AOR* (95% CI)	1	1.29 (0.92 to 1.82)	1.54 (1.08 to 2.20)	1.73 (1.15 to 2.61)	1	0.93 (0.70 to 1.22)	1.33 (1.01 to 1.77)	1.46 (1.05 to 2.02)
AOR† (95% CI)	1	1.26 (0.89 to 1.77)	1.46 (1.02 to 2.11)	1.59 (1.02 to 2.47)	1	0.92 (0.70 to 1.22)	1.33 (1.00 to 1.77)	1.43 (1.02 to 2.00)
Physically strenuous work								
Cases with frequent pain/n	75/673	93/677	98/636	90/587	127/894	125/814	143/757	150/677
OR (95% CI)	1	1.27 (0.92 to 1.76)	1.48 (1.07 to 2.05)	1.49 (1.07 to 2.07)	1	1.09 (0.84 to 1.43)	1.42 (1.09 to 1.84)	1.76 (1.35 to 2.29)
AOR* (95% CI)	1	1.29 (0.92 to 1.82)	1.54 (1.08 to 2.20)	1.73 (1.15 to 2.61)	1	1.09 (0.82 to 1.43)	1.40 (1.03 to 1.91)	1.70 (1.23 to 2.35)
AOR† (95% CI)	1	1.23 (0.88 to 1.71)	1.52 (1.00 to 2.32)	1.47 (0.93 to 2.30)	1	1.08 (0.82 to 1.43)	1.40 (1.03 to 1.91)	1.68 (1.21 to 2.34)
Fast breathing								
Cases with frequent pain/n	*74*/661	*94*/678	*100*/639	*88*/595	*124*/853	*119*/843	*147*/738	*155*/708
OR (95% CI)	1	1.29 (0.93 to 1.79)	1.51 (1.09 to 2.09)	1.41 (1.01 to 1.97)	1	0.97 (0.74 to 1.28)	1.48 (1.13 to 1.92)	1.69 (1.30 to 2.20)
AOR* (95% CI)	1	1.28 (0.92 to 1.77)	1.63 (1.08 to 2.45)	1.63 (1.07 to 2.47)	1	0.96 (0.73 to 1.27)	1.45 (1.08 to 1.95)	1.64 (1.21 to 2.22)
AOR† (95% CI)	1	1.25 (0.89 to 1.75)	1.47 (0.98 to 2.21)	1.30 (0.84 to 2.03)	1	0.96 (0.73 to 1.27)	1.46 (1.09 to 1.97)	1.62 (1.19 to 2.21)
Forward bent position								
Cases with frequent pain/n	77/676	102/727	89/590	88/580	124/856	128/828	144/760	149/698
OR (95% CI)	1	1.29 (0.94 to 1.77)	1.41 (1.01 to 1.95)	1.45 (1.04 to 2.01)	1	1.08 (0.83 to 1.41)	1.40 (1.07 to 1.82)	1.61 (1.23 to 2.10)
AOR* (95% CI)	1	1.30 (0.93 to 1.81)	1.58 (1.07 to 2.34)	1.47 (0.97 to 2.22)	1	1.08 (0.82 to 1.42)	1.40 (1.01 to 1.96)	1.61 (1.14 to 2.29)
AOR† (95% CI)	1	1.23 (0.89 to 1.72)	1.39 (0.90 to 2.14)	1.41 (0.88 to 2.24)	1	1.07 (0.81 to 1.40)	1.41 (1.01 to 1.97)	1.56 (1.09 to 2.24)
Twisted position								
Cases with frequent pain/n	72/651	99/688	89/621	96/613	129/896	127/786	138/769	151/691
OR (95% CI)	1	1.37 (0.99 to 1.89)	1.38 (0.99 to 1.93)	1.53 (1.10 to 2.13)	1	1.14 (0.87 to 1.49)	1.32 (1.01 to 1.72)	1.68 (1.29 to 2.19)
AOR* (95% CI)	1	1.29 (0.94 to 1.79)	1.50 (0.99 to 2.28)	1.56 (1.01 to 2.43)	1	1.16 (0.88 to 1.53)	1.32 (0.93 to 1.86)	1.66 (1.16 to 2.37)
AOR† (95% CI)	1	1.33 (0.95 to 1.87)	1.37 (0.87 to 2.11)	1.45 (0.92 to 2.28)	1	1.15 (0.87 to 1.51)	1.30 (0.91 to 1.85)	1.63 (1.13 to 2.36)
Hands above shoulder level								
Cases with requent pain/n	77/648	85/672	105/655	89/598	124/882	137/789	129/754	155/717
OR (95% CI)	1	1.09 (0.78 to 1.51)	1.46 (1.06 to 2.00)	1.33 (0.96 to 1.85)	1	1.30 (1.00 to 1.69)	1.27 (0.97 to 1.67)	1.73 (1.32 to 2.25)
AOR*	1	1.09 (0.78 to 1.52)	1.56 (1.06 to 2.16)	1.43 (0.94 to 2.16)	1	1.27 (0.96 to 1.67)	1.17 (0.82 to 1.67)	1.57 (1.11 to 2.23)
AOR† (95% CI)	1	1.04 (0.74 to 1.47)	1.46 (0.98 to 2.18)	1.27 (0.81 to 1.97)	1	1.26 (0.95 to 1.66)	1.17 (0.82 to 1.68)	1.56 (1.09 to 2.23)
Repetitive work								
Cases with frequent pain/n	78/647	103/687	82/654	93/585	131/769	147/789	129/832	138/752
OR (95% CI)	1	1.30 (0.95 to 1.79)	1.07 (0.76 to 1.49)	1.43 (1.03 to 1.98)	1	1.12 (0.87.1.46)	0.92 (0.71 to 1.20)	1.12 (0.86 to 1.46)
AOR* (95% CI)	1	1.09 (0.78 to 1.52)	1.56 (1.06 to 2.31)	1.43 (0.94 to 1.16)	1	1.12 (0.86 to 1.46)	1.05 (0.79 to 1.41)	1.08 (0.83 to 1.42)
AOR† (95% CI)	1	1.22 (0.88 to 1.68)	0.96 (0.68 to 1.36)	1.21 (0.83 to 1.76)	1	1.07 (0.81 to 1.41)	1.00 (0.73 to 1.35)	1.02 (0.76 to 1.37)
Frequent bending or twisting								
Cases with frequent pain/n	*81*/692	*82*/633	*104*/673	*89*/575	*141*/875	*130*/803	*123*/765	*151*/699
OR (95% CI)	1	1.12 (0.80 to 1.56)	1.41 (1.03 to 1.93)	1.43 (1.03 to 1.98)	1	1.01 (0.78 to 1.31)	1.01 (0.79 to 1.31)	1.46 (1.13 to 1.89)
AOR* (95% CI)	1	1.26 (0.92 to 1.73)	1.02 (0.73 to 1.42)	1.33 (0.93 to 1.90)	1	0.95 (0.71 to 1.26)	0.94 (0.71 to 1.26)	1.26 (0.91 to 1.73)
AOR† (95% CI)	1	1.08 (0.77 to 1.51)	1.31 (0.92 to 1.85)	1.33 (0.88 to 2.02)	1	0.94 (0.71 to 1.25)	0.90 (0.66 to 1.23)	1.19 (0.84 to 1.70)

Crude analysis adjusted for age.
*AOR adjusted for age, long-term health condition, psychological distress, smoking, BMI, leisure-time physical activity and decision authority.
†AOR adjusted for age, completed education, long-term health condition, psychological distress, smoking, BMI, leisure-time physical activity and decision authority.
AOR, adjusted OR; BMI, body mass index; MSP, musculoskeletal pain; PWL, physical workload.

Comparison with previous studies

Only a few studies have explored the association between heavy PWL and the progression of MSP. Two cohort studies have associated heavy lifting[16] or overall heavy PWL[17] with worsening MSP, which is consistent with the results of this study. In contrast, two longitudinal studies did not identify lifting[18] or overall heavy PWL[19] as a risk factor for persistent pain.

The studies' varied methodological approaches might stand behind their heterogenous conclusions. First, the studies define specific PWL exposures differently. For example, two studies explore heavy lifting, yet one estimates frequency[16] and one lifts greater than or equal to 11 kg.[18] Moreover, the use of non-uniform definitions of PWL hinders the ability to compare the results of this study with previous studies. A second difference is how the studies have measured exposure to PWL. Unlike this study, the majority of the above studies use a self-reported exposure measure.[16 18 19] To our knowledge, only one other study has used a JEM to estimate the effect of PWL on worsening pain.[17] Madsen *et al* concluded that overall heavy PWL (a JEM index score) was associated with an increased risk of worsening pain for both sexes. As their final model only adjusted for baseline MSP, age and education, they stressed that their results should be interpreted as minimally adjusted. However, in our study, adjusting for several confounders did not notably lower the risk estimates.

A final methodological difference in the aforementioned studies is the operationalisation of MSP at the baseline and outcome. Fransen *et al*[16] explored workers with acute baseline MSP and concluded that exposure to a high level of heavy lifting was associated with a transition from acute to chronic back pain. Our results support their conclusion. Fransen *et al* reported a higher risk estimate than we observed. The risks from heavy PWL may vary depending on the severity of baseline MSP as workers with lower levels of pain may be able to cope better with the strain imposed on the musculoskeletal system. However, we cannot confirm that our sample had a lower severity of baseline pain than the sample of Fransen *et al*.

Additionally, risk factors for MSP may differ, depending on the pain site explored.[10] This could partially explain why studies exploring neck pain[18 19] did not find associations between lifting or overall PWL and worsening pain, whereas studies investigating low back pain[16] or different MSP sites such as this study and Madsen *et al*'s study[17] did.

Strengths and limitations

One strength of this study is its access to a breadth of self-reported and register-based data that allowed for the adjustment of a range of potential confounding variables. Nonetheless, as exposure to PWL is complex and extends beyond the work environment (eg, housework and childcare), the effect of residual confounding on the results must be considered.

Another strength is the use of a JEM. JEMs have been shown to be valid and reliable methods for estimating exposure to physical and psychosocial workplace factors.[17 27–30] The application of JEMs reduces the likelihood of reverse causality as the self-reported data used to construct the JEMs is taken from different samples other than the one under investigation. It should be stressed that observational and direct methods of measuring PWL are typically classed as more reliable and valid than self-reported methods.[31] Nevertheless, objective methods can be impractical to carry out on a large scale.[10 32] Furthermore, as JEMs aggregate exposure data at a group, the variation of PWL within occupations is lost. This might cause exposure misclassification. Therefore, due to non-differential error, the risks presented in this study may be an underestimation of the true risk.[30] It is worthwhile noting that Madsen *et al*[17] found similar associations between PWL and MSP using aggregate and individual measurements.

The JEM allowed for the exploration of multiple PWL exposures. However, many of the eight exposures explored in this study were highly correlated (data not shown) due to the interdependence of physical movements. We cannot therefore completely distinguish between the effects of the different PWL exposures. This limitation restricts the ability to draw any causal relationship between the separate exposures and increased frequency of MSP.

Another limitation of this study is the grouping of workers with different MSP sites into one sample. Risk factors for MSP may vary based on pain site.[10] Considering this, we may have observed stronger associations between specific exposures if separate MSP sites (eg, repetitive work with shoulder/arm pain) were explored. We combined the sample to create enough power to conduct sex-stratified analysis. Furthermore, the ability to explore independent MSP sites was restricted because the SPHC's question on upper limb MSP amalgamated neck, arm and shoulder pain.

The largest dropouts in our sample occurred with the exclusion of non-responders to the follow-up questionnaire. Only around 50% of the eligible responders to the 2006 survey completed the 2010 follow-up survey. Responses to large-scale surveys are generally lower in subgroups with greater social disadvantage and poorer health, which somewhat limits the generalisability of our findings and might have resulted in conservative estimates.[33]

Our exposure measures were collected from 1 year, therefore, did not cover the long-term effects of PWL. A sensitivity analysis explored a sample of workers that maintained the same exposure throughout the follow-up period. The unadjusted estimates were similar to our final results, but we observed more conservative adjusted estimates.

Interpretation of the results

This study suggests that a high level of heavy PWL is associated with an increased risk of worsening MSP, even though many associations among the men lost significance after confounder adjustments. Among the men, the inclusion of education as a confounder resulted in the largest attenuation of the estimates. Education is a key factor influencing the selection into occupations, and the subsequent level of exposure to workplace risk factors, thus, can be highly correlated with PWL.[34] In our sample, educational attainment was more correlated with PWL for men than women (data not shown). Therefore, the lack of significant adjusted results among the men may have been partly due to some 'overadjustment'. On the other hand, inclusion of the education variable could act as a proxy for socioeconomic factors, for example, lifestyle factors,[34] which may have had a greater effect on the estimates among men than women. Additionally, as we observed a higher prevalence of baseline MSP and frequent MSP among women, which is consistent with previous studies,[35 36] the findings for men were potentially influenced by low statistical power.

It is worth noting that anthropometric and physiological differences between men and women, such as height and muscle mass, might cause variation in the risk from heavy PWL.[21 22] Our observations can be compared with previous studies that have observed sex-based disparities for PWL risk factors for the incidence of musculoskeletal complaints. A systematic review exploring gender differences in relation to PWL and musculoskeletal complaints reported strong evidence to suggest that men have a higher risk of low back complaints from lifting and women have a higher risk of neck–shoulder complaints from awkward arm postures.[37] It is reasonable to suggest that the risk of increased MSP, when exposed to heavy PWL, manifests differently for men and women.

A sensitivity analysis showed that heavy PWL was not associated with an increased risk of frequent MSP among a sample of pain-free workers. By definition, this sample consists of healthier workers that could exhibit higher endurance capacities to manage exposure to heavy PWL. Nevertheless, associations between PWL and MSP might have been observed if the outcome had been defined differently, for example, any severity of MSP.

The aim of this study was to explore the effect of PWL on the transition to frequent MSP. Our findings suggest that workers with occasional MSP have an increased risk of experiencing more severe MSP when exposed to heavy PWL. Reducing exposure to heavy PWL among workers with milder MSP could help prevent the transition to severe MSP and promote labour market participation. However, evidence for the effectiveness of workplace interventions for the management of less severe MSP is scarce as the majority of occupational guidelines focus on the prevention of MSP or the reduction of severe pain.[38–40] More studies are needed to corroborate our findings and to explore whether changes in exposure could have protective effects.

CONCLUSION

A high level of exposure to most aspects of PWL explored in this study was associated with frequent MSP over time for men and women with baseline occasional pain. However, after adjusting for confounders, many results for the male workers lost significance.

Correction notice This article has been corrected since it was published Online First. Stockholm County Council has been amended to Region Stockholm in affiliation 3.

Contributors All authors conceived the study, designed the analyses, contributed to the interpretations of the results, and reviewed and edited the final manuscript. KB analysed the data and wrote the paper. KK is listed as guarantor of this study.

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