International Journal of Occupational Safety and Ergonomics

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tose20

Associations between observed time sitting at work and musculoskeletal symptoms: a repeated-measures study of manufacturing workers

Jennifer L. Garza, J. M. Cavallari & M. G. Cherniack

To cite this article: Jennifer L. Garza, J. M. Cavallari & M. G. Cherniack (2023) Associations between observed time sitting at work and musculoskeletal symptoms: a repeated-measures study of manufacturing workers, International Journal of Occupational Safety and Ergonomics, 29:1, 329-334, DOI: 10.1080/10803548.2022.2043638

To link to this article: https://doi.org/10.1080/10803548.2022.2043638

Published online: 17 Mar 2022.

Submit your article to this journal

Article views: 112

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=tose20

INTERNATIONAL JOURNAL OF OCCUPATIONAL SAFETY AND ERGONOMICS (JOSE)
2023, VOL. 29, NO. 1, 329–334
https://doi.org/10.1080/10803548.2022.2043638

Taylor & Francis
Taylor & Francis Group

Check for updates

Associations between observed time sitting at work and musculoskeletal symptoms: a repeated-measures study of manufacturing workers

Jennifer L. Garza[a], J. M. Cavallari[a,b] and M. G. Cherniack[a]

[a]Department of Medicine, University of Connecticut School of Medicine, USA; [b]Department of Public Health Sciences, University of Connecticut School of Medicine, USA

ABSTRACT
Time sitting at work is known to affect health overall, but its specific effects on musculoskeletal symptoms are unclear. We evaluated the relationship between observed time sitting at work and self-reported musculoskeletal symptoms among 195 manufacturing workers. Longer time sitting at work was significantly associated with lower prevalence of neck/shoulder (prevalence ratio [PR] = 0.70, 95% confidence interval [CI] [0.68, 0.72]; $p < 0.001$) and arm/wrist/hand (PR = 0.46, 95% CI [0.31, 0.69]; $p < 0.001$) musculoskeletal symptoms. Associations remained largely unchanged after adjusting for job type or occupational postures and load. Time sitting at work was associated with musculoskeletal symptoms, and should be taken into consideration as part of interventions to prevent musculoskeletal disorders (MSDs) and promote health of manufacturing workers.

KEYWORDS
musculoskeletal symptoms; time sitting; occupational health

1. Introduction

Although the health benefits of leisure-time physical activity are clear, the effects of occupational activity on health are less certain [1]. For example, there is currently a debate over the effects of sitting at work, with some studies promoting reductions in prolonged occupational sedentary time (e.g., Plotnikoff and Karunamuni [2]) and others arguing the potential benefits of sitting in some populations (e.g., Messing et al. [3]).

Musculoskeletal symptoms represent one type of health outcome that may be affected by time sitting at work. Sitting has been proposed to affect the musculoskeletal system via a variety of physiological mechanisms such as sustained muscle activity [4–6] or reduced muscle strength [7]. However, previous studies on this topic have reported contradictory findings. Laboratory studies have reported associations between prolonged periods of sitting and musculoskeletal discomfort [8,9]. Several observational occupational studies have also reported similar findings [10,11]. However, other studies have observed inverse associations between time sitting at work and musculoskeletal symptoms, indicating a protective effect [12–15].

Even if time sitting at work is associated with musculoskeletal symptoms, it is still not clear whether this association is consistent across different job types. For instance, Messing et al. [3] point out that results obtained by studying office workers might not be the same as results for those in the manufacturing or service sectors. One explanation may be that workers with different job types may be differentially exposed to other physical job exposures such as postures or loads, which are known to affect musculoskeletal symptoms [16]. If jobs requiring prolonged time sitting also have a different pattern of associated physical job exposures, the associations reported between time sitting and musculoskeletal symptoms might really reflect the effects of these other exposures. This mechanism has also been proposed in previous studies [12,13,15].

In the current study, we investigated the relationship between observed time sitting at work and musculoskeletal symptoms among workers in manufacturing companies. The workers recruited include representatives across a variety of job types including administrative and production workers. As demonstrated in previous studies, prolonged time sitting at work occurs in blue-collar occupations including manufacturing [10]. We hypothesized that time sitting at work would be associated with neck/shoulder, arm/wrist/hand, lower back and leg/foot musculoskeletal symptoms. We also explored whether other observed job exposures including head, trunk and hand grip postures and handling loads may be associated with musculoskeletal symptoms directly, and whether adjusting for these postures or loads might change the association between time sitting at work and musculoskeletal symptoms.

2. Materials and methods

2.1. Study design and participants

This study is part of a large longitudinal cohort study of six medium-sized manufacturing companies in Connecticut, USA [17]. The full study protocol was approved by University of Connecticut Health Center's Institutional Review Board Ethics Committee (IRB Number: 18-072S-2). Eligibility criteria for study sites were: medium company size; broad age distribution centered on late fifth and sixth decades; and a workforce engaged in skilled light-manufacturing with high degrees of repetition.

The current study used data on job exposures collected from observational analysis and information on musculoskeletal symptoms and participant demographics collected from paper-and-pencil surveys. Data collections were performed at two time points, time 1 and time 2, approximately 18

CONTACT Jennifer L. Garza garza@uchc.edu

© 2022 Central Institute for Labour Protection – National Research Institute (CIOP-PIB)

months apart. During the workday, following informed consent, surveys were distributed and collected by members of the research team. Participants were given a small financial incentive for completing the survey or observations. All employees at selected sites were considered eligible and invited to participate in the study; no exclusion criteria were specified. Employees of all job classifications participated (e.g., production, sales, administrative, managerial staff).

2.2. Musculoskeletal symptoms

Musculoskeletal symptoms were assessed with the survey question 'During the past 3 months, how much symptoms, aching or stiffness/limited motion have you had in the areas shown on the diagram below?'. The measure listed seven body regions including the neck, shoulder, wrist or forearm, hands, lower back, knee and foot, and asked respondents to rate how severely each area was affected on a 5-point rating scale from 0 = *mild* to 4 = *extreme*. This question has been used previously in research in other populations of North American workers [18,19]. We combined body parts into four categories: neck/shoulder, wrist/forearm/hands, lower back and knee/foot, as commonly reported in the literature [20]. Participants were considered to have musculoskeletal symptoms if they indicated a score of two (moderate) or more in any of the areas in the body region.

2.3. Job exposures

Posture, activity, tools and handling (PATH) observational analysis was used to characterize occupational job exposures including time sitting at work, head posture, trunk posture, hand grip and load. PATH is a work sampling-based approach that was developed to characterize the ergonomic hazards of non-repetitive work. The posture codes in the PATH method are based on the Ovako work posture analysing system (OWAS), with other codes included for describing worker activity, tool use, loads handled and grasp type. PATH has been used previously in research among other working populations in North America [21]. A researcher observed each participant at 10 time points each on 1–2 days and noted when participants were sitting, had neutral head, trunk and hand grip postures or handled loads. We calculated the percent time in each job exposure across the 10 observation points.

2.4. Job type

Each participant was classified as having an administrative or production job type based on interviews with company representatives.

2.5. Covariates

We obtained information on participants' age (continuous) and gender (male = reference) from responses to the survey.

2.6. Statistical analysis

Summary statistics including means, standard deviations and percentages were calculated to describe participant and worksite demographics, musculoskeletal symptoms and observed job exposures. Correlation analysis was used to obtain Pearson correlation coefficients for the relationship between percent time sitting and percent time in other job exposures. To test the hypothesis that percent time sitting at work was associated with musculoskeletal symptoms, we used generalized linear models with time as a repeated measure to calculate β coefficients and standard errors for each outcome separately adjusted for age and gender (model 1). The 'estimate' statement was used to estimate the prevalence ratios (PRs) and 95% confidence intervals (CIs) using the delta method and to obtain the p value from a Wald χ^2 test. We next used the same generalized linear models with time as a repeated measure and including percent time sitting at work, all covariates and job type (model 2). Finally, we used the generalized linear models with time as a repeated measure and including percent time sitting at work, all covariates, job type and percent time neutral head, trunk and hand grip postures, and not handling loads (model 3). All data analyses were performed in SAS version 9.4.

Table 1. Participant demographics.

Characteristic		Time 1 (N = 195) *n*	Time 1 %	Time 2 (N = 95) *n*	Time 2 %
Neck/shoulder pain		50	31	13	15
Arm/wrist/hand pain		24	15	12	14
Lower back pain		37	23	20	23
Leg/foot pain		36	23	20	23
Gender	Male	129	66	65	68
Job type	Production	128	67	64	68
		M	*SD*	*M*	*SD*
Age (years)		51	10	53	9
Percent time sitting		0.36	0.37	0.30	0.35
Percent neutral head		0.75	0.18	0.71	0.29
Percent neutral trunk		0.87	0.13	0.81	0.16
Percent neutral hand grip		0.39	0.19	0.33	0.18
Percent no load		0.32	0.23	0.67	0.21

3. Results

Our final population consisted of a convenience sample of 195 manufacturing workers measured at time 1, with 95 workers also having repeated measures at time 2. Our study participants were primarily male and had production jobs. Table 1 presents the distribution of musculoskeletal symptoms and job exposures at time 1 and time 2. Time sitting at work was weakly and positively correlated with percent neutral head posture (r = 0.11) and percent neutral hand grip (r = 0.22), and weakly and negatively correlated with percent neutral trunk posture (r = −0.16) and percent time not handling loads (r = −0.07).

After adjusting for covariates (Table 2, model 1), we observed a significant association between time sitting at work and neck/shoulder musculoskeletal symptoms. Higher percent time sitting at work was significantly ($p < 0.001$) associated with lower prevalence of neck/shoulder musculoskeletal symptoms (PR = 0.75, 95% CI [0.73, 0.78]). After including job type, time sitting at work remained significantly ($p < 0.001$) associated with lower prevalence of neck/shoulder musculoskeletal symptoms with a similar effect estimate (PR = 0.73, 95% CI [0.70, 0.76]) (model 2). Time sitting at work also remained significantly ($p < 0.001$) associated with lower prevalence of neck/shoulder musculoskeletal symptoms with a similar effect estimate (PR = 0.70, 95% CI [0.68, 0.72])

Table 2. Associations between observed occupational time sitting, postures, loads and neck/shoulder musculoskeletal symptoms.

		Model 1			Model 2			Model 3		
Characteristic		PR	95% CI	p	PR	95% CI	p	PR	95% CI	p
Percent time sitting		**0.75**	**[0.73, 0.78]**	**< 0.001**	**0.73**	**[0.70, 0.76]**	**< 0.001**	**0.70**	**[0.68, 0.72]**	**< 0.001**
Age		**0.99**	**[0.98, 1.00]**	**0.007**	**0.99**	**[0.98, 1.00]**	**0.015**	**0.99**	**[0.98, 1.00]**	**0.008**
Gender	Male	Ref.			Ref.			Ref.		
	Female	**1.45**	**[1.10, 0.91]**	**0.009**	**1.33**	**[1.09, 1.63]**	**0.006**	**1.39**	**[1.08, 1.78]**	**0.010**
Job type	Production				Ref.			Ref.		
	Administrative				**1.26**	**[1.02, 1.56]**	**0.036**	**1.24**	**[1.04, 1.50]**	**0.018**
Posture	Percent time neutral head posture							0.69	[0.34, 1.40]	0.298
	Percent time neutral trunk posture							2.40	[0.85, 6.74]	0.097
	Percent time neutral hand grip							**3.69**	**[2.80, 4.88]**	**< 0.001**
Percent time not handling loads								**0.48**	**[0.31, 0.73]**	**0.007**

Note: Bold data indicate significant values ($p < 0.050$). CI = confidence interval; PR = prevalence ratio.

Table 3. Associations between observed occupational time sitting, postures, loads and arm/wrist/hand musculoskeletal symptoms.

		Model 1			Model 2			Model 3		
Characteristic		PR	95% CI	p	PR	95% CI	p	PR	95% CI	p
Percent time sitting		**0.61**	**[0.39, 0.99]**	**0**.045	**0.61**	**[0.39, 0.97]**	**0.037**	**0.46**	**[0.31, 0.69]**	**< 0.001**
Age		**1.02**	**[1.02, 1.03]**	**< 0.001**	**1.02**	**[1.02, 1.03]**	**< 0.001**	**1.02**	**[1.02, 1.02]**	**< 0.001**
Gender	Male	Ref.			Ref.			Ref.		
	Female	**2.98**	**[2.35, 3.77]**	**< 0.001**	**2.84**	**[2.38, 3.37]**	**< 0.001**	**2.86**	**[2.63, 3.11]**	**< 0.001**
Job type	Production				Ref.			Ref.		
	Administrative				1.09	[0.92, 1.30]	0.310	**1.23**	**[1.09, 1.39]**	**< 0.001**
Posture	Percent time neutral head posture							**0.41**	**[0.20, 0.82]**	**0.012**
	Percent time neutral trunk posture							**16.76**	**[5.98, 46.97]**	**< 0.001**
	Percent time neutral hand grip							0.31	[0.06, 1.65]	0.168
Percent time not handling loads								**1.69**	**[1.30, 2.20]**	**< 0.001**

Note: Bold data indicate significant values ($p < 0.050$). CI = confidence interval; PR = prevalence ratio.

after including postures and loads (model 3). Age was significantly ($p = 0.008$) associated with lower prevalence of neck/shoulder musculoskeletal symptoms (PR = 0.99, 95% CI [0.98, 1.00]), and female gender (PR = 1.39, 95% CI [1.08, 1.78]; $p = 0.010$) and administrative job type (PR = 1.24, 95% CI [1.04, 1.50]; $p = 0.018$) were each significantly associated with higher prevalence of neck/shoulder musculoskeletal symptoms (model 3). Percent time in neutral hand grip posture (PR = 3.69, 95% CI [2.80, 4.88]) was significantly ($p < 0.001$) associated with higher prevalence of neck/shoulder musculoskeletal symptoms. Percent time not handling loads (PR = 0.48, 95% CI [0.31, 0.73]) was significantly ($p = 0.007$) associated with lower prevalence of neck/shoulder musculoskeletal symptoms (model 3). No significant association were observed for percent time in neutral head or trunk postures.

After adjusting for covariates (Table 3, model 1), we observed a significant association between time sitting at work and arm/wrist/hand musculoskeletal symptoms. Higher percent time sitting at work was significantly ($p = 0.045$) associated with lower prevalence of arm/wrist/hand musculoskeletal symptoms (PR = 0.61, 95% CI [0.39, 0.97]). After including job type, time sitting at work remained significantly ($p = 0.037$) associated with lower prevalence of arm/wrist/hand musculoskeletal symptoms with a similar effect estimate (PR = 0.61, 95% CI [0.39, 0.97]) (model 2). Time sitting at work also remained significantly ($p < 0.001$) associated with lower prevalence of arm/wrist/hand musculoskeletal symptoms, with a lower effect estimate (PR = 0.46, 95% CI [0.31, 0.69]) after including postures and loads (model 3). Age (PR = 1.02, 95% CI [1.02, 1.02]; $p < 0.001$), female gender (PR = 2.86, 95% CI [2.63, 3.11]; $p < 0.001$) and administrative job type (PR = 1.23, 95% CI [1.09, 1.39]; $p < 0.001$) were each significantly associated with higher prevalence of arm/wrist/hand musculoskeletal symptoms (model 3). Percent time in neutral head posture was significantly ($p = 0.012$) associated with a lower prevalence of arm/wrist/hand musculoskeletal symptoms (PR = 0.41, 95% CI [0.20, 0.82]). Percent time in neutral trunk posture (PR = 16.76, 95% CI [5.98, 46.97]; $p < 0.001$) and percent time not handling loads (PR = 1.69, 95% CI [1.30, 2.20]; $p < 0.001$) were significantly associated with a higher prevalence of arm/wrist/hand musculoskeletal symptoms. No significant association was observed for percent time in neutral hand grip posture (model 3).

We observed no significant associations between time sitting at work and lower back musculoskeletal symptoms (Table 4, models 1–3). Age was significantly ($p < 0.001$) associated with lower prevalence of lower back musculoskeletal symptoms (PR = 0.99, 95% CI [0.98, 1.00]), and female gender (PR = 1.53, 95% CI [1.21, 1.93]; $p = 0.005$) and administrative job type (PR = 1.35, 95% CI [1.26, 1.44]; $p < 0.001$) were significantly associated with higher prevalence of lower back musculoskeletal symptoms (model 3). Percent time in neutral head posture (PR = 0.24, 95% CI [0.18, 0.33]) was significantly ($p < 0.001$) associated with a lower prevalence of lower back musculoskeletal symptoms (model 3). Percent time in neutral trunk posture (PR = 4.66, 95% CI [3.70, 5.86]) and percent time not handling loads (PR = 1.97, 95% CI [1.39, 2.80]) were significantly ($p < 0.001$) associated with a higher prevalence of

Table 4. Associations between observed occupational time sitting, postures, loads and lower back musculoskeletal symptoms.

Characteristic		Model 1			Model 2			Model 3		
Characteristic		PR	95% CI	p	PR	95% CI	p	PR	95% CI	p
Percent time sitting		1.06	[0.57, 1.97]	0.848	1.03	[0.56, 1.89]	0.915	1.04	[0.51, 2.14]	0.915
Age		**0.99**	**[0.99, 1.00]**	**< 0.001**	**0.99**	**[0.99, 1.00]**	**< 0.001**	**0.99**	**[0.98, 1.00]**	**< 0.001**
Gender	Male	Ref.			Ref.			Ref.		
	Female	**1.58**	**[1.30, 1.93]**	**< 0.001**	**1.47**	**[1.25, 1.73]**	**< 0.001**	**1.53**	**[1.21, 1.93]**	**0.005**
Job type	Production				Ref.			Ref.		
	Administrative				**1.28**	**[1.13, 1.46]**	**< 0.001**	**1.35**	**[1.26, 1.44]**	**< 0.001**
Posture	Percent time neutral head posture							**0.24**	**[0.18, 0.33]**	**< 0.001**
	Percent time neutral trunk posture							**4.66**	**[3.70, 5.86]**	**< 0.001**
	Percent time neutral hand grip							0.83	[0.61, 1.13]	0.229
Percent time not handling loads								**1.97**	**[1.39, 2.80]**	**< 0.001**

Note: Bold data indicate significant values ($p < 0.050$). CI = confidence interval; PR = prevalence ratio.

Table 5. Associations between observed occupational time sitting, postures, loads and leg/foot musculoskeletal symptoms.

		Model 1			Model 2			Model 3		
Characteristic		PR	95% CI	p	PR	95% CI	p	PR	95% CI	p
Percent time sitting		0.92	[0.70, 1.22]	0.577	0.91	[0.69, 1.21]	0.531	0.86	[0.57, 1.31]	0.493
Age		1.01	[1.00, 1.03]	0.127	1.02	[0.99, 1.04]	0.158	1.02	[1.00, 1.04]	0.116
Gender	Male	Ref.			Ref.			Ref.		
	Female	**2.20**	**[1.91, 2.53]**	**< 0.001**	**2.13**	**[2.00, 2.27]**	**< 0.001**	**2.24**	**[2.16, 2.33]**	**< 0.001**
Job type	Production				Ref.			Ref.		
	Administrative				1.04	[0.78, 1.39]	0.791	1.01	[0.80, 1.27]	0.943
Posture	Percent time neutral head posture							1.80	[0.84, 3.85]	0.130
	Percent time neutral trunk posture							0.98	[0.13, 7.30]	0.988
	Percent time neutral hand grip							1.15	[0.97, 1.35]	0.106
Percent time not handling loads								**0.89**	**[0.83, 0.95]**	**< 0.001**

Note: Bold data indicate significant values ($p < 0.050$). CI = confidence interval; PR = prevalence ratio.

lower back musculoskeletal symptoms. No significant association was observed for percent time in neutral hand grip posture.

We observed no significant associations between percent time sitting and leg/foot musculoskeletal symptoms (Table 5). Administrative job type (PR = 2.24, 95% CI [2.16, 2.33]) was significantly ($p < 0.001$) associated with higher leg/foot musculoskeletal symptoms (model 3). No significant association was observed for age or gender. Percent time not handing loads (PR = 0.89, 95% CI [0.83, 0.95]) was significantly ($p < 0.001$) associated with a lower prevalence of leg/foot musculoskeletal symptoms. No significant association was observed for percent time in neutral head posture, trunk posture or hand grip.

4. Discussion

In the current study, we investigated the relationship between time sitting at work and musculoskeletal symptoms in a cohort of manufacturing workers. We observed significant associations between time sitting at work and neck/shoulder and arm/wrist/hand symptoms, with higher time sitting associated with lower prevalence of symptoms. We also explored whether job type or other job exposures including head, trunk and hand grip postures and handling loads may be associated with musculoskeletal symptoms directly, and whether adjusting for these postures or loads might reduce the association between time sitting and musculoskeletal symptoms. Head, trunk and hand grip postures were all associated with musculoskeletal symptoms. We observed little change in the association between time sitting at work and musculoskeletal symptoms after adjusting for job type or postures or loads.

Our findings of a lower prevalence of musculoskeletal symptoms among workers with higher time sitting was in line with reports from several previous studies. Lunde et al. [13] observed that long duration of sitting at work was associated with lower levels of lower back pain (LBP) intensity among healthcare workers. Korshøj et al. [14] reported that longer duration of total and temporal sitting periods at work was significantly associated with a favorable time course of LBP. Also, in one 15-year longitudinal study, Picavet et al. [15] observed a lower risk of chronic upper extremity pain among those who were sedentary at work. However, our findings oppose the results of several other studies on this topic. Gupta et al. [10] observed a positive association between sitting and LBP. Similarly, in a 2015 study, Hallman et al. [11] reported an association between time sitting at work and greater intensity of neck/shoulder pain.

In this study we observed no association between time sitting and LBP among manufacturing workers. This finding aligns with the results of a previous systematic review. Roffey et al. [22] reported that, among 24 studies meeting their inclusion criteria, 'strong, consistent evidence was found for no association between occupational sitting and lower back pain' (page 252). However, one more recent study did report an association between objectively measured time sitting and LBP among healthcare workers (although they also observed no association for construction workers) [13]. Also, in contrast to Lunde et al.'s results, Gupta et al. [10] observed a positive association between sitting and LBP.

We hypothesized that associations between time sitting at work and musculoskeletal symptoms could potentially be attributed to differences in the workers' job types or associated physical job exposures. The manufacturing workers included in this study performed a variety of different job tasks that we grouped into 'administrative' and 'production' categories, which we then included as covariates in our analyses (Tables 2–5, models 2 and 3). After adjusting for job type, the associations that we observed between time sitting at work and musculoskeletal symptoms remained similar – neck/shoulder and arm/wrist/hand musculoskeletal symptoms remained significantly associated with time sitting at work, with similar PRs, and lower back and leg/foot musculoskeletal symptoms were still not associated with time sitting at work. Similarly, after adjusting for job exposures including head posture, trunk posture, hand grip and load, we still observed significant associations between time sitting and lower prevalence of neck/shoulder and arm/wrist/hand, with similar effect estimates (Tables 2–5, model 3). Taken together, these findings support the notion that there may be effects of occupational time sitting on occupational health independent of job types or physical job exposures. Our findings are consistent with those reported by Hallman et al. [12], who also observed associations between more time sitting at work and a favorable development of pain intensity over time even after adjusting for self-reported occurrence of lifting/carrying, and objectively measured physical activity and upper arm elevation. However, Lunde et al. [13] did report attenuated associations between sitting and LBP after adjusting for lifting and forward bending in their analyses. In our study, time sitting was only weakly correlated with the other observed occupational postures or loads.

Along with the associations reported between time sitting and musculoskeletal symptoms, we also observed significant associations between observed postures and musculoskeletal symptoms (Tables 2–5). Non-neutral postures have long been associated with musculoskeletal symptoms [16]. In the current study, we observed a significantly lower prevalence of some symptoms, including LBP, associated with time in neutral head posture (Table 4). However, we also observed a significantly higher prevalence of neck/shoulder pain, arm/wrist/hand pain and LBP among participants with higher observed percent time in neutral trunk posture and neutral hand grip (Tables 2–5), which contradicts previous literature [16].

Our study adds to the debate over the effects of occupational sitting on health. In the past decade, there has been substantial recognition of sitting at work as an occupational health hazard [23]. In consequence, some recent publications have encouraged workers to reduce occupational time sitting (e.g., Plotnikoff and Karunamuni [2]). Yet, as others have pointed out (e.g., Messing et al. [3]) and our results support, there may be some advantages associated with seated work, including advantages to the musculoskeletal system. More research is needed to fully elucidate the appropriate amount of sitting recommended at work, which will also likely vary by industry and job type.

This study has several strengths as well as limitations that should be considered. Strengths include the repeated measures of job exposures and musculoskeletal symptoms that were obtained for nearly half of our participants. Further, measurements of job exposures were observational, which can be less biased than self-reports [24]. Also, as previously mentioned, observational studies that extend over several hours and include adequate numbers of workers are rare [3]. Limitations include the smaller sample size as well as limited generalizability of these results to other populations.

5. Conclusions

Higher observed time sitting at work was associated with lower prevalence or neck/shoulder and arm/wrist/hand musculoskeletal symptoms in the current study, and this association remained significant after adjusting for other observed postures and loads. Time sitting at work should be taken into consideration as part of interventions to prevent musculoskeletal disorders (MSDs) and promote health of workers.

Acknowledgements

The authors would like to acknowledge the UConn-SAM research team for their contributions to this project. The authors would also like to thank the study participants.

Data availability statement

The data underlying this article will be shared on reasonable request to the corresponding author.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by National Institute of Occupational Safety and Health [2R01OH008929-06A1].

References

[1] Holtermann A, Krause N, van der Beek AJ, et al. The physical activity paradox: six reasons why occupational physical activity (OPA) does not confer the cardiovascular health benefits that leisure time physical activity does. Br J Sports Med. 2018 Feb;52(3):149–150. doi:10.1136/bjsports-2017-097965

[2] Plotnikoff R, Karunamuni N. Reducing sitting time: the new workplace health priority. Arch Environ Occup Health. 2012;67(3):125–127. doi:10.1080/19338244.2012.697407

[3] Messing K, Stock S, Tissot F. The importance of not standing too long. Arch Environ Occup Health. 2013;68(2):128–129. doi:10.1080/19338244.2013.764714

[4] Henson J, Yates T, Edwardson CL, et al. Sedentary time and markers of chronic low-grade inflammation in a high risk population. PLoS One. 2013 Oct 29;8(10):e78350. doi:10.1371/journal.pone.0078350

[5] Larsen RN, Kingwell BA, Sethi P, et al. Breaking up prolonged sitting reduces resting blood pressure in overweight/obese adults. Nutr Metab Cardiovasc Dis. 2014 Sep;24(9):976–982. doi:10.1016/j.numecd.2014.04.011

[6] Yates T, Khunti K, Wilmot EG, et al. Self-reported sitting time and markers of inflammation, insulin resistance, and adiposity. Am J Prev Med. 2012 Jan;42(1):1–7. doi:10.1016/j.amepre.2011.09.022

[7] Beach TA, Parkinson RJ, Stothart JP, et al. Effects of prolonged sitting on the passive flexion stiffness of the *in vivo* lumbar spine. Spine J. 2005;5(2):145–154. doi:10.1016/j.spinee.2004.07.036

[8] Karakolis T, Barrett J, Callaghan JP. A comparison of trunk biomechanics, musculoskeletal discomfort and productivity during simulated sit–stand office work. Ergonomics. 2016 Oct;59(10):1275–1287. doi:10.1080/00140139.2016.1146343

[9] Baker R, Coenen P, Howie E, et al. The short term musculoskeletal and cognitive effects of prolonged sitting during office computer work. Int J Environ Res Public Health. 2018 Aug 7;15(8):1678. doi:10.3390/ijerph15081678

[10] Gupta N, Christiansen CS, Hallman DM, et al. Is objectively measured sitting time associated with low back pain? A cross-sectional investigation in the NOMAD study. PLoS One. 2015 Mar 25;10(3):e0121159.

[11] Hallman DM, Gupta N, Mathiassen SE, et al. Association between objectively measured sitting time and neck–shoulder pain among blue-collar workers. Int Arch Occup Environ Health. 2015 Nov;88(8): 1031–1042. doi:10.1007/s00420-015-1031-4
[12] Hallman DM, Gupta N, Heiden M, et al. Is prolonged sitting at work associated with the time course of neck–shoulder pain? A prospective study in Danish blue-collar workers. BMJ Open. 2016 Nov 10;6(11):e012689. doi:10.1136/bmjopen-2016-012689
[13] Lunde LK, Koch M, Knardahl S, et al. Associations of objectively measured sitting and standing with low-back pain intensity: a 6-month follow-up of construction and healthcare workers. Scand J Work Environ Health. 2017 May 1;43(3):269–278. doi:10.5271/sjweh.3628
[14] Korshøj M, Jørgensen MB, Hallman DM, et al. Prolonged sitting at work is associated with a favorable time course of low-back pain among blue-collar workers: a prospective study in the DPhacto cohort. Scand J Work Environ Health. 2018 Sep 1;44(5):530–538. doi:10.5271/sjweh.3726
[15] Picavet HS, Pas LW, van Oostrom SH, et al. The relation between occupational sitting and mental, cardiometabolic, and musculoskeletal health over a period of 15 years – the Doetinchem Cohort Study. PLoS One. 2016 Jan 11;11(1):e0146639. doi:10.1371/journal.pone.0146639
[16] National Research Council and Institute of Medicine. Musculoskeletal disorders and the workplace: low back and upper extremities. Washington (DC): National Academy of Sciences; 2001.
[17] Cherniack M, Dussetschleger J, Farr D, et al. Workplace cohort studies in times of economic instability. Am J Ind Med. 2015 Feb;58(2):138–151. doi:10.1002/ajim.22417
[18] Miranda H, Punnett L, Gore RJ, et al. Musculoskeletal pain and reported workplace assault: a prospective study of clinical staff in nursing homes. Hum Factors. 2014 Feb;56(1):215–227. doi:10.1177/0018720813508778
[19] Miranda H, Punnett L, Gore R, et al. Violence at the workplace increases the risk of musculoskeletal pain among nursing home workers. Occup Environ Med. 2011 Jan;68(1):52–57. doi:10.1136/oem.2009.051474
[20] Caruso CC, Waters TR. A review of work schedule issues and musculoskeletal disorders with an emphasis on the healthcare sector. Ind Health. 2008 Dec;46(6):523–534. doi:10.2486/indhealth.46.523
[21] Buchholz B, Paquet V, Punnett L, et al. PATH: a work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. Appl Ergon. 1996 Jun;27(3):177–187. doi:10.1016/0003-6870(95)00078-X
[22] Roffey DM, Wai EK, Bishop P, et al. Causal assessment of occupational sitting and low back pain: results of a systematic review. Spine J. 2010 Mar;10(3):252–261. doi:10.1016/j.spinee.2009.12.005
[23] Straker L, Healy GN, Atherton R, et al. Excessive occupational sitting is not a 'safe system of work': time for doctors to get chatting with patients. Med J Aust. 2014 Aug 4;201(3):138–140. doi:10.5694/mja13.00037
[24] Lagersted-Olsen J, Korshøj M, Skotte J, et al. Comparison of objectively measured and self-reported time spent sitting. Int J Sports Med. 2014 Jun;35(6):534–540.