HHS Public Access

Author manuscript

J Occup Environ Med. Author manuscript; available in PMC 2017 August 01.

Published in final edited form as:

J Occup Environ Med. 2016 August ; 58(8): 760–764. doi:10.1097/JOM.0000000000000790.

Impact of work organizational factors on carpal tunnel syndrome and epicondylitis

Stephen S. Bao, PhD[1], **Jay M. Kapellusch, PhD**[2], **Andrew S. Merryweather, PhD**[3], **Matthew S. Thiese, PhD**[4], **Arun Garg, PhD**[2], **Kurt T. Hegmann, MD, MPH**[4], **Barbara A. Silverstein, PhD**[1], **Jennifer L. Marcum, PhD**[1], and **Ruoliang Tang, PhD**[2]

[1]Safety and Health Assessment and Research for Prevention (SHARP) Program, Washington State Department of Labor and Industries, Olympia, Washington, USA

[2]Department of Occupational Science & Technology, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin, USA

[3]Department of Mechanical Engineering, University of Utah, Salt Lake City, Utah, USA

[4]Rocky Mountain Center for Occupational and Environmental Health (RMCOEH), University of Utah, Salt Lake City, Utah, USA

Abstract

Objective—To identify relationships between work organizational variables (job rotation, overtime work, having a second job and work pacing)[a] and health outcome measures [carpal tunnel syndrome (CTS), lateral and medial epicondylitis (LEPI/MEPI)].

Methods—Using a pooled baseline cohort of 1834 subjects, the relationships were studied using logistic regression models.

Results—Varied degrees of associations between the work organizational and outcomes variables were found. Job rotation was significantly associated with being a CTS case (OR = 1.23, 95% CI: 1.00–1.50). Overtime work was significantly associated with lower LEPI prevalence (OR = 0.48, 95% CI: 0.28–0.84). No statistically significant associations were found between having a second job and different work pacing and any of the three health outcome measures.

Conclusions—Work organizational variables were only partially associated with the studied health outcomes.

Keywords

Work-related musculoskeletal disorders; job rotation; work pacing; overtime worka; biomechanical exposure; psychosocial factors

[a]These work organizational variables and their relationships with biomechanical and psychosocial exposures were studied previously and published in a separate paper[20].

Corresponding author: Stephen Bao, PO Box 44330, SHARP Program, Washington State Department of Labor and Industries, Olympia, WA 98504-4330, USA. Fax number: 1-360-902-5672, Telephone number: 1-360-902-5676, baos235@lni.wa.gov.

There is no conflict of interest for all authors.

Introduction

Many workforces have high occupational morbidity, lost workdays and incur significant costs from work-related musculoskeletal disorders (WMSDs)[1–4]. Anderson et al.[5] recently reported that WMSDs of the back, upper extremity and knee accounted for approximately 43% of all worker's compensation claims between 2002 and 2010 in Washington State. Among all work-related compensable claims, the compensable claims rates for WMSDs of the back, upper extremity and knee were the highest. In Washington State, non-traumatic onset carpal tunnel syndrome (CTS), and non-traumatic onset epicondylitis had annual compensable workers' compensation claims incidence rates of 6.4 and 1.6 per 10,000 full time employees respectively during the period between 2002 and 2010, resulting in an average of 321 and 378 lost workdays per claim and an average annual direct cost of $49,481 and $55,121 per claim respectively[5].

CTS and EPI are the two most common distal upper extremity WMSDs. EPI may occur in either the lateral or medial epicondyle. CTS is common in workplaces and often results in high treatment costs, lost work time and associated disability[6]. LEPI is one of the major upper extremity musculoskeletal disorders in active workers[78]. MEPI is less common than LEPI, with prevalence ranges from 0.2 to 3.8% in working populations[9–11].

The etiologies of CTS, LEPI, and MEPI are multi-factorial[812–18]. Besides some personal factors such as age, gender and the body mass index (BMI), excessive biomechanical exposures due to forceful exertions, repetitive movements, duration of exertions, awkward hand/wrist postures and hand-arm vibrations are often considered workplace risk factors to CTS and EPI[19].

Bao et al examined the relationships between the work organizational factors and the biomechanical and psychosocial exposures based on a simplified causation model (Figure 1). They found that (i) job rotation had significant effects on biomechanical and most psychosocial measures, (ii) job rotation was generally associated with higher job biomechanical stressors, and lower job satisfaction, (iii) overtime work was associated with higher job biomechanical stressors, (iv) those having second jobs reported getting along well with co-workers, and (v) work pacing had significant influences on biomechanical stressors[20].

The present paper examines the relationships between four work organizational factors (job rotation, overtime work, having a second job, and work pacing)[a] and prevalence of three health outcomes (CTS, LEPI and MEPI).

Materials and methods

This study's data are drawn from three study cohorts collected by the University of Wisconsin-Milwaukee (UWM), University of Utah (UU) and Department of Labor and Industries of the State of Washington (LNI). These studies were approved by their respective

[a]These work organizational variables and their relationships with biomechanical and psychosocial exposures were studied previously and published in a separate paper[20].

Institutional Review Boards (IRB). The data pooling process was coordinated by UWM and approved by its IRB.

One thousand eight hundred and thirty-four (1834) subjects were included in the final pooled dataset (Table 1). The pooled data were from 35 diverse facilities representing 25 different industries located in Illinois, Utah, Washington and Wisconsin. These facilities include manufacturing, food processing, healthcare and office employment sectors. All participants provided informed consent.

Work organizational data were collected through questionnaires, interviews and on-site observations[2122]. CTS, LEPI and MEPI cases were determined through structured interviews, physical examinations and nerve conduction tests[2324].

Work organizational variables[a]

Four work organizational variables[a] were included in the analyses: (1) job rotation, (2) working overtime, (3) having second job(s) and (4) work pacing.

The dichotomous “job rotation” variable was obtained through interviews and observations during worksite visits. A worker was considered as having a job rotation when he or she was assigned to more than one task in a typical workday. Job rotation was also verified by ergonomics analysts through observations during worksite visits.

“Working overtime” is also a dichotomized variable. When a worker works more than 40 hours per week, he or she is considered “working overtime”. This variable was collected from workers through questionnaires or interviews.

The third dichotomous work organizational variable, “having a second job” was defined as having an additional job with a different employer. Information for this variable was reported by the workers through interviews or questionnaires.

The trichotomous “work pacing” variable was obtained through ergonomists’ on-site observations. This variable had three different categories: (i) machine-paced (including line-paced, and paced by another worker), (ii) self-paced, and (iii) piece rate (including work by quota). The work pacing variable was a task-specific variable and was determined by the workstation at which a worker performed a specific task. For workers with job rotation, the pace from the task the worker performed for the greatest proportion of the shift was used to describe job pace.

Case definitions

Only dominant hand data were used in these analyses for all three health outcomes. For CTS, the case definition was: (1) symptoms consistent with CTS, i.e. pain, numbness, tingling and/or burning with no acute or traumatic onset in one or more of the first three digits of the hand for greater than one week or three or more times in the prior year and (2) abnormal median nerve conduction. For details see Silverstein et al[25].

The LEPI case definition was: (i) lateral epicondylar pain, (ii) tenderness on palpation and (iii) at least one positive physical maneuver, either resisted wrist extension or resisted middle finger extension, evoking lateral epicondylar pain..

MEPI case definition was: (i) medial epicondylar pain, and (ii) medial epicondylar pain with resisted wrist flexion. For all three health outcomes, participants were excluded if they reported symptoms that were a result of an acute injury.

Physical examination maneuvers and measurements were consistent among the three research sites. However, LEPI and MEPI symptoms were defined slightly differently. UWM and UU defined the LEPI symptom as pain in the lateral elbow[22], while LNI included pain, aching, stiffness, burning, numbness or tingling in the elbow or forearm for either 4 or more episodes in the past year, one episode of at least 7 days duration in the past year, or an episode of at least 1 day duration in the past 7 days[23]. Similar differences existed for the MEPI symptoms between UWM, UU and LNI.

Statistical analysis

Frequency analysis was performed to obtain the numbers and proportions of subjects by the four different work organizational variables, and CTS, LEPI and MEPI prevalent cases.

The relationships between the health outcomes variables and work organizational variables were assessed using logistic regression models fitted by the generalized estimating equations (GEE) method to account for non-independence of data collected by the same research team. Odds ratios and their 95% confidence intervals (95% CI) were estimated for each work organizational variables separately, while always adjusting for age, gender and BMI[2]. All analyses were performed using the SAS statistical software (version 9.4, SAS Institute, Inc., Cary, NC, USA). Statistical significance was at $p<0.05$.

Results

Table 2 provides the distributions of job categories in terms of the work organizational variables. Thirty-nine percent (39%) of the participants had job rotations. There was a minority of participants who worked overtime (20%) or had a second job (8%). Similar numbers of participants either worked on machine-paced workstations (47%), or self-paced workstations (48%). Few (5%) worked piece-rate work.

There were 249 dominant hand CTS prevalent cases (13.8%), 65 dominant hand LEPI prevalent cases (3.6%) and 14 dominant hand MEPI prevalent cases (0.8%) among the participants. While the prevalence of epicondylitis was low compared to CTS, epicondylitis was more than 4-fold more common in the lateral than medial elbow.

Table 3 provides the odds ratios for CTS, LEPI and MEPI for the four work organizational variables adjusted for age, gender and BMI. Job rotation was significantly associated with increased risk of CTS (OR=1.23, 95% CI 1.00–1.50). Job rotation was also borderline associated with lateral epicondylitis (OR=1.69, 95% CI 0.96–2.97). However, overtime work was associated with lower risk of lateral epicondylitis (OR=0.48, 95% CI 0.28–0.84). Having a second job and different work pacing had no statistically significant associations

with any of the health outcome variables (Table 3), although having a second job was borderline protective for risk of CTS (OR=0.90, 95% CI 0.80–1.01). Due to the low numbers of cases for MEPI (8 of machine-paced, 0 of piece rate and 6 of self-paced), no odds ratios could be calculated for the association of work pace and MEPI. No associations were found between work pace and CTS or LEPI (Table 3).

Discussion

This study found job rotation is associated with increased risk of CTS and is borderline associated with LEPI. However, it also found that overtime was associated with a lower risk of LEPI. Work organizational factors have been less studied among upper extremity WMSDs than biomechanical factors, where certain biomechanical factors, particularly forceful exertions and repetition contribute to the development of CTS and LEPI[1,3,19,26–29]. By contrast, MEPI has been seldom studied in a prospective cohort with measured job physical factors. Certain psychosocial factors (such as job satisfaction, job monotonous nature, lack of social support, low perceived decision authority on the job) have also been reported to have some evidence of associations with CTS and LEPI[2,6,28,30–33].

The relationships between biomechanical factors and CTS and LEPI have been confirmed in recent publications using this pooled dataset[34,35]. Silverstein et al. reported that biomechanical exposure measures such as forceful exertions and repetitions as well as quantified biomechanical risk levels calculated using the ACGIH TLV for HAL method[36] and the Strain Index (SI) method[37] had modest exposure-response relationships with the prevalence of CTS[34]. Both the TLV for HAL and the SI had similar effect sizes for workers with “high risk” exposures with an odds ratio of 1.43 and 1.58 respectively.

In the analysis of relationships between the psychosocial factor variables and LEPI and MEPI prevalent cases, Thiese et al. found that 9 of the 10 psychosocial factors assessed had significant associations or significant increasing trends with lateral epicondylitis[35]. The largest of these was between self-reported physical exhaustion after work and LEPI with an odds ratio of 7.04 (95%CI: 2.02 – 24.51). Job satisfaction as measured by several questions (e.g. how satisfied are you with your job, how likely would you recommend your job to someone else, how likely would you take this job again, and my employer cares about my health and safety on the job?)[b] had significant association with LEPI. Eight of the 10 psychosocial factors had significant relationships or significant increasing trends with MEPI with the largest being between mental exhaustion after work with an odds ratio of 6.51 (95% CI: 1.57 – 27.04).

Ergonomics interventions to address risks of WMSDs often include modifying one or more aspects of the work organization. The present study attempts to identify the direct linkage between the four work organizational variables and the health outcomes. We found those workers with job rotations had significantly higher odds ratio (OR=1.23) of developing CTS compared to those who did not have job rotations and those who had overtime work had significantly lower odds ratio (OR=0.48) of developing CTS compared to those who did not

[b]These psychosocial factors and their relationships with LEPI and MEPI were studied and published in a separate paper[35].

work overtime. These findings contradict general beliefs that job rotation is often used as an ergonomics intervention[38–40] and overtime work is usually believed to be hazardous[41].

Closer examination of our pooled data showed that those with job rotations generally had higher job biomechanical risk levels as evaluated by the Strain Index[37] and the ACGIH TLV for HAL[36], and higher exposure levels in terms of measurements of forceful exertions, repetition and duration of exertions20[a]. Those with job rotations also often reported lower job satisfaction – they were more likely not to recommend their jobs to others, more likely to report dissatisfaction with their jobs, more unlikely to take the same jobs again, more likely to disagree that their employer cared about their health and safety and more likely to report hardly ever getting along with their supervisors20[a]. These worsened biomechanical and psychosocial exposures among those workers with job rotation in our pooled data may explain the increased risk of developing CTS.

Yet, our results on job rotation may not be unique. In studying a cohort of 3710 French workers, Rigouin et al.[42] also found that male workers who had job rotations had increased prevalence of CTS (OR = 2.45, 95% CI: 1.41–4.24) compared to those without job rotations. Both studies suggest that job rotations, as practiced in some of today's industries, may not effectively minimize the risk of CTS.

While some studies found that long work hours have associations with WMSDs[43], others found no clear relationship[44]. In our pooled cohort, those workers who work overtime usually had lower peak forces compared to those without overtime work, even though they had higher job biomechanical risks evaluated by the Strain Index method[37] which were primarily due to the higher repetitions of exertions and longer task durations20[a]. Those with overtime work were often more satisfied than those without overtime work[20]. The somewhat negative biomechanical exposures but positive psychosocial factors might be the reasons that we saw the decreased risks of developing LEPI in the present study (Table 3).

Working multiple jobs is associated with an increased risk of injuries as found in a recent study of the US National Health Interview Survey (NHIS)[45], we were not able to find any statistical significant association between having a second job and any of the health outcome measures (Table 3). This seems to be as expected for our pooled cohort as having a second job did not have any statistically significant association with the biomechanical measures and most psychosocial measures as we previously reported20[a].

Reviews on work pacing showed inconsistent results[4647]. We were unable to identify any significant relationships between work pacing and the health outcome variables (Table 3).The relationships between the work pacing variable and biomechanical/psychosocial variables were complicated and inconsistent as we found previously20[a]. Therefore, their relationships with the health outcome variables might be difficult to predict from crude characterizations of pace alone. The numbers of cases were low (e.g. the MEPI cases). These limitations prevent valid statistical inferences and might partially explain the negative results.

Another reason that might explain not only this negative finding between the work pacing and the health outcomes, but also the negative findings in general between the four work

organizational variables and most health outcome variables is the mediation effect of the biomechanical and psychosocial variables. The biomechanical and psychosocial mediation variables are determined not only by the work organizational variables but also the other workplace factors such as technology used (Figure 1). The work organizational variables likely had modest impacts on the biomechanical and psychosocial variables. Therefore, although we were able to demonstrate associations between the biomechanical/psychosocial variables and the health outcome variables, the reduced impact of work organizational variables might not be able to demonstrate significant relationships with the health outcome variables. This reinforces the notion that effective ergonomics interventions should be multi-faceted.

One of this study's weaknesses is that there are some differences in terms of the case definitions among the participating research teams in spite of efforts to make them consistent. For example, the LEPI and MEPI symptoms were defined slightly different between UWM, UU and LNI as mentioned previously[2223]. Using the "research team" as one of the variables in the logistic regression models should have accounted for the non-independence of data collected by the same research teams. However, broader, less specific case definitions at one site would be anticipated to have biased towards the null.

Somewhat different definitions/questions have been used for psychosocial and work organizational variables in the literature. This makes comparisons between research results more challenging. Nevertheless, contributions to the knowledge of work organizational impacts on biomechanical exposures, psychosocial factors and the WMSD health conditions from various research teams including ours will eventually help inform the development of more effective and efficient ergonomic interventions by modifying the various work organizational parameters.

The present analyses were based on prevalence data. Therefore, we could only identify whether there are associative relationships between the studied work organizational variables and the health outcome variables. Incidence analyses are needed to confirm effects and contribute to a determination of causality.

Conclusions

While the four work organizational variables studied influence both the biomechanical and psychosocial variables among the workers in this pooled cohort, we found varying associations between them and the health outcomes (CTS, LEPI and MEPI prevalent cases). Job rotation was associated with being a CTS case, but overtime work was associated with reduced LEPI prevalence. Having a second job and different machine pacing were not found to be related to any of these three WMSDs in this baseline cohort.

Acknowledgments

This study was supported in part by research funding from the Centers for Disease Control/National Institute for Occupational Safety and Health (R01OH010474), 1 U 01 OH007917-01, and T42/CCT810426-10. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health. We would like to acknowledge the efforts and assistants from our

colleagues of each research team who helped with data collections and analyses. The study participant's and their employer's cooperation is also greatly appreciated.

References

1. Roquelaure Y, Mariel J, Dano C, Leclerc A, Moisan S, Penneau-Fontbonne D. Surveillance program of neck and upper limb musculoskeletal disorders: assessment over a 4 year period in a large company. Ann Occup Hyg. 2004; 48:635–642. [PubMed: 15381509]
2. Shiri R, Viikari-Juntura E, Varonen H, Heliovaara M. Prevalence and determinants of lateral and medial epicondylitis: a population study. Am J Epidemiol. 2006; 164:1065–1074. [PubMed: 16968862]
3. Silverstein BA, Viikari-Juntura E, Fan ZJ, Bonauto DK, Bao S, Smith C. Natural course of nontraumatic rotator cuff tendinitis and shoulder symptoms in a working population. Scand J Work Environ Health. 2006; 32:99–108. [PubMed: 16680380]
4. Occhionero V, Korpinen L, Gobba F. Upper limb musculoskeletal disorders in healthcare personnel. Ergonomics. 2014; 57:1166–1191. [PubMed: 24840049]
5. Anderson, N.; Adams, D.; Bonauto, D.; Howard, N.; Silverstein, B. Work-related musculoskeletal disorders of the back, upper extremity, and knee in Washington State, 2002–2010. Olympia, Washington, USA: Safety and Health Assessment and Research for Prevention (SHARP) Program, Washington State Department of Labor and Industries; 2015.
6. Foley M, Silverstein B, Polissar N. The economic burden of carpal tunnel syndrome: long-term earnings of CTS claimants in Washington State. Am J Ind Med. 2007; 50:155–172. [PubMed: 17216630]
7. Ware JEJ, Kosinki M, Keller SD. A 12-item short-form health survey. Medical Care. 1996; 34:220–233. [PubMed: 8628042]
8. Silverstein, B.; Adams, D. Work-related musculoskeletal disorders of the neck, back and upper extremity in Washington State. Olympia, WA: Washington State Department of Labor and Industries; 2007.
9. Oriet, LP. An epidemiological analysis of a Canaddian automotive manufacturer. In: Lee, GCH., editor. Advances in Occupational Ergonomics and Safety. IOS Press; 1999. p. 53-57.
10. Descatha A, Leclerc A, Chastang JF, Roquelaure Y. Study Group on Repetitive W. Medial epicondylitis in occupational settings: prevalence, incidence and associated risk factors. J Occup Environ Med. 2003; 45:993–1001. [PubMed: 14506342]
11. Gold JE, d'Errico A, Katz JN, Gore R, Punnett L. Specific and non-specific upper extremity musculoskeletal disorder syndromes in automobile manufacturing workers. Am J Ind Med. 2009; 52:124–132. [PubMed: 19016265]
12. Garg A, Kapellusch J, Hegmann K, et al. The Strain Index (SI) and Threshold Limit Value (TLV) for Hand Activity Level (HAL): risk of carpal tunnel syndrome (CTS) in a prospective cohort. Ergonomics. 2012; 55:396–414. [PubMed: 22397385]
13. Harris-Adamson C, Eisen EA, Kapellusch J, et al. Biomechanical risk factors for carpal tunnel syndrome: a pooled study of 2474 workers. Occup Environ Med. 2015; 72:33–41. [PubMed: 25324489]
14. Bonfiglioli R, Mattioli S, Armstrong TJ, et al. Validation of the ACGIH TLV for hand activity level in the OCTOPUS cohort: a two-year longitudinal study of carpal tunnel syndrome. Scand J Work Environ Health. 2013; 39:155–163. [PubMed: 22752342]
15. Kapellusch, JmJM.; Gerr, FE.; Malloy, EJ., et al. Exposure-response relationships for the ACGIH threshold limit value for hand-activity level: results from a pooled data study of carpal tunnel syndrome. Scand J Work Environ Health. 2014; 40:610–620. [PubMed: 25266844]
16. Silverstein BA, Fine LJ, Armstrong TJ. Occupational factors and carpal tunnel syndrome. Am J Ind Med. 1987; 11:343–358. [PubMed: 3578290]
17. Sluiter JK, Rest KM, Frings-Dresen MH. Criteria document for evaluating the work-relatedness of upper-extremity musculoskeletal disorders. Scand J Work Environ Health. 2001; 27(Suppl 1):1–102. [PubMed: 11401243]

18. Hegmann KT, Hoffman HE, Belcourt RM, et al. ACOEM practice guidelines: elbow disorders. J Occup Environ Med. 2013; 55:1365–1374. [PubMed: 23963225]
19. NIOSH. Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back. Cincinnati, USA: National Institute for Occupational Safety and Health, DHHS; 1997.
20. Bao S, Kapellusch J, Merryweather A, et al. Relationships between job organizational factors, biomechanical and psychosocial exposures. Ergonomics. 2015
21. Howard N, Spielholz P, Bao S, Silverstein B, Fan ZJ. Reliability of an observational tool to assess the organization of work. International Journal of Industrial Ergonomics. 2009; 39:260–266.
22. Garg A, Hegmann KT, Wertsch JJ, et al. The WISTAH hand study: a prospective cohort study of distal upper extremity musculoskeletal disorders. BMC Musculoskelet Disord. 2012; 13:90. [PubMed: 22672216]
23. Fan ZJ, Bao S, Silverstein BA, Howard NL, Smith CK, Bonauto DK. Predicting work-related incidence of lateral and medial epicondylitis using the strain index. Am J Ind Med. 2014; 57:1319–1330. [PubMed: 25242446]
24. Thiese MS, Gerr F, Hegmann KT, et al. Effects of Varying Case Definition on Carpal Tunnel Syndrome Prevalence Estimates in a Pooled Cohort. Arch Phys Med Rehabil. 2014
25. Silverstein BA, Fan ZJ, Bonauto DK, et al. The natural course of carpal tunnel syndrome in a working population. Scand J Work Environ Health. 2010; 36:384–393. [PubMed: 20352175]
26. Fan ZJ, Silverstein BA, Bao S, et al. Quantitative exposure-response relations between physical workload and prevalence of lateral epicondylitis in a working population. Am J Ind Med. 2009; 52:479–490. [PubMed: 19347903]
27. Fan ZJ, Harris-Adamson C, Gerr F, et al. Associations between workplace factors and carpal tunnel syndrome: A multi-site cross sectional study. Am J Ind Med. 2015; 58:509–518. [PubMed: 25778111]
28. Werner RA, Franzblau A, Gell N, Hartigan A, Ebersole M, Armstrong TJ. Predictors of persistent elbow tendonitis among auto assembly workers. J Occup Rehabil. 2005; 15:393–400. [PubMed: 16119229]
29. Garg A, Kapellusch JM, Hegmann KT, et al. The strain index and TLV for HAL: risk of lateral epicondylitis in a prospective cohort. Am J Ind Med. 2014; 57:286–302. [PubMed: 24243166]
30. Ahlgren C, Malmgren Olsson E-B, Brulin C. Gender analysis of musculoskeletal disorders and emotional exhaustion: interactive effects from physical and psychosocial work exposures and engagement in domestic work. Ergonomics. 2012; 55:212–228. [PubMed: 22248390]
31. Fredriksson K, Alfredsson L, Thorbjornsson CB, et al. Risk factors for neck and shoulder disorders: a nested case-control study covering a 24-year period. Am J Ind Med. 2000; 38:516–528. [PubMed: 11025493]
32. Harkness EF, Macfarlane GJ, Nahit ES, Silman AJ, McBeth J. Mechanical and psychosocial factors predict new onset shoulder pain: a prospective cohort study of newly employed workers. Occup Environ Med. 2003; 60:850–857. [PubMed: 14573715]
33. Harris-Adamson C, Eisen EA, Dale AM, et al. Personal and workplace psychosocial risk factors for carpal tunnel syndrome: a pooled study cohort. Occup Environ Med. 2013; 70:529–537. [PubMed: 23645610]
34. Silverstein BA, Kapellusch JM, Garg A, et al. Prevalence of CTS: comparing risk using the SI and TLV for HAL with emphasis on job rotation. manuscript. 2016
35. Thiese MS, Hegmann KT, Kapellusch J, et al. Psychosocial factors related to lateral and medial epicondylitis: results from pooled study analyses. 2016 in press.
36. ACGIH. Hand activity level TLVs and BEIs - Threshold limit values for chemical substances and physical agents. Cincinnati, Ohio: ACGIH; 2001. p. 110-112.
37. Moore JS, Garg A. The Strain Index: a proposed method to analyze jobs for risk of distal upper extremity disorders. Am Ind Hyg Assoc J. 1995; 56:443–458. [PubMed: 7754975]
38. Jonsson B. The static load component in muscle work. Eur J Appl Physiol. 1988; 57:305–310.
39. NIOSH. Elements of Ergonomics Programs - A primer based on workplace evaluations of musculoskeletal disorders. USA: National Institutue for Occupational Safety and Health; 1997.

40. Westgaard RH, Winkel J. Occupational musculoskeletal and mental health: Significance of rationalization and opportunities to create sustainable production systems - A systematic review. Appl Ergon. 2011; 42:261–296. [PubMed: 20850109]

41. Johnson JV, Lipscomb J. Long working hours, occupational health and the changing nature of work organization. American Journal of Industrial Medicine. 2006; 49:921–929. [PubMed: 16986150]

42. Rigouin P, Ha C, Bodin J, et al. Organizational and psychosocial risk factors for carpal tunnel syndrome: A cross-sectional study of French workers. International Archives of Occupational and Environmental Health. 2014; 87:147–154. [PubMed: 23358663]

43. Trinkoff AM, Le R, Geiger-Brown J, Lipscomb J, Lang G. Longitudinal relationship of work hours, mandatory overtime, and on-call to musculoskeletal problems in nurses. American Journal of Industrial Medicine. 2006; 49:964–971. [PubMed: 16691609]

44. Caruso CC, Waters TR. A review of work schedule issues and musculoskeletal disorders with an emphasis on the healthcare sector. Ind Health. 2008; 46:523–534. [PubMed: 19088404]

45. Marucci-Wellman HR, Willetts JL, Lin TC, Brennan MJ, Verma SK. Work in multiple jobs and the risk of injury in the US working population. Am J Public Health. 2014; 104:134–142. [PubMed: 24228681]

46. Hoogendoorn WE, van Poppel MN, Bongers PM, Koes BW, Bouter LM. Systematic review of psychosocial factors at work and private life as risk factors for back pain. Spine. 2000; 25:2114–2125. [PubMed: 10954644]

47. Koukoulaki T. The impact of lean production on musculoskeletal and psychosocial risks: an examination of sociotechnical trends over 20 years. Appl Ergon. 2014; 45:198–212. [PubMed: 23981516]

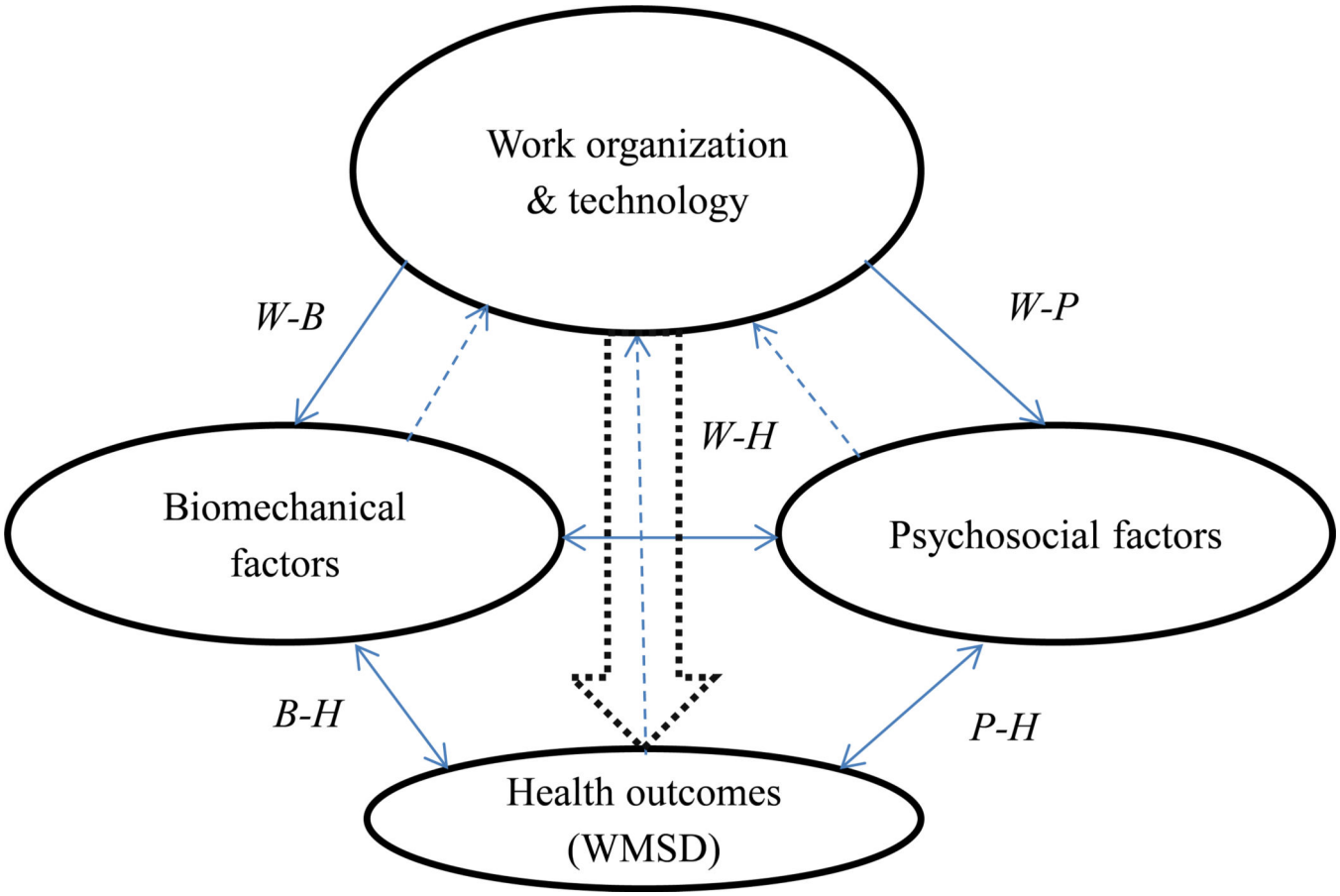

Figure 1.

A simplified causation model between work organization, biomechanical exposure, psychosocial factors, and health outcomes in terms of work-related musculoskeletal disorders (WMSD) – Work organization and technology determine biomechanical stressors on the workers (*W-B*) and influence their psychosocial factors (*W-P*). These biomechanical and psychosocial exposures may result in or be associated with different musculoskeletal health consequences (*B-H* and *P-H*). These exposures and musculoskeletal health status of the workers may also influence the changes in work organization and technology. The status of WMSDs in a workplace may reflect the conditions of their work organization or the changes of their work organization (*W-H*).

Table 1

Subjects from the three study cohorts

	Female	Male	All
Number	1096	738	1834
Age	43.3 (10.4)	38.0 (11.9)	41.1 (11.3)
Height (meter)	1.62 (0.08)	1.76 (0.08)	1.68 (0.10)
Weight (kg)	76.7 (19.2)	87.1 (21.4)	80.9 (20.8)
BMI (kg/m^2) *	29.1 (6.8)	28.0 (6.0)	28.7 (6.5)
Tenure (yrs) **	9.5 (8.4)	7.0 (8.6)	8.5 (8.5)

* BMI – Body Mass Index

** Not all subjects had information on tenure. Data were from 1033 females and 707 males.

Table 2

Distributions of the work organizational variables

Work organizational Variable	Number (% of total)
Without job rotation	1124 (61.3%)
With job rotation	710 (38.7%)
Do not work overtime	1460 (79.6%)
Work overtime	374 (20.4%)
Do not have a 2nd job	1597 (92.1%)
Have a 2nd job	137 (7.9%)
Machine-paced	851 (46.7%)
Piece rate	97 (5.3%)
Self-paced	876 (48.0%)

Note: Total numbers of subjects were different for the different work organizational variables due to missing responses.

Table 3

Adjusted odds ratios (OR) and 95% confidence intervals (95% CI) for the prevalent cases of carpal tunnel syndrome (CTS), lateral epicondylitis (LEPI) and medial epicondylitis (MEPI) for the four work organizational variables. **bold** numbers – statistically significant at $p<0.05$

Independent variables	CTS	LEPI	MEPI
Job rotation	**1.23 (1.00–1.50)**	1.69 (0.96–2.97)	0.91 (0.22–3.74)
Overtime work	0.98 (0.77–1.25)	**0.48 (0.28–0.84)**	0.59 (0.21–1.63)
Having a second job	0.90 (0.80–1.01)	1.08 (0.44–2.64)	0.86 (0.24–3.12)
Work pace: machine- vs self-paced	1.26 (0.71–2.24)	0.97 (0.65–1.46)	-
Work pace: piece rate vs self-paced	1.35 (0.79–2.31)	0.80 (0.23–2.76)	-
Work pace: machine- vs piece rate	0.93 (0.62–1.39)	1.21 (0.40–3.72)	-

Note: Adjusted for age, gender and body mass index (BMI)