Journal of Safety Research 71 (2019) 79–85

Contents lists available at ScienceDirect

Journal of Safety Research

journal homepage: www.elsevier.com/locate/jsr

Cervical musculoskeletal disorders and their relationships with personal and work-related factors among electronic assembly workers

Nazhakaiti Maimaiti [a,1], Jingjing Wang [a,1], Xianning Jin [a], Shijuan Wang [a], Dongliang Qin [a], Lihua He [a,*], Fujiang Wang [a], Zhongbin Zhang [b], Mikael Forsman [c,d], Liyun Yang [c,d], Qiuyue Yang [e], Haijiao Wang [e]

[a] Department of Occupational and Environmental Health, School of Public Health, Peking University Health Science Center, Beijing 100191, China
[b] China Academy of Safety Science and Technology, Beijing 100029, China
[c] Institute of Environmental Medicine, Karolinska Institutet, 171 77 Stockholm, Sweden
[d] Division of Ergonomics, KTH Royal Institute of Technology, 141 57 Huddinge, Sweden
[e] National Research Center for Occupational Safety and Health, State Administration of Work Safety, Beijing 100191, China

ARTICLE INFO

Article history:
Received 8 July 2018
Received in revised form 9 June 2019
Accepted 12 September 2019
Available online 13 November 2019

Keywords:
Cervical musculoskeletal disorders
risk factors
structural equation modeling
electronic assembly workers
occupational health

ABSTRACT

Introduction: Electronics assembly workers are reported to have a high prevalence of musculoskeletal disorders (MSDs). This study investigated the prevalence of cervical MSDs and the complex relationships between cervical MSDs and individual, physical, psychosocial factors among electronics assembly workers. *Methods:* In this cross-sectional survey, self-administered questionnaires from 700 workers in electronics manufacturing workshops were analysed. Information concerning musculoskeletal symptoms, personal and work-related factors was collected. Finally, the prevalence of cervical MSDs was computed for different subgroups, and the relationships with different factors were analyzed using logistic regression and structural equation modeling (SEM). *Results:* The total 12 month prevalence of cervical MSDs among the survey population was 29.4%. Variables of gender, job tenure, twisting head frequently, neck flexion/extension for long time and work required to be done quickly showed significant associations with MSDs in a multivariate logistic regression ($P < 0.05$). The SEM analysis showed moderate and significant correlations between postural load ($\gamma = 0.279$), gender ($\gamma = 0.233$) and cervical MSDs, while there were weak but significant correlations between vibration ($\gamma = 0.024$), work stress ($\gamma = 0.126$), job tenure ($\gamma = 0.024$) and cervical MSDs. Both work stress and vibration affected the MSDs indirectly through postural load. *Conclusions:* The logistic regression results support previous general epidemiological MSD studies, and indicates that individual, physical, and psychosocial factors are related to cervical MSDs. The SEM provides a better approximation of the complexity of the relationship between risk factors and cervical MSDs. Improving awkward postures may be effective ways to control the influence of occupational stressors or vibration on MSDs. *Practical Applications:* The study is to improve prevention of MSDs among electronics assembly workers and promote their occupational health.

1. Introduction

Work-related musculoskeletal disorders (MSDs) refer to injuries or disorders of the muscles, nerves, tendons, joints, cartilage, and spinal discs associated with exposure to risk factors in the workplace. They are characterized as localized pain, numbness, or physical limitation. Neck, shoulder, and the lower back are the most vulnerable parts (European Agency for Safety and Health at Work, 2013). These diseases will not only affect the workers' quality of life, but also impose a major economic burden to society. By 2013, one of the five leading causes of disability adjusted life years (DALYs) worldwide was low back and neck pain, and there has been an increasing trend of such pain prevalence in recent years (Murray et al., 2015). According to the U.S. Bureau of Labor Statistics, in 2015 MSDs were the most important part of workers' compensation, which accounted for at least one third of the labor time losses (The U.S. Bureau of Labor Statistics, 2015).

With the progress of information technology, China's electronic equipment manufacturing industry has developed rapidly and had a working population of over 10 million in 2013. Because of price competition, many enterprises acquire profit by increasing productivity and efficiency, which may increase workers'

* Corresponding author at: Department of Occupational and Environmental Health, School of Public Health, Peking University Health Science Center, Beijing 100191, China.

E-mail address: alihe2009@126.com (L. He).

[1] These authors contributed to the work equally and should be regarded as co-first authors.

https://doi.org/10.1016/j.jsr.2019.09.018
0022-4375/

workload and stress, making electronic assembly workers prone to musculoskeletal problems. In particular, long-term sitting and constrained postures will increase the risk of upper quadrant musculoskeletal pain (Brink, Louw, Grimmer, & Jordaan, 2015).

MSDs have been shown to be multifactorial and are influenced by various demographic, physical, and psychosocial factors, such as repetitive work, awkward posture, vibration, and work stress (Da & Vieira, 2010; Long, Johnston, & Bogossian, 2012). There are also elements of complexity among these factors, since they are not independent but may interact with one another (Huang, Feuerstein, & Sauter, 2002). However, the specific etiological mechanism remains to be explored in depth. The identification and evaluation of these risk factors and the understanding of their mechanisms are of great significance in preventing and controlling these disorders. Research on MSDs risk factors mainly adopt the method of logistic regression (Abledu & Abledu, 2012; Cheng, Cheng, & Ju, 2013; Roquelaure et al., 2009), which is not effective in the study of complex etiological networks, especially in the analysis of mediating effects and comprehensive interrelationship between variables (Park, 2009). Structural equation modeling (SEM) is a statistical method for establishing, estimating, and verifying causality models, which is able to compute multiple variables at the same time, to reduce the influence of measurement errors, and to study variables' potential direct or indirect effects. Because of these strengths, it is very suitable for the etiological study of MSDs (Francis et al., 1988; Arlinghaus, Lombardi, Willetts, Folkard, & Christiani, 2012; Abdul Rahman, Abdul-Mumin, & Naing, 2017).

The overall aim of this study is to improve prevention of MSDs among electronics assembly workers. In this study, the aims were to investigate the prevalence of cervical MSDs and their complex relationships with personal and work-related factors among electronic assembly workers.

2. Materials and methods

A cross-sectional questionnaire survey was conducted among electronic assembly workers. Logistic regression and structural equation modeling (SEM) were used for statistical analyses.

2.1. The questionnaire

The questionnaire was designed for evaluating MSDs and ergonomic factors in the workplace, which has been done with reliability and validity tests in previous studies (Yang et al., 2017; Wang et al., 2017). The questionnaire consists of three parts: (1) personal factors; (2) musculoskeletal symptoms; (3) work-related factors.

For personal factors, information concerning gender, age, job tenure, Body Mass Index (*BMI*), education, monthly income, smoking and drinking behaviors was collected.

The second domain captured information on musculoskeletal symptoms experienced in the past 7 days and in the past 12 months in a body map with nine body regions: neck, shoulders, upper back, elbows, hands/wrists, lower back, knees, thighs and feet. Only cervical MSDs were studied in this article. Furthermore, symptoms in the past 12 months were assessed by self-reported pain frequency ($1\sim2$ times/year, $1\sim2$ times/quarter, $1\sim2$ times/month, once a week, almost every day), pain duration (less than an hour, less than a day, less than a week, less than a months, more than a month) and pain intensity (score $0\sim10$, with score 0 for no pain and score 10 for unbearable pain) in each body part. The design of this domain was in accordance with the Standardized Nordic Musculoskeletal Questionnaire (Crawford, 2007).

Work-related factors involved postural, psychosocial, and work-environmental factors. Postural factors constituted several items on each body regions, which were modified from Rapid Entire Body Assessment (Hignett & Mcatamney, 2000). Postural items in the neck region include keeping head twisted for long time, twisting one's head frequently, neck flexion/extension for long time, bending the head forwards/backwards frequently, keeping head twisted sideways for long time, and twisting one's head sideways frequently. Psychosocial factors mainly focused on job demand, social support, and job control, which were selected from the full recommended version of the Karasek Job Content Questionnaire (Karasek et al., 1998). The participants were asked to respond to all the work-related items on a 5 point Likert scale. In question concerning frequency of certain postures or psychosocial status at work, the subjects were asked to use the scale: never, seldom, sometimes, often, always. And for work environment items, subjects were asked to report every aspect of the work environment with the scale: very satisfied, somewhat satisfied, neutral, somewhat dissatisfied, very dissatisfied. Besides, the questionnaire also asks whether the workers use hand-held vibration tools at work.

2.2. Sampling and data collection

In this study, a two-stage cluster sampling method was used to select subjects from three electronic accessories processing enterprises with unified inclusion and exclusion criteria. In the first stage, we selected three electronic accessories processing enterprises in Beijing through convenience sampling. In the second stage, the workshop was used as a unit to carry out the cluster sampling, and we selected 4 workshops from 12 workshops in 3 enterprises. All workers in the selected workshops who were eligible to participate gave their informed consent to take part in the survey. Electronic accessories processing workers usually work in lines in a sitting position and in aseptic workshops at a constant temperature. Workers who had worked in the industry for at least 1 year were recruited in this study. Those who have been diagnosed with musculoskeletal system injuries, rheumatoid arthritis, tumors, tuberculosis, or infections were excluded. Finally, 928 subjects were included in this study.

Between June 2017 and July 2017, the questionnaires with a cover letter explaining the purposes and procedure of the study were delivered to those workers. Those who agreed to participate provided their signatures as informed consents. The questionnaire was completed under the guidance of trained investigators and went through strict quality control. Subjects who did not return filled questionnaire were contacted and reminded to respond to the survey. Approval for all study procedures was obtained from Medical ethics committee of Peking University (IRB00001052−16015).

2.3. Data analysis

Descriptive statistics were performed with SPSS 20.0 (IBM, www.ibm.com) to reveal the distribution for demographic and occupational characteristics such as gender, age, *BMI*, education level, monthly income, job tenure, physical exercise, smoking, and drinking behaviors. The prevalence of cervical MSDs in different working groups was also analyzed and compared with chi-square test. Multivariate logistic regression analysis was carried out to evaluate the influence of potential risk factors on the occurrence of cervical musculoskeletal symptoms in the past 12 months. Continuous variables were converted to the ordinal scale according to distribution to make the model stable. The stepwise backward removing method was used for variable selection. The inclusion level is 0.05, the elimination level is 0.10 and the significant level is 0.05. Adjusted odd ratios (*ORs*) with 95% confidence intervals (95% *CI*) were obtained as measurement of association.

Mplus 7.0 (Muthén & Muthén, Los Angeles, USA) software was used to conduct SEM on risk factors of cervical MSDs in the following steps: (1) Model construction: On the basis of literature review and previous researches, the initial model of structural equation is constructed, composing of six measurement models and one structure model. In the hypothesis, latent variable postural load and observed variable gender, age as well as job tenure affect cervical MSDs directly, while latent variable work stress and observed variable vibration affect the disorders directly and indirectly through postural load; (2) Model fitting and evaluation: The weighted least squares with mean and variance adjusted method (WLSMV) was adopted to estimate the parameters because most of the variables are categorical. The reliability and validity of latent variable was evaluated by composite reliability (*CR*) and the average of variance extracted (*AVE*). According to Fornell and Larcker (1981), a *CR* above 0.6 and an AVE above 0.36 are needed for representing the concept of latent variables. Model fit indexes included χ^2/df, comparative fit index (*CFI*), root mean square error of approximation (*RMSEA*), Tucker-Lewis index (*TLI*), weighted root mean square residual (*WRMR*). The following criteria indicate goodness of fit: $\chi^2/df < 5.000$, $RMSEA < 0.080$, CFI and $TLI > 0.900$ as well as $WRMR < 1.000$ are considered acceptable (Karadağ et al., 2015; Kline, 2011); (3) Model correction and parameter estimation: The model was adjusted by referring to professional knowledge and the correction index (*CI*) if necessary. The path coefficient γ of the final model is a reflection of the correlation level. If the absolute value of γ value is greater than 0 and less than 0.20, the two variables are correlated weakly; if it is greater than or equal to 0.20 and less than 0.50, the two variables have a moderate collection; if it is greater than or equal to 0.50, the two variables are strongly correlated. The level of significance was set to $P < 0.05$.

3. Results

3.1. The distribution of cervical musculoskeletal disorders

Of the 928 questionnaires sent to subjects who were eligible to participate, there were 752 questionnaires returned and 700 questionnaires were valid, yielding a response rate of 81.0% and an effective rate of 93.1%. The total year prevalence of cervical MSDs among the survey population was 29.4%, among them, 15.9% had pain in the past 7 days. For detailed information on self-reported pain, see Table 1. For demographic characteristics of the subjects, see Table 2 (males constituted 47.5% of the population). The majority of the respondents were young, with an average age of 26.7 (SD: 5.35) years old, and the number of people who had been working in their current position for less than 5 years accounted for 89.0% of all the respondents. The average level of BMI was 22.7 (SD: 3.48) kg/m^2; most of the respondents were less-educated with an educational level of below college (94.0%); monthly income was mainly 2000–5000 yuan (92.5%); only 11.4% of the subjects exercised more than 3 times a week; 20.5% of them had smoking behaviors, and 18.7% of them had drinking behaviors. The results of chi-square tests showed that the prevalence of cervical MSDs in females was significantly higher than that in males ($P < 0.01$), and the prevalence was higher in workers with longer job tenure ($P < 0.05$).

Table 1
Detailed information on self-reported pain.

Variables	Categories	*n*(%)
Symptom duration	no pain	494(70.5)
	less than an hour	61(8.7)
	less than a day	48(6.9)
	less than a week	83(11.9)
	less than a months	7(1.0)
	more than a month	7(1.0)
Symptom frequency	no pain	494(70.6)
	1 ~ 2 times/year	26(3.7)
	1 ~ 2 times/quarter	14(2.0)
	1 ~ 2 times/month	109(15.6)
	once a week	29(4.1)
	almost every day	28(4.0)
Symptom intensity	Mean ± SD	4.22 ± 1.84

3.2. Risk factors modeling by multivariate logistic regression

Subjects who had had neck symptoms such as discomfort, numbness, pain, or limitation of movement, during the past 12 months, were defined as cases. Taking all the individual, postural, and psychosocial factors into consideration, the results of multivariate logistic regression analysis revealed that there were six variables entering the final equation: gender, job tenure, education level, twisting one's head frequently, neck flexion/extension for long time and work required to be done quickly, as shown in Table 3. The risk of cervical MSDs in female was higher than that in male ($OR = 1.636$, $95\%CI = 1.002 \sim 2.668$). The risk also increased with job tenure, as the risk among workers who had worked for 16 years or more was 13.399 times higher than those who had worked for less than 5 years ($OR = 13.399$, $95\%CI = 1.481 \sim 121.203$). Subjects who sometimes twisted head frequently had a higher risk than those who never twisted head frequently at work ($OR = 2.420$, $95\%CI = 1.179 \sim 4.966$). The risk among workers who always need to keep neck flexed/extended for long time was 2.648 times higher than those who never kept neck flexed/extended at work ($OR = 2.648$, $95\%CI = 1.069 \sim 6.563$). Workers who felt that work was always required to be done quickly had a higher risk than those who didn't ($OR = 6.495$, $95\%CI = 2.038 \sim 20.703$).

3.3. Structural equation modeling

Based on the epidemiological theoretical model (Bongers, de Winter, Kompier, & Hildebrandt, 1993) and previous studies, a SEM on etiological network of cervical MSDs was established. Information on latent variables and observed variables was shown in Table 4. The model consisted of six latent variables: job demand, social support, job control, work stress, postural load, and cervical MSDs. The composite reliability was higher than 0.6, and the convergence validity was higher than 0.36 for all latent variables, which indicated that the observed variables can represent the concept of latent variables.

The path coefficients of the final model are shown in Fig. 1. The direct and indirect effects of each factor are shown in Table 5. Work stress, which was composed of job stress, social support, and job control, had a direct effect on postural load and an indirect effect on cervical MSDs; vibration had a direct effect on postural load and an indirect effect on cervical MSDs; posture load had a direct effect on cervical MSDs; age, gender and job tenure would also affect the occurrence of cervical MSDs. The total effects of postural load, vibration, occupation tension, gender and job tenure on cervical MSDs were 0.279, 0.024, 0.019, 0.233, 0.126, respectively, indicating that there were moderate correlations between postural load, gender and cervical MSDs, while there were weak correlations between vibration, work stress, job tenure and cervical MSDs.e1-e20 are residual errors of the observed variables. Observed variables x1-x17 and y1-y3 can be referred to Table 3.

4. Discussion

In this study, we investigated the prevalence of cervical MSDs and the complex interrelationship between demographic, physical,

Table 2
Demographic characteristics of the subjects ($N = 700$).

Variables	Categories	*n*	Number of cases (%)	χ^2	*P* value
Gender[a]	Male	327	72(22.0)	17.202	<0.001[b]
	Female	362	132(36.5)		
Age (years old)[a]	≤20	92	18(19.6)	6.848	0.077
	21 ~ 30	469	141(30.1)		
	31 ~ 40	125	40(32.0)		
	≥41	10	5(50.0)		
Job tenure (years)[a]	1 ~ 5	544	160(29.4)	10.558	0.032[b]
	6 ~ 10	44	19(43.2)		
	11 ~ 15	17	7(41.2)		
	≥16	6	4(66.7)		
BMI (kg/m^2)[a]	＜18.5	84	25(29.8)	1.487	0.685
	18.5 ~ 23.9	440	131(29.8)		
	24 ~ 27.9	131	35(26.7)		
	＞28	38	14(36.8)		
Education[a]	Junior middle school or below	130	37(28.5)	9.119	0.058
	Senior high school	448	129(28.8)		
	Junior college	58	15(25.9)		
	Bachelor degree or above	41	20(48.8)		
Monthly income (RMB)[a]	≤2000	5	1(20.0)	2.522	0.471
	2001 ~ 4000	496	142(28.6)		
	4001 ~ 5000	95	29(30.5)		
	≥5001	43	17(39.5)		
Exercise[a]	Never	179	56(31.3)	3.071	0.546
	1 ~ 3 times/quarter	90	32(35.6)		
	2 ~ 3 times/month	135	39(28.9)		
	1 ~ 2 times/week	171	44(25.7)		
	More than 3 times/week	74	23(31.1)		
Smoking behavior[a]	Yes	143	35(24.5)	2.112	0.146
	No	554	170(30.7)		
Drinking behavior[a]	Yes	129	39(30.2)	0.056	0.813
	No	562	164(29.2)		

[a] Variables with missing values.
[b] $P < 0.05$, with statistical significance.

Table 3
The results of the multivariate logistic regression describing the associations between personal and work-related factors with cervical MSDs.

Variables (reference)	Categories	*B*	*Wald*	*P* value	*OR*	95% *CI*	CLRs
Gender (male)	Female	0.492	3.881	0.049[a]	1.636	1.002 ~ 2.668	2.663
Job tenure (1 ~ 5 years)	6 ~ 10 years	1.276	7.780	0.005[a]	3.581	1.461 ~ 8.778	6.008
	11 ~ 15 years	0.795	1.493	0.222	2.215	0.619 ~ 7.930	12.811
	≥16 years	2.595	5.335	0.021[a]	13.399	1.481 ~ 121.203	86.429
Education level (junior middle school or below)	Senior high school	0.467	2.216	0.137	1.596	0.862 ~ 2.952	3.425
	Junior college	−0.545	1.097	0.295	0.580	0.209 ~ 1.608	7.694
	Bachelor degree or above	−0.029	0.003	0.954	0.971	0.354 ~ 2.667	7.534
Twisting one's head frequently (never)	Seldom	0.939	9.299	0.002[a]	2.557	1.399 ~ 4.676	3.342
	Sometimes	0.884	5.802	0.016[a]	2.420	1.179 ~ 4.966	4.212
	Often	0.445	1.249	0.264	1.560	0.715 ~ 3.405	4.762
	Always	0.520	0.516	0.473	1.683	0.407 ~ 6.965	17.113
Neck flexion/extension for long time (never)	Seldom	−0.432	0.831	0.362	0.649	0.256 ~ 1.644	6.422
	Sometimes	−0.126	0.072	0.788	0.881	0.351 ~ 2.212	6.302
	Often	0.602	2.064	0.151	1.825	0.803 ~ 4.146	5.163
	Always	0.974	4.424	0.035[a]	2.648	1.069 ~ 6.563	6.139
Work required to be done quickly (never)	Seldom	0.664	1.648	0.199	1.942	0.705 ~ 5.348	7.586
	Sometimes	0.780	2.247	0.134	2.181	0.787 ~ 6.048	7.685
	Often	1.365	7.035	0.008[a]	3.915	1.428 ~ 10.732	7.515
	Always	1.871	10.008	0.002[a]	6.495	2.038 ~ 20.703	10.158

[a] $P < 0.05$, with statistical significance.

and psychosocial factors on cervical MSDs among electronic accessories processing workers. The prevalence of cervical MSDs in present study was 29.4%, which was comparable to rates found in the same industry in other studies ranging from 16.9% to 41.8% (Chen et al., 1993; Park, 2009; CAO et al., 2014). When compared to other professions (Wang et al., 2017; Cho, Jeon, Lee, Seok, & Cho, 2014; Liu et al., 2015), these values vary greatly, which may partly depend on differences in methodological details and on cultural differences in the interpretation of discomfort, but which indicates that it is necessary to identify specific hazards in different occupations. The definition of WMSDs in our study is that any pain had occurred during the last 12 months. However, workers who suffered from severe pain may have switched to another job, or into early retirement. Those workers' data may be missed in the study. This may have caused a challenging bias that is known as the healthy worker survivor effect (HWSE); results from less-healthy workers accumulate less occupational exposure because they take more time off work, retire earlier than healthier workers, or switch to a job with lower exposure levels. The HWSE usually leads to a downward bias and underestimation of the effects of

Table 4
Information on latent variables and observed variables.

Latent variable	Item code	Observed variable	Item loading	P value	CR[a]	AVE[b]
Job demand	x_1	Work is required to be done quickly	0.729	<0.001	0.716	0.464
	x_2	Work requires very hard work	0.776	<0.001		
	x_3	Work tasks are considered to be in contradiction with each other	0.508	<0.001		
Social support	x_4	Colleagues have no ability to finish their work	0.650	<0.001	0.886	0.664
	x_5	Colleagues don't care about you	0.862	<0.001		
	x_6	Colleagues are unfriendly to you	0.866	<0.001		
	x_7	Colleagues are unable to help you at work	0.860	<0.001		
Job control	x_8	You are unable to make your own decisions at work	0.705	<0.001	0.845	0.578
	x_9	Your opinions are not influential at work	0.828	<0.001		
	x_{10}	You are unable to give full play to your specialty at work	0.780	<0.001		
	x_{11}	You can't decide how to finish the work	0.722	<0.001		
Postural load	x_{12}	You need to keep your head twisted for long time at work	0.631	<0.001	0.824	0.440
	x_{13}	You need to twist your head frequently at work	0.702	<0.001		
	x_{14}	You need to keep head flexed/extended for long time	0.559	<0.001		
	x_{15}	You need to bend the head forwards/backwards frequently	0.646	<0.001		
	x_{16}	You need to keep your head twisted sideways for long time	0.728	<0.001		
	x_{17}	You need to twist your head sideways frequently	0.701	<0.001		
Cervical musculoskeletal disorders	y_1	Symptom duration	0.875	<0.001	0.929	0.812
	y_2	Symptom frequency	0.936	<0.001		
	y_3	Symptom intensity	0.892	<0.001		

Results of the model fit test revealed that χ^2/df was 3.994 (preferable range < 5.000), *RMSEA* was 0.072(preferable range < 0.080), *CFI* was 0.932 (preferable range > 0.900) and *TLI* was 0.922 (preferable range > 0.90), *WRMR* was 1.819 (preferable range < 1.000). With the exception of *WRMR*, all of these indexes were acceptable.
[a] *CR* was composite reliability (acceptable range > 0.60).
[b] *AVE* was average of variance extracted (acceptable range > 0.36).

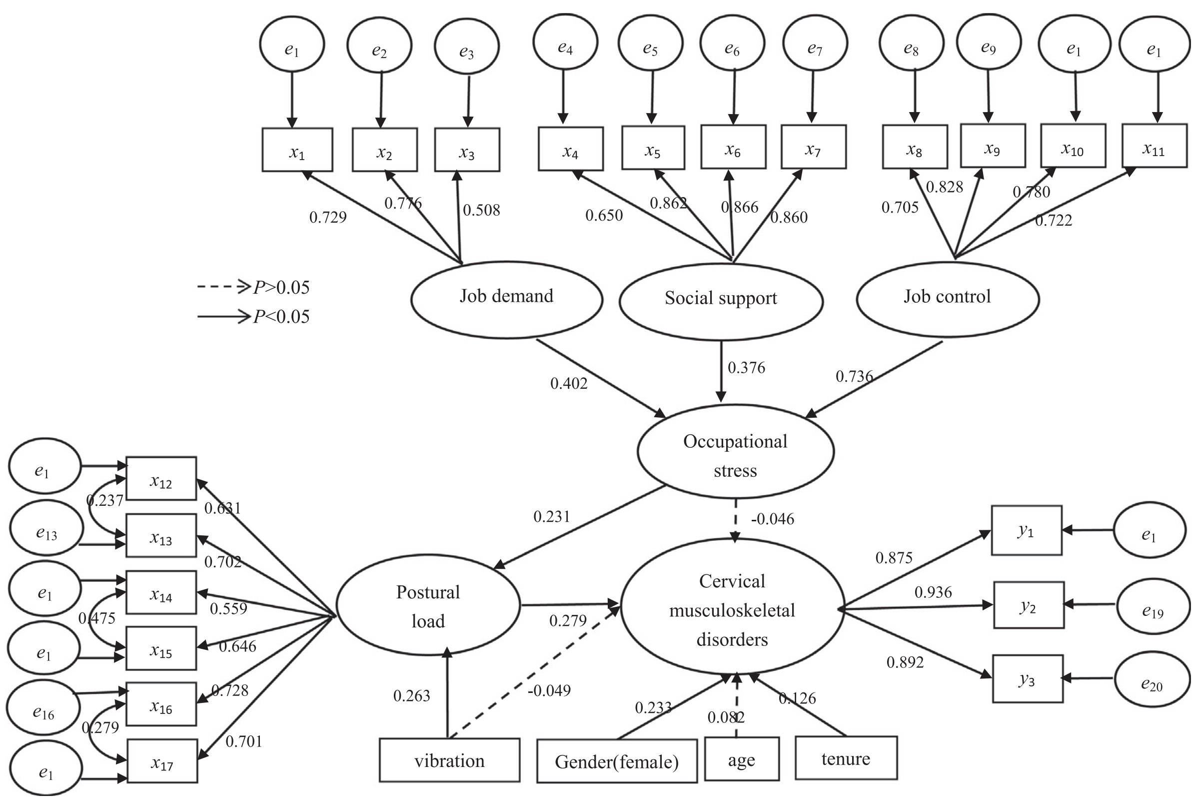

Fig. 1. . Results of structural equation modeling.

possibly harmful occupational exposures. We assume that there may be such bias in our study and we plan to conduct a prospective cohort study to reduce the possible effect of this problem, in the future.

In this etiological network of the cervical MSDs, postural load would directly affect the occurrence of cervical disorders, which was in line with Yuan et al. (2016). Previous research showed that awkward postures may change the physical load level or muscle tolerance level by adjusting the physiologic reaction of the cervical muscles, which in turn will cause tissue damages and lead to the occurrence of MSDs (Keester & Sommerich, 2017). Vibration and work stress were associated with cervical MSDs as well, which was in agreement with other studies (Mirzaei & Mohammadi, 2010; Haukkaa, Ojajärvi, Takala, Viikari-Juntura, & Riihimäki, 2011). Furthermore, the present study indicates that these two factors affected symptoms in indirect ways rather than in direct ways.

Table 5
Effects of exogenous variables on endogenous variables.

Factors	Effects	Postural load	Cervical musculoskeletal disorders
Gender(female)	Total	–	0.233[a]
	Direct	–	0.233[a]
	Indirect	–	–
Age	Total	–	0.082
	Direct	–	0.082
	Indirect	–	–
Job tenure	Total	–	0.126[a]
	Direct	–	0.126[a]
	Indirect	–	–
Work stress	Total	0.231[a]	0.019
	Direct	0.231[a]	−0.046
	Indirect	–	0.064[a]
Postural load	Total	–	0.279[a]
	Direct	–	0.279[a]
	Indirect	–	–
Vibration	Total	0.263[a]	0.024
	Direct	0.263[a]	−0.049
	Indirect	–	0.073[a]

[a] $p < 0.05$, with statistical significance.

According to Bongers et al. (1993), work stress is likely to increase the work pace and bring greater physical load to workers, the combination would greatly increase the risk of MSDs. There may be several mechanisms for the effects of vibration on MSDs. For example, the handgrip force required for controlling the tool under vibration may be increased and the vibration transmitted to the muscles and joints may influence the postures of the workers (Charles, Ma, Burchfiel, & Dong, 2017).

The risk of cervical MSDs was also influenced by the individual factors gender and job tenure, which has also been observed in previous studies (Nag et al., 2010; Warren et al., 2015). Females had a higher prevalence than males. This is commonly seen in working populations (Nordander et al., 2009), and might be explained by several factors related to gender differences, such as the traditional demand on females to perform the household activities that reduces their physical recovery throughout the day, the design of equipment and workstations that were usually developed for males rather than for females, and the differences between males and females in motor control, fatigue response mechanism, and reaction to stress and pain (Côté, 2012). Prevalence of cervical MSDs increased with job tenure since the damages accumulate and the ability to repair damage decreases over time.

Although this is a general ergonomic recommendation, the above described findings very specifically points out that unfavorable postures in the neck should be avoided as much as possible. This includes redesigning workstations and providing assisting equipment (Beek et al., 2017). Employers are also encouraged to arrange work content reasonably to allow for muscular micro-breaks, and pay attention to the psychological burden of employees. The use of vibration tools should be minimized. Other possible interventions can be to offer opportunities for workers to take breaks with exercises to relax the joints and muscles in the neck, which will improve blood circulation (Andersen et al., 2011).

Logistic regression analysis and SEM were used to study the influencing factors of cervical MSDs in this article. Logistic regression computes coefficients at the observed variable level, while SEM studies causes at the comprehensive level and calculate measurement errors in the model, it is also able to analyze mediating effects. Therefore, the SEM is not only a verification of the results of logistic regression, but it also provides us with more valuable information on the functional routes, giving hints for the explanation of the pathological mechanism (Kline, 2011). When it comes to case definition, the SEM takes more information (pain frequency and duration etc.) into consideration, which will be comprehensive and dependable. As for the model fit, several indexes were adopted because there is no specific fit indices reliable in all conditions and current indices available should be used with caution.

The limitations of this study should be acknowledged when interpreting the results. First, self-reporting has its limitations with regard to memory recall, and some variables may be influenced by subjective factors, for example, according to Hansson et al. (2001), subjects with complaints tend to rate their exposures as higher. There is a rapid development of micro technology and cost and time-efficient methods for posture and movement measurements which, to a larger extent, may be used in the future (Jørgensen et al., 2013; Forsman., 2017). In addition, the occupational population mobility was high, and the long-term effect of some occupational hazards remains to be seen. Finally, the causality indicated in cross-sectional studies need to be further verified in cohort or experimental studies (Infante-Rivard & Jacques, 2000; Hennekens, Buring, & Mayrent, 1987). The aforementioned limitations indicated that our results should be interpreted with caution and further research on the mechanism and progress of MSDs were warranted.

5. Conclusion

Work-related musculoskeletal disorders among electronic assembly workers are worth attention. This study's logistic regression results support previous general epidemiological MSD studies, and indicates that individual, physical and psychosocial factors are related to cervical MSDs. The SEM provides a better approximation of the complexity of the actual relationship between risk factors and cervical MSDs. Improving awkward postures may be effective ways to control the influence of occupational stressors or vibration on MSDs.

The results of this study should motivate an improved prevention of MSDs among electronics assembly workers and promote their occupational health. Employers are suggested to pay attention to the psychological burden of employees, to reduce the use of vibration tools to a minimum, and most importantly, unfavorable postures should be avoided as much as possible.

Declaration of Competing Interest

The authors report no conflict of interest.

Acknowledgments

This work was supported by National Key Technologies Research & Development Program of the People's Republic of China (grant number 2016YFC0801700) and Basic Research Foundation of China Academy of Safety Science and Technology (grant number 2017JBKY02).

References

Abdul Rahman, H., Abdul-Mumin, K., & Naing, L. (2017). Psychosocial factors, musculoskeletal disorders and work-related fatigue amongst nurses in brunei: Structural equation model approach. *International Emergency Nursing, S1755599X16302087*. https://doi.org/10.1016/j.ienj.2017.04.001.

Abledu, J. K., & Abledu, G. K. (2012). Multiple logistic regression analysis of predictors of musculoskeletal disorders and disability among bank workers in Kumasi, Ghana. *Journal of Ergonomics, 4*(2), 556–559. https://doi.org/10.4172/2165-7556.1000111.

Andersen, L. L., Saervoll, C. A., Mortensen, O. S., Poulsen, O. M., Hannerz, H., & Zebis, M. K. (2011). Effectiveness of small daily amounts of progressive resistance training for frequent neck/shoulder pain: Randomised controlled trial. *Pain, 152*(2), 440–446. https://doi.org/10.1016/j.pain.2010.11.016.

Arlinghaus, A., Lombardi, D. A., Willetts, J. L., Folkard, S., & Christiani, D. C. (2012). A structural equation modeling approach to fatigue-related risk factors for

occupational injury. *American Journal of Epidemiology, 176*(7), 597–607. https://doi.org/10.1093/aje/kws219.
Bongers, P. M., de Winter, C. R., Kompier, M. A., & Hildebrandt, V. H. (1993). Psychosocial factors at work and musculoskeletal disease. *Scandinavian Journal of Work Environment & Health, 19*(5), 297–312. https://doi.org/10.5271/sjweh.1470.
Brink, Y., Louw, Q., Grimmer, K., & Jordaan, E. (2015). The relationship between sitting posture and seated-related upper quadrant musculoskeletal pain in computing South African adolescents: A prospective study. *Manual Therapy, 20*(6), 820–826. https://doi.org/10.1016/j.math.2015.03.015.
Charles, L. E., Ma, C. C., Burchfiel, C. M., & Dong, R. G. (2017). Vibration and ergonomic exposures associated with musculoskeletal disorders of the shoulder and neck. *Safety & Health at Work., 9*(2), 125–132. https://doi.org/10.1016/j.shaw.2017.10.003.
Cheng, H. Y. K., Cheng, C. Y., & Ju, Y. Y. (2013). Work-related musculoskeletal disorders and ergonomic risk factors in early intervention educators. *Applied Ergonomics, 44*(1), 134–141. https://doi.org/10.1016/j.apergo.2012.06.004.
Cho, T. S., Jeon, W. J., Lee, J. G., Seok, J. M., & Cho, J. H. (2014). Factors affecting the musculoskeletal symptoms of Korean police officers. *Journal of Physical Therapy Science, 26*(6), 925–930. https://doi.org/10.1589/jpts.26.925.
Côté, J. N. (2012). A critical review on physical factors and functional characteristics that may explain a sex/gender difference in work-related neck/shoulder disorders. *Ergonomics, 55*(2), 173–182. https://doi.org/10.1080/00140139.2011.586061.
Crawford, J. O. (2007). The Nordic musculoskeletal questionnaire. *Occupational Medicine, 57*(4), 300–301. https://doi.org/10.1093/occmed/kqm036.
Da, C. B., & Vieira, E. R. (2010). Risk factors for work-related musculoskeletal disorders: A systematic review of recent longitudinal studies. *American Journal of Industrial Medicine, 53*(3), 285–323. https://doi.org/10.1002/ajim.20750.
Forsman. (2017). The search for practical reliable risk assessment methods–a key for successful interventions against work-related musculoskeletal disorders. *Agronomy Research, 15*(3), 680–686.
Hansson, G. A., Balogh, I., Byström, J. U., Ohlsson, K., Nordander, C., & Asterland, P. (2001). Questionnaire versus direct technical measurements in assessing postures and movements of the head, upper back, arms and hands. *Scandinavian Journal of Work Environment & Health, 27*(1), 30–40. https://doi.org/10.5271/sjweh.584.
Haukkaa, E., Ojajärvi, A., Takala, E. P., Viikari-Juntura, E., & Riihimäki, H. (2011). Mental stress and psychosocial factors at work in relation to multiple-site musculoskeletal pain: A longitudinal study of kitchen workers. *European Journal of Pain, 15*(4), 432–438. https://doi.org/10.1016/j.ejpain.2010.09.005.
Hennekens, C. H., Buring, J. E. Mayrent, S. L. (1987). Epidemiology in medicine. Little, Brown.
Hignett, S., & Mcatamney, L. (2000). Rapid entire body assessment (reba). *Applied Ergonomics, 31*(2), 201–205. https://doi.org/10.1016/S0003-6870(99)00039-3.
Huang, G. D., Feuerstein, M., & Sauter, S. L. (2002). Occupational stress and work-related upper extremity disorders: Concepts and models. *American Journal of Industrial Medicine, 41*(5), 298. https://doi.org/10.1002/ajim.10045.
Infante-Rivard, C., & Jacques, L. (2000). Empirical study of parental recall bias. *American Journal of Epidemiology, 152*(5), 480–486.
Jørgensen, M. B., Korshøj, M., Lagersted-Olsen, J., Villumsen, M., Mortensen, O. S., & Skotte, J. (2013). Physical activities at work and risk of musculoskeletal pain and its consequences: Protocol for a study with objective field measures among blue-collar workers 213-213. *BMC Musculoskeletal Disorders, 14*(1). https://doi.org/10.1186/1471-2474-14-213.
Karadağ, E., Erzen, E., Duru, P., Bostan, N., Çulha, İ. L. K. A. Y., & Babadağ, B. (2015). Determinants of phubbing, which is the sum of many virtual addictions: A structural equation model. *Journal of Behavioral Addictions, 4*(2), 60–74. https://doi.org/10.1556/2006.4.2015.005.
Karasek, R., Brisson, C., Kawakami, N., Houtman, I., Bongers, P., & Amick, B. (1998). The job content questionnaire (jcq): An instrument for internationally comparative assessments of psychosocial job characteristics. *Journal of Occupational Health Psychology, 3*(4), 322–355. https://doi.org/10.1037/1076-8998.3.4.322.
Keester, D. L., & Sommerich, C. M. (2017). Investigation of musculoskeletal discomfort, work postures, and muscle activation among practicing tattoo artists. *Applied Ergonomics, 58*, 137–143. https://doi.org/10.1016/j.apergo.2016.06.006.
Kline, R. B. (2011). *Principles and practice of structural equation modeling* (3rd edn). New York: Guilford Press.
Liu, L., Chen, S. G., Tang, S. C., Wang, S., Li Hua, H. E., & Guo, Z. H. (2015). How work organization affects the prevalence of wmsds: A case-control study. *Biomedical and Environmental Science, 28*(9), 627–633. https://doi.org/10.3967/bes2015.088.
Long, M. H., Johnston, V., & Bogossian, F. (2012). Work-related upper quadrant musculoskeletal disorders in midwives, nurses and physicians: A systematic review of risk factors and functional consequences. *Applied Ergonomics, 43*(3), 455–467. https://doi.org/10.1016/j.apergo.2011.07.002.
Mirzaei, R., & Mohammadi, M. (2010). Survey of vibration exposure and musculoskeletal disorder of Zahedan city tractor drivers by Nordics questionnaire. *International Journal of Occupational Hygiene, 2*(2), 51–55.
Murray, C. J. L., Barber, R. M., Foreman, K. J., Ozgoren, A. A., Abd-Allah, F., Abera, S. F., et al. (2015). Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990–2013: Quantifying the epidemiological transition. *The Lancet, 386*(10009), 2145–2191. https://doi.org/10.1016/S0140-6736(15)61340-X.
Nag, A., Vyas, H., & Nag, P. K. (2010). Gender differences, work stressors and musculoskeletal disorders in weaving industries. *Industrial Health, 48*(3), 339–348. https://doi.org/10.2486/indhealth.48.339.
Nordander, C1, Ohlsson, K., Balogh, I., Hansson, G. A., Axmon, A., Persson, R., Skerfving, S. (2009) Risk of musculoskeletal disorders among females and males in repetitive/constrained work. Ergonomics, 52(10), 12261239. DOI: 10.1007/s00420-007-0286-9.
Park, J. S. (2009). *A study on actual conditions of muscular strength in Korean electronics industry., 11*(3), 27–32.
Roquelaure, Y., Ha, C., Rouillon, C., Fouquet, N., Leclerc, A., & Descatha, A. (2009). Risk factors for upper-extremity musculoskeletal disorders in the working population. *Arthritis Care & Research, 61*(10), 1425–1434. https://doi.org/10.1002/art.24740.
Wang, J., Cui, Y., He, L., Xu, X., Yuan, Z., & Jin, X. (2017). Work-related musculoskeletal disorders and risk factors among chinese medical staff of obstetrics and gynecology. *International Journal of Environmental Research & Public Health, 14*(6), 562. https://doi.org/10.3390/ijerph14060562.
Warren, N., Dussetschleger, J., Punnett, L., & Cherniack, M. G. (2015). Musculoskeletal disorder symptoms in correction officers: Why do they increase rapidly with job tenure? *Human Factors, 57*(2), 262–275. https://doi.org/10.1177/0018720814547569.
Yuan, Z. W., Cui, Y., Xiang-Rong, X. V., Zhi-Min, L. I., Cao, Y., & Li-Hua, H. E. (2016). Present incidence of wmsds and postural load in medical staff of obstetrics and gynecology. *Chinese Journal of Industrial Medicine, 29*(4), 259–262.

Nazhakaiti Maimaiti, Master degree Candidate at Department of Occupational and Environmental Health, School of Public Health, Peking University. She has been engaged in the State 13th Five-year Scientific and Technological Support Projects.

Jingjing Wang, Master degree Candidate at Department of Occupational and Environmental Health, School of Public Health, Peking University. She has been engaged in the State 13th Five-year Scientific and Technological Support Projects. She has published 5 articles in domestic and foreign journals with 2 articles covered in SCI.

Xianning Jin, Master degree Candidate at Department of Occupational and Environmental Health, School of Public Health, Peking University. He has been engaged in the State 13th Five-year Scientific and Technological Support Projects.

Shijuan Wang, Master degree Candidate at Department of Occupational and Environmental Health, School of Public Health, Peking University. She has been engaged in the State 13th Five-year Scientific and Technological Support Projects.

Dongliang Qin, Master degree Candidate at Department of Occupational and Environmental Health, School of Public Health, Peking University. He has been engaged in the State 13th Five-year Scientific and Technological Support Projects.

He Li-hua, M.D. of Peking University, professor and doctoral supervisor at Department of Occupational and Environmental Health, School of Public Health, Peking University. She majors in ergonomics and occupational hazards of physical factors and has been engaged in teaching and research work on occupational health over the years. She has made major contributions to several National Natural Science Foundation Projects as well as the State Five-year Scientific and Technological Support Projects. She has published more than 70 articles in domestic and foreign journals with 20 articles covered in SCI.

Fujiang Wang, Master degree Candidate at Department of Occupational and Environmental Health, School of Public Health, Peking University. He has been engaged in the State 13th Five-year Scientific and Technological Support Projects.

Zhongbin Zhang, D.E., professorate senior engineer at China Academy of Safety Science and Technology.

Mikael Forsman, Professor at Unit of Occupational Medicine, IMM Institute of Environmental Medicine, Karolinska Institute. At the same time, he is professor and head of Division, Division of Ergonomics, CBH-School, KTH.

Liyun Yang, PhD Student at Unit of Ergonomics, School of Technology and Health, KTH, Royal Institute of Technology.

Qiuyue Yang, researcher at National Research Center for Occupational Safety and Health, State Administration of Work Safety. She graduated from Peking university and had been engaged in the State 12th Five-year Scientific and Technological Support Projects.

Haijiao Wang, researcher at National Research Center for Occupational Safety and Health, State Administration of Work Safety.