SH@W Safety and Health at Work www.e-shaw.org

Safety Health Work 2010;1:124-133 | DOI:10.5491/SHAW.2010.1.2.124

pISSN : 2093-7911
eISSN : 2093-7997

Original Article

Risk Factors of Work-related Upper Extremity Musculoskeletal Disorders in Male Shipyard Workers: Structural Equation Model Analysis

Byung-Chan PARK[1], Hae-Kwan CHEONG[2], Eun-A KIM[3] and Soo Geun KIM[4]

[1]Department of Preventive Medicine, Dongguk University School of Medicine, Gyeongju
[2]Department of Social and Preventive Medicine, Sungkyunkwan University School of Medicine, Suwon
[3]Occupational Safety and Health Research Institute, Korea Occupational Safety and Health Agency, Incheon
[4]Department of Occupational Medicine, Kangbuk Samsung Hospital, Sungkyunkwan University School of Medicine, Seoul, Korea

Objectives: This study was conducted to develop a model describing the interaction between lifestyle, job, and postural factors and parts of the upper extremities in shipyard workers.
Methods: A questionnaire survey was given to 2,140 workers at a shipyard in Ulsan City. The questionnaire consisted of questions regarding the subjects' general characteristics, lifestyle, tenure, physical burden, job control, posture and musculoskeletal symptoms. The overall relationship between variables was analyzed by a structural equation model (SEM).
Results: The positive rate of upper extremity musculoskeletal symptoms increased in employees who worked longer hours, had severe physical burden, and did not have any control over their job. Work with a more frequent unstable posture and for longer hours was also associated with an increased positive rate of musculoskeletal symptoms. Multiple logistic regression analysis showed that unstable posture and physical burden were closely related to the positive rate of musculoskeletal symptoms after controlling for age, smoking, drinking, exercise, tenure, and job control. In SEM analysis, work-related musculoskeletal disease was influenced directly and indirectly by physical and job stress factors, lifestyle, age, and tenure ($p < 0.05$). The strongest correlations were found between physical factors and work-related musculoskeletal disease.
Conclusion: The model in this study provides a better approximation of the complexity of the actual relationship between risk factors and work-related musculoskeletal disorders. Among the variables evaluated in this study, physical factors (work posture) had the strongest association with musculoskeletal disorders.

Key Words: Work-related musculoskeletal disorders, Risk factors, Shipyard, Structural equation model

Introduction

Work-related musculoskeletal disorders (WRMSD) are one of the most common work-related diseases in developed countries [1]. Korea has seen a marked increase in WRMSDs since the 1990s, with increased use of computer terminals, repetitive work due to automation of the production process, increased work stress, and aging of the working population [2]. WRMSD has been reported by employees from a wide variety of jobs, including video display terminal workers [3,4], packing workers [5], semiconductor workers [6], electronics assembly workers [7], hair shop workers [8], and classical musicians [9].

Development of WRMSD is known to be an accumula-

Received: June 23, 2010, **Accepted:** October 11, 2010
Correspondence to: Hae-Kwan CHEONG
Department of Social and Preventive Medicine
Sungkyunkwan University School of Medicine
300, Cheoncheon-dong, Jangan-gu, Suwon 440-746, Korea
Tel: +82-31-299-6300, **Fax:** +82-31-299-6299
E-mail: hkcheong@skku.edu

tion of micro injuries as a result of repetitive motion or physical stress. During the development and aggravation of such disorders, various factors including stress-related and work-related factors are engaged. Socio-psychological, demographic, and lifestyle factors play a significant role in the effects of physical stressors [1,10].

Analysis of the factors related to development and progression of WRMSD is important in its prevention and management in the workplace. Generalized linear model analyses, which are commonly used to understand risk factors of WRMSD, are not effective when several intermediate variables and effect modifiers are present in the model, and therefore cannot provide a comprehensive assessment of the complex interrelationship between risk factors. Covariance structural analysis, or the structural equation model (SEM), developed in the 1980s for use in marketing, is a useful analytic tool for evaluation of complex causal relationships in social sciences [11]. SEM focuses on the covariance calculated from various sets of variables, rather than identifying a regression line from the variables [12]. SEM has been adopted for the formulation of job stress models [13-16]. In addition, SEM is increasingly used for analysis of complex interrelationships between risk factors involved in development of musculoskeletal disorders [17-19]. However, use of SEM in the study of WRMSD risk factors is very rare in Korea.

In this study, we applied SEM to obtain an integrated assessment of the complex associations between various musculoskeletal disorders and their risk factors.

Materials and Methods

A questionnaire survey was conducted on 2,214 workers who agreed to participate in the study out of 10,000 production process workers in a shipyard on the southeast coast of Korea. After excluding 29 female workers, 20 workers that had been employed for less than a year, and those with an incomplete response to the questionnaire, 2,140 male workers were finally selected for the study population. Mean age of the subjects was 43.3 years (SD 24.5 years) and more than 75% of respondents were over the age of 40 (Table 1). Most subjects were married (2,026, 94.7%), 82.2% (1,759) were smokers, and 82.2% (1,759) were drinkers. Only 25.3% (541) exercised regularly. Mean length of employment at the shipyard was 16.8 (SD 6.4) years, and more than 85% of employees had worked at this company for more than 10 years. This study was approved by the Institutional Review Board of Dongguk University Gyeongju Hospital, and informed consent was obtained from each worker.

Table 1. General characteristics of subjects (N = 2,140)

Characteristics		Number of subjects	%
Age (yrs)	20-29	110	5.1
	30-39	416	19.4
	40-49	1,123	52.5
	50-	491	22.9
Smoking	Non-smoker*	935	43.7
	Smoker	1,205	56.3
Drinking	Non-drinker†	381	17.8
	Drinker	1,759	82.2
Marital status	Unmarried	114	5.3
	Married	2,026	94.7
Regular physical exercise	Yes‡	541	25.3
	No	1,599	74.7
Tenure (yrs)	1-9	314	14.7
	10-19	1,230	57.5
	20-	596	27.9

*Non-smoker included in ex-smoker.
†Non-drinker included in ex-drinker.
‡Yes: > 3 times/week, > 40 minutes/one time.

Questionnaire

The questionnaire consisted of a series of self-administered questions regarding subjective symptoms of work-related upper extremity musculoskeletal disorders (WRUEMSD) experienced in the previous year and risk factors including lifestyle, psychological, physical, and constitutional factors.

Selection of variables

To select variables associated with musculoskeletal symptoms, univariate analyses were conducted setting musculoskeletal symptoms as a dependent variable. Continuous variables were converted to the ordinal scale according to distribution to make the model stable and ensure biological plausibility. Thus, age and tenure were categorized by 10-year intervals, and postural stability was divided into four categories: 0-3, 4-7, 8-11, and 12-15. Physical burden and job control were categorized into three scales. For risk factors related to postural stability, five indices were adopted among the scales developed by Lee and Yim (1998) [20], modified from American National Standards Institute (ANSI) Z-365 [21] and the Occupational Safety and Health Administration (OSHA) Draft Ergonomics Standard [22].

Table 2. Criteria of musculoskeletal disorders based on symptom questionnaire

Category	Symptom score				
	1	2	3	4	5
Duration	1 hr	< 1 day	< 1 week	< 1 month	1 month
Frequency	Rare	1/2-3 months	1/month	1/week	Every day
Severity	None	Mild	Moderate	Severe	Very severe

Source, Kim SG et al. (1998).

Each scale assigns a score between zero and three according to the hours spent for the specific posture in a day, and the scales are added to give a total score between 0 and 15. During regression analysis, the total score was categorized into four ranges - 0-3, 4-7, 8-11, and 12-15 - and then used as an independent variable. Total score was used in the SEM analysis.

Criteria of work related musculoskeletal disease

Subjective symptoms of WRUEMSD were composed of four body parts: the hand, wrist, and fingers; arm and elbow; shoulder; and neck. WRUEMSD was defined according to criteria developed by one of the authors (KSG). Specifically, the score was calculated based on duration, frequency, and severity of the symptoms multiplied by the symptom score (Table 2). These criteria were validated in a previous study [23].

Hypothesis

To conduct SEM analysis, a hypothetical structure was established based on the relationship of variables. Physical burden [24] and job stress factors [25] are major pathways used to develop WRUEMSD. Other factors including lifestyle [26] and demographic factors [27] will also have an effect on the WRUEMSD through an indirect pathway by influencing physical and job stress factors to aggravate or diminish a WRUEMSD.

Statistical analysis

Descriptive statistics and multiple regression analysis

After examining the distribution of each variable to determine its normality, univariate analyses were conducted to assess the effect of each variable on WRUEMSD symptoms. Chi-squared for trend test and chi-square test were used to analyze categorical variables. To adjust for the effect of confounders, multiple logistic regressions were conducted.

Structural equation model

SEM was established in two stages. First, latent variables were constructed through the Pearson correlation and factor analyses to represent the different categories of risk factors. Next, a diagram of the integrated pathway was formulated to assess relationships among groups of risk factors [28].

The latent variable for WRUEMSD was composed of four groups: physical, job stress, lifestyle, and demographic factors [29]. Multivariate normality testing showed that the multivariate normal distribution index was 13.5, and the distribution was markedly skewed from normal. Therefore, we adopted an asymptotically distribution-free method instead of using the maximum likelihood method for analysis [30].

The integrated structural model was formulated by comparing alternative assumptions regarding associations between each pair of variables in the causal network and involving the of risk factor groups and WRUEMSD symptoms. Demographic factors were adjusted because they are known predictors of WRUEMSD. Because the number of subjects was greater than 200, the fitness of the model was assessed using indices less affected by sample size such as χ^2/df, parsimony normed fit index (PNFI), Tucker-Lewis Index (TLI), root mean square error of approximation (RMSEA), and normed fit index (NFI). Our final model was determined based on theoretical feasibility and goodness of fit. With the final model, direct and indirect effects of the four groups of risk factors on WRUEMSD symptoms were estimated.

We used SPSS for Windows ver 10.1 (SPSS Inc., Chicago, IL, USA) for univariate and multivariate analyses and AMOS 4.0 (SPSS Inc., Chicago, IL, USA) for SEM analysis.

Results

Positive rate of symptoms by body parts

As shown in Table 3, the positive rate of WRUEMSD symptoms by body parts was found to be highest in the shoulder (37.2%) and lowest in the hand and wrist (22.5%).

Factors related to the symptoms of WRUEMSD

Univariate analyses

As shown in Table 3, complaints of symptoms by workers

Table 3. Positive rate of musculoskeletal symptoms by general- and job characteristics, and posture stability scale of subjects (n = 2,140)

		No. of subjects	Hand/wrist (%)	Arm/elbow (%)	Shoulder (%)	Neck (%)
Total		2,140	481 (22.5)	597 (27.5)	796 (37.2)	511 (23.9)
Age	20-29	110	17 (15.5)*	11 (10.0)†	23 (20.9)†	17 (15.5)†
	30-39	416	85 (20.4)	75 (18.0)	131 (31.5)	93 (22.4)
	40-49	1,123	245 (21.8)	330 (29.4)	419 (37.3)	265 (23.6)
	50-	491	134 (27.3)	181 (36.9)	223 (45.4)	136 (27.7)
Smoking	Non-smoker	935	188 (20.1)*	253 (27.1)	339 (36.3)	210 (22.5)
	Smoker	1,205	292 (24.3)	344 (28.5)	457 (37.9)	301 (25.0)
Drinking	Non-drinker	1,759	71 (18.6)*	95 (24.9)	137 (36.0)	81 (21.3)
	Drinker	381	410 (23.3)	502 (28.5)	659 (37.5)	430 (24.4)
Exercise	Yes	541	134 (24.8)	157 (29.0)	206 (38.1)	137 (25.3)
	No	1,599	347 (21.7)	440 (27.5)	590 (36.9)	374 (23.4)
Tenure (yrs)	1-9	314	60 (19.1)	49 (15.6)†	85 (27.1)†	61 (19.4)
	10-19	1,230	279 (22.7)	352 (28.6)	471 (38.3)	309 (25.1)
	20-	596	142 (23.8)	196 (32.9)	240 (40.3)	141 (23.7)
Physical burden	None to moderate	443	35 (7.9)†	43 (9.7)†	73 (16.5)†	41 (9.3)†
	Hard	1,005	207 (20.6)	262 (26.1)	350 (34.8)	217 (21.6)
	Very hard	692	239 (34.5)	292 (42.2)	373 (53.9)	253 (36.6)
Job control	High	305	58 (16.6)†	71 (20.3)†	105 (30.0)†	54 (15.4)†
	Moderate	1,186	246 (20.7)	302 (25.5)	419 (35.3)	267 (22.5)
	Low	604	177 (29.3)	224 (37.1)	272 (45.0)	190 (31.5)
Posture stability scale	0-3	633	59 (9.3)†	81 (12.8)†	141 (22.3)†	79 (12.5)†
	4-7	712	154 (21.6)	184 (25.8)	248 (34.8)	150 (21.1)
	8-11	479	142 (29.6)	176 (36.7)	222 (46.3)	145 (30.3)
	12-15	316	126 (39.9)	156 (49.4)	185 (58.5)	137 (43.4)

Chi-square test: smoking, drinking, exercise.
Chi-square test for trend: age, tenure, physical burden, job control.
*$p < 0.05$ by chi-square test or chi-square test for trend, comparison between subgroups.
†$p < 0.01$ by chi-square test or chi-square test for trend, comparison between subgroups.

increased with age ($p < 0.05$). Smokers and drinkers had higher symptom complaints regarding the hand and wrist ($p < 0.05$). There was no significant difference in symptoms between exercising and non-exercising workers ($p > 0.05$).

Symptoms were more prevalent among workers with a longer duration of work in all body parts ($p < 0.05$). Physical burden had a strong positive relationship with WRUEMSD symptoms ($p < 0.05$). However, workers with higher job control had fewer complaints of symptoms ($p < 0.05$).

Symptoms were more prevalent among individuals with a higher score in the posture stability scale for all body parts ($p < 0.01$) (Table 3).

Multivariate analyses

Logistic regression analysis revealed that the risk of symptoms in the arm and elbow increased with age (OR = 2.74 and 4.15 in the 40-49 and 50+ age groups, respectively). In addition, the risk of symptoms associated with the arm and elbow were higher in the 50+ age group (OR = 2.45, 95% CI 1.29-4.67) than in other age groups. However, no such findings were ob-

Table 4. Odds ratios of factors related to musculoskeletal symptoms by multiple logistic regression (n = 2,140)

Factors		Odds ratio (95% confidence interval)			
		Hand/wrist	Arm/elbow	Shoulder	Neck
Age (20-29)	30-39	1.35 (0.72-2.56)	1.74 (0.83-3.64)	1.49 (0.84-2.64)	1.40 (0.75-2.65)
	40-49	1.27 (0.64-2.53)	2.74 (1.26-5.94)	1.58 (0.86-2.01)	1.27 (0.65-2.51)
	50-	1.85 (0.90-3.81)	4.15 (1.86-9.25)	2.45 (1.29-4.67)	1.77 (0.87-3.62)
Tenure (1-9)	10-19	1.15 (0.75-1.76)	1.39 (0.89-2.16)	1.38 (0.95-2.02)	1.31 (0.86-1.99)
	20-	1.16 (0.71-1.91)	1.51 (0.92-2.47)	1.35 (0.87-2.09)	1.15 (0.71-1.86)
Smoking (Non-smoker)	Smoker	1.27 (1.01-1.58)	1.09 (0.86-1.35)	1.08 (0.89-1.31)	1.15 (0.91-1.40)
Drinking (Non-drinker)	Drinker	1.23 (0.91-1.67)	1.19 (0.90-1.57)	1.04 (0.80-1.33)	1.12 (0.84-1.49)
Exercise (Yes)	No	0.80 (0.62-1.02)	0.91 (0.72-1.15)	0.93 (0.75-1.16)	0.87 (0.68-1.11)
Physical burden (None to moderate)	Hard	2.19 (1.48-3.24)	2.28 (1.59-3.26)	2.08 (1.55-2.80)	1.97 (1.36-2.84)
	Very hard	3.83 (2.55-5.75)	4.04 (2.77-5.89)	4.09 (2.97-5.62)	3.48 (2.37-5.10)
Job control (High)	Moderate	1.09 (0.78-1.52)	1.10 (0.80-1.51)	1.05 (0.79-1.38)	1.37 (0.98-1.91)
	Low	1.23 (0.86-1.76)	1.38 (0.98-1.94)	1.09 (0.80-1.49)	1.53 (1.07-2.20)
Posture stability scale (0-3)	4-7	2.37 (1.70-3.29)	2.09 (1.55-2.82)	1.63 (1.27-2.11)	1.62 (1.19-2.19)
	8-11	3.10 (2.20-4.39)	3.03 (2.21-4.14)	2.28 (1.73-3.00)	2.28 (1.66-3.14)
	12-15	4.46 (3.09-6.43)	4.63 (3.29-6.51)	3.46 (2.54-4.72)	3.75 (2.66-5.28)

served for the hand and wrist and neck (Table 4). Smoking was related to a slightly increased risk of musculoskeletal symptoms in the hand and wrist (OR = 1.27, 95% CI 1.01-1.91). However, drinking and exercise were not significant predictors of musculoskeletal symptoms. Work duration was not significant after controlling for age. Job control was only a significant predictor of musculoskeletal symptoms in the neck in those with the lowest control (OR = 1.53, 95% CI 1.07-2.20). Posture stability was a highly significant predictor of musculoskeletal symptoms in all body parts with a strong dose-response relationship (OR = 4.46, 4.63, 3.46, and 3.75 in the posture stability scale 12-15 group in the hand and wrist, arm and elbow, shoulder, and neck, respectively).

Correlation and factor analyses

Pearson correlation analysis was conducted to assess the intensity and direction of the association between observed variables (Table 5). Exploratory factor analysis was conducted on observed variables. Principal factors extraction was selected based on this analysis. Because observed variables were expected to be interrelated, promax rotation was used for analysis [31]. This resulted in grouping of the variables into five latent categories: demographic factors (F1: age and tenure), lifestyle (F2: smoking, drinking, and exercise), job stress factors (F3: physical burden and job control), physical factors (F4: lift pull, arm folding, neck posture, arm up, and wrist folding), and WRUEMSD (F5: symptoms of hand and wrist, arm and elbow, shoulder and neck) (Table 6).

Structural equation model

The model was formulated based on factor analysis and logistic regression. The effects of exogenous latent variables on endogenous latent variables are shown in Table 7. Age had a direct effect on lifestyle and an indirect effect on physical factors and symptoms of WRUEMSD. Work duration had a direct effect on WRUEMSD symptoms. Lifestyle had a direct effect on job stress factors, but this effect was not significant. In addition, lifestyle had a positive direct and indirect effect on physical factors and a positive indirect effect on WRUEMSD symptoms. Job stress factors had a direct positive effect on physical factors and a positive direct and indirect effect on WRUEMSD symptoms. Physical factors had a positive direct effect on WRUEMSD symptoms.

Direct effects between endogenous variables and path coefficients calculated from the structural equation are depicted in a path diagram (Fig. 1). Path coefficients from the four latent variables to the measured variables were all significant ($p < 0.05$). Testing of the fit for the model revealed that χ^2/df was

Table 5. Correlation coefficient matrix for demographic, physical burden, job control, posture, and musculoskeletal symptoms

	Age	Tenure	Smoking	Drinking	Exercise	Physical burden	Job control	Lift pull	Arm fold	Neck posture	Arm up	Wrist fold	Symptom of hand/ wrist	Symptom of arm/ elbow	Symptom of shoulder
Tenure	0.664*														
Smoking	-0.066*	-0.115*													
Drinking	-0.087*	-0.081*	0.164*												
Exercise	-0.049*	-0.043*	0.069*	0.008											
Physical burden	0.033*	-0.005	0.011	-0.008	0.024										
Job control	0.014	-0.008	0.009	0.023	0.026	0.325*									
Lift pull	0.081*	0.058*	0.016	0.047*	0.015	0.305*	0.122*								
Arm fold	0.008	-0.029	0.026	0.069*	0.053*	0.335*	0.135*	0.425*							
Neck posture	-0.017	-0.044*	0.036	0.069*	0.008	0.175*	0.082*	0.196*	0.334*						
Arm up	0.007	-0.035	0.043*	0.042	0.016	0.214*	0.088*	0.210*	0.334*	0.609*					
Wrist fold	-0.007	-0.028	0.014	0.093*	0.005	0.191*	0.097*	0.211*	0.384*	0.674*	0.635*				
Symptom of hand/wrist	0.021	-0.019	0.076*	0.073*	0.005	0.285*	0.105*	0.233*	0.334*	0.208*	0.200*	0.247*			
Symptom of arm/elbow	0.140*	0.086*	0.040	0.046*	0.014	0.312*	0.156*	0.273*	0.375*	0.198*	0.214*	0.231*	0.531*		
Symptom of shoulder	0.092*	0.052*	0.043*	0.030	0.011	0.324*	0.134*	0.256*	0.294*	0.211*	0.203*	0.219*	0.479*	0.512*	
Symptom of neck	-0.014	-0.041	0.072*	0.054	-0.007	0.262*	0.129*	0.187*	0.256*	0.270*	0.195*	0.236*	0.498*	0.461*	0.618*

*$p < 0.05$.

Table 6. Factor loadings, communalities (h^2) for principal factors extraction, and promax rotation

Variable	Factors					h^2
	F1	F2	F3	F4	F5	
Age	**0.92**	0.01	0.00	0.00	0.01	0.84
Tenure	**0.92**	-0.02	-0.03	-0.02	-0.03	0.84
Smoking	-0.03	**0.74**	-0.09	-0.04	0.09	0.56
Drinking	0.01	**0.70**	-0.06	0.05	0.00	0.50
Exercise	-0.01	**0.35**	0.34	-0.11	-0.20	0.22
Physical burden	-0.04	-0.10	**0.70**	-0.02	0.15	0.57
Job control	-0.07	-0.06	**0.74**	-0.12	-0.11	0.45
Lift pull	0.10	0.06	0.57	**0.10**	0.04	0.42
Arm folding	-0.01	0.06	0.49	**0.31**	0.13	0.50
Neck posture	-0.02	-0.01	-0.07	**0.88**	0.00	0.74
Arm up	0.00	-0.02	0.02	**0.86**	-0.06	0.71
Wrist folding	0.00	0.00	-0.03	**0.89**	-0.01	0.77
Symptom of hand and wrist	-0.05	0.06	0.01	-0.01	**0.77**	0.60
Symptom of arm and elbow	0.14	0.03	0.12	0.17	**0.69**	0.60
Symptom of shoulder	0.02	-0.03	0.00	-0.05	**0.85**	0.69
Symptom of neck	-0.09	-0.02	-0.11	0.00	**0.87**	0.68

F1: demographic factors, F2: lifestyle, F3: psychological factors, F4: physical factors, F5: work-related musculoskeletal disorders.

3.12, the overall fit index, NFI, was 0.924 (preferable range 0.9-0.95), the RMSEA was 0.135 (preferable range < 1.0) and PNFI was 0.680 (preferable range 0.6-0.8). With the exception of RMSEA, all of these values were acceptable.

Discussion

In this study, we demonstrated the complex interrelationship between physical factors, job stress, and lifestyle factors on WRUEMSD symptoms of using a structural equation model. Physical factors had the greatest direct effect on WRUEMSD symptoms, while job stress factors had both direct and indirect effects that occurred via physical factors. Lifestyle only had an indirect effect on symptoms.

Diagnosis of WRUEMSD is often controversial because of lack of standardized diagnostic criteria, on which WRUEMSD prevalence is dependent. In mass surveys, subjective symptoms are usually adopted for case definitions because of their applicability. Although objective studies are preferable, they are not usually applicable in mass surveys. In the present study, we adopted diagnostic criteria developed by the authors, which have been validated for the same study population [23,32]. When compared with NIOSH criteria, the positive rate of WRUEMSD was up to 20% lower for the same study population, but there were a few false negative cases and high agreement with those diagnosed using NIOSH criteria (kappa = 0.62) [23].

The positive rates of WRUEMSD in this study were 22.5% and 37.5% depending on the body parts, which is comparable to rates found in shipyard workers in Greece, which ranged from 15% to 37% [33]. When compared to other jobs, these values were lower than those of watch and auto part assembly workers [34].

Many studies have been conducted to evaluate risk factors associated with WRMSD, including individual, socio-psychological, and ergonomic factors [35-37]. In the present study, we evaluated risk factors of each of these categories. Ergonomic factors, job characteristics, duration of work, and age were found to be significant from univariate analysis; however, after controlling for confounders, physical burden and ergonomic factors were the main determinants of symptoms. Furthermore, formulation of an association between these risk factor groups could not be obtained from multiple regression analysis.

Table 7. Effect of exogenous latent variables for endogenous latent variables

Latent variable	Effect	Lifestyle	Job stress factors	Physical factors	WRUEMSD
Age	Total	-0.169	-0.005	-0.035	-0.020
	Direct	-0.169	-	-	-
	Indirect	-	-0.005	-0.035	-0.020
Tenure	Total	-	-	-	0.096
	Direct	-	-	-	0.096
	Indirect	-	-	-	-
Lifestyle	Total	-	0.032	0.206	0.121
	Direct	-	0.032	0.188	-
	Indirect	-	-	0.018	0.121
Job stress factors	Total	-	-	0.533	0.480
	Direct	-	-	0.533	0.171
	Indirect	-	-	-	0.309
Physical factors	Total	-	-	-	0.559
	Direct	-	-	-	0.559
	Indirect	-	-	-	-

WRUEMSD: work-related upper extremity musculoskeletal disorders.

Additionally, the results of SEM analysis were not much different from those of univariate analysis, but lifestyle factors that were not found to be significant upon univariate and multiple analyses, such as smoking, drinking, and exercise, were significant upon SEM analysis. In addition, age and duration of work, which were not significant in multiple logistic regression analysis, were significant in SEM.

Few studies have been conducted to analyze risk factors of WRMSD using SEM. However, there have been some reports evaluating the relationship between musculoskeletal symptoms, work load and socio-psychological factors among truck drivers [17], nurses [18], and auto part assembly workers [19]. Furthermore, a study of risk factors in cargo truck drivers did not enable identification of a model to explain the relationship between job stress and musculoskeletal symptoms, stressing the need for simultaneous inclusion of both physical factors and socio-psychological factors [17].

During SEM analysis, model fitness is indicated by several indices, chi-square/degrees of freedom, RMSEA, PNFI, and NFI. In general, model fitting is difficult to attain in models with very large sample sizes because of the larger covariance. In this study, goodness of fit indices were generally good considering the large sample size.

In the present study, subjects did not comprise a representative sample, which could result in selection bias. In terms

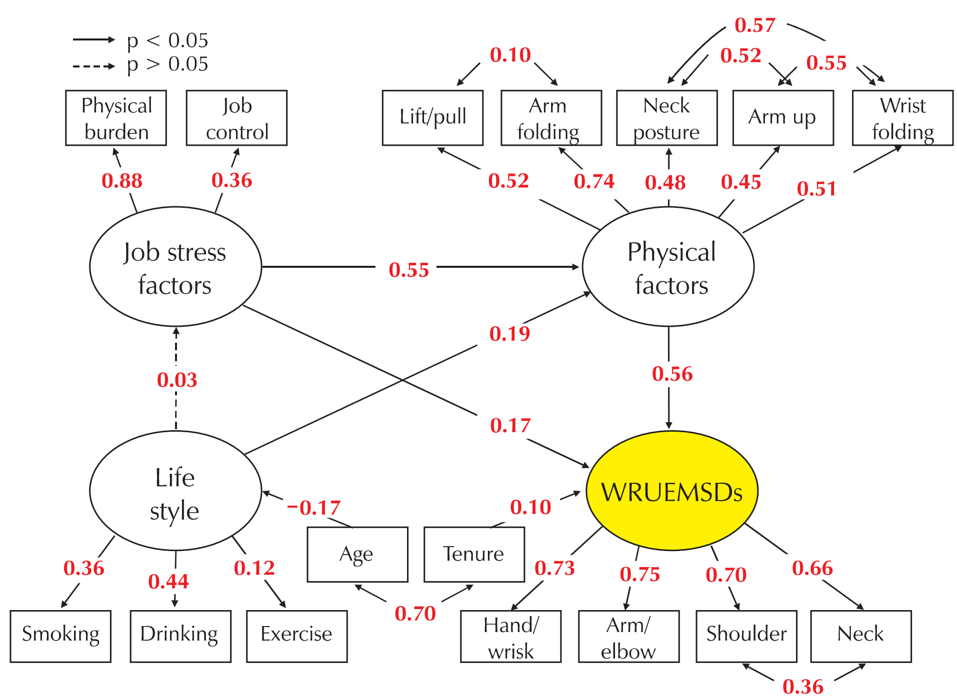

Fig. 1. Path diagram of structural equation modeling. χ^2 = 289.72 (df = 93), χ^2/df = 3.12, AGFI = 0.993, NFI = 0.924, RMSEA = 0.135, PNFI = 0.680. WRUEMSD: work-related upper extremity musculoskeletal disorders.

of prevalence, selection can be distorting. It is possible that workers with more complaints of musculoskeletal symptoms could be overrepresented, leading to prevalence overestimation. Additionally, those with greater concern for work-related risk factors could be oversampled. The net effect on the relationship between risk factors and musculoskeletal symptoms can be bidirectional. As described above, the positive rate of musculoskeletal symptoms in our study subjects was not much higher than that in other shipyard workers [38]. Frequency of risk factors also does not seem to be overrepresented when compared to other shipyards or the general population. Thus, subject selection would not appear to bring about a major distortion of the relationship between risk factors and symptoms.

The cross-sectional nature of this study can be a problem with respect to interpretation of the causal pathway. In WRMSD, symptom development can lead the worker to reduce their work load when control over the work is possible [4]. Increasing age and tenure can also act as factors that lead to a reduction of work load. Such types of reverse causation are inevitable in cross-sectional studies. In SEM, analysis of interrelationships between risk factors and parameter estimation in the multiple covariate structure is less prone to the presence of effect modifiers or intermediate variables.

In conclusion, the results of our study have shown that the effect of physical factors was greatest in the development of WRUEMSD and that job stress factors contribute to the development of WRUEMSD through both direct and indirect pathways. SEM is very useful for the assessment of interrelationships between factors related to WRMSD development, which can provide a potent tool for development of preventive interventions in the workplace.

References

1. World Health Organization. Identification and control of work related disorders. Geneva: Technical Report series; 1985. No. 714.
2. Ministry of Labor. Statistics of industrial accidents and occupational diseases. 2001-2009. Ministry of Labor, Republic of Korea, 2010. p. 10-4.
3. Park J, Kim YO, Ryu SY, Ha SH, Park BG. A study on the cervicobrachial syndrome among the microwave-oven assemblers (II): a review on the findings of the examinations. Korean J Occup Environ Med 1995;7:320-31.
4. Cheong HK, Choi BS, Kim JY, Yu SH, Lim HS, Kim YM, et al. Cumulative trauma disorders among telephone directory assistance operators. Korean J Occup Environ Med 1997;9:140-55.
5. Lee WJ, Lee EI, Cha CW. Carpal tunnel syndrome among packing workers in a rayon manufacturing factory. Korean J Prev Med 1992;25:26-33.
6. Son JI, Lee SJ, Song J, Park HB. A study on the relationship between subjective symptoms and psychological symptoms on some VDT workers. Korean J Prev Med 1995;28:433-49.
7. Choi JW, Yum YT, Spng DB, Park JT, Chang SH, Choi JA. Musculoskeletal diseases of upper extremities among the electronic assembly workers and telecommunication workers. Korean J Occup Environ Med 1996;8:301-19.
8. Park SK, Choi YJ, Moon DH, Chun JH, Lee JT, Sohn HS. Work related musculoskeletal disorders of hairdresser. Korean J Occup Environ Med 2000;12:395-404.
9. Sung NJ, Sakong J, Chung JH. Musculoskeletal disorders and related factors of symphony orchestra players. Korean J Occup Environ Med 2000;12:48-58.
10. Cha BS, Ko SB, Chang SJ, Park CS. A study on the relationship between subjective symptoms and psychosocial well-being status of VDT operators. Korean J Occup Environ Med 1996;8:403-13.
11. Francis DJ. An introduction to structural equation models. J Clin Exp Neuropsychol 1988;10:623-39.
12. Lee KJ. Structural equation modeling. Seoul: Kyoyook-Gwahak Inc.; 2000. p. 7-15.
13. Boyle GJ, Borg MG, Falzon JM, Baglioni AJ Jr. A structural model of the dimensions of teacher stress. Br J Educ Psychol 1995;65:49-67.
14. Rahim MA, Psenicka C. A structural equation model of stress, locus of control, social support, psychiatric symptoms, and propensity to leave a job. J Soc Psychol 1996;136:69-84.
15. Elovainio M, Kivimäki M. Work and strain on physicians in Finland. Scand J Soc Med 1998;26:26-33.
16. Janssen PP, Jonge JD, Bakker AB. Specific determinants of intrinsic work motivation, burnout and turnover intentions: a study among nurses. J Adv Nurs 1999;29:1360-9.
17. Van der Beek AJ, Oort-Marburger D, Frings-Dresen MH. The relations between work demands and health complaints in lorry drivers. A model tested by means of LISREL. Int Arch Occup Environ Health 1994;66:179-84.
18. Byström P, Hanse JJ, Kjellberg A. Appraised psychological workload, musculoskeletal symptoms, and the mediating effect of fatigue: a structural equation modeling approach. Scand J Psychol 2004;45:331-41.
19. Lee GK, Chan F, Berven NL. Factors affecting depression among people with chronic musculoskeletal pain: a structural equation model. Rehab Psychol 2007;52:33-43.
20. Lee YG, Yim SH. Relationships between work postures and upper extremity cumulative trauma disorders in medical insurance bill reviewers. Korean Ind Hyg Assoc J 1998;8:36-49.
21. Control of work-related cumulative trauma disorders, Part 1, Upper extremities working draft. New York (NY): ANSI; 1994. Report No.: ANSI Z-365.
22. OSHA Draft Ergonomic Standard, Washington, DC: OSHA;

1996.

23. Park BC, Cheong HK, Kim SK. Risk factors related to musculoskeletal symptoms in shipyard workers. Korean J Occup Environ Med 2003;15:373-87.
24. Kilbom A. Isometric strength and occupational muscle disorders. Eur J Appl Physiol Occup Physiol 1988;57:322-6.
25. Linton SJ, Kamwendo K. Risk factors in the psychosocial work environment for neck and shoulder pain in secretaries. J Occup Med 1989;31:609-13.
26. Kivimäki M, Voutilainen P, Koskinen P. Job enrichment, work motivation, and job satisfaction in hospital wards: testing the job characteristics model. J Nurs Manag 1995;3:87-91.
27. Armstrong TJ, Silverstein BA. Upper-extremity pain in the workplace role of usage in causality. In: Hadler NM ed. Clinical concepts in regional musculoskeletal illness. New York (NY): Grune & Stratton; 1987. p. 18.
28. Loehlin JC. Latent variable models: an introduction to factor, path, and structural analysis. 4th ed. Mahwah: Lawrence Erlbaum Associates, Inc.; 2004. p. 32-137.
29. White RF, Proctor SP. Research and clinical criteria for development of neurobehavioral test batteries. J Occup Med 1992; 34:140-8.
30. Browne MW. Asymptotically distribution-free methods for the analysis of covariance structures. Br J Math Stat Psychol 1984;37:62-83.
31. Costello AB, Osborne JW. Best practices in exploratory factor analysis: four recommendations for getting the most from your analysis. Pract Assess Res Eval 2005;10:1-9.
32. Kim SK, Bae GR, Lim HS, Kim DH, Lee JM. Validity of the symptom screening criteria on the cumulative trauma disorders. J Korean Public Health Assoc 1998;24:15-25.
33. Alexopoulos EC, Tanagra D, Konstantinou E, Burdorf A. Musculoskeletal disorders in shipyard industry: prevalence, health care use, and absenteeism. BMC Musculoskelet Disord 2006;7:88.
34. Yoon CS, Lee SH. Symptom prevalence and related factors of upper limb musculoskeletal symptoms in automobile related job workers. Korean J Occup Environ Med 1999;11:439-48.
35. Kiesler S, Finholt T. The mystery of RSI. Am Psychol 1988;43:1004-15.
36. Bigos SJ, Battié MC, Spengler DM, Fisher LD, Fordyce WE, Hansson TH, et al. A prospective study of work perceptions and psychosocial factors affecting the report of back injury. Spine (Phila Pa 1976) 1991;16:1-6.
37. Hales TR, Sauter SL, Peterson MR, Fine LJ, Putz-Anderson V, Schleifer LR, et al. Musculoskeletal disorders among visual display terminal users in a telecommunications company. Ergonomics 1994;37:1603-21.
38. Alexopoulos EC, Konstantinou EC, Bakoyannis G, Tanagra D, Burdorf A. Risk factors for sickness absence due to low back pain and prognostic factors for return to work in a cohort of shipyard workers. Eur Spine J 2008;17:1185-92.