

# BMJ Open Influence of coexposure to long working hours and ergonomic risk factors on musculoskeletal symptoms: an interaction analysis

Jeong woo Park <sup>1</sup>, Mo-Yeol Kang,<sup>2</sup> Jung Il Kim,<sup>1</sup> JongHyun Hwang,<sup>3</sup> Seong-Soo Choi <sup>4</sup>, Seong-Sik Cho <sup>1</sup>

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For numbered affiliations see end of article.

## Correspondence to

Dr Seong-Sik Cho;  
sscho@dau.ac.kr

## ABSTRACT

**Objectives** This study explores the interaction between ergonomic risk factors and long working hours on musculoskeletal symptoms by additive and multiplicative scales.

**Design** We used the data of the fifth Korean Working Condition Survey (KWCS). The KWCS is a cross-sectional study.

**Setting** To represent the entire Korean working population, the probability proportion stratified cluster sampling method was used. The face-to-face interview was carried out with a structured questionnaire.

**Main outcomes and measures** To assess the combined effect of ergonomic risk factors and long working hours on musculoskeletal symptoms, the relative excess risk due to interaction (RERI) and the ratio of ORs were calculated using multiple survey-weighted logistic analysis and postestimation commands.

**Results** The OR for musculoskeletal symptoms was 1.75 (95% CI 1.28 to 1.39) for exposure to long working hours, 3.49 (95% CI 3.06 to 3.99) for exposure to ergonomic risk factors and 5.07 (95% CI 4.33 to 5.93) for coexposure to long working hours and ergonomic risk factors. The RERI was 0.82 (95% CI 0.11 to 1.53) and the ratio of ORs was 0.83 (95% CI 0.50 to 1.14)

**Conclusion** Our findings suggest that coexposure to both ergonomic risk factors and long working hours has a supra-additive interaction effect on musculoskeletal symptoms. Regulations on working hours and workplace interventions might reduce the musculoskeletal diseases of workers.

## INTRODUCTION

Musculoskeletal disorders are an important work-related health issue worldwide, as they increase medical costs due to their high prevalence.<sup>1</sup> Work-related musculoskeletal disorders account for 40% of all work-related medical expenses worldwide.<sup>2</sup> In South Korea, they accounted for 57.6% of all work-related diseases in 2018.<sup>3</sup> A variety of risk factors, including physical and psychosocial factors, are associated with musculoskeletal disorders. Ergonomic risk factors, such as awkward

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study analysed a nationally representative sample (the Korean Working Condition Survey) with a large sample size (34 316).
- ⇒ This study conducted interaction analysis in both additive and multiplicative scales.
- ⇒ The causality between exposures and musculoskeletal disorders could not be established due to the nature of the study design (a cross-sectional study).
- ⇒ Self-reporting of working hours and musculoskeletal symptoms may lead to information bias.
- ⇒ The potential confounders, such as body mass index, history of musculoskeletal diseases, were not assessed in this study.

or painful posture, heavy physical workload, lifting and forceful movements, and repetitive hand or arm movements, are well-known risk factors of musculoskeletal disorders.<sup>4</sup> Moreover, an increased risk of developing work-related musculoskeletal disorders is linked to psychosocial factors, including poor job control and low social support.<sup>5 6</sup>

Long working hours can be harmful to workers' health and well-being, and are linked to physical health problems such as atrial fibrillation, coronary heart disease, stroke, occupational injury, depression and suicidal ideation.<sup>7-11</sup> The Korean government has acknowledged the adverse effects of excessive working hours and has legally stipulated a maximum of 52 working hours per week. However, the average annual working hours of Korea were still 1967 hours in 2019, which is 241 more hours than in Organisation for Economic Co-operation and Development countries.<sup>12</sup>

Long working hours imply that workers in a hazardous working environment are exposed to risks for longer periods. Thus, coexposure to long working hours combined with other occupational risk factors could

be more harmful. From this perspective, coexposure to long working hours and ergonomic risk factors may lead to a higher prevalence of musculoskeletal disorders in the workplace. However, few studies have reported the combined effect of long working hours and ergonomic risk factors on musculoskeletal disorders, particularly using both additive and multiplicative scales. Thus, this study aimed to identify the combined effect of long working hours and ergonomic risk factors on musculoskeletal symptoms by interaction analysis on both additive and multiplicative scales.

## METHODS

### Study participants

We used a data sample from the fifth Korean Working Condition Survey (KWCS), conducted by the Korea Occupational Safety and Health Agency (KOSHA). The KWCS is comparable to the European Working Conditions Survey; it aims to survey the working conditions in various occupations. The sample from the fifth KWCS was recruited from 17 cities and provinces in Korea and excludes individuals younger than 15 years.

The target population included nationwide employed individuals aged 15 years or older in all Korean households in 2017. The survey was conducted through face-to-face interviews after obtaining consent from the participants. Students, stay-at-home spouses, unemployed and retired individuals were excluded to ensure that the sample represented the economically active population. A sample design was constructed using a secondary probability proportion stratified cluster sample survey. Census districts were chosen based on the number of households. Thereafter, in each selected census district, 10 households were randomly selected. Finally, one randomly selected eligible person in each household was interviewed (eligible persons were individuals employed at the point of the survey). The data of the fifth KWCS used design-weight to adjust the non-response rate and sample selection. In addition, the raking ratio method was used for poststratification to adjust for the characteristics of gender, age, region, locality and occupation.

Of the total 50 205 employees (unweighted sample size=50 205), 34 316 wage workers (unweighted sample size=27 927)—excluding self-employed, unpaid family workers and employers—were included in the analysis. Only employees whose weekly working hours totalled more than 30 hours were included to exclude the impact of incomplete employment.

### Patient and public involvement

Participants in the study were not involved in the design of the study. The raw data of KWCS is available to the public. The study findings were only published in peer-reviewed journals, with no other information about the results provided to participants.

### Study variables

All study variables were collected from the KWCS questionnaire. Sociodemographic variables included gender,

age, educational level and income. Age was divided into five categories: <30, 30–39, 40–49, 50–59, ≥60. Education was classified according to three levels: middle school or less, high school graduate, or college or more. Monthly income was categorised into quartiles. Employment status was classified into three categories: regular, temporary and daily. Shift work was classified into two categories (yes or no). The information about working hours per week was collected using the following question: ‘How many hours do you work per week?’. Answers were divided into two categories: 30–52 hours/week was classed as ‘standard working hours’, while more than 52 hours/week was classed as ‘long working hours’.

Exposure to ergonomic risk factors was assessed using a questionnaire. First, the percentage of time that workers were exposed to a specific motion or posture during their working time was recorded. There were five items assessing ergonomic risk factors, namely tiring or painful position, lifting or moving people, carrying or moving heavy loads, continuous standing, and repetitive hand or arm movements.<sup>4</sup> For each item, the results were dichotomised into ‘with exposure’ when the exposure time was half of the working hours or more per day, or ‘without exposure’ when the exposure time was less than half of the working hours per day. Finally, if any of the five items were reported as ‘with exposure’, ‘ergonomic risk factor’ was considered present, while if all five items were reported as ‘without exposure’, ‘ergonomic risk factor’ was considered not present.

Musculoskeletal symptoms were present when workers had any of the three following symptoms: neck and upper limb (shoulder, arm, elbow, wrist, hand) pain, lower limb (feet, knee, legs, hips) pain or back pain during the last 12 months. Musculoskeletal symptoms were considered not present when workers had none of the three musculoskeletal problems (pain in neck and upper limb, lower limb or back).

### Statistical analysis

The characteristics of study participants (expressed in counts and proportions) were demonstrated according to long working hours by using  $\chi^2$  tests. To investigate the risk of musculoskeletal symptoms, a survey-weighted multiple logistic analysis was used. Other potential confounding variables—including age, sex, education level, income, shift work and employment status—were adjusted in the model. Also, by the weekly working hours and exposure to ergonomic risk factors OR for musculoskeletal symptoms were estimated. Finally, the relative excess risk due to interaction (RERI) and ratio of ORs were estimated to perform the interaction analysis between long working hours and ergonomic risk factors. The ratio of ORs and 95% CI, which were calculated by the postestimation commands ‘linear combination of coefficients’ (lincom), estimated the combined effects based on multiplicative scales. The RERI and 95% CI, which were calculated by the postestimation commands ‘non-linear combination of coefficients’ (nlcom), estimated the combined effects

**Table 1** Characteristics of study population

	Total		Long working hours (-)*		Long working hours (+)†		P value‡
	n	Proportion	n	Proportion	n	Proportion	
Gender	34 316						<0.001
Male	20 212	0.59	16 730	0.83	3482	0.17	
Female	14 104	0.41	12 636	0.90	1468	0.10	
Age							<0.001
15–29	6233	0.18	5319	0.85	913	0.15	
30–39	8874	0.26	7846	0.88	1028	0.12	
40–49	9025	0.26	7870	0.87	1154	0.13	
50–59	7084	0.21	5963	0.84	1120	0.16	
≥60	3101	0.09	2367	0.76	734	0.24	
Education							<0.001
Middle school or less	2265	0.06	1178	0.79	487	0.21	
High school	10 534	0.31	8115	0.77	8119	0.23	
College or more	21 493	0.63	19 450	0.90	2043	0.10	
Employment							<0.001
Regular	29 375	0.86	25 362	0.86	4012	0.14	
Temporary	3524	0.10	2822	0.80	701	0.20	
Daily	1418	0.04	1182	0.83	237	0.17	
Income							<0.001
Lowest	5060	0.16	4449	0.88	611	0.12	
Low–middle	7970	0.25	6555	0.82	1415	0.18	
High–middle	9365	0.29	7838	0.84	1528	0.16	
Highest	9826	0.30	8688	0.88	1138	0.12	
Shift work							<0.001
No	30 236	0.88	26 221	0.87	4014	0.13	
Yes	4073	0.12	3144	0.77	928	0.23	
Ergonomic risk factors							<0.001
Risk factors (-)	8775	0.26	8069	0.92	707	0.08	
Risk factors (+)	25 533	0.74	21 292	0.83	4241	0.17	

\*Long working hours (-): ≤30 and ≤52 hours.  
 †Long working hours (+): >52 hours.  
 ‡Estimated by survey-weighted  $\chi^2$  test.

based on additive scale. Stata V.16.1 software was used for all statistical analyses, with a two-tailed statistical significance level of  $p < 0.05$ .

For an additive scale of the interaction between long working hours and ergonomic risk factor, RERI was estimated:

$$\text{RERI} = \text{OR}_{\text{combined exposure to long working hours and ergonomic factor}} - \text{OR}_{\text{exposure to only ergonomic factor}} - \text{OR}_{\text{exposure to only long working hours}} + 1$$

For a multiplicative scale of the interaction between long working hours and ergonomic risk factors, the ratio of ORs was estimated:

$$\frac{\text{OR}_{\text{combined exposure to long working hours and ergonomic factor}}}{(\text{OR}_{\text{exposure to only ergonomic factor}} \times \text{OR}_{\text{exposure to only long working hours}})}$$

In the epidemiological study, if the RERI was greater than 0, it indicates there is a supra-additive interaction of two concurrent exposures. If the estimated ratio of the ORs was greater than 1, it indicates there is a supra-multiply interaction of two simultaneous exposures.<sup>13</sup>

## RESULTS

Of the 34 316 study participants (unweighted sample size=27 927), 14 104 (41%) were female. We observed that 14.4% of Korean employees worked more than 52 hours per week (table 1). Higher proportions of participants reporting long working hours were found among males (17%), older adults (24%), high school graduates (23%) and low/middle-income (18%) workers.

**Table 2** Factors associated with musculoskeletal symptoms by survey-weighted multiple logistic analysis (population size=32 184)

	OR	95% CI	p-value
Weekly working hours			
30–52	Reference		
>52	1.51	1.36 to 1.67	<0.001
Ergonomic risk factor			
Risk factor (–)	Reference		
Risk factor (+)	3.37	2.99 to 3.80	<0.001
Employment			
Regular	Reference		
Temporary	0.82	0.73 to 0.93	<0.001
Daily	2.13	1.81 to 2.49	<0.001
Shift work			
No	Reference		
Yes	1.29	1.15 to 1.44	<0.001
Income			
Highest	Reference		
High–middle	1.02	0.89 to 1.18	0.735
Low–middle	1.04	0.92 to 1.18	0.533
Lowest	1.07	0.96 to 1.19	0.244
Education			
College or more	Reference		
High school	1.86	1.69 to 2.04	<0.001
Middle school or less	3.10	2.65 to 3.63	<0.001
Gender			
Male	Reference		
Female	1.21	1.11 to 1.32	<0.001
Age			
15–29	Reference		
30–39	1.88	1.60 to 2.21	<0.001
40–49	2.31	1.98 to 2.69	<0.001
40–59	2.55	2.19 to 2.98	<0.001
≥60	2.18	1.82 to 2.61	<0.001

Regarding work-related variables, workers with temporary jobs (20%) and shift work (23%) had the highest percentage of long working hours. In addition, workers who were exposed to ergonomic risk factors were more likely to report long working hours.

Table 2 shows the relationship between independent variables and musculoskeletal symptoms. Ergonomic risk factors (OR=3.37; 95% CI 2.99 to 3.80), long working hours (OR=1.51, 95% CI 1.36 to 1.67), female workers (OR=1.21, 95% CI 1.11 to 1.32) and shift workers (OR=1.29, 95% CI 1.15 to 1.44) were more likely to report musculoskeletal symptoms. Compared with regular workers, temporary workers were less likely (OR=0.82, 95% CI 0.73 to 0.93) and daily workers were more likely to experience musculoskeletal symptoms (OR=2.13, 95%

CI 1.81 to 2.49). Regarding education level, workers with middle school graduation or less (OR=3.10, 95% CI 2.65 to 3.63) and those with high school graduation (OR=1.86, 95% CI 1.69 to 2.04) had a higher risk of musculoskeletal symptoms than college graduates or more. However, there was no statistically significant association between income and musculoskeletal symptoms.

The effects of weekly work hours and ergonomic risk factors on musculoskeletal symptoms are shown in table 3 and online supplemental figure 1. Ergonomic risk factors increased the risk of musculoskeletal symptoms in the same working hours groups. The OR (0.90, 95% CI 0.54 to 1.50) was lowest for workers who were not exposed to ergonomic risk factors with their 41–45 working hours and the OR (2.51, 95% CI 1.39 to 4.52) was lowest for workers with standard work hours (36–40) who were exposed to ergonomic risk factors.

Additionally, when working hours exceeded the standard working hours, the risk of musculoskeletal symptoms gradually increased among workers exposed to ergonomic risk factors. The OR was highest (5.01, 95% CI 2.97 to 8.45) among employees with ergonomic risk factors and more than 60 weekly work hours.

Table 4 and figure 1 show the effect of the interaction between long working hours and ergonomic risk factors on musculoskeletal symptoms. For long working hours without ergonomic risk factors, the OR for musculoskeletal symptoms was 1.75 (95% CI 1.28 to 1.39). For ergonomic risk factors without long working hours, the OR of musculoskeletal symptoms was 3.49 (95% CI 3.06 to 3.99). In addition, if workers were exposed to simultaneous long working hours and ergonomic risk factors, the OR for musculoskeletal symptoms was 5.07 (95% CI 4.33 to 5.93). The RERI was 0.82 (95% CI 0.11 to 1.53) and the ratio of ORs was 0.83 (95% CI 0.50 to 1.14). Thus, we observed a supra-additive interaction between long working hours and ergonomic risk factors regarding their effect on musculoskeletal symptoms

Online supplemental tables demonstrate the interaction between long working hours and heavy load on back pain and between long working hours and painful position on neck and upper limb pains. RERI for long working hours and heavy load on back pain was 0.98 (95% CI 0.06 to 1.90), and RERI for long working hours and painful position on neck and upper limb pains was 1.30 (95% CI 0.53 to 2.06). This study observed supra-additive interactions between long working hours and heavy load on back pain and between long working hours and painful position on neck and upper limb pains.

## DISCUSSION

The current study results showed that long working hours and ergonomic risk factors are associated with musculoskeletal symptoms. These results share similarities with previous studies showing that long working hours increased the risk of back pain and the diagnosis of neck and shoulder disorders, and that ergonomic risk

**Table 3** Association weekly working hours and musculoskeletal symptoms by ergonomic risk factors

	Ergonomic risk factors (-)			Ergonomic risk factors (+)		
	OR	95% CI	P value	OR	95% CI	P value
Weekly working hours						
30–35	Reference			3.16	1.89 to 5.28	<0.001
36–40	1.14	0.37 to 3.51	0.826	2.51	1.39 to 4.52	0.002
41–45	0.90	0.54 to 1.50	0.677	3.01	1.84 to 4.92	<0.001
46–50	1.28	0.73 to 2.25	0.385	4.35	2.65 to 7.15	<0.001
51–55	1.31	0.62 to 2.77	0.482	4.86	2.88 to 8.22	<0.001
56–60	2.13	1.15 to 3.96	0.017	4.90	2.95 to 8.14	<0.001
61	1.31	0.61 to 2.83	0.490	5.01	2.97 to 8.45	<0.001

Survey weighted multiple logistic regression was employed, and age, sex, education, income, employment and shift work were adjusted in the model.

factors such as heavy physical work, lifting movements and awkward postures can increase the risk of lower back pain.<sup>414–18</sup> Furthermore, repetitive work was also found to be associated with musculoskeletal disorders of the neck, shoulder, hand and wrist.<sup>419–21</sup>

When working hours were divided into smaller scales, workers who were exposed to ergonomic risk factors had the lowest OR for musculoskeletal symptoms when working standard working hours in this study. Given the study's design (a cross-sectional study) and considering healthy worker effect, workers with musculoskeletal symptoms may reduce their working hours.

There was a synergy between long working hours and ergonomic risk factors on musculoskeletal symptoms. To the best of our knowledge, few studies have analysed the combined effect of ergonomic risk factors and long working hours via interaction analysis on both additive and multiplicative scales. The most appropriate method is to report interactions by using both scales.<sup>22 23</sup> Therefore,

in this study, RERI (an additive scale) and ratio of ORs (a multiplicative scale) were calculated to conduct an interaction analysis. Although no statistical significance was observed on the multiplicative scale, RERI was greater than 0, which indicates the supra-additive interaction between long working hours and ergonomic risk factors. We observed a synergistic effect of the coexposure to long work hours and ergonomic risk factors on musculoskeletal symptoms that was more detrimental than a simple addition of harmful effects by each exposure. As seen in online supplemental tables, similar supra-additive interactions were observed in long working hours and heavy load on back pain, and long working hours and painful position on the neck and upper limbs. This finding is consistent with the results of table 4. This result may support the main hypothesis of the study.

As long working hours imply prolonged exposure to ergonomic risk factors (eg, repetitive tasks, heavy lifting and uncomfortable posture) and insufficient recovery,

**Table 4** Interaction effect of long working hours and ergonomic risk factors on musculoskeletal symptoms

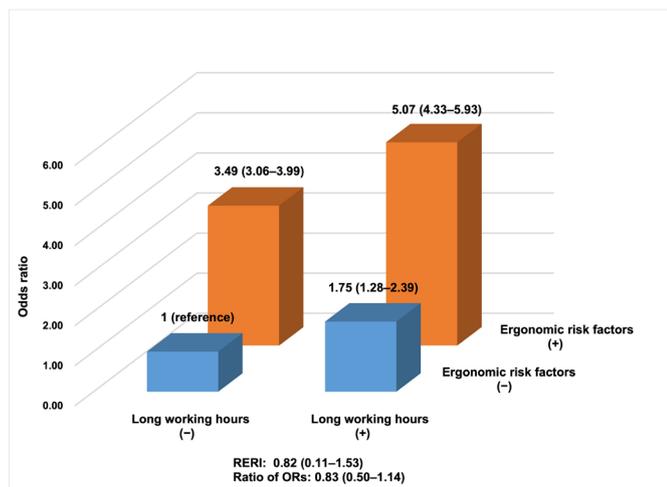
	Long working hours (-)* OR (95% CI): p value	Long working hours (+)† OR (95% CI): p value	OR for long working hours (-)* vs long working hours (+)† within strata of ergonomic risk factor OR (95% CI): p value
Ergonomic risk factors (-)	Reference	1.75 (1.28 to 2.39): <0.001	1.75 (1.28 to 2.39): <0.001
Ergonomic risk factors (+)	3.49 (3.06 to 3.99): <0.001	5.07 (4.33 to 5.93): <0.001	1.45 (1.30 to 1.61): <0.000
OR for ergonomic risk factors (-) vs ergonomic risk factors (+) within strata of long working hours	3.49 (3.06 to 3.99): <0.001	2.89 (2.14 to 3.90): <0.001	
Measure of interaction on additive scale: RERI	0.82 (0.11 to 1.53): 0.024		
Measure of interaction on multiplicative scale: ratio of ORs	0.83 (0.50 to 1.14): 0.256		

Age, sex, education, income, employment and shift work were adjusted for in the model.

\*Long working hours (-): ≤30 and ≤52 hours.

†Long working hours (+): >52 hours.

RERI, relative excess risk due to interaction.



**Figure 1** Combined effect of long working hours and ergonomic risk factors on musculoskeletal symptoms. Age, sex, education, income, employment and shift work adjusted in the model. RERI, relative excess risk due to interaction.

the interaction of long working hours and ergonomic risk factors can lead to a higher risk of musculoskeletal symptoms, compared with their simple additive effect. Several studies have suggested a dose-response relationship between coexisting ergonomic risk factors, such as workload, lifting and awkward posture.<sup>24-26</sup> However, the results of this study suggest that the supra-additive interaction between long working hours and ergonomic risk factors can worsen the problem.

The current study proposed that stricter regulation of working hours is required. In 2018, concerns over the long working hours of Korean workers led the government to limit the legal working hours to 52 hours or fewer per week. However, regulations on working hours are not strict and are applied only to large enterprises with 300 or more employees.<sup>27</sup> This means that employees in small-scale workplaces have a higher risk of working long hours.<sup>28</sup> In addition, it is well known that employees in small-scale workplaces work under unfavourable conditions more often than those in large-scale workplaces. Implementing legal systems prohibiting long working hours, especially more than 52 hours, may help reduce the prevalence of musculoskeletal symptoms, particularly among workers in small-scale workplaces. Moreover, working conditions should be improved. As such, multifocal ergonomic interventions programmes, such as training in ergonomic principles, workstation modification (modifying working postures), surveying ergonomics and exercise programmes, are recommended to reduce musculoskeletal symptoms and the risk of developing musculoskeletal disorders.<sup>29-32</sup>

This study had several limitations. First, it was a cross-sectional study; therefore, causality between exposure and musculoskeletal disorders could not be established because of the nature of the study design. However, when employees have musculoskeletal pain, they could not extend their working hours, owing to their symptoms.

Therefore, the possibility of a reverse causal relationship between long working hours and musculoskeletal symptoms is low. Second, the assessment of working hours and musculoskeletal symptoms was self-reported, which can lead to information bias. Third, this study did not consider other possible confounders, such as medical history of injury, exercise and body mass index, which could affect musculoskeletal symptoms. Fourth, we assessed musculoskeletal symptoms instead of musculoskeletal disorders. However, musculoskeletal symptoms are highly correlated with physical findings of musculoskeletal disorders as well as accompanying or preceding musculoskeletal diseases.<sup>33 34</sup> Therefore, to prevent the occurrence of work-related musculoskeletal disorders, it makes sense to investigate the musculoskeletal symptoms in the workplace.

In conclusion, the findings of this study suggest that long working hours combined with ergonomic risk factors can have harmful synergistic effects on musculoskeletal symptoms. The health of workers who experience unfavourable working conditions, especially those concurrently exposed to ergonomic risk factors and long working hours, could be improved by reduced working hours and ergonomic improvement. Strict regulation of working hours and ergonomic intervention programmes could be helpful to prevent musculoskeletal disease in the workplace.

#### Author affiliations

<sup>1</sup>Department of Occupational and Environmental Medicine, Dong-A University College of Medicine, Busan, Korea

<sup>2</sup>Department of Occupational and Environment Medicine, Catholic University of Korea College of Medicine, Seoul, Korea

<sup>3</sup>Department of Occupational and Environment Medicine, Dong-A University Hospital, Busan, South Korea

<sup>4</sup>Department of Anesthesiology and Pain Medicine, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

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**Patient consent for publication** Not applicable.

**Ethics approval** The data used in our study are the fifth Korean Working Condition Survey which is open to the public with personally identifiable information deleted. The need for written informed consent was waived off, and this study was approved by the Institutional Review Board of Dong-A University Hospital (approval no: DAUHIRB-TEMP-20-212).

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**Data availability statement** Data are available upon reasonable request. KWCSs are open to public. Available on: <https://oshri.kosha.or.kr/oshri/researchField/downWorkingEnvironmentSurvey.do#>

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#### ORCID iDs

Jeong woo Park <http://orcid.org/0000-0002-2444-789X>

Seong-Soo Choi <http://orcid.org/0000-0002-2333-0235>

Seong-Sik Cho <http://orcid.org/0000-0002-1875-1377>

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