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Research Article

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Relationship between job rotation and work-related low back pain: a cross-sectional study using data from the fifth Korean working conditions survey

Ji-Su Shin [1], **Kwanghyun Seo** [1], **Hyun-Jeong Oh** [1], **MyeongSeob Lim** [1], **Hee-Tae Kang** [1], **Kyeong-Sook Jeong** [1], **Sang-Baek Koh** [2], **Sung-Kyung Kim** [1*], **and Sung-Soo Oh** [1*]

[1]Department of Occupational and Environmental Medicine, Wonju Severance Christian Hospital, Yonsei University Wonju College of Medicine, Wonju, Korea
[2]Department of Preventive Medicine and Genomic Cohort Institute, Yonsei University Wonju College of Medicine, Wonju, Korea

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***Correspondence:**
Sung-Kyung Kim
Department of Occupational and Environmental Medicine, Wonju Severance Christian Hospital, Yonsei University Wonju College of Medicine, 20 Ilsan-ro, Wonju 26426, Korea.
E-mail: stacte@yonsei.ac.kr

Sung-Soo Oh
Department of Occupational and Environmental Medicine, Wonju Severance Christian Hospital, Yonsei University Wonju College of Medicine, 20 Ilsan-ro, Wonju 26426, Korea.
E-mail: oss0609@yonsei.ac.kr

ORCID iDs
Ji-Su Shin
https://orcid.org/0000-0003-2434-1005
Kwanghyun Seo
https://orcid.org/0000-0002-1796-002X

ABSTRACT

Background: Job rotation was introduced in various industries as a strategic form of work for improving workers' job skills and health management. This study aims to examine the relationship between job rotation and work-related low back pain (LBP), one of the typical work-related musculoskeletal symptoms of Korean workers.
Methods: We conducted this study using the data of the 5th Korean Working Conditions Survey (KWCS). As the subject of this study, 27,163 wage workers were selected, and classified into three groups according to occupational type (white-collar, service and sales, and blue-collar). In this study, job rotation means to change the work-related activities with other colleagues periodically and work-related LBP was defined as whether there was work-related LBP in the last 12 months. Chi-square test and logistic regression were used to analyze the relationship between job rotation and work-related LBP.
Results: Out of 27,163 workers, 2,421 (8.9%) answered that they had job rotation and 2,281 (8.4%) answered that they experienced work-related LBP. According to the results from logistic regression, job rotation was significantly associated with low prevalence of work-related LBP among blue-collar workers (odds ratio [OR]: 0.71, 95% confidence interval [CI]: 0.58–0.88), whereas no significant relationship was observed among white-collar, service and sales groups. In addition, the negative association between job rotation and work-related LBP among blue-collar workers was more pronounced when exposed to ergonomic risk factors (uncomfortable posture OR: 0.79, 95% CI: 0.64–0.98; heavy work OR: 0.74, 95% CI: 0.57–0.96; repetitive work OR: 0.74, 95% CI: 0.60–0.92).
Conclusions: Job rotation was associated with low prevalence of work-related LBP among workers in the blue-collar occupational group in Korea. It is necessary to evaluate the effect of job rotation by occupational type and introduce an appropriate method of job rotation to reduce workers' work-related musculoskeletal symptoms.

Keywords: Job rotation; Work-related low back pain; Fifth Korean Working Conditions Survey

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Hyun-Jeong Oh
https://orcid.org/0000-0003-1458-7781
MyeongSeob Lim
https://orcid.org/0000-0002-1339-2280
Hee-Tae Kang
https://orcid.org/0000-0002-8470-814X
Kyeong-Sook Jeong
https://orcid.org/0000-0002-6897-8289
Sang-Baek Koh
https://orcid.org/0000-0001-5609-6521
Sung-Kyung Kim
https://orcid.org/0000-0002-2742-6410
Sung-Soo Oh
https://orcid.org/0000-0003-0801-3052

Abbreviations

CI: confidence interval; KRW: Korean won; KWCS: Korean Working Conditions Survey; LBP: low back pain; OR: odds ratio; WMSD: work-related musculoskeletal disorder.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

Korean Working Conditions Survey (KWCS) data is open to all researchers. KWCS data are available on the Korea Occupational Safety and Health Agency (KOSHA) website (http://www.kosha.or.kr/kosha/data/primitiveData.do).

Authors contributions

Conceptualization: Shin JS; Data curation: Seo K, Oh HJ, Lim M; Formal analysis: Shin JS; Supervision: Kang HT, Jeong KS, Koh SB, Kim SK, Oh SS; Writing - original draft: Shin JS; Writing - review & editing: Kim SK, Oh SS.

BACKGROUND

Work-related low back pain (LBP) is one of the most prevalent symptoms of musculoskeletal disorders among workers [1]. Work-related musculoskeletal symptoms decrease workers' productivity, increase absenteeism [2], and lead to early retirement [3]. Work-related LBP is known to arise from occupational environments with heavy workload [4], an awkward posture or prolonged standing posture [5], repetitive movement [6] and high exposure to vibrations [7].

Job rotation is one of the methods that have been devised and applied in many working places for reducing work-related LBP. Job rotation has been introduced in various industries as a strategic form of work for the purpose of increasing workers' work efficiency and health management [8]. Job rotation is defined in various ways depending on the application field and purpose of use, but generally refers to working in rotation between tasks with different exposure levels and different occupational needs [9]. The implementation of job rotation is becoming more common not only in the manufacturing industry but also in medical personnel such as nurses [10], especially after the outbreak of coronavirus disease 2019 with an aim to promote cost efficiency and flexibility of labor.

Job rotation can increase workers' performance and autonomy, and improve organizational flexibility by exposing workers to various types of tasks [11]. In addition, it is well known that it helps manage mental health by reducing monotony and boredom from simple repetition of the same task, and prevents work-related musculoskeletal disorders (WMSD) [12]. However, recent systematic reviews show that the evidence for the protective effect of job rotation is weak for musculoskeletal disorders or symptoms including low back pain [13,14]. In addition, studies have shown that job rotation is costly and time consuming, partly due to workers' reluctance to change their tasks repeatedly [15], and that new tasks increase the burden on workers and negatively affect their productivity and work satisfaction [16].

However, most previous studies were conducted on a small number of workers in a limited set of occupational groups and workplaces, whereas studies based on a large number of Korean workers were rare to confirm the relationship between job rotation and musculoskeletal symptoms.

The goal of this study is to examine the relationship between job rotation and work-related LBP, one of typical musculoskeletal symptoms among Korean workers. We adopted the data of more than 25,000 workers from the 5th Korean Working Conditions Survey (KWCS) for analyzing the effects of job rotation on work-related LBP, and discussed the implication of results for the prevention and management of musculoskeletal disorders of workers.

METHODS

Participants

This study used the data of the 5th KWCS. The KWCS is a benchmark of the European Union's European Working Conditions Survey and the UK Labor Force Survey, and aims to understand the overall work environment such as working pattern, employment pattern, occupations, industries, exposure to risk factors, and employment stability for employees aged 15 or older nationwide. The 5th survey was conducted in 2017 by the Korea Occupational

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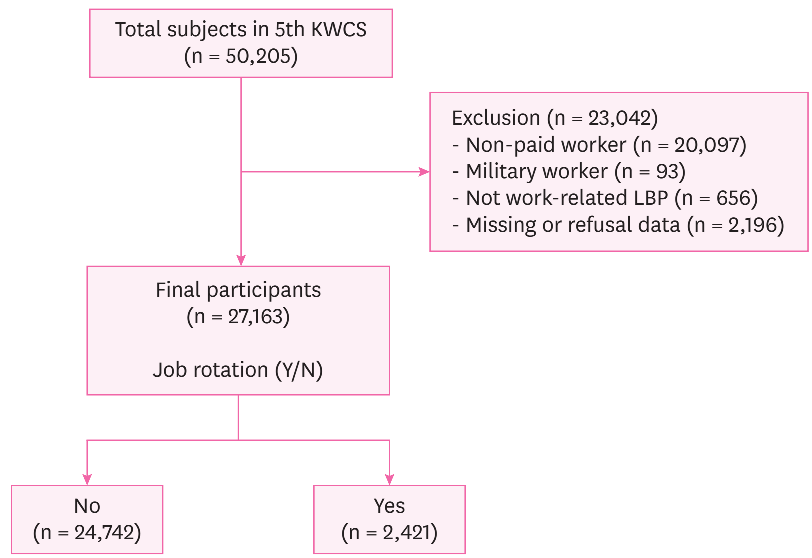

Fig. 1. A flow of the study design.
KWCS: Korean Working Conditions Survey, LBP: low back pain.

Safety and Health Agency. The population of the working environment survey is based on the 2010 Population and Housing Census, and targets those who are aged 15 years or older in all households in Korea. The data include the characteristics of 50,205 subjects, from which non-wage workers (n = 20,097), those who complained of low back pain other than work-related (n = 656), military personnel (n = 93) and those who did not respond or refuse to answer the questionnaire (n = 2,196) were excluded. Finally, the final sample includes 27,163 participants (**Fig. 1**).

Major variables

In KWCS, job rotation was assessed by the following question: "Does your work include job rotation with colleagues (periodically changing work-related activities with other coworkers)?" And the subjects who answered "yes" were defined as job rotation group.

Work-related LBP was identified with two survey questions. The first question is to identify any health problem in the last year (i.e., "Did you have any of the following health problems in the last 12 months?"), while the second one probes its relationship, if any, with work (i.e., "Is it work related?"). In this study, the respondents who reported "low back pain" and answered "yes" to its work-relatedness are considered to have work-related LBP. Those who had low back pain but answered "no" to the probing question were excluded from the study.

As potential factors that can affect low back pain, ergonomic factors and vibration exposure were identified with survey questions in the KWCS. KWCS assessed ergonomic factors by 5 dimensions (i.e., fatiguing or painful posture; continuously standing posture; lifting or moving people; pulling, pushing, or moving a heavy object; repetitive hand movements or arms) with 7 levels (i.e., full working hours; almost all working hours; 3/4 working hours; half working hours; 1/4 working hours; barely exposed; never exposed).

This study combined five dimensions into three: uncomfortable posture (i.e., any exposure to 'fatiguing or painful posture' or 'continuously standing posture'), heavy work (i.e., any exposure to 'lifting or moving people' or 'pulling, pushing, or moving a heavy object'), and repetitive hand or arm movements (e.g., exposure to 'using keyboard or mouse repeatedly' or 'using knives in a restaurant kitchen' or 'sawing, hammering in a carpenter's shop'). Each dimension was dichotomized with a threshold of ≤ barely exposed. Vibration exposure was also measured by 7 levels, which was divided into the control and exposed groups in the same way.

Covariates

Potential confounding factors were gender, age, education level, monthly income, job classification, workplace size, working hours per week, and shift work. Age was divided into 5 groups: under the age of 30, 30s, 40s, 50s, and 60s or older. Education level was divided into 2 groups: high school graduate or below and college graduate or above. Monthly income is assessed with four categories: less than 1,000,000, 1,000,000–1,999,999, 2,000,000–2,999,999, 3,000,000 or more (Korean won, KRW). Occupational classification was divided into 3 groups according to the Korean Standard Occupational Classification (6th revision): white-collar (manager, professionals and office workers), service and sales (service workers, sales workers), and blue-collar workers (agricultural and fishery workers, skilled workers, machine operators, assembly workers and simple labor workers). Workplace size was classified into 3 groups: less than 50 employees, 50–249 employees, and more than 250 employees. Working hours are divided into 3 groups: 40 hours per week or less, 41–52 hours per week, and 53 hours per week or more. Lastly, shift work was divided into two groups, depending on whether or not shift work.

Analysis

We used the PASW SPSS version 25 (SPSS Inc., Armonk, NY, USA) program for statistical analyses and set the significance level as below 0.05. The χ^2 test was used to analyze the general characteristics of the study population with job rotation and the prevalence of self-reported work-related LBP (**Tables 1** and **2**). Logistic regression analysis was conducted to confirm relationship between job rotation and work-related LBP, stratified by occupational classification (**Table 3**). The odds ratio (OR) and 95% confidence interval (CI) were calculated.

Regression models were additionally adjusted for gender, age, education level, monthly income, job classification, workplace size, working hours per week, shift work, ergonomic factors, and vibration exposure. In the blue-collar occupational group where job rotation was significantly associated with work-related LBP, we examined additional logistic regression analyses stratified by ergonomic risk factors and vibration exposure (**Table 4**).

Ethics statement

This is a secondary data analysis, which is approved by the Institutional Review Board (IRB) of Wonju Severance Christian Hospital (IRB No. CR320363).

RESULTS

General characteristics

Table 1 shows general characteristics of the study population. Total 27,163 subjects were included as the final subjects of this study, of which 13,118 were men and 14,045 were women. Among the subjects, 2,421 (8.9%) workers responded that they had job rotation. The average age of the study population was 44.9 years, and the percentage of job rotation was the highest among those aged 60s or older (10.1%). As for the educational level, the proportion of job rotation was higher in the subjects under high school graduation (9.8%), and the proportion

Table 1. General characteristics according to presence or absence of job rotation

Variables	Total	Job rotation		
		No	Yes	*p*-value[a]
Total	27,163 (100.0)	24,742 (91.1)	2,421 (8.9)	
Sex				< 0.001
Male	13,118 (48.3)	11,759 (89.6)	1,359 (10.4)	
Female	14,045 (51.7)	12,983 (92.4)	1,062 (7.6)	
Age (years)				0.039
< 30	3,828 (14.1)	3,501 (91.5)	327 (8.5)	
30–49	6,303 (23.2)	5,748 (91.2)	555 (8.8)	
40–49	7,039 (25.9)	6,448 (91.6)	591 (8.4)	
50–59	6,228 (22.9)	5,661 (90.9)	567 (9.1)	
≥ 60	3,765 (13.9)	3,384 (89.9)	381 (10.1)	
Education level				< 0.001
High school or below	12,659 (46.6)	11,419 (90.2)	1,240 (9.8)	
University or above	14,504 (53.4)	13,323 (91.9)	1,181 (8.1)	
Monthly income (KRW)				< 0.001
< 1,000,000	2,451 (9.0)	2,323 (94.8)	128 (5.2)	
1,000,000–1,999,999	8,223 (30.3)	7,501 (91.2)	722 (8.8)	
2,000,000–2,999,999	8,090 (29.8)	7,363 (91.0)	727 (9.0)	
≥ 3,000,000	8,399 (30.9)	7,555 (90.0)	844 (10.0)	
Occupational type				< 0.001
White-collar	11,054 (40.7)	10,256 (92.8)	798 (7.2)	
Service and sales	7,220 (26.6)	6,615 (91.6)	605 (8.4)	
Blue-collar	8,889 (32.7)	7,871 (88.5)	1,018 (11.5)	
Workplace scale (person)				< 0.001
1–49	21,040 (77.5)	19,332 (91.9)	1,708 (8.1)	
50–249	4,014 (14.8)	3,576 (89.1)	438 (10.9)	
≥ 250	2,109 (7.8)	1,834 (87.0)	275 (13.0)	
Weekly working time (hours)				< 0.001
≤ 40	15,824 (58.3)	14,548 (91.9)	1,276 (8.1)	
41–52	7,492 (27.6)	6,831 (91.2)	661 (8.8)	
≥ 53	3,847 (14.2)	3,363 (87.4)	484 (12.6)	
Shift work				< 0.001
No	23,802 (87.6)	22,228 (93.4)	1,574 (6.6)	
Yes	3,361 (12.4)	2,514 (74.8)	847 (25.2)	
Work-related LBP				0.293
No	24,882 (91.6)	22,678 (91.1)	2,204 (8.9)	
Yes	2,281 (8.4)	2,064 (90.5)	217 (9.5)	
Uncomfortable posture				< 0.001
No	6,295 (23.2)	5,929 (94.2)	366 (5.8)	
Yes	20,868 (76.8)	18,813 (90.2)	2,055 (9.8)	
Heavy work				< 0.001
No	16,810 (61.9)	15,597 (92.8)	1,213 (7.2)	
Yes	10,353 (38.1)	9,145 (88.3)	1,208 (11.7)	
Repetitive hand or arm movements				< 0.001
No	8,210 (30.2)	7,769 (94.6)	441 (5.4)	
Yes	18,953 (69.8)	16,973 (89.6)	1,980 (10.4)	
Vibration exposure				< 0.001
No	21,465 (79.0)	19,825 (92.4)	1,640 (7.6)	
Yes	5,698 (21.0)	4,917 (86.3)	781 (13.7)	

Values are reported as number (%).
KRW: Korean won, LBP: low back pain.
[a]Calculated by χ^2 test.

of job rotation was the highest in the group with monthly income of 3,000,000 won or more (10.0%). The proportion of job rotation was also higher in groups with a larger workplace (13.0%), longer weekly working hours (12.6%), and shift work (25.2%). In addition, job rotation was more common among those with uncomfortable posture, heavy work, repetitive work, and vibration exposure. Except for work-related LBP, all other variables were found to

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Table 2. The prevalence of self-reported work-related LBP according to the subjects

Variables	Total	Work-related LBP		
		No	Yes	*p*-value[a]
Total	27,163 (100.0)	24,882 (91.6)	2,281 (8.4)	
Sex				< 0.001
Male	13,118 (48.3)	12,131 (92.5)	987 (7.5)	
Female	14,045 (51.7)	12,751 (90.8)	1,294 (9.2)	
Age (years)				< 0.001
< 30	3,828 (14.1)	3,712 (97.0)	116 (3.0)	
30–49	6,303 (23.2)	5,996 (95.1)	307 (4.9)	
40–49	7,039 (25.9)	6,500 (92.3)	539 (7.7)	
50–59	6,228 (22.9)	5,499 (88.3)	729 (11.7)	
≥ 60	3,765 (13.9)	3,175 (84.3)	590 (15.7)	
Education level				< 0.001
High school or below	12,659 (46.6)	11,048 (87.3)	1,611 (12.7)	
University or above	14,504 (53.4)	13,834 (95.4)	670 (4.6)	
Monthly income (KRW)				< 0.001
< 1,000,000	2,451 (9.0)	2,165 (88.3)	286 (11.7)	
1,000,000–1,999,999	8,223 (30.3)	7,354 (89.4)	869 (10.6)	
2,000,000–2,999,999	8,090 (29.8)	7,492 (92.6)	598 (7.4)	
≥ 3,000,000	8,399 (30.9)	7,871 (93.7)	528 (6.3)	
Occupational type				< 0.001
White-collar	11,054 (40.7)	10,610 (96.0)	444 (4.0)	
Service and sales	7,220 (26.6)	6,659 (92.2)	561 (7.8)	
Blue-collar	8,889 (32.7)	7,613 (85.6)	1,276 (14.4)	
Workplace scale (person)				< 0.001
1–49	21,040 (77.5)	19,226 (91.4)	1,814 (8.6)	
50–249	4,014 (14.8)	3,668 (91.4)	346 (8.6)	
≥ 250	2,109 (7.8)	1,988 (94.3)	121 (5.7)	
Weekly working time (hours)				< 0.001
≤ 40	15,824 (58.3)	14,677 (92.8)	1,147 (7.2)	
41–52	7,492 (27.6)	6,878 (91.8)	614 (8.2)	
≥ 53	3,847 (14.2)	3,327 (86.5)	520 (13.5)	
Shift work				< 0.001
No	23,802 (87.6)	21,857 (91.8)	1,945 (8.2)	
Yes	3,361 (12.4)	3,025 (90.0)	336 (10.0)	
Job rotation				0.293
No	24,882 (91.6)	22,678 (91.7)	2,064 (8.3)	
Yes	2,281 (8.4)	2,204 (91.0)	217 (9.0)	
Uncomfortable posture				< 0.001
No	6,295 (23.2)	6,135 (97.5)	160 (2.5)	
Yes	20,868 (76.8)	18,747 (89.8)	2,121 (10.2)	
Heavy work				< 0.001
No	16,810 (61.9)	15,880 (94.5)	930 (5.5)	
Yes	10,353 (38.1)	9,002 (87.0)	1,351 (13.0)	
Repetitive hand or arm movements				< 0.001
No	8,210 (30.2)	7,780 (94.8)	430 (5.2)	
Yes	18,953 (69.8)	17,102 (90.2)	1,851 (9.8)	
Vibration exposure				< 0.001
No	21,465 (79.0)	19,942 (92.9)	1,523 (7.1)	
Yes	5,698 (21.0)	4,940 (86.7)	758 (13.3)	

Values are reported as number (%).
KRW: Korean won, LBP: low back pain.
[a]Calculated by χ^2 test.

have significant differences with job rotation. In this study, 2,281 (8.4%) workers answered that they experienced work-related LBP (**Table 2**). The rate of work-related LBP was the highest among the blue-collar group (14.4%). It was also found that the proportion of work-related LBP was high in the group with ergonomic risk factors and vibration exposure.

Table 3. Odds ratios for work-related LBP by job rotation according to occupational classification

Occupational type	Job rotation	Work-related LBP		
		Crude	Model 1[a]	Model 2[b]
White-collar	No	(ref)	(ref)	(ref)
	Yes	1.71 (1.27–2.32)	1.75 (1.30–2.37)	1.24 (0.90–1.71)
Service and sales	No	(ref)	(ref)	(ref)
	Yes	1.05 (0.77–1.43)	1.06 (0.77–1.44)	0.88 (0.63–1.22)
Blue-collar	No	(ref)	(ref)	(ref)
	Yes	0.75 (0.61–0.92)	0.79 (0.64–0.96)	0.71 (0.58–0.88)

Data presented as odds ratios and 95% confidence intervals.
LBP: low back pain.
[a]Model 1: adjusted by sex, age, education level, monthly income; [b]Model 2: model 1+ shift work, workplace scale, weekly working hours, working motion, working posture and vibration exposure.

Table 4. Odds ratios for work-related LBP by job rotation in blue-collar workers

With/without risk factor	Job rotation	Work-related LBP		
		Crude	Model 1	Model 2
Without uncomfortable posture	No	(ref)	(ref)	(ref)
	Yes	0.79 (0.28–2.24)	0.73 (0.25–2.01)	0.63 (0.21–1.89)
With uncomfortable posture	No	(ref)	(ref)	(ref)
	Yes	0.73 (0.60–0.90)	0.77 (0.63–0.95)	0.79 (0.64–0.98)
Without heavy work	No	(ref)	(ref)	(ref)
	Yes	0.86 (0.61–1.21)	0.94 (0.67–1.34)	0.84 (0.58–1.20)
With heavy work	No	(ref)	(ref)	(ref)
	Yes	0.68 (0.53–0.88)	0.69 (0.54–0.89)	0.74 (0.57–0.96)
Without repetitive hand or arm movements	No	(ref)	(ref)	(ref)
	Yes	0.79 (0.43–1.46)	0.87 (0.47–1.63)	0.86 (0.44–1.65)
With repetitive hand or arm movements	No	(ref)	(ref)	(ref)
	Yes	0.73 (0.59–0.91)	0.77 (0.62–0.96)	0.74 (0.60–0.92)
Without vibration exposure	No	(ref)	(ref)	(ref)
	Yes	0.67 (0.49–0.92)	0.71 (0.52–0.98)	0.66 (0.48–0.91)
With vibration exposure	No	(ref)	(ref)	(ref)
	Yes	0.79 (0.61–1.03)	0.78 (0.61–1.04)	0.79 (0.61–1.04)

Data presented as odds ratios and 95% confidence intervals.
LBP: low back pain.
[a]Model 1: adjusted by sex, age, education level, monthly income; [b]Model 2: model 1+ shift work, workplace scale, weekly working hours.

Relationship between job rotation and work-related LBP according to occupational classification

Despite no significant association between job rotation and work-related LBP, we analyzed the relationship between job rotation and work-related LBP by stratifying jobs into white-collar, service and sales, blue-collar to confirm the relationship by occupational type (**Table 3**). Among white-collar workers, job rotation was positively associated with work-related LBP in crude model (OR: 1.71, 95% CI: 1.27–2.32) and model 1 (OR: 1.75, 95% CI: 1.30–2.37), which became insignificant in Model 2 with additional control variables (OR: 1.24, 95% CI: 0.90–1.71). For the service and sales group, job rotation was not significantly associated with work-related LBP in all models. On the contrary, job rotation was a significant predictor of work-related LBP among blue-collar workers: blue-collar workers with job rotation was 0.75 times less likely to have work-related LBP in crude model (95% CI: 0.61–0.92), which was similarly observed in model 1 with basic control variables (OR: 0.79, 95% CI: 0.64–0.96) and Model 2 with additional controls for work environment (OR: 0.71, 95% CI: 0.58–0.88).

Relationship between job rotation and work-related LBP in blue-collar workers with/without risk factors

Table 4 shows the results from logistic regression analyses of work-related LBP stratified by ergonomic hazards and vibration exposure among blue-collar workers. In all groups without ergonomic risk factors, job rotation did not have a significant association with work-related LBP in all models. On the contrary, the negative association of job rotation and work-related LBP was significant among those with uncomfortable posture (OR: 0.79, 95% CI: 0.64–0.98), heavy work (OR: 0.74, 95% CI: 0.57–0.96) and repetitive hand or arm movements (OR: 0.74, 95% CI: 0.60–0.92). As for vibration exposure, the negative association between job rotation and work-related LBP was weaker among those with vibration exposure, whereas ORs were significantly differ from one only among those without vibration exposure.

DISCUSSION

This study aims to examine the effect of job rotation on work-related LBP, one of the most prevalent musculoskeletal symptoms among workers. The results show that job rotation was negatively associated with the risk of work-related LBP only in blue-collar occupations. Further analyses show that the effect of job rotation was stronger for blue-collar workers exposed to uncomfortable posture, heavy work, and repetitive work, whereas the effect did not vary by vibration exposure.

Previous studies reported inconsistent effects of job rotation on musculoskeletal symptoms. The primary goal of job rotation is to reduce the physical burden on workers by facilitating the use of various parts of muscles in turn. However, recent studies have shown that the effect of job rotation is ambiguous due to various characteristics of work and workplace environment [13].

For addressing the limitation of previous studies, we examined the effects of job rotation in separate models by the type of occupation. The results from logistic regression analyses show that job rotation was positively associated with work-related LBP among white-collar workers, whereas the association was not statistically significant after controlling for potential confounding factors such as working environment. In contrast, job rotation had a negative association with the risk of work-related LBP among blue-collar workers, which was statistically significant even after adjustment for confounders. The difference in the effect of job rotation may arise from intensive manual labor of blue-collar occupation.

We provided three reasons that might have driven the association between job rotation and work-related LBP. First, job rotation is known to be helpful in preventing long hours of work with fixed posture and reducing the concentration of burden on specific parts of muscles, which may get rid of many risk factors of musculoskeletal symptoms such as uncomfortable posture, heavy work, repetitive work, and vibration exposure. One study examined the effect of job rotation using electromyography, and reported that job rotation had a positive effect on anterior deltoid, trapezius, and lumbar erector spinae muscles [17]. In addition, a study of shoe factory workers reported that long-term continuous work without rest increases the risk of musculoskeletal diseases. These results can be explained by the increased risk of musculoskeletal symptoms due to the prolonged exposure to risk factors for musculoskeletal disorders [18]. Therefore, job rotation can prevent the continuation of repetitive work and inappropriate posture and reduce the occurrence of WMSDs. By rotating tasks, workers can diversify their patterns of body posture and shorten the duration of certain tasks. In fact, a study of laser scanner workers showed a significant decrease in workers' complaints and medical findings after introducing job rotation in work [19]. Therefore, job rotation is expected to significantly reduce the biomechanical strain of the body due to work.

Second, job rotation can prevent the musculoskeletal symptoms through the recovery of accumulated muscle fatigue caused by sustained work. By working with different physical needs, workers can have time to recover from muscle fatigue and strain caused by uncomfortable posture, heavy work and repetitive work [20,21]. A previous study of the mechanism of muscle damage reported that sustained work had noxious effects on muscles through the accumulation of calcium ion (Ca^{2+}), causing problems with blood-supply and subsequent muscle disorders [22]. Therefore, job rotation prevents the mechanism by which muscles are damaged and allow workers to have time to recover from fatigue. Another study found that stress hormones such as cortisol and catecholamines (e.g., epinephrine, norepinephrine) increased after physical work, and the excretion of these hormones was incomplete when not given sufficient recovery [23]. Therefore, these stress hormones may increase due to insufficient recovery, leading to musculoskeletal symptoms [24]. Likewise, job rotation can reduce the burden on the musculoskeletal system by releasing stress hormones through recovery time, and help muscles have time to recover. As shown in the results (**Table 4**), job rotation was significantly associated with the low prevalence of work-related LBP among workers with exposure to uncomfortable posture, heavy work, and repetitive work. In addition, the effect of job rotation was larger for workers exposed to such risk factors than those in better working environment. This result is consistent with previous study that more dynamic tasks with real variation in muscular load can benefit from job rotation [25].

Lastly, along with the diversification of workers' physical and psychological needs, the change of tasks through job rotation would have a protective effect on both the biomechanical and psychosocial risk factors of WMSDs [26]. Considering that psychological problems such as low social support and low job satisfaction at work induce back pain [27], job rotation can help reduce work-related musculoskeletal symptoms by relieving psychological stress in work places. Similarly, a study of nurses reported that job rotation had a positive effect on the job satisfaction, which subsequently increased organizational commitment among nurses [10]. Likewise, prior research has demonstrated a positive attitude among shoe factory workers with job rotation [28]. Shoe factory workers reported that job rotation enables them to produce better shoes, think of colleagues, and feel the improvement of work quality since they can get better knowledge over all factory processes through rotating tasks. Therefore, through the job rotation, workers can experience various tasks, reduce work aversion and increase the motivation of work. The increase in job satisfaction may reduce the subjective workload, which can decrease the risk of work-related LBP [29].

However, we also have evidence that job rotation was not helpful or ineffective for reducing work-related musculoskeletal symptoms [30]. In another study, the effect of job rotation on work-related LBP was weak since its impact was not on the peak workload but limited to only the cumulative workload [31]. Previous studies of work-related LBP concluded that back pain could arise from different mechanisms of the cumulative and peak workload [32,33]. According to this argument, the effect of job rotation may decrease when the peak workload has a greater effect on the back pain than the cumulative workload does. Therefore, it is expected that the effect of job rotation may vary by occupational characteristics and job rotation schedule.

In the white-collar occupational group, job rotation was positively associated with the risk of work-related LBP, whereas the association was not statistically significant. The white-collar occupational group has relatively less manual work demands than blue-collar or service and sales occupations. Therefore, job rotation may increase the stress of new work and

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unwanted rotation of tasks rather than reduce physical burden of work, which could result in the elevated risk of musculoskeletal symptoms [34]. This argument is consistent with the previous finding of the increased risk of musculoskeletal symptoms due to job stress [35].

Therefore, when adopting job rotation in the workplace, it is necessary to properly understand the effect of job rotation on musculoskeletal symptoms and introduce it with appropriate schedule of job rotation according to the characteristics of work. The introduction of a proper schedule of job rotation will be effective in managing the intensity of workload and muscle fatigue among blue-collar workers who are highly exposed to various risk factors of musculoskeletal symptoms (e.g., uncomfortable posture, heavy workload, repetitive work, and vibration exposure). On the other hand, this study implies that the introduction of job rotation may have limited effects in preventing work-related LBP among white-collar, service and sales workers.

There are several limitations in this study. First, this study cannot confirm the causal relationship due to the cross-sectional design of the KWCS. Future study will be able to examine the causal direction in more detail with a longitudinal study of job rotation. Second, the KWCS data are from face-to-face interview and self-report of work-related LBP and related risk factors in workplace. Therefore, the results may be imprecise and vulnerable to recall-bias [36]. Third, several factors that could affect musculoskeletal symptoms such as height, weight, exercise, and musculoskeletal disorders were not available in the KWCS data [37]. Fourth, workers who already complain of severe musculoskeletal pain may have been excluded from the study due to the healthy worker effect. Studies have shown that workers with WMSDs are more likely to move to positions with lower risk or leave their jobs [38]. Therefore, the effect of job rotation on work-related LBP may have been underestimated. Finally, it is not possible to know the exact characteristics of work and the schedule of job rotation of workers who answered that they were performing job rotation. For this reason, it was impossible to determine whether job rotation was introduced efficiently or systematically. The effectiveness of job rotation highly depends on factors of the working environment such as productivity, ergonomic training program for job rotation and acceptance of worker. Future studies need to investigate the optimal schedule of rotation and the amount of change in exposure needed in each work place.

In spite of these limitations, there are three strengths of this study. First, this study is based on a large size of sample—more than 20,000 people—from the KWCS data, a representative large-scale study of Korean population. Second, this study investigated the relationship between job rotation and work-related LBP in various occupational groups including white-collar, service and sales, and blue-collar workers. Lastly, there have been few studies in Korea to find out the relationship between job rotation and work-related LBP.

CONCLUSIONS

In conclusion, it has been confirmed that job rotation was associated with low prevalence of work-related LBP in blue-collar occupations. Further research should reveal the mechanism by which job rotation reduces work-related musculoskeletal symptoms so that the introduction of job rotation can result in reduced musculoskeletal symptoms for workers. In addition, it is necessary to investigate the introduction method and schedule management of job rotation by characteristics of work.

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