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Original Article

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The relevant factors of work-related fatigue for occupational vibration-exposed employees

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Abbreviations
ACGIH: American Conference of Governmental Industrial Hygienists; CI: confidence interval; HAV: hand-arm vibration; KWCS: Korean Working Conditions Survey; OFER: Occupational Fatigue Exhaustion Recovery; OR: odds ratio; TLV: threshold limit value. WBV: whole-body vibration.

Competing interests
The authors declare that they have no competing interests.

ABSTRACT

Background: To date, little is known about the effects of factors linked to work-related fatigue on vibration-exposed workers. Thus, the purpose of this study was (1) to assess the effects of vibration exposure time per week and work-related fatigue on workers and (2) to identify factors associated with work-related fatigue caused by long-term exposure to occupational vibration.
Methods: This study used data collected from the 5th Korean Working Conditions Survey. A total of 34,820 non-vibration-exposed and 10,776 vibration-exposed employees were selected from the data. The χ^2 and multiple logistic regression were used to determine the effect of vibration exposure time per week and the effects of factors of work-related fatigue on workers.
Results: The prevalence of work-related fatigue in vibration-exposed workers (30.5%) was higher than that of non-exposed workers (15.9%). The prevalence of work-related fatigue was higher for female and workers with depression, anxiety, and shift work, and those with authority to control their work pace had statistically significantly higher odds than those who did not. The employees who had the authority to control their order of work (odds ratio [OR]: 0.88; 95% confidence interval [CI]: 0.81–0.95) and method of work (OR: 0.90; 95% CI: 0.82–0.98) had statistically significantly lower odds than those who did not. The OR of work-related fatigue symptoms was highest among employees whose vibration exposure time per week were 30.0%–40.0% (OR: 2.36; 95% CI: 1.96–2.83). Lower OR was observed as vibration exposure time per week decreased.
Conclusions: The results of the present study suggest an association between occupational vibration and work-related fatigue and longer vibration exposure time per week, causing an increased prevalence of work-related fatigue symptoms. Measures to protect workers exposed to occupational vibration from work-related fatigue must be taken.

Keywords: Fatigue; Vibration; Occupational medicine; Surveys and questionnaires

BACKGROUND

Fatigue is typically recognized as a subjective state characterized by extreme and persistent weariness, weakness, and mental and/or physical exhaustion. It is an everyday condition that prevails after excessive physical exercise, mental effort, or insufficient sleep, and is a common complaint during doctor consultations, with patients normally presenting

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non-specific fatigue symptoms in a variety of medical situations.[1] Acute fatigue has short duration, generally affecting healthy individuals, and relieved after exercise, rest, or stress management. In contrast, chronic fatigue is perceived to be persistent abnormal state. It has a significant negative impact on daily activities and quality of life, which is relatively difficult to be recovered.[2] Impaired neuromuscular transmission in peripheral nervous system is considered as physical etiology, associated with myasthenia gravis and metabolic myopathies. Malfunction of central nervous system may have psychological effect, including deficits of motivation, integration and organization.[2-5] In psychological point of view, fatigue is defined as subjective state of weariness, which may be associated to overlong mental activity, decreased motivation, tediousness activity or monotonous surroundings.[6,7] The Epidemiologic Catchment Area Program included single question asking if interviewees ever felt tired all the time for 2 weeks or more to investigate history of fatigue and further researches were conducted for positive responses.[8]

With the many hours people typically spend working, it is difficult to avoid fatigue. Such work-related fatigue is caused by mental and emotional exhaustion linked to work, accompanied by burnout and work-induced stress, and correlated with other psychological hazards, including anxiety and depression.[9,10] Specifically, work-related fatigue results from sleep deprivation and work environment factors, such as vibration, noise, and temperature. Sleep deprivation is the most common cause of both muscular and mental fatigue, affecting between 15% and 20% of US adults. Schedule irregularities, such as shift work, make it difficult for workers to sleep sufficiently.[11] Waking up at night for night shifts is particularly difficult for workers due to sleep loss and a disrupted circadian rhythm, resulting in sleepiness and decreased work performance.[12] That is, work-related fatigue leads to diminished motivation to perform tasks, decreased physical and mental function, and ultimately, reduced work efficiency. Moreover, its occurrence among workers may cause an increase in hospital expenses, eventually leading to social costs.[10] This is because the outcomes of fatigue include short-term cognitive and physical degradation, and as it worsens, injury and illness may occur.

Considering how much loss fatigue may cause, it is essential to prevent workers from harmful effect. It stands to reason that workers should be protected from factors known to be associated with work-related fatigue. Moreover, researches covering risk factors which have possibility of having relationship with work-related fatigue. Physical agents, which include noise, radiation, extreme temperatures, and vibration, not only cause musculoskeletal disorders, but also have psychosocial effects on those exposed. Exposure to vibration take place in variety of work places. Whole-body vibration (WBV) exposure is usually transmitted in sitting or standing position from a vibrating seat and platform. Driving vehicles or operating heavy construction equipment is another source of WBV exposure. The most frequently reported adverse effects of long-term exposure to WBV are low-back pain, early degeneration of lumbar spinal system and herniated lumbar disc.[13] Continuous handling of vibrating hand-held machinery including drills, impulse tools and jackhammers may result vascular, neural and musculoskeletal diseases. In addition, low-frequency vibrations originating from a motorized hand tool may press down a nerve in the hand or arm and cause carpal tunnel syndrome. Long-term exposure to high levels of vibration can lead to motion sickness, fatigue, and headaches.[14] Vibration frequencies also influence heart rate variability and have been found to cause fatigue in drivers during simulated driving.[15] Even though plenty of previous studies explored into vibration about its characteristics and potential effect toward human body, only a few studies have examined the relationship between occupational

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vibration exposure and psychosocial factors. In particular, very few articles explore general fatigue in vibration-exposed workers.

Therefore, the purpose of this study was (1) to investigate the relationship between occupational vibration exposure time and work-related fatigue and (2) identify factors associated with work-related fatigue caused by long-term exposure to occupational vibration.

METHODS

Study subjects

For the sample, 35,695 non-vibration-exposed and 11,049 vibration-exposed workers were selected from the 5th Korean Working Conditions Survey (KWCS) data.[16]

The KWCS was conducted by the Occupational Safety and Health Research Institute (OSHRI) and the data are freely available upon request. The Korean survey benchmarked European Working Conditions Survey, which is performed by European Foundation for the Improvement of Living and Working Conditions.[17] The target population of KWCS is employees aged ≥ 15 years selected from across the nation using multistage systematic cluster sampling methods. The 5th KWCS was undertaken in 2017 through face-to-face interviews during house-to-house visits. In cases of more than 2 qualified employees in a household, trained interviewers interviewed only those whose dates of birth were closest to the research date. The KWCS collected data on each employee's general and work-related characteristics, work environment, and health status. The sample size in the 5th KWCS was 50,205 native employees, and all participants provided informed consent for inclusion before they participated in the survey. This study targeted workers whose data was complete in terms of the following items: vibration exposure, general fatigue symptom, sex, age, employment period, education, anxiety, depression, factory size, shift work, job rotation, commute time, working hours per week, and authority to control one's work pace, method, and order. As a result, 45,596 workers were selected as final sample. Survey results reflected the non-response adjustment, the extraction rate of eligible candidates in the sample household.

Measurement tools

This study used responses from questionnaire of the KWCS. Whether an employee is exposed to occupational vibration or suffering work-related fatigue symptom was determined with following questions: "How often are you exposed to vibration during your work?" "Have you experienced general fatigue symptom in last 12 months?" "Is general fatigue symptom you experienced work-related?"

Occupational vibration was classified as 1/4 of working hours, 2/4 of working hours, 3/4 of working hours, 4/4 of working hours. The percentage of vibration exposure time per week was calculated as the total number of work hours per week multiplied by the exposure rate of vibrations caused by hand tools or machinery during work hours per day (1/4, 2/4, 3/4, 4/4) was divided by 168 (24 × 7) hours. Workers in the (4/4) group included workers with full-time exposure and almost full-time exposure to vibration during working hours. For example, if a male respondent worked 9 to 5 every Monday to Friday, his working hours per week would be 40 hours. If his work included occupational vibration exposure to 2/4 of his working hours, the percentage of vibration exposure time per week would be $40 \times 2/4 \div 168 = 0.12$. The control group included workers with little or no exposure to vibrations. Existence of depression, and anxiety was determined based on the presence of symptoms during the previous 12 months.

Statistical methods

Study subjects were divided depending on prevalence of work-related fatigue symptoms. To identify the differences in work-related fatigue according to the vibration exposure time per week, general factors (sex, age, employment period, education, anxiety, and depression), and work-related factors (factory size, shift work, job rotation, commute time, working hours per week, and authority to control order/method/pace of work), the χ^2 test was used in non- and vibration-exposed employees. Linear by linear association was used as a test for trends. Next, multiple logistic regression was used to determine how each variable, including vibration exposure, sex, age, employment period, education, anxiety, depression, factory size, shift work, job rotation, commute time, working hours per week, and authority to control pace/method/order of work, affects work-related fatigue. Multiple logistic regression was performed to measure the effect of the vibration exposure time per week on work-related fatigue in vibration-exposed workers. Both multiple logistic regressions were adjusted for general factors (age, sex, employment period, education, anxiety, and depression) and job-related factors (factory size, tenure, shift work, job rotation, and authority to control pace/method/order of work). All statistical analyses were performed using SPSS (version 26.0; IBM Corp., Armonk, NY, USA).

Ethics statement

The study was approved by the Institutional Review Board of Dankook University Hospital (DKUH 2020-12-001-002), which exempted the requirement of informed consent owing to the use of public information.

RESULTS

The prevalence of work-related fatigue symptoms in non- (n = 34,820) and vibration-exposed employees (n = 10,776)

The prevalence of work-related fatigue symptoms in vibration-exposed workers (30.5%) was higher than that in non-vibration-exposed workers (15.9%), and the prevalence of work-related fatigue symptoms in non-vibration-exposed employees increased with increasing age (p for trend < 0.01). Conversely, the prevalence of work-related fatigue decreased as education level and factory size (number of workers) increased (p for trend < 0.01). The prevalence of work-related fatigue symptoms in non-vibration-exposed workers was statistically different for sex, anxiety, depression, shift work, job rotation, authority to control work order, authority to control work method, and authority to control work pace.

The prevalence of work-related fatigue symptoms in vibration-exposed employees increased with an increase in the percentage of vibration exposure time per week and age ($p < 0.01$, p for trend < 0.01). However, the prevalence of work-related fatigue symptoms in vibration-exposed employees was not statistically significant by sex. On the contrary, the prevalence of work-related fatigue symptoms decreased with an increase in education level and factory size (number of workers) ($p < 0.01$, p for trend < 0.01). The prevalence of work-related fatigue symptoms in vibration-exposed workers was statistically different in terms of sex, employment period, anxiety, depression, shift work, job rotation, factory size, commute time, working hours per week, authority to control order, authority to control method, and authority to control the pace of work (**Table 1**).

Table 1. The prevalence of work-related fatigue symptoms among non- and vibration-exposed employees

Work-related fatigue	Vibration exposure					
	Non (n = 34,820)			Yes (n = 10,776)		
	No (n = 29,299)	Yes (n = 5,521)	*p*-value	No (n = 7,490)	Yes (n = 3,286)	*p*-value
Vibration exposure time per week (%)						0.00[a]
0.0–10.0				3,303 (74.2)	1,147 (25.8)	
10.1–20.0				2,169 (71.8)	853 (28.2)	
20.1–30.0				1,607 (62.7)	954 (37.3)	
30.0–40.0				336 (55.3)	272 (44.7)	
≥ 40.0				75 (55.1)	60 (44.9)	
Sex			0.00			0.60
Male	15,607 (85.0)	2,745 (15.0)		5,955 (69.6)	2,598 (30.4)	
Female	13,692 (83.1)	2,776 (16.9)		1,535 (69.1)	688 (30.9)	
Age (years)			0.00[a]			0.00[a]
≤ 40	12,288 (88.3)	1,623 (11.7)		2,390 (78.4)	658 (21.6)	
40.1–50.0	7,321 (84.0)	1,390 (16.0)		1,839 (69.5)	807 (30.5)	
50.1–60.0	5,955 (80.4)	1,448 (19.6)		2,050 (64.8)	1,113 (35.2)	
≥ 60.1	3,735 (77.9)	1,060 (22.1)		1,211 (63.1)	708 (36.9)	
Education			0.00[a]			0.00[a]
Elementary school	1,041 (74.8)	351 (25.2)		321 (58.4)	229 (41.6)	
Middle school	1,350 (74.7)	459 (25.3)		580 (57.3)	433 (42.7)	
High school	8,562 (80.1)	2,127 (19.9)		3,309 (66.4)	1,675 (33.6)	
University	18,346 (87.7)	2,584 (12.3)		3,280 (77.6)	949 (22.4)	
Employment period (years)			0.00[a]			0.00[a]
≤ 5	16,737 (85.1)	2,941 (14.9)		3,460 (72.5)	1,310 (27.5)	
6–9	3,722 (84.5)	684 (15.5)		785 (67.0)	386 (33.0)	
≥ 10	8,840 (82.3)	1,896 (17.7)		3,245 (67.1)	1,590 (32.9)	
Anxiety			0.00			0.00
No	28,896 (85.4)	4,931 (14.6)		7,397 (71.3)	2,972 (28.7)	
Yes	403 (40.6)	590 (59.4)		93 (22.9)	314 (77.1)	
Depression			0.00			0.00
No	28,971 (85.1)	5,092 (14.9)		7,404 (70.7)	3,069 (29.3)	
Yes	328 (43.3)	429 (56.7)		86 (28.4)	217 (71.6)	
Factory size (number of workers)			0.00[a]			0.00[a]
1	3,669 (80.2)	907 (19.8)		1,064 (66.9)	527 (33.1)	
2–9	10,980 (83.1)	2,231 (16.9)		2,615 (66.4)	1,326 (33.6)	
10–49	8,442 (85.9)	1,389 (14.1)		2,088 (71.0)	853 (29.0)	
≥ 50	6,208 (86.2)	994 (13.8)		1,723 (74.8)	580 (25.2)	
Shift work			0.00			0.02
No	26,639 (84.7)	4,806 (15.3)		6,702 (69.9)	2,889 (30.1)	
Yes	2,660 (78.8)	715 (21.2)		788 (66.5)	397 (33.5)	
Job rotation			0.02			0.64
No	28,727 (84.2)	5,385 (15.8)		7,065 (69.6)	3,093 (30.4)	
Yes	572 (80.9)	136 (19.1)		425 (68.7)	193 (31.3)	
Authority to control one's order of work			0.00			0.00
No	16,706 (85.2)	2,902 (14.8)		4,123 (70.9)	1,693 (29.1)	
Yes	12,593 (82.8)	2,619 (17.2)		3,367 (67.9)	1,593 (32.1)	
Authority to control one's method of work			0.00			0.00
No	17,580 (85.5)	2,974 (14.5)		4,183 (71.1)	1.698 (28.9)	
Yes	11,719 (82.2)	2,547 (17.8)		3,307 (67.6)	1,588 (32.4)	
Authority to control one's pace of work			0.00			0.00
No	18,289 (86.2)	2,924 (13.8)		4,093 (73.4)	1,486 (26.6)	
Yes	11,010 (80.9)	2,597 (19.1)		3,397 (65.4)	1,800 (34.6)	
Commute time (hours)			0.00[a]			0.01[a]
≤ 30	13,828 (82.9)	2,859 (17.1)		3,614 (69.1)	1,615 (30.9)	
31–59	8,098 (85.1)	1,414 (14.9)		1,940 (68.7)	885 (31.3)	
≥ 60	7,373 (85.5)	1,248 (14.5)		1,936 (71.1)	786 (28.9)	
Working hours per week			0.00[a]			0.00[a]
≤ 40	17,036 (88.1)	2,294 (11.9)		3,556 (76.0)	1,124 (24.0)	
41–52	7,467 (82.4)	1,591 (17.6)		2,354 (68.4)	1,090 (31.6)	
≥ 53	4,796 (74.6)	1,636 (25.4)		1,580 (59.6)	1,072 (40.4)	

Values are presented as number (%).
[a]*p* for trend test < 0.05.

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The odds of work-related fatigue symptoms for non- and vibration-exposed employees (n = 45,596)

The odds ratio (OR) of work-related fatigue symptoms was statistically significant higher for non- and vibration-exposed female workers than for male workers, and the OR increased with age. Conversely, the OR decreased as education level and factory size (number of workers) increased among non- and vibration-exposed workers. The OR was also statistically significantly higher for employees with anxiety than for those without (OR: 5.84; 95% confidence interval [CI]: 5.10–6.68) and statistically significantly higher for employees with depression than for those without (OR: 2.49; 95% CI: 2.12–2.92). Employees who worked shift-based jobs had statistically significantly lower odds than those who did not (OR: 1.37; 95% CI: 1.26–1.48). Similarly, employees with the authority to control their order of work (OR: 0.88; 95% CI: 0.81–0.95) had statistically significantly lower odds than those without. Moreover, employees with the authority to control their work method (OR: 0.90; 95% CI: 0.82–0.98) had statistically significantly lower odds than those without, and those with the authority to control their work pace (OR: 1.68; 95% CI: 1.56–1.81) had statistically significantly higher odds than those without (**Table 2**).

The OR of vibration exposure time per week to work-related fatigue for vibration-exposed workers

The OR of work-related fatigue symptoms was highest among employees whose vibration exposure time per week were 30.0%–40.0% (OR: 2.36; 95% CI: 1.96–2.83). Debasement of the OR was noted as vibration exposure time per week decreased. Employees whose vibration exposure time per week were 20.0%–30.0% (OR: 1.71; 95% CI: 1.53–1.91), which was still higher than the OR of 10.0%–20.0% group (OR: 1.15; 95% CI: 1.03–1.28) and 0.0%–10.0% group (**Table 3**).

DISCUSSION

Among 45,596 employees, 8,807 employees answered that they had suffered general fatigue within a 12-month period, which was related to their work. Investigation was proceeded in order to examine relationship between exposure to occupational vibration and work-related fatigue. As a result, the prevalence of work-related fatigue symptoms was significantly higher in vibration-exposed workers than in non-exposed workers, and the prevalence of work-related fatigue symptoms increased with vibration exposure time. Assessment of factors which worsen work-related fatigue symptoms were conducted along, and factors such sex (female), anxiety, depression, shift-based jobs, extended working hours, and authority to control one's work pace led to an increased prevalence of work-related fatigue symptoms. The prevalence of work-related fatigue symptoms was lower in those with higher education, younger age, larger factory, and authority to control order and method of work.

The result of present study is similar to result of past studies, which suggest increased fatigue symptoms in female sex,[12, 18, 19] depression and anxiety,[20, 21] extended working hours[22, 23] and shift work,[24] although it contradict to previous study indicating that application of job rotation led to less accumulation of fatigue.[25] Previous study of Faro investigated fatigue symptom of 1,309 patients, and more chronic pain were reported by female patients compared to male patients (27.9% vs. 18.5%),[18] which was consistent with the trend of present study. Chung compared patients with sustained fatigue over one month and control group, and significant difference of Hospital Anxiety and Depression scale in depression part was noted.[20] Park et

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Table 2. The odds of work-related fatigue symptom for non- and vibration-exposed employees

Variables	OR (95% CI)
Vibration exposure	
No	1.00
Yes	1.99 (1.88–2.10)
Sex	
Male	1.00
Female	1.21 (1.14–1.28)
Age	
≤ 40	1.00
40.1–50.0	1.33 (1.24–1.42)
50.1–60.0	1.42 (1.31–1.53)
≥ 60.1	1.28 (1.16–1.41)
Education	
Elementary school	1.00
Middle school	0.91 (0.79–1.03)
High school	0.63 (0.56–0.71)
University	0.43 (0.38–0.49)
Employment period (years)	
≤ 5	1.00
6–9	1.11 (1.02–1.20)
≥ 10	1.11 (1.05–1.18)
Anxiety	
No	1.00
Yes	5.84 (5.10–6.68)
Depression	
No	1.00
Yes	2.49 (2.12–2.92)
Factory size (number of workers)	
1	1.00
2–9	1.19 (1.10–1.29)
10–49	1.17 (1.08–1.28)
≥ 50	1.18 (1.07–1.30)
Shift work	
No	1.00
Yes	1.37 (1.26–1.48)
Job rotation	
No	1.00
Yes	1.05 (0.91–1.21)
Authority to control one's order of work	
No	1.00
Yes	0.88 (0.81–0.95)
Authority to control one's work method	
No	1.00
Yes	0.90 (0.82–0.98)
Authority to control one's work pace	
No	1.00
Yes	1.68 (1.56–1.81)
Commute time (hours)	
≤ 30	1.00
31–59	1.02 (0.97–1.10)
≥ 60	1.05 (0.99–1.12)
Working hours per week	
≤ 40	1.00
41–52	1.57 (1.47–1.66)
≥ 53	2.23 (2.09–2.38)

Adjusted for general factors (age, sex, education, employment period, anxiety, and depression) and job-related factors (factory size, shift work, work rotation, commute time, working hours per week, and authority to control one's order, method, and pace of work).
OR: odds ratio; CI: confidence interval.

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Table 3. The OR of vibration exposure time per week to work-related fatigue for vibration-exposed workers

Vibration exposure time per week (%)	OR (95% CI)
0.0–10.0	1.00
10.0–20.0	1.15 (1.03–1.28)
20.0–30.0	1.71 (1.53–1.91)
30.0–40.0	2.36 (1.96–2.83)
≥ 40.0	1.85 (1.29–2.64)

Adjusted for general factors (age, sex, education, employment period, anxiety, and depression) and job-related factors (factory size, shift work, work rotation, commute time, and authority to control one's order, method, and pace of work).
OR: odds ratio; CI: confidence interval.

al.[21] investigated fatigue and anxiety of 223 student nurses in training, applying subjective symptoms of fatigue test and State-Trait Anxiety Inventory as tools. Physical, mental, neurosensory fatigue showed significant association with anxiety, respectively. Prior research of nurses providing full-time patient care identified significant relationship between shift rotation and fatigue, which measured by Occupational Fatigue Exhaustion Recovery (OFER) scale.[26] Survey conducted by Park et al.[22] showed significant increase of fatigue dimension of drowsiness and dullness in subjects working longer hours. Beaulieu also emphasized how driver fatigue induced by extended working time increase risk of accident and occupational disease rate.[23]

Previous studies suggest that having more job control contributes to reducing occupational strain, including work pace.[9, 27-29] Nevertheless, employees with the authority to control their work pace had a higher prevalence of work-related fatigue in this study. This may be because many of the employees worked under the incentive system, receiving additional economic benefit pursuant to their accomplishment, which lures employees to increase their work pace beyond their bearable range. This result correlate to a past trial implying that fatigue should be considered when designing incentive plan.[30]

The significance of this study is that, compared to the extensive research on the association between vibration and musculoskeletal health effects, there have been few previous attempts to investigate the relationship between occupational vibration and psychosocial health effects, work-related fatigue in particular. As importance of mental care arise, inspection of exposure sources traditionally considered to cause mechanical problems should take place to confirm their effect to psychological aspects. Another strength of this study include plentiful number of participants, which apply as reinforcement to statistical analysis. Past studies of work-related fatigue symptoms often based on questionnaires answered by few hundreds of workers. However, since the KWCS was conducted nationwide, it represent large number of workers working in various age, area, job, and factory size, which minimize bias which originate from the distinctiveness of certain working field questionnaires received.

One of the limitation of present study is that questionnaires of present study did not categorize occupational vibration specifically, therefore, it would be better for following study on this issue to provide a more detailed classification of occupational vibration and more information about the characteristics of each occupational vibration type. Two major types of vibration–body interactions affect human health: segmental vibration and WBV.[31] Local (segmental or hand-arm) vibration refers to the application of vibration to a certain part of the body, for example the hand and arm region (thus, hand-arm vibration [HAV]). Although exposed to same minutes, influence toward human body may differ depending on various factors, including range of amplitude and frequency, method of application, exercise protocol, and training intensity.[32] Accurate measurement at working field followed by passionate analysis is required to identify specific trait that deteriorate workers' health.

Subsequent studies may consider more elaborate assessment of work-related fatigue. The effort-reward imbalance model purports that structural conditions of nonsymmetrical contracts result in strain from an imbalance between high effort and low reward.[33] The Job Content Questionnaire measures the psychological and social aspects of jobs, including decision latitude, psychological demands, social support, physical demands, and job insecurity. It aims to assess the relative risks of each worker's vibration exposure, which helps to predict coronary heart disease, reproductive disorders, psychological disorders, and musculoskeletal disease.[34] OFER scale starts from the hypothesis that persistent low recovery from acute fatigue is related to chronic fatigue of higher levels, predicting chronic fatigue score from negative correlation between recovery scores.[26]

As negative health effect of exposure to occupational vibration is revealed, measures to protect workers from vibration is essential, of which both reducing the vibration level from the vibrations' origin and blocking the vibration transmission are effective. Minimized exposure time and implementation of low-vibration machinery may be considered options, although lower vibration levels of tools often result in inefficient productivity. Therefore, anti-vibration gloves are worn in an attempt to stop the transmission of vibration from the tool to the body.[35] Anti-vibration gloves also contribute to decreasing the risk caused by vibration by keeping hands dry and warm, while blocking contaminants.[36] Both the advantages and disadvantages of anti-vibration gloves must be considered carefully, especially since thicker gloves—while reducing vibration transmission—also decrease deftness and require more grip force to operate machines.[37]

Strengthening regulations to prevent workers from being exposed to harmful degree of occupational vibration is another option. The guidelines developed by the American Conference of Governmental Industrial Hygienists (ACGIH) provide threshold limit values (TLVs) for both WBV and HAV. The TLV for workers with an HAV exposure time of 8 hours is 5 ahv(rms)m/s^2.[38] Directive 2002/44/EC of the EU states a daily exposure limit value of 5 m/s^2 for 8-hour HAV exposure per day. However, such regulations are currently absent in Korea. According to a previous study on the 2018 revised ACGIH® hand activity TLV to protect workers from carpal tunnel syndrome,[39] advanced regulation may contribute to modifying the work environment for occupational vibration, ultimately improving the health status of workers. Considering the unique features of Korean industries, adequate evaluation of the current occupational vibration exposure status is also necessary for the Korean context.

CONCLUSIONS

The results of the present study suggest an association between occupational vibration and work-related fatigue and longer vibration exposure time per week, causing an increased prevalence of work-related fatigue symptoms. Further, work-related fatigue symptoms were prevalent in female workers, as well as workers with anxiety, depression, shift-based jobs, and authority to control their work pace, and diminished in workers with authority to control their order and method of work. Less work-related fatigue symptoms were observed among workers with higher levels of education, younger age, or working at a larger factory. More specific classification of occupational vibration and more elaborate assessment of work-related fatigue would make a better study. Measures to protect workers exposed to occupational vibration from work-related fatigue must be taken.

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