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Article

Evaluation of the Burden of Musculoskeletal Disorders in Korean Workers Using the Job-Exposure Matrix

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Abstract: Background: This study attempted to construct musculoskeletal JEM using KWCS data and use it to evaluate the burden of these disorders in Korean workers. **Methods:** This study was conducted using data from the second to the sixth KWCS, and a total of 210,500 people were included. The jobs of the subjects were reclassified based on the unit groups of the 7th Korean Standard Classification of Occupation (KSCO). The intensity of exposure to work-related risk factors for musculoskeletal disorders was classified into 'high', 'moderate', and 'low' for the body segments involving the 'upper extremities and neck', 'lower back', and 'lower extremities'. **Results:** The time of exposure was longest in the standing posture and repetitive hand and arm movements. An analysis of the intensity of exposure by body segments revealed that the highest intensity of exposure was to the upper extremities. For the upper extremities and neck, and the lower back, there was an exposure-response relationship in the association between intensity of exposure and musculoskeletal symptoms. However, for the lower extremities, there was an exposure-response relationship only at high exposure. **Conclusion:** In this study, a JEM for work-related risk factors for musculoskeletal disorders was constructed for the first time in Korea. The intensity of exposure to musculoskeletal risk factors was estimated for each occupation. The JEM constructed in this study is expected to have high applicability for assessing the risk of musculoskeletal disorders for each job with respect to the upper extremities and neck, and lower back.

Keywords: Job exposure matrix; Musculoskeletal symptoms; Exposure assessment

1. Introduction

Musculoskeletal disorders account for more than 60% of occupational diseases in Korea [1-2]. Although the approval rate for the recognition of occupational diseases has recently been increasing in Korea, disputes about the work-relatedness of musculoskeletal diseases still continuously occur. These disputes occur because musculoskeletal disorders are characteristically associated with a diverse set of factors, including individual, ergonomic, and psychosocial. Another reason for the dispute about work as the cause of musculoskeletal disorders is that it is difficult to make a quantitative assessment of exposure leading to the disorder because a wide range of exposures occur depending on the type and nature of the occupation.

Job exposure matrices (JEMs) have played a very important role in assessing exposure to risk factors [3]. Therefore, JEMs have been constructed for various hazardous factors such as asbestos [4-7], noise [8-9], job stress [10-11], and solvents [12-13]. These kinds of occupational risk factors do not universally exist in all industries, and the diseases caused by such hazardous factors in the working environment are limited. However, musculoskeletal disorders can occur in almost all types of industries and occupations, and there are various types of musculoskeletal conditions, making it

difficult to construct a musculoskeletal disorder-specific JEM. As a result, attempts to construct a JEM for musculoskeletal disorders were not made until 2010. A JEM focused on the musculoskeletal system is the Comparison Between a Self-Reported Job Exposure Matrix (CONSTANCES JEM) developed in France [14]. This JEM consists of 407 job codes and 27 occupational and ergonomic factors. In Finland, a JEM for workers living in Helsinki has been proposed, and it comprises 40 job codes and the following three types of factors: physical effort, heavy lifting, and carrying [15]. In addition, a JEM built in the Netherlands [16] and a JEM using data from the Occupational Information Network (O*NET) in the United States [17] have been presented, and there was also a prior study to construct a JEM limited to hip and knee arthritis [18]. However, the existing JEMs available in these countries are limited by region or occupation or were specifically constructed for certain diseases in particular occupations, limiting their utility across all job types.

In Korea, it was possible to construct JEMs for occupational exposures to asbestos, benzene, and trichlorethylene because relevant data, such as measurement of exposure in the work environment and associated research, were available. On the other hand, in work-related musculoskeletal disorders, there was no data on types of exposure in different types of industries and occupations. Since the initiation of the Korean Working Conditions Survey (KWCS) conducted by the Occupational Safety and Health Research Institute (OSHRI) every 3 years since 2006 to monitor changes in the working conditions of Koreans, it has become possible to identify risk factors for musculoskeletal disorders in across industries. However, no attempt has yet been made to construct a JEM for musculoskeletal disorders for Korean workers. Moreover, although the assessments of occupational burden have been made for individual tasks or occupations, such assessments have not yet been made for all types of occupations.

Therefore, this study attempted to evaluate the musculoskeletal burden among Korean workers by constructing a JEM using data from the KWCS.

2. Materials and Methods

2.1. Data sources and study population

The KWCS has been carried out six times since 2006. This survey was developed based on the European Working Conditions Survey, and it is conducted triennially to examine the overall working environment, including the type of work, employment, occupation, industry, exposure to risk factors, and employment stability, among workers aged 15 years or older in Korea. The first and second KWCS surveyed only 10,000 people, but 50,000 people have been surveyed since the third KWCS. In this study, data from the 2nd to 6th KWCSs were used. Data from the 1st KWCS, which used a different occupational classification system, has been excluded. A total of 210,500 people were finally selected as subjects, excluding people whose occupations were difficult to classify. The subjects included 9,991 participants of the 2nd KWCS, 49,957 participants of the 3rd KWCS, 49,905 participants of the 4th KWCS, 50,110 participants of the 5th KWCS, and 50,537 participants of the 6th KWCS.

2.2. Job classification

In this study, the job classification was based on the Korean Standard Classification of Occupations (KSCO) developed by Statistics Korea. Initially, the KWCS data categorized occupations using either the unit group or the detailed occupational categories of the 6th KSCO. Subsequently, for this study, these classifications were updated to align with the unit group categories of the 7th KSCO, the updated version of which was published in 2017.

2.3. Musculoskeletal risk factors

To assess the risk factors related to work-related musculoskeletal disorders, questionnaire items about local vibrations among physical risk factors and ergonomic factors were used. To identify musculoskeletal risk factors related to the upper extremities and neck, the questions included the following: ① Vibrations from hand tools or machines, ② Postures that cause fatigue or pain, and ③

Repetitive hand or arm movements. To identify musculoskeletal risk factors associated with the lower back, the questions included the following: ① Lifting, pushing or carrying heavy objects, ② Posture that causes fatigue or pain, and ③ Lifting or moving people. The musculoskeletal risk factors of the lower extremities were examined using questions related to ① Lifting, pushing, or moving heavy objects and ② Prolonged standing posture. The exposure intensity was measured on a 7-point scale. The duration of exposure to risk factors was classified as 'high', 'moderate', or 'low' exposure. When the exposure encompassed the entire working hours or most or 3/4th of the working hours, the responses were classified as 'high exposure', and when the duration of exposure was 1/2, or 1/4th of the total working hours, the responses were classified as 'moderate exposure'. When the subjects responded, 'rarely exposed/never exposed', these cases were categorized as 'low exposure'.

2.4. Musculoskeletal symptoms

Musculoskeletal symptoms were examined based on responses to questions about the presence or absence of upper extremity and neck pain, low back pain, and lower extremity pain.

2.5. Exposure intensity to musculoskeletal risk factors by body segment and job categories

The questionnaire on the exposure intensity of the subjects comprised 3 questions about each body segment in the case of the upper extremities, neck, and lower back and 2 questions about the lower extremities, and the exposure intensity was determined by combining the responses. When one or more responses were high intensity, the exposure intensity of the body part was determined as high intensity, and when two or more responses were moderate intensity, the exposure intensity was determined to be moderate intensity. When all the responses were low intensity or when only one response was moderate intensity and the other responses were low intensity, the exposure intensity of the body part was determined to be low intensity. Based on these results, the exposure intensity by job category was determined as follows: When the proportion of high intensity was 60% or higher, the exposure intensity was determined as high intensity; when the proportion of low intensity was 60% or higher, the exposure intensity was determined as low intensity; and, in other cases, exposure intensity was determined as moderate intensity.

2.6. Validity of JEM

To assess the validity of the estimated exposure intensities by job categories using the constructed JEM, two ergonomics experts were provided with the survey questions, job titles, and job descriptions as indicated by the KSCO and were asked to assess the exposure intensity for each body segment. For the items where the evaluations of the two ergonomists were not in agreement, a consensus was derived through discussion. Then, the level of agreement between the assessment results of the two ergonomists and the estimates of exposure intensity from the JEM was analyzed, and a kappa coefficient value of 0.8 or greater was considered to indicate a very high level of agreement [19]. Additionally, a logistic regression analysis was performed to determine whether there was a exposure-response relationship between exposure intensity by job category and musculoskeletal symptoms.

2.7. Statistical analysis

Statistical analysis was conducted using SAS (version 9.4), and the k2 test, t-test, logistic regression analysis, and Cohen's kappa coefficient analysis were performed.

3. Results

3.1. General characteristics of the subjects

The general characteristics of the subjects are shown in Table 1. The 40-49- and 50-59-year age groups accounted for the largest proportion of the subjects. The mean age of the subjects was 48.4 years, and the mean ages of the males and females were 48.1 years and 48.8 years, respectively.

Table 1. General characteristics of the subjects.

Age	Gender		Total	p-value
	Male	female		
<30	9,825 (9.23%)	10,452 (10.05%)	20,277 (9.63%)	<0.01*
30 ≤ age < 40	22,115 (20.77%)	17,929 (17.23%)	40,044 (19.02)	
40 ≤ age < 50	26,721 (25.10%)	26,694 (25.66%)	53,415 (25.38%)	
50 ≤ age <60	24,589 (23.10%)	25,925 (24.92%)	50,514 (24.00%)	
60 ≤ age	23,217 (21.81%)	23,033 (22.14%)	46,250 (21.97%)	
Total	106,467 (100%)	104,033 (100%)	210,500 (100%)	
Mean(SD)	48.10 (±14.03)	48.80 (±14.50)	48.44 (±14.30)	<0.01**

* k² test, ** t-test.

3.2. Distributions of exposure intensity by question

The results of exposure intensity for each question in the questionnaire are shown in Table 2. The standing posture and repetitive hand or arm movements were associated with the highest intensity of exposure, while hand tool or machine vibrations, and activities involving lifting, pushing, or moving heavy objects, were linked to lower levels of high-intensity exposure. (Table 2).

Table 2. Distributions of exposure intensity by survey items.

Question	High exposure	Medium exposure	Low exposure	p-value
Vibration from hand tools, machines, etc.	17,377 (8.26%)	33,581 (15.95%)	159,542 (75.79%)	<0.01*
Postures that cause fatigue or pain	38,072 (18.09%)	70,259 (33.38%)	102,169 (48.54%)	
Lifting, pushing, or moving heavy objects	19,563 (9.28%)	65,269 (31.01%)	125,695 (59.71%)	
Standing posture	64,982 (30.87%)	77,776 (36.95%)	67,742 (32.18%)	
Repetitive hand or arm movements	52,584 (39.23%)	59,879 (28.45%)	68,037 (32.32%)	

* k² test.

3.3. Distributions of exposure intensity by body segment

In terms of the exposure intensity of body segments, the greatest amount of high-intensity exposure was to the upper extremities, followed by the neck, lower extremities, and lower back in descending order (Table 3).

Table 3. Distributions of exposure intensity by body parts.

Body parts	High exposure	Medium exposure	Low exposure	p-value
Upper extremity and neck	93,082 (44.22%)	35,627 (16.92%)	87,791 (38.86%)	<0.01*

Back	33,373 (15.85%)	64,746 (30.76%)	112,381 (53.39%)
Lower extremity	69,774 (33.15%)	74,661 (35.47%)	66,065 (31.38%)

* k² test.

3.4. Validity of the JEM for musculoskeletal disorders

As described above, two ergonomics experts were asked to evaluate the intensity of exposure by occupation and body segment, and the exposure intensity was determined by reaching a consensus through discussion. For some items where there was a disagreement in the assessment results between the two ergonomics experts. Cohen’s kappa coefficient was used to compare the results of the evaluation of the exposure intensity by the two ergonomics experts with the exposure intensity determined by the JEM. In the case of the upper extremities, neck, and lower back, the evaluations of both experts showed a kappa coefficient value of 0.8 or greater in terms of the level of their agreement with the estimates of exposure intensity based on the JEM. Also, for the items of disagreement in the expert evaluations, the level of agreement was higher in the evaluation results obtained through consensus than in the individual evaluation results presented by each ergonomics expert. On the other hand, for the lower extremities, the kappa coefficient value was less than 0.8 (Table 4).

A logistic regression analysis adjusted for gender and age was conducted to examine the relationship between exposure intensity and musculoskeletal symptoms. The results of the analysis showed that there was a exposure-response relationship between the exposure intensity and symptoms in the upper extremities, neck, and lower back. In contrast, for the lower extremities, this relationship was significant only at high exposure levels. (Table 5).

Table 4. Cohen and Fleiss kappa coefficient between JEM and 2 ergonomists.

Body parts	JEM and Ergonist 1 ^a	JEM and Ergonist 2 ^a	JEM and results of consensus ^a
Upper extremity and neck	0.93	0.87	0.93
Back	0.89	0.89	0.96
Lower extremity	0.83	0.74	0.79

^a Cohen’s kappa coefficient.

Table 5. Results of logistic regression between exposure intensity and musculoskeletal pain.

Body parts	variables	OR [†]	95% CI
Upper extremity and neck	Medium vs low	1.57	1.53-1.61
	High vs low	3.06	2.99-3.14
Back	Medium vs low	1.51	1.47-1.55
	High vs low	2.28	2.21-2.36
Lower extremity	Medium vs low	0.93	0.90-0.97
	High vs low	1.41	1.37-1.45

[†] Age and gender were adjusted.

4. Discussion

4.1. Difficulty of construction and importance of the musculoskeletal JEM in Korea

In Korea, the construction of a JEM for musculoskeletal disorders has been hampered by a lack of comprehensive data encompassing all the regions, types of industries, and occupations. Since 2004,

investigations into musculoskeletal risk factors have been conducted at all workplaces triennially in Korea. Although the detailed and accurate data from these investigations related to the burden of musculoskeletal risk is available at each company, it is confidential and not in the public domain for use by researchers. Meanwhile, the data on the compensation for occupational injuries and diseases from the Korea Workers' Compensation and Welfare Service (KCOMWEL) allows us to determine the presence or absence of the musculoskeletal burden by job category for some occupations based on reports of on-site investigations and approval status. However, this data has limitations since it only contains data on some specific occupations. The KWCS, which has been implemented since 2006, is conducted by selecting a representative sample of the total population of workers. It provides data on various harmful factors and health status [20]. Hence, it provides an opportunity to construct a musculoskeletal JEM. Nevertheless, attempts to construct a musculoskeletal JEM have not been made so far in Korea.

As is well known, multiple factors lead to the development of musculoskeletal disorders. Specifically, musculoskeletal risk factors include not only occupational risk factors but also individual factors such as gender, age, and hobbies, thus making it difficult to exclusively associate musculoskeletal disorders with work. The reasons for the non-approval of the applications for recognition of musculoskeletal disorders as occupational diseases include the lack of a confirmed diagnosis of the disease for which the compensation claim was filed, a short period of employment, and a low level of occupational burden. Above all, differences in judgments regarding occupational burdens between occupational and environmental medicine (OEM) physicians can be problematic. In some cases, although the musculoskeletal condition of the workers was judged to be strongly related to occupational exposure in special examinations performed by OEM physicians, compensation claims were rejected in the actual workers' compensation adjudication on the grounds that the diseases had a low level of work-relatedness. There have also been cases with contrary outcomes. This phenomenon may be attributed to differences in the experience regarding occupational burdens between OEM physicians due to the differences in the types of main industries in each region. It is common to find cases where there are also differences in the judgments about occupational burdens. Since the musculoskeletal JEM constructed in this study can provide data encompassing all types of industries and occupations, it is expected to reduce the differences among OEM physicians in determining the work-relatedness or occupational burden of musculoskeletal conditions. Furthermore, in Korea, a fast-track system including 'presumption principles' has been implemented to resolve delays in handling workers' compensation adjudication cases due to the on-site investigations of musculoskeletal disorders. Since the presumption principles have been basically established with respect to specific types of occupations, it is very important to determine the occupational burden for each occupation. To assess the burden of work caused by each type of occupation on the musculoskeletal system, the construction of a musculoskeletal JEM is considered to be of great significance.

4.2. Job classification and validity of musculoskeletal JEM

The job classification used in this study was based on the unit groups of the 7th KSCO and some occupations such as nurses, designers, and welders were classified into separate job categories. However, some job categories corresponded to unit groups that included several occupations, such as construction-related technical workers, production-related elementary workers, and health and medical service-related workers. With respect to these categories, the job classification was not performed in a uniform, consistent manner but was based on mixed classification criteria in terms of the hierarchical levels of job classification. While the most ideal approach would be to classify jobs according to the detailed job categories of the KSCO, in the occupational classifications of the 2nd to 6th KWCS, the unit groups, and detailed job categories were mixed. Thus, in this study, they were reclassified into unit groups of jobs. However, the classification of occupations into unit group categories rather than detailed job categories is believed to have the advantage of reducing classification errors by investigators. To evaluate the validity of the estimated exposure intensities for musculoskeletal risk factors by job category and body part, this study asked two ergonomists to

evaluate exposure intensities by job category and body part. For items for which the evaluation results of the two ergonomists were not in agreement, the exposure intensity was determined through consensus. Subsequently, the evaluation results of the two ergonomists were compared with the exposure intensity determined by the JEM. Thus, for the upper extremities, neck, and lower back, the kappa coefficient values were all 0.9 or greater, showing almost perfect agreement, and a exposure-response relationship was also confirmed in the analysis of the association between the exposure intensity and musculoskeletal symptoms. On the other hand, for the lower extremities, the kappa coefficient value was less than 0.8, indicating substantial agreement, and in terms of the association between exposure intensity and musculoskeletal pain, there was a exposure-response relationship only at high exposure intensities. This is presumed to be because questions about the upper extremities, neck, and lower back comprised questions related to actual musculoskeletal disorders and symptoms, such as work posture and handling heavy objects. However, questions about the lower extremities were not directly related to ergonomic factors regarded as the actual musculoskeletal burden, such as handling heavy objects and the duration of standing posture. Therefore, when using the JEM results of this study, it is possible to directly apply the study results as is in the case of the upper extremities, neck, and lower back, but it is recommended that they be applied only to the cases of high intensity exposure in the case of the lower extremities.

4.3. Advantages and limitations of this study

4.3.1. Advantages

The primary advantage of this study lies in its pioneering effort to construct a Korean musculoskeletal JEM. In addition, the data from the KWCS is highly reliable because the survey is conducted by selecting a representative sample from the entire population of workers. Hence, the musculoskeletal JEM constructed in this study can be applied to a wide population, since it was built by using large-scale data collected from more than 200,000 people. Another advantage of the present study is that the musculoskeletal JEM built in this study has high applicability since it was constructed to provide data for all the major body segments of the musculoskeletal system, including the upper extremities, neck, lower back, and lower extremities.

4.3.2. Limitations

One of the limitations of this study is that the questions on the physical and ergonomic factors used to examine the exposure intensity were simple and did not include all the risk factors for musculoskeletal disorders. Specifically, the questions on the lower extremities were not directly related to the actual risk factors associated with musculoskeletal symptoms or conditions. Moreover, the KWCS was conducted by survey interviewers using the one-on-one interview method. Thus, there is a possibility of misclassification of the occupation. In addition, data on ergonomic factors and symptoms may be inaccurate or have low reliability because they were based on the self-reports of survey participants. Individual factors, including height, weight, and recreational activities, could contribute to musculoskeletal symptoms. However, such variables were excluded from this analysis due to their absence in the KWCS dataset.

4.4. Further study

Since it is considered more effective to construct a JEM by classifying jobs into detailed categories, it is necessary to reconstruct the JEM through the reclassification of occupations into detailed job categories in the future. Furthermore, while ergonomic factors are recognized as significant contributors to musculoskeletal symptoms, the potential influence of social and psychological factors on musculoskeletal disorders should not be overlooked. Incorporating these dimensions into the construction of a musculoskeletal JEM is expected to enhance its comprehensiveness and accuracy.

5. Conclusions

In this study, a musculoskeletal JEM was constructed in Korea for the first time. The body segments where musculoskeletal disorders commonly develop were divided into the following four regions: The upper extremities, neck, lower back, and lower extremities. The intensity of exposure to risk factors was determined for each occupation, and high validity was secured through expert reviews and an analysis of the association between the exposure intensity and symptoms. The analysis results with respect to the upper extremities, neck, and lower back are expected to be highly useful in evaluating the musculoskeletal risks by occupation. However, for the lower extremities, it is recommended that the JEM be applied only in cases of high-intensity exposure.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

The appendix below shows the intensity of exposure to musculoskeletal risk factors by occupation and area according to the order of the 7th KSCO Korean job title.

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