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Eun-Soo Lee , Myong-Hwan Kim , Dongmug Kang , Yeon-Hyang Lee , Yoon-Ji Kim , Se-Yeong Kim , Youngki Kim *

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Musculoskeletal Symptom Burden Across Occupations in Korea: Linking Korean Working Conditions Survey Data with a Body-Part–Specific Exposure Assessment

Eun-Soo Lee [1], Myong-Hwan Kim [1], Dongmug Kang [1,2,3], Yeon-Hyang Lee [4], Yoon-Ji Kim [2], Se-Yeong Kim [1,2,3] and Youngki Kim [1,2,3,*]

[1] Department of Occupational and Environmental Medicine, Pusan National University Yangsan Hospital, 50612 Yangsan, Republic of Korea
[2] Department of Preventive, and Occupational & Environmental Medicine, School of Medicine, Pusan National University, 50612 Yangsan, Republic of Korea
[3] Research Institute for Convergence of Biomedical Science and Technology, Pusan National University Yangsan Hospital, 50612 Yangsan, Republic of Korea
[4] Department of Nursing, Choonhae College of Health Sciences, 44965 Ulsan, Republic of Korea
* Correspondence: mungis@pusan.ac.kr; Tel.: +82-51-510-8031

Abstract

Background and objectives: Musculoskeletal disorders (MSDs) are the most common work-related diseases in Korea, yet nation-wide estimations of their occupational burden remain scarce. This study aimed to (1) assess the prevalence and distribution of MSD symptoms by body part; (2) construct a body-part–specific job exposure matrix (JEM) for ergonomic risk factors using representative national data; (3) validate the JEM through expert consensus; and (4) examine dose–response relationships between exposure intensity and MSD symptoms. ***Materials and Methods:*** We analyzed data from 215,000 Korean workers across five waves (2006–2020) of the Korean Working Conditions Survey (KWCS). A JEM was created based on self-reported ergo-nomic exposures by occupational category. Expert review and agreement statistics were used to validate exposure estimates. Logistic regression was applied to evaluate associations between exposure levels and MSD symptoms. ***Results:*** Symptoms were re-ported in the upper extremities and neck (35.3%), back (20.3%), and lower extremities (24.6%), with over 40% of respondents experiencing symptoms in multiple body parts. The JEM showed strong agreement with expert ratings ($\kappa \geq 0.80$ for upper body and back), and exposure intensity was positively associated with symptom prevalence, particularly in the upper body and back. Occupations such as crop growers and construction workers had high levels of both exposure and symptom burden. ***Conclusions:*** This study developed and validated the first body-part–specific ergonomic JEM for Korean workers using nationally representative data. Findings support data-driven prioritization of high-risk occupations and provide a foundation for future surveillance and prevention of work-related MSDs in Korea.

Keywords: Exposure assessment; Job classification; Risk assessment; ergonomic risk factors; Exposure-response relationship; Workplace risk evaluation

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1. Introduction

Musculoskeletal disorders (MSDs) represent the most common occupational disease in Korea, accounting for more than 60% of compensated cases [1,2]. Despite increasing recognition of occupational diseases in recent years, disputes over the work-relatedness of MSDs persist. One reason for this is the inherent difficulty in quantifying ergonomic risk exposures that vary widely across job categories. MSDs are also influenced by multiple factors, including ergonomic, individual, and psychosocial characteristics, which further complicates occupational attribution [3].

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A comprehensive understanding of MSD burden across job groups is essential for prioritizing high-risk occupations and informing preventive strategies. However, direct measurement of exposure in large populations is rarely feasible. As a solution, Job Expo-sure Matrices (JEMs) have emerged as practical tools for estimating exposure to occupational risk factors based on job classifications [4]. JEMs have been successfully constructed for a variety of hazardous agents such as asbestos [5–7], noise [8,9], job stress [10,11], and solvents [12,13].

Compared to chemical and physical hazards, MSDs pose greater challenges for JEM development, as they occur across nearly all industries and occupations. Moreover, the heterogeneous nature of MSDs by body part and the wide range of relevant ergonomic factors makes it difficult to define a single exposure pathway. Attempts to build MSD-specific JEMs began only in the 2010s. France developed the CONSTANCES JEM, consisting of 407 job codes and 27 occupational and ergonomic factors [14]. A Finnish JEM focused on physical effort, heavy lifting, and carrying for 40 job codes [15]. Similar matrices have been constructed in the Netherlands [16] and the United States using O*NET data [17]. Some JEMs have even been designed for specific MSD conditions, such as hip and knee osteoarthritis [18]. However, these JEMs often have limitations in geographic scope, occupational classification, or disease specificity.

In Korea, JEMs have been developed for selected chemical exposures like asbestos, benzene, and trichloroethylene, drawing up-on workplace measurement data. In contrast, no JEM has yet been constructed for ergonomic exposures related to MSDs, mainly due to the absence of nationwide exposure data across occupations. The Korean Working Conditions Survey (KWCS), conducted by the Occupational Safety and Health Research Institute (OSHRI) every three years since 2006, provides nationally representative data on ergonomic exposures and self-reported MSD symptoms. Despite this resource, previous studies using KWCS have either focused on selected job groups or limited anatomical regions, and no attempt has been made to build a nationwide JEM for MSDs.

Therefore, the objectives of this study were to estimate the prevalence and distribution of musculoskeletal disorder (MSD) symptoms across the Korean working population; to construct a body-part–specific Job Exposure Matrix (JEM) for ergonomic risk factors using data from the Korean Working Conditions Survey (KWCS); to validate the developed JEM through expert evaluation; and to examine the dose–response relationships between exposure intensity and MSD symptoms by body part.

2. Materials and Methods

2.1. Data sources and Study Population

The Materials and Methods should be described with sufficient details to allow 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,

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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 MSDs, questionnaire items about local vibrations among physical risk factors and ergonomic factors were used. To identify MS 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. Development and Validation of the Job Exposure Matrix (JEM)

To evaluate body part–specific ergonomic risk by occupation in the Korean workforce, a Job Exposure Matrix (JEM) was con-structed using questionnaire items from the KWCS. The items were selected to reflect exposure to musculoskeletal risk factors, with three items pertaining to the upper extremities and neck (hand–arm vibration, awkward postures, and repetitive movements), three for the lower back (heavy lifting, awkward postures, and moving people), and two for the lower extremities (heavy lifting and prolonged standing).

Individual-level exposure intensity was determined by combining the responses for each body part. If at least one item was rated as "high" (i.e., exposure for most or all of the working hours), the body part was classified as high exposure. If at least two items were rated as "moderate," the region was classified as moderate exposure. All other combinations were considered low exposure. These individual responses were then aggregated by job category. For each occupation and body part, if 60% or more of workers were classified as having high exposure, the occupation was assigned a high exposure level for that region. Similarly, if 60% or more were classified as low exposure, the occupation was assigned a low exposure level; all remaining cases were assigned moderate exposure.

This occupation-based classification of exposure levels for each anatomical region constituted the JEM. The JEM was used as an analytic tool to examine occupational patterns of exposure and their association with musculoskeletal symptom prevalence.

To assess the validity of this JEM, two ergonomics experts independently evaluated the exposure intensity for each body part by job category. The experts were provided with the relevant KWCS survey items, KSCO job titles, and job descriptions. Discrepancies between the two assessments were resolved through consensus discussion. Agreement between the expert consensus ratings and the JEM-based estimates was assessed using *Cohen's kappa* coefficient. For the upper extremities and neck, as well as the lower back, the level of agreement was high ($\kappa \geq 0.80$), supporting the validity of the JEM classification. For the lower extremities, the level of agreement was moderate, indicating relatively greater uncertainty in this anatomical region [19].

2.5. Relationship Between Exposure and MSD Symptoms

MS 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 [20]. Although the original

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KWCS dataset included 210,500 respondents from the 2nd to 6th waves, 2,502 participants were excluded due to missing or unclassifiable occupational codes or incomplete responses to key variables. The final analytical sample consisted of 207,998 individuals. Logistic regression analysis was performed to determine whether there were an exposure-response relationships between exposure intensity by job category and MS symptoms by body parts.

2.6. Statistical Analysis

Statistical analysis was conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA), and the k^2 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%)	
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%)	<0.01*
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**

* k^2 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. 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%)	
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%)	<0.01*
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%)	

* k^2 test;

3.3. Distributions of Exposure Intensity by Body Parts

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In terms of the exposure intensity of body parts, 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%)	

* k^2 test

3.4. Agreement Between Expert Ratings and JEM-Based Classification

The level of agreement was high ($\kappa \geq 0.80$) for the upper extremities and neck, as well as for the back, supporting the consistency between expert judgment and JEM-based exposure estimates. Agreement for the lower extremities was lower ($\kappa = 0.79$), indicating variability or uncertainty in exposure classification for this body part (Table 4).

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

Body parts	JEM and Ergonomist 1$^{\alpha}$	JEM and Ergonomist 2$^{\alpha}$	JEM and results of consensus$^{\alpha}$
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

$^{\alpha}$ Cohen's kappa coefficient

3.5. Distribution of MSD Symptoms by Exposure Level

Appendix Table S1 presents the overall distribution of musculoskeletal disorder (MSD) symptoms and ergonomic exposure intensity across all 207,998 participants. Among them, 35.3% reported symptoms in the upper extremities and neck, 20.3% in the back, and 24.6% in the lower extremities. A total of 16.8% of participants had a composite MSD score of 1, while 15.5% had a score of 2, and 10.8% reported symptoms in all three body parts (composite score = 3).

Table 5 presents the distribution of work-related musculoskeletal disorder (MSD) symptoms among occupations with the maxi-mum ergonomic exposure score (i.e., total score = 6, comprising 2 points each for all three body parts). These occupations were ranked by the proportion of workers reporting MSD symptoms in all three body parts (symptom score = 1 per region; total score = 3), representing the most severe multi-site burden. The highest prevalence of multi-region MSD symptoms was observed among Crop Growers (32.9%), followed by Agriculture, Forestry and Fishery Related Elementary Workers (31.7%) and Fishery Related Workers (31.1%). Construction-related occupations such as Construction Related Technical Workers (25.8%) and Construction and Mining Laborers (18.6%) also exhibited high proportions of workers with MSD symptoms across all three body parts. Other occupational groups with relatively high symptom prevalence included Cleaners and Sanitation Workers (22.6%), Livestock and Stockbreeding Related Workers (19.9%), and Ship Workers (18.2%). Notably, even among occupations with lower prevalence rates (e.g., Pipe and Sheet Metal Makers, 6.8%), all included workers were exposed to the highest level of ergonomic risk.

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Table 5. High risk occupations with maximum ergonomic exposure (score = 6) ranked by the prevalence of MSD symptoms in all three body parts.

KSCO		Occupation	Total	Symptoms in all 3 body parts	
1-digit code	3-digit code		n	n	%
6	611	Crop Growers	18,702	6,150	32.9
9	991	Agriculture, Forestry and Fishery Related Elementary Workers	665	211	31.7
6	630	Fishery Related Workers	525	163	31.1
7	782	Construction Related Technical Workers	442	114	25.8
9	941	Cleaners and Sanitation Workers	7,469	1,691	22.6
6	613	Livestock and Stockbreeding Related Workers	502	100	19.9
7	781	Construction Structure Related Technical Workers	61	12	19.7
6	620	Forestry Related Workers	78	15	19.2
9	910	Construction and Mining Laborers	2,082	387	18.6
8	876	Ship Workers and Related Workers	11	2	18.2
7	784	Mining and Civil Engineering Related Technical Workers	84	14	16.7
6	612	Horticultural and Landscape Workers	435	64	14.7
7	741	Die and Mold Makers, Metal Casting Workers and Forge Hammersmiths	177	25	14.1
9	921	Loading and Lifting Elementary Workers	479	67	14.0
7	783	Construction Finishing Related Technical Workers	2,265	301	13.3
9	930	Production Related Elementary Workers	1,708	211	12.4
7	772	Broadcasting and Telecommunications Equipment Related Fitters and Repairers	1,609	192	11.9
7	743	Welders	976	97	9.9
8	841	Metal Casting and Metal Processing Related Operators	383	38	9.9
7	751	Automobile Mechanics	2,004	173	8.6
8	891	Wood and Paper Related Machine Operators	328	28	8.5
8	854	Transportation Vehicle and Machine Related Assemblers	2,240	189	8.4
7	792	Plumbers	565	46	8.1
7	730	Wood and Furniture, Musical Instrument and Signboard Related Trade Occupations	491	38	7.7
7	752	Transport Equipment Mechanics	324	23	7.1
7	762	Electricians	1,169	81	6.9
7	742	Pipe and Sheet Metal Makers	44	3	6.8

3.6. Association Between Exposure Intensity and Musculoskeletal Pain

Table 6 presents the results of logistic regression analyses. In the upper extremities and neck, compared to workers with low exposure, those with medium exposure had 1.57 times higher odds of reporting musculoskeletal pain (95% CI 1.53–1.61), and those with high exposure had over three times the odds (OR = 3.06, 95% CI 2.99–3.14). In the back, the odds of reporting pain were 1.51 times higher for medium exposure (95% CI 1.47–1.55) and 2.28 times higher for high exposure (95% CI 2.21–2.36), compared to the low exposure group. In contrast, for the lower extremities, medium exposure was not positively associated with pain (OR = 0.93, 95% CI 0.90–0.97), whereas high exposure was

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significantly associated with increased pain (OR = 1.41, 95% CI 1.37–1.45). These results indicate a strong dose–response relationship between exposure intensity and musculoskeletal pain in the upper body and back, but a more attenuated or inconsistent pattern in the lower extremities.

Table 6. Results of logistic regression between exposure intensity and musculoskeletal pain.

Body parts	variables	OR[γ]	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

[γ] Age and gender were adjusted

4. Discussion

Our findings reveal that MSD symptoms are highly prevalent, with 35.3% of participants reporting symptoms in the upper extremities and neck, 20.3% in the back, and 24.6% in the lower extremities. Notably, over 40% of respondents experienced symptoms in two or more body regions, highlighting the considerable burden of MSDs in the Korean workforce. When comparing these results to the European Working Conditions Survey (EWCS), it becomes apparent that the burden of MSDs is not unique to Korea. The EWCS reports that 43% of European workers experience back pain, 41% report pain in the shoulders, neck, or upper limbs, and 29% report pain in the lower limbs [21, 22]. Both KWCS and EWCS consistently identify MSDs as the most prevalent work-related health problem, and multi-site symptoms are common in both populations. However, certain differences are also evident. While the prevalence of upper limb and neck symptoms is similar between Korea and Europe, back pain appears to be more frequently reported in Europe. Lower extremity symptoms, although less common, still affect a significant proportion of workers in both regions. These findings underscore the global nature of MSDs and the need for comprehensive prevention strategies tailored to the specific pat-terns observed in each country [23].

The development and validation of the Korean JEM represent a significant advancement in the assessment of ergonomic risk factors. The JEM was constructed based on self-reported ergonomic exposures by occupational category, with validation achieved through expert consensus and high inter-rater agreement (κ ≥ 0.80 for upper extremity and back exposures). This approach is conceptually similar to JEMs developed in France (CONSTANCES JEM), Finland, and the Netherlands. All of these matrices utilize large, nationally representative surveys and standardized occupational codes, relying primarily on self-reported exposure to physical and ergonomic risk factors, and are validated through expert review and statistical agreement measures [14-17].

Despite these shared features, there are notable differences between the Korean JEM and its international counterparts. The French CONSTANCES JEM, for example, includes 27 physical exposures and is stratified by gender, while the Korean JEM focuses on region-specific exposures and employs a simpler classification system. European JEMs often use more granular occupational codes and in-corporate psychosocial and organizational factors, whereas the Korean JEM currently emphasizes physical ergonomic risks. Interestingly, the agreement between expert ratings and JEM-based classification is slightly higher in the Korean JEM for upper body and back exposures compared to some European JEMs, suggesting robust validity for the Korean model.

High-risk occupational groups reveals that both the KWCS and EWCS identify manual labor occupations—such as agriculture, construction, and manufacturing—as having a particularly high burden of MSDs. In Korea, crop growers, agricultural/forestry/fishery workers, construction laborers, cleaners, and ship workers are among the groups with the highest prevalence of multi-site symptoms, with some groups reporting over 30% of workers affected. Similarly, in Europe, agriculture, construction, manufacturing, and health care sectors are recognized as high-risk, with comparable patterns of multi-site and severe MSD symptoms. Despite these similarities, the prevalence rates within occupational groups may differ due to variations in work organization, ergonomic standards, and reporting practices. For instance, some European countries report higher overall MSD prevalence, which may reflect differences in survey methodology or cultural factors influencing symptom reporting [21,22].

In Korea, over 60% of compensated occupational diseases are MSDs [1,2], yet there are wide regional and inter-expert discrepancies in recognition decisions. These inconsistencies are partly due to the absence of standardized exposure benchmarks. The JEM developed in this study addresses this gap by providing consistent, occupation-specific estimates of ergonomic risk. As such, it can support Korea's presumption-based system for occupational MSDs and reduce variability in adjudication outcomes. Furthermore, the JEM offers a quantitative framework for OEM physicians, labor authorities, and policymakers to base their decisions on uniform reference points.

The strengths of this study include the use of a large, nationally representative dataset and the construction of a body-part–specific JEM tailored to the Korean occupational context. The inclusion of over 200,000 participants across multiple waves of the KWCS enhances the generalizability of the findings. The body-part -specific approach of the JEM allows for targeted ergonomic interventions and policy recommendations.

However, certain limitations must be acknowledged. The reliance on self-reported exposures and symptoms may introduce recall and reporting bias, a limitation shared with other JEMs. Additionally, the KWCS survey questions may not fully capture biomechanical loads or task-specific risks, particularly for lower extremity exposures. Occupational mis-classification is also possible due to variation in job titles and codes, and the cross-sectional design limits causal inference between exposure and MSD outcomes

To enhance the utility and accuracy of the JEM, future research should incorporate additional dimensions, including psychosocial and organizational stressors. Developing a JEM with more granular occupational classifications—such as 4-digit or 5-digit KSCO codes—could further improve exposure precision. Longitudinal validation using clinical diagnosis, medical claims, or compensation records is also needed to assess predictive validity. In addition, updated JEMs using future waves of KWCS data would ensure its applicability in a rapidly changing labor market.

5. Conclusions

This study presents the first nationwide estimation of musculoskeletal disorder (MSD) burden across occupational groups in Korea using data from the Korean Working Conditions Survey (KWCS). By constructing and validating a body-region–specific Job Exposure Matrix (JEM), we quantified ergonomic exposure intensities and demonstrated their association with MSD symptom prevalence. The JEM showed high agreement with expert assessments and revealed dose–response relationships for several body regions. Furthermore, we identified specific occupations with both high exposure intensity and high symptom burden, providing a data-driven basis for targeting future preventive efforts. These findings lay the groundwork for improving occupational MSD surveillance and prioritizing high-risk groups for intervention.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Table S1: 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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Abbreviations

MSDs	Musculoskeletal disorders
JEM	Job Exposure Matrix
CONSTANCES JEM	Cohorte des consultants des Centres d'examens de santé JEM
KWCS	The Korean Working Conditions Survey
OSHRI	The Occupational Safety and Health Research Institute
KSCO	The Korean Standard Classification of Occupations

Appendix Table S

Table S1. 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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