Preplanned Studies

Prevalence and Patterns of Multi-Site Musculoskeletal Disorders Among Occupational Populations in Key Industries — China, 2018–2023

Fengqiong Chen[1,&]; Junyan Lei[2,&]; Yiwei Song[3]; Ning Jia[3]; Zhongxu Wang[3]; Meibian Zhang[3]; Qing Xu[3]; Mimi Yang[3]; Xinwei Guo[3]; Huadong Zhang[1,#]; Xin Sun[3,#]

Summary

What is already known about this topic?

Work-related musculoskeletal disorders (WMSDs) represent a major global occupational health burden. Previous research has primarily focused on single-site WMSDs, with limited attention to multi-site WMSDs, which impose a substantially greater burden on health and the economy.

What is added by this report?

Multi-site WMSDs were more prevalent (26.4%) than single-site disorders (11.3%), accounting for 69.9% of all cases. The highest multi-site prevalence was seen in packaging and printing, healthcare, and nonferrous metal smelting. Female sex, higher education, prolonged standing, prolonged sitting, fixed postures, and insufficient rest were key risk factors, with risks rising with disorder severity.

What are the implications for public health practice?

Multi-site WMSDs impose a heavy burden on workers in China. Prevention and control strategies should prioritize high-risk industries and implement interventions targeting modifiable risk factors. WMSDs should be incorporated into the occupational disease surveillance system and promoted for inclusion in the statutory list of occupational diseases in China.

ABSTRACT

Introduction: This study investigated the prevalence, patterns, and risk factors of multi-site work-related musculoskeletal disorders (WMSDs) among workers in key industries across China.

Methods: A total of 88,609 workers from 441 enterprises across 29 industries were surveyed using stratified cluster sampling (2018–2023). The Chinese Musculoskeletal Disorders Questionnaire assessed symptoms. WMSDs were classified as single-site (1 body part), dual-site (2 body parts), triple-site (3 body parts), and over-3-site (>3 body parts). Cross-classified multilevel generalized linear mixed models identified associated factors.

Results: The prevalence of multi-site WMSDs was 26.4%, exceeding that of single-site disorders (11.3%), with multi-site cases comprising 69.9% of all WMSDs. Packaging and printing (28.0%), healthcare (20.5%), and nonferrous metal smelting (20.5%) exhibited the highest prevalence of multi-site WMSDs. Female sex was an independent risk factor for all WMSD types. Higher education levels correlated with increased risk, with a master's degree or above showing the strongest association with triple-site WMSDs. Prolonged standing, prolonged sitting, and fixed postures demonstrated dose–response relationships with WMSD severity. Insufficient rest was associated with the highest risk of multi-site WMSDs.

Conclusion: Multi-site WMSDs represented the predominant pattern among Chinese workers. Prevention strategies should prioritize high-risk industries and target modifiable factors, particularly insufficient rest and prolonged static postures.

Work-related musculoskeletal disorders (WMSDs) are conditions involving injuries or dysfunctions of muscles, bones, nerves, joints, tendons, ligaments, and cartilage that are induced or aggravated by occupational hazards such as adverse ergonomic factors during work activities, manifesting as pain, numbness, burning, tingling, limited movement, and related discomfort, thereby seriously threatening worker health (*1*). According to the Global Burden of Disease study, WMSDs account for 21.30% of disability-adjusted life years (DALYs), ranking third among all diseases (*2*). Compared with single-site involvement, patients with multi-site WMSDs are more prone to developing

severe dysfunction, occupational absenteeism, increased medical burden, and reduced quality of life (*3*). Although low back pain and neck pain have been identified as major contributors to DALYs in the Global Burden of Disease Study (*4*), the prevalence pattern of multi-site WMSDs is often underestimated or overlooked in routine epidemiological surveillance. Previous studies have mostly focused on single-site WMSDs or specific high-risk industries, and epidemiological data on multi-site WMSDs based on nationally representative samples remain lacking. Using cross-sectional survey data from 88,609 workers at 441 enterprises across 29 industries provided in Supplementary Table S1 (available at https://weekly.chinacdc.cn/), this study systematically described the prevalence and distribution characteristics of multi-site WMSDs among occupational populations in China, providing a scientific basis for formulating precise hierarchical and classified intervention strategies.

A multistage stratified cluster random sampling approach was adopted. We selected 23 provincial-level administrative divisions (PLADs) across 7 regions, stratified industries by WMSD relevance, workforce size, and economic importance, and then sampled enterprises by size (large/medium/small/micro). Within each enterprise, all eligible frontline workers were cluster-sampled at the workshop level. From 2018 to 2023, 91,560 workers completed the questionnaire (Cronbach's α =0.86) via Quick Response (QR) code, yielding 88,609 valid responses (96.8% response rate). The survey employed a 1∶N format in which one investigator organized N respondents to scan the QR code of the electronic questionnaire and complete the survey online, with further elaboration provided in Supplementary Figure S1 (available at https://weekly.chinacdc.cn/).

The Chinese Version of the Musculoskeletal Disorders Questionnaire, embedded in the Ergonomic Assessment and Analysis System for WMSDs developed by the Department of Occupational Protection and Ergonomics at the National Institute of Occupational Health and Poison Control, was used. The electronic questionnaire included items on general information, musculoskeletal symptoms, and work conditions. The WMSD criteria followed the National Institute for Occupational Safety and Health (NIOSH) definition: the presence of discomfort such as pain, stiffness, burning, numbness, or tingling. Exclusion criteria included congenital spinal deformities and non-WMSD conditions due to trauma, infectious diseases, or malignant tumors, with further elaboration provided in Supplementary Material (available at https://weekly.chinacdc.cn/). WMSDs were categorized as single-site (1 body part) and multi-site, including dual-site (2 body parts), triple-site (3 body parts), and over-3-site (>3 body parts). All participants provided informed consent, and the study was approved by the Medical Ethics Review Committee of the National Institute of Occupational Health and Poison Control of the Chinese Centers for Disease Control and Prevention (NIOHP202122).

SPSS (version 29.0, SPSS Inc, Chicago, IL, USA) was used to characterize the basic demographic and occupational features of the surveyed population. Cross-classified multilevel generalized linear mixed models (CCMM) were employed to examine associations between potential risk factors and WMSDs, accounting for unobserved clustering at both regional and industrial levels. Statistical significance was set at a two-tailed α level of 0.05.

Among the 83,006 respondents, 31,314 had WMSDs (37.7%), including 9,418 with single-site (11.3%) and 21,896 with multi-site (26.4%) disorders. Among multi-site WMSDs, 6,574 were dual-site (20.99%), 4,779 were triple-site (15.26%), and 10,543 were over-3-site (33.67%). Patients with multi-site WMSDs accounted for 69.9% of all WMSD cases, indicating that multi-site involvement represents the predominant manifestation of WMSDs among occupational populations in China (Table 1).

Significant variations in multi-site WMSD prevalence were observed across industries. The top three industries for dual-site WMSDs were packaging and printing (20.00%), general aviation services (11.26%), and electricity, heat, gas, and water production and supply (9.30%). For triple-site WMSDs, the top three were packaging and printing (28.00%), healthcare (10.84%), and animal husbandry (10.20%). For over-3-site WMSDs, the leading four were toy manufacturing (26.77%), packaging and printing (26.00%), nonferrous metal smelting and pressing (20.54%), and healthcare (20.54%). Packaging and printing ranked among the high-prevalence industries across all multi-site categories, representing a key high-risk industry for multi-site WMSDs (Figure 1).

The prevalence of WMSDs by site number is presented in Supplementary Tables S2–S3 (available at https://weekly.chinacdc.cn/). Cross-classified multilevel generalized linear mixed model (CCMM) analysis revealed that the industry-level intraclass correlation coefficient (ICC) increased with the

TABLE 1. Distribution of musculoskeletal disorders by number of affected body parts among occupational populations in China (*N*=83,006).

Category	*n*	Proportion of total population (%)	Proportion of all WMSDs patients (%)
Single-site WMSDs (1 body part)	9,418	11.3	30.08
Multi-site WMSDs (≥2 body parts)			
Dual-site (2 body parts)	6,574	7.9	20.99
Triple-site (3 body parts)	4,779	5.8	15.26
Over-3-site (>3 body parts)	10,543	12.7	33.67
Total	31,314	37.7	100.00

Note: 5,603 non-frontline workers (logistics, office, and management) were excluded from the analysis.
Abbreviation: WMSDs=work-related musculoskeletal disorders.

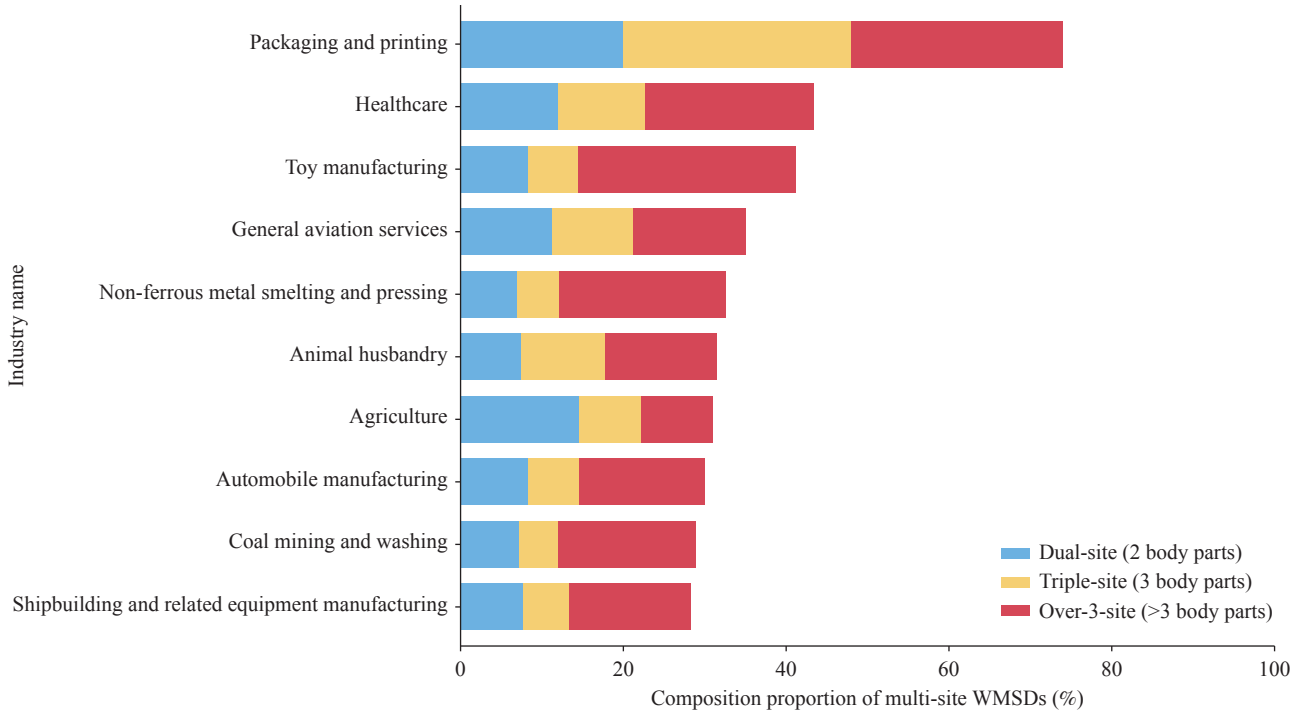

FIGURE 1. Top 10 industries with the highest prevalence of multi-site musculoskeletal disorders (*n*=83,006).
Abbreviation: WMSDs=work-related musculoskeletal disorders.

number of affected body sites, suggesting that the risk of multi-site WMSDs was more strongly influenced by industrial factors. The city-level ICC remained below 4% across all subgroups, reflecting a minor impact of regional disparities. The median odds ratio (MOR) results were consistent with the ICC trends. In addition, sex, age, education, physical exercise, ergonomic exposure, and work organizational factors were significantly associated with WMSD risk at different severity levels, with varying trends in effect strength as the number of affected sites increased (Table 2). Female sex was identified as an independent risk factor for all WMSD types. Using males as the reference group, females had a significantly higher risk for all WMSD types, and the protective effect of male sex increased gradually with disease severity. Age showed a non-linear association with WMSD risk. Using the <30-year group as the reference, the 30–39-year group showed a significantly elevated risk for all WMSDs. Education showed a significant positive correlation with WMSD risk. Using junior high school and below as the reference group, the risk progressively increased with education level. Physical exercise demonstrated protective effects.

For ergonomic risk factors, very frequent prolonged standing, prolonged sitting, fixed neck posture, trunk bending and twisting, wrist bending, and fixed back posture significantly increased risk for all WMSDs,

TABLE 2. Multilevel modeling analysis of WMSDs among frontline workers.

Variable	a*OR* (95% *CI*)			
	Single-site (1 body part)	Dual-site (2 body parts)	Triple-site (3 body parts)	Over-3-site (>3 body parts)
Fixed effects				
Gender				
Male	1	1	1	1
Female	1.19 (1.12, 1.27)	1.50 (1.40, 1.62)	1.66 (1.52, 1.82)	1.71 (1.60, 1.84)
Age (years)				
<30	1	1	1	1
30–34	1.06 (1.00, 1.13)	1.18 (1.10, 1.27)	1.17 (1.07, 1.28)	1.11 (1.04, 1.19)
35–39	1.12 (1.04, 1.21)	1.15 (1.05, 1.25)	1.21 (1.09, 1.34)	1.17 (1.08, 1.26)
40–44	1.07 (0.98, 1.17)	1.10 (0.99, 1.22)	1.12 (0.99, 1.27)	1.12 (1.02, 1.23)
45–49	1.10 (1.01, 1.21)	0.99 (0.88, 1.11)	0.99 (0.86, 1.14)	1.08 (0.97, 1.19)
50–54	1.02 (0.91, 1.15)	1.05 (0.91, 1.20)	1.11 (0.94, 1.31)	1.04 (0.92, 1.18)
55–59	1.20 (1.01, 1.41)	1.17 (0.95, 1.45)	1.01 (0.77, 1.33)	0.98 (0.80, 1.20)
≥60	0.97 (0.83, 1.13)	1.03 (0.86, 1.23)	1.12 (0.92, 1.37)	1.12 (0.96, 1.30)
Education				
Junior high and below	1	1	1	1
Senior high/technical	1.10 (1.04, 1.18)	1.10 (1.01, 1.19)	1.18 (1.07, 1.30)	1.12 (1.05, 1.20)
College and undergraduate	1.29 (1.20, 1.40)	1.29 (1.17, 1.41)	1.43 (1.28, 1.60)	1.23 (1.13, 1.33)
Master's and above	1.44 (1.16, 1.79)	1.49 (1.18, 1.88)	1.60 (1.23, 2.08)	1.08 (0.86, 1.37)
BMI (kg/m²)				
<18.5	1	1	1	1
18.5–23.9	1.00 (0.92, 1.09)	1.00 (0.90, 1.10)	1.09 (0.98, 1.23)	1.02 (0.94, 1.11)
24.0–27.9	1.04 (0.95, 1.14)	1.03 (0.93, 1.15)	1.16 (1.02, 1.31)	1.01 (0.92, 1.11)
≥28.0	1.06 (0.95, 1.19)	1.07 (0.94, 1.22)	1.16 (1.00, 1.35)	1.13 (1.01, 1.26)
Physical exercise				
No	1	1	1	1
Occasionally	0.89 (0.85, 0.94)	0.91 (0.85, 0.96)	0.90 (0.84, 0.96)	0.97 (0.92, 1.03)
2–3 times/month	0.88 (0.78, 0.99)	0.97 (0.85, 1.10)	0.92 (0.79, 1.08)	0.95 (0.84, 1.07)
2–3 times/week	0.82 (0.74, 0.90)	0.85 (0.76, 0.95)	0.86 (0.76, 0.98)	0.89 (0.80, 0.98)
>2 times/week	0.82 (0.73, 0.91)	0.84 (0.74, 0.96)	0.64 (0.54, 0.76)	0.84 (0.75, 0.95)
Workplace risk factors				
Standing often at work				
No	1	1	1	1
Occasionally	1.00 (0.92, 1.09)	1.00 (0.90, 1.10)	1.02 (0.91, 1.14)	0.98 (0.89, 1.07)
Frequent	1.10 (1.01, 1.18)	1.20 (1.09, 1.33)	1.13 (1.00, 1.28)	1.10 (1.01, 1.21)
Very frequent	1.19 (1.08, 1.30)	1.54 (1.39, 1.72)	1.48 (1.31, 1.68)	1.48 (1.34, 1.63)
Sitting often at work				
No	1	1	1	1
Occasionally	0.92 (0.87, 0.98)	0.92 (0.86, 1.00)	0.91 (0.83, 0.99)	0.88 (0.82, 0.94)
Frequent	1.09 (1.01, 1.18)	1.28 (1.17, 1.40)	1.36 (1.23, 1.51)	1.30 (1.20, 1.40)
Very frequent	1.19 (1.08, 1.30)	1.56 (1.40, 1.73)	1.80 (1.60, 2.02)	1.63 (1.49, 1.78)
Fixed neck posture				
No	1	1	1	1

Continued

Variable	a*OR* (95% *CI*)			
	Single-site (1 body part)	Dual-site (2 body parts)	Triple-site (3 body parts)	Over-3-site (>3 body parts)
Yes	1.21 (1.15, 1.33)	1.50 (1.37, 1.64)	1.55 (1.38, 1.73)	1.40 (1.30, 1.53)
Frequent repetitive lower limb/ankle movements				
No	1	1	1	1
Yes	0.99 (0.94, 1.05)	1.08 (1.02, 1.15)	1.15 (1.07, 1.24)	1.64 (1.56, 1.73)
Lifting heavy loads (more than 20 kg)				
No	1	1	1	1
Occasionally	1.01 (0.95, 1.06)	1.03 (0.96, 1.10)	1.07 (0.99, 1.16)	1.32 (1.25, 1.40)
Frequent	0.98 (0.90, 1.07)	1.13 (1.03, 1.25)	1.10 (0.98, 1.24)	1.49 (1.37, 1.61)
Very frequent	1.03 (0.92, 1.16)	1.16 (1.02, 1.32)	1.06 (0.91, 1.24)	1.58 (1.43, 1.75)
Trunk bending and twisting				
No	1	1	1	1
Yes	1.11 (1.05, 1.17)	1.09 (1.02, 1.16)	1.26 (1.17, 1.35)	1.49 (1.41, 1.57)
Wrist bending				
No	1	1	1	1
Yes	1.02 (0.97, 1.07)	1.14 (1.07, 1.21)	1.24 (1.16, 1.33)	1.68 (1.59, 1.77)
Prolonged fixed back posture				
No	1	1	1	1
Yes	1.14 (1.08, 1.21)	1.17 (1.09, 1.25)	1.21 (1.11, 1.32)	1.21 (1.14, 1.29)
Work organizational factors				
Frequent overtime				
No	1	1	1	1
Yes	1.11 (1.05, 1.16)	1.15 (1.08, 1.22)	1.14 (1.06, 1.22)	1.24 (1.18, 1.32)
Insufficient rest				
No	0.72 (0.69, 0.76)	0.63 (0.60, 0.67)	0.54 (0.50, 0.58)	0.44 (0.42, 0.47)
Yes	1	1	1	1
Staff shortages				
No	1	1	1	1
Yes	1.14 (1.08, 1.19)	1.17 (1.10, 1.24)	1.17 (1.09, 1.25)	1.40 (1.33, 1.47)
Do same working				
No	1	1	1	1
Yes	1.18 (1.10, 1.28)	1.12 (1.02, 1.23)	1.43 (1.28, 1.62)	1.36 (1.24, 1.49)
Job rotation				
No	1.00 (0.95, 1.06)	1.03 (0.97, 1.10)	1.06 (0.98, 1.15)	1.14 (1.07, 1.21)
Yes	1	1	1	1
Random effects				
City level				
ICC (%)	2.78	3.33	3.57	3.09
mOR	1.34	1.38	1.43	1.39
Industry level				
ICC (%)	1.09	2.15	11.52	10.34
mOR	1.20	1.30	1.89	1.82

Abbreviation: WMSD=work-related musculoskeletal disorders; a*OR*=adjusted odds ratio; BMI=body mass index; *CI*=confidence interval; ICC=intraclass correlation coefficient; mOR=median odds ratio.

with the greatest risk amplification observed for multi-site WMSDs.

Among work organizational factors, frequent overtime, insufficient rest, and staff shortage were associated with elevated WMSD risk. Compared with insufficient rest, adequate rest reduced the risk of multi-site WMSDs. Performing the same work repeatedly increased the risk of all WMSDs, whereas job rotation showed a protective effect against over-3-site WMSDs.

DISCUSSION

From 2018 to 2023, all annual surveys adopted a standardized research protocol and questionnaire. Therefore, all valid data were pooled for comprehensive analysis to enhance statistical power. The prevalence of multi-site WMSDs among occupational populations in China reached 26.4%, substantially exceeding the single-site prevalence (11.3%), with multi-site cases accounting for 69.9% of all WMSDs. This finding indicates that multi-site WMSDs are highly prevalent and cause functional impairment, medical burden, and productivity loss that exceed those of single-site disorders.

Regarding industry distribution, packaging and printing ranked among the high-prevalence industries for dual-site, triple-site, and over-3-site WMSDs, suggesting that high-intensity repetitive operations and prolonged fixed postures characterize this industry. The healthcare and nonferrous metal smelting and pressing industries displayed over-3-site WMSD prevalence exceeding 20.5%, likely related to occupational characteristics (*5*) that contribute to cumulative multi-site musculoskeletal damage. In toy manufacturing, the prevalence of over-3-site WMSDs reached 26.77%. Given the relatively small sample size of this industry, these results cannot be generalized.

Based on CCMM analysis, female sex was identified as an independent risk factor for all WMSD types, and the sex difference became increasingly pronounced with a greater number of affected body sites. Compared with males (reference group), the adjusted odds ratios (a*OR*) for females were 1.19, 1.50, 1.66, and 1.71 for single-site, dual-site, triple-site, and over-3-site WMSDs, respectively. This finding aligns with the Global Burden of Disease study and previous occupational health surveys (*2*,*6*) and may relate to lower spinal load-bearing capacity in females, hormonal differences, and the dual burden of domestic labor. Accordingly, strengthening gender-targeted protection strategies for female workers is critical, with focused attention on the prevention and intervention of multi-site musculoskeletal disorders in high-risk female populations. Education was positively correlated with WMSD risk, with the strongest dose–response relationship observed for triple-site WMSDs (master's degree and above: a*OR*=1.60), possibly because highly educated individuals more frequently engage in sedentary work, experience greater psychological stress, and hold higher occupational expectations (*7*). Highly educated employees predominantly engage in prolonged sedentary work with long-term static loading, causing sustained tension of the cervical, shoulder, lumbar, and wrist muscles, local microcirculation disturbance, metabolic by-product accumulation, and chronic fascial strain, thereby increasing physiological susceptibility to multi-site musculoskeletal injuries. They also face heavy work pressure; chronic stress alters somatic nerve excitability, induces muscle contraction, and reduces pain tolerance, while higher career expectations reduce recovery time, leading to cumulative adverse occupational exposure.

Ergonomic factors demonstrated significant dose–response relationships between adverse posture exposure and WMSD risk. Very frequent prolonged standing and sitting exhibited the strongest effects for multi-site WMSDs (≥2 body parts) (a*OR*>1.4), while prolonged fixed neck and back postures displayed the most prominent effects for over-3-site WMSDs (a*OR*=1.55 and 1.21, respectively). This confirms that multi-site WMSDs are not simple additions of single-site disorders but result from systemic ergonomic load accumulation, with cumulative adverse ergonomic exposure serving as the core driver of multi-site damage (*8*). Frequent repetitive lower limb/ankle movements shifted from protective for single-site WMSDs (a*OR*=0.99) to a risk factor for over-3-site WMSDs (a*OR*=1.64), further confirming the unique pathogenic pattern of multi-site WMSDs.

Among work organization factors, sufficient rest was the strongest protective factor for all WMSDs, with the most pronounced association identified for over-3-site WMSDs (a*OR*=0.44). Adequate rest can effectively relieve musculoskeletal strain and reduce cumulative occupational physical damage (*9*). Physical exercise also served as a protective factor against WMSDs. Therefore, increasing physical activity is recommended to reduce the incidence of WMSDs.

This study has two major strengths. The large sample size ensures good representativeness of the

occupational population, and the use of validated standardized tools fills the domestic multi-site WMSD data gap with sound external validity.

In conclusion, future interventions should prioritize the following: first, industry-specific interventions for printing and toy manufacturing should reduce repetitive motions through automation while optimizing ergonomic design; for healthcare, mandatory implementation of rest break systems and proper patient-handling technique training are essential; and finally, multi-site WMSDs should be incorporated into China's occupational disease surveillance system to dynamically monitor high-risk industry trends and precisely target prevention priorities.

The findings in this report are subject to at least three limitations. First, the cross-sectional design cannot establish causal relationships between risk factors and WMSDs; it captures only associations at a single point in time, which may introduce temporal ambiguity regarding exposure and outcome sequences. Second, retrospective self-reporting of symptoms may involve recall bias, potentially leading to underestimation or overestimation of symptom severity and affecting the accuracy of associations between exposures and outcomes. Finally, the study focused on frontline operational personnel, which may limit generalizability to other occupational populations such as administrative staff or management personnel.

These findings highlight that multi-site WMSDs constitute the predominant pattern of WMSDs among occupational populations in China. Targeted prevention strategies should prioritize high-risk industries, including packaging and printing, toy manufacturing, and healthcare. This study suggests that implementing standardized rest break policies and reducing prolonged static postures can effectively prevent multi-site WMSDs. Workplace interventions should focus on modifiable ergonomic risk factors, with key protective measures tailored for female workers. In line with International Labour Organization occupational safety guidelines, China should integrate multi-site WMSDs into the national occupational disease surveillance system and strengthen legal safeguards for targeted preventive interventions.

Conflicts of interest: No conflicts of interest.

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[#] Corresponding authors: Xin Sun, sunxin@niohp.chinacdc.cn; Huadong Zhang, cdczhanghuadong@163.com.

[1] Chongqing Center for Disease Control and Prevention (Chongqing Academy of Preventive Medical Sciences), Chongqing, China; [2] Fuling District Center for Disease Control and Prevention, Chongqing, China; [3] National Institute of Occupational Health and Poison Control, Chinese Center for Disease Control and Prevention & Chinese Academy of Preventive Medicine, Beijing, China.
[&] Joint first authors.

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SUPPLEMENTARY MATERIAL

Questionnaire Survey

The Chinese version of the Musculoskeletal Disorders Survey (*1*), embedded within the work-related musculoskeletal disorders (WMSDs) Ergonomic Assessment and Analysis System developed by the Department of Occupational Protection and Ergonomics, National Institute of Occupational Health and Poison Control, Chinese Center for Disease Control and Prevention, was used to investigate general characteristics, WMSD occurrence, and associated risk factors among key occupational populations across various regions of China. The questionnaire demonstrated good internal consistency, with a Cronbach's α coefficient of 0.86. Survey content encompassed three domains: general characteristics, musculoskeletal symptom occurrence, and occupational characteristics.

Quality Control

During the initial study design phase, research objectives and survey strategies were clearly defined, with core content and key indicators for investigation and analysis established to minimize information bias. The survey team comprised professional technical personnel from provincial-level administrative division (PLAD)-level centers for disease control and prevention and occupational disease prevention and treatment institutes, all of whom received systematic training on professional knowledge and research protocols to ensure consistency and accuracy in questionnaire administration. Prior to survey implementation, all investigators underwent standardized training to ensure full comprehension of research objectives, significance, and survey methods. During data collection, uniform survey content and completion standards were strictly enforced. Face-to-face centralized questionnaire completion was conducted, with on-site real-time review to ensure the authenticity and reliability of information. To address potential logical errors, the questionnaire incorporated built-in logic correction functions and completeness verification mechanisms, enabling timely verification, supplementation, and correction of omissions, missing data, and logical inconsistencies, thereby ensuring the data quality and scientific validity of the research findings.

Diagnostic Criteria for WMSDs

WMSDs were defined according to the National Institute for Occupational Safety and Health (NIOSH) criteria (*2*). A case was confirmed when all four of the following conditions were met simultaneously: 1) presence of symptoms including pain, stiffness, burning sensation, numbness, or tingling; 2) symptoms occurring during the preceding 12 months; 3) symptom onset after beginning current employment; and 4) no prior accidents or acute injuries affecting the symptomatic body region. Additionally, symptoms had to have occurred at least monthly or persisted for more than one week to qualify as WMSDs in the affected body region.

Study Design and Participants

This study employed a multistage stratified cluster sampling method. Industries were stratified based on their association with WMSDs, workforce size, and economic importance to the national economy. Within each stratum, cluster sampling was conducted by enterprise size (large, medium, small, and micro enterprises) to select representative enterprises, with on-duty workers selected as the study subjects to ensure sample representativeness and diversity. The study covered 9 major categories of national economic industries, including agriculture, forestry, animal husbandry, and fishery; mining; manufacturing; production and supply of electricity, heat, gas, and water; construction; wholesale and retail trade; transportation, warehousing, and postal services; resident services, repair, and other services; and health and social work, involving 29 specific industries or job types. A total of 441 enterprises were included, comprising 72 large enterprises (16.3%), 48 medium enterprises (10.9%), 182 small enterprises (41.3%), and 139 micro enterprises (31.5%). The number of surveyed workers by industry nationwide is shown in Supplementary Table S1; the national sampling flowchart is shown in Supplementary Figure S1. The prevalence of WMSDs by number of affected body sites is shown in Supplementary Tables S2–S3.

SUPPLEMENTARY TABLE S1. Number of surveyed participants by industry nationwide.

No.	Industry (Code)	Frequency
1	Packaging and Decoration, and Other Printing (C2319)	50
2	Animal Husbandry (A03)	245
3	Shipbuilding and Related Equipment Manufacturing (C373)	3,431
4	Road Transport (G54)	2,296
5	Production and Supply of Electric Power, Heat, Gas, and Water (D44)	86
6	Electrical Machinery and Equipment Manufacturing (C38)	3,434
7	Smelting and Rolling of Ferrous Metals (C31)	3,494
8	Manufacture of Chemical Raw Materials and Chemical Products (C26)	95
9	Manufacture of Computers, Communication, and Other Electronic Equipment (C39)	10,638
10	Furniture Manufacturing (C21)	9,004
11	Construction (E47)	1,434
12	Metal Products (C33)	3,195
13	Coal Mining and Washing (B06)	3,356
14	Agriculture (A01)	239
15	Automobile Repair and Maintenance (O8111)	777
16	Automobile Manufacturing (C36)	21,759
17	Petrochemical Industry (C251)	150
18	Food Manufacturing (C14)	828
19	Manufacture of Cement, Lime and Plaster (C301)	194
20	Manufacture of Railway Transport Equipment (C371)	1,674
21	General Aviation Services (G562)	1,341
22	Toy Manufacturing (C245)	325
23	Health Services (Q84)	7,011
24	Pharmaceutical Manufacturing (C27)	1,738
25	Non-ferrous Metal Ore Mining and Dressing (B09)	1,225
26	Smelting and Rolling of Non-ferrous Metals (C32)	2,312
27	Footwear Manufacturing (C195)	7,100
28	Handling, Loading and Unloading, and Warehousing (G59)	92
29	General Retail Trade (F521)	1,086
Total		88,609

SUPPLEMENTARY TABLE S2. Characteristics and proportions of populations with different numbers of affected sites of WMSDs.

Basic variables	*N*	Single-site (1 body part)		Dual-site (2 body parts)		Triple-site (3 body parts)		Over-3-site (>3 body parts)	
		n	Proportion (%)	*n*	Proportion (%)	*n*	Proportion (%)	*n*	Proportion (%)
Gender									
Male	56,149	6,176	11.0	3,982	7.1	2,753	4.9	6,692	11.9
Female	26,857	3,242	12.1	2,592	9.7	2,026	7.5	3,851	14.3
Age (years)									
<30	29,245	3,305	11.3	2,294	7.8	1,716	5.9	3,850	13.2
30–34	16,837	1,926	11.4	1,490	8.8	1,078	6.4	2,273	13.5
35–39	11,660	1,374	11.8	949	8.1	706	6.1	1,503	12.9
40–44	8,641	979	11.3	681	7.9	482	5.6	1,051	12.2
45–49	7,809	902	11.6	544	7.0	372	4.8	914	11.7
50–54	4,748	495	10.4	323	6.8	223	4.7	512	10.8
55–59	1,665	205	12.3	122	7.3	65	3.9	135	8.1
≥60	2,401	232	9.7	171	7.1	137	5.7	305	12.7
Education									
Junior high and below	27,285	2,942	10.8	1,885	6.9	1,197	4.4	2,789	10.2
Senior high/technical	30,861	3,395	11.0	2,330	7.5	1,696	5.5	4,073	13.2
College and undergraduate	23,814	2,942	12.4	2,225	9.3	1,779	7.5	3,533	14.8
Master's and above	1,046	139	13.3	134	12.8	107	10.2	148	14.1
BMI (kg/m²)									
<18.5	6,896	795	11.5	585	8.5	412	6.0	924	13.4
18.5–23.9	47,311	5,341	11.3	3,756	7.9	2,763	5.8	6,013	12.7
24.0–27.9	21,433	2,447	11.4	1,653	7.7	1,199	5.6	2,579	12.0
≥28.0	7,366	835	11.3	580	7.9	405	5.5	1,027	13.9
Physical exercise									
No	25,892	3,233	12.5	2,236	8.6	1,622	6.3	3,481	13.4
Occasionally	43,229	4,716	10.9	3,289	7.6	2,429	5.6	5,475	12.7
2–3 times/month	3,675	403	11.0	306	8.3	218	5.9	440	12.0
2–3 times/week	5,952	614	10.3	434	7.3	332	5.6	684	11.5
>2 times/week	4,258	452	10.6	309	7.3	178	4.2	463	10.9

Abbreviation: WMSDs=work-related musculoskeletal disorders; BMI=body mass index.

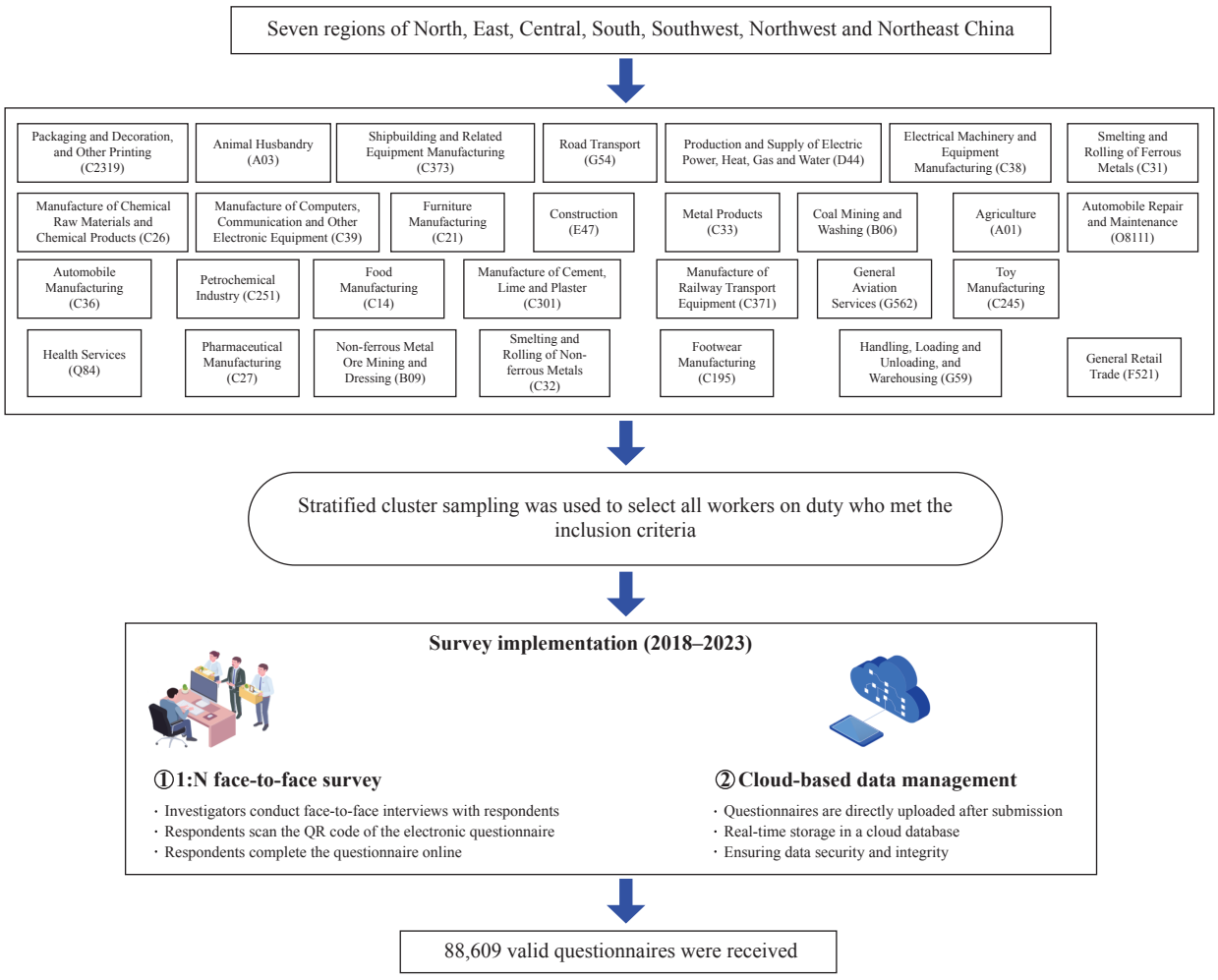
SUPPLEMENTARY TABLE S3. Characteristics and proportions of populations with different numbers of affected sites of WMSDs.

Work related variables	*N*	Single-site (1 body part)		Dual-site (2 body parts)		Triple-site (3 body parts)		Over-3-site (>3 body parts)	
		n	Proportion (%)	*n*	Proportion (%)	*n*	Proportion (%)	*n*	Proportion (%)
Workplace risk factors									
Standing often at work									
No	12,701	1,294	10.2	987	7.8	745	5.9	1,358	10.7
Occasionally	18,427	1,859	10.1	1,266	6.9	944	5.1	1,761	9.6
Frequent	27,979	3,134	11.2	2,070	7.4	1,446	5.2	3,295	11.8
Very frequent	23,899	3,131	13.1	2,251	9.4	1,644	6.9	4,129	17.3
Sitting often at work									
No	37,069	4,465	12.0	2,900	7.8	1,979	5.3	4,826	13.0
Occasionally	23,919	2,548	10.7	1,656	6.9	1,160	4.8	2,434	10.2
Frequent	13,754	1,510	11.0	1,195	8.7	919	6.7	1,866	13.6
Very frequent	8,264	895	10.8	823	10.0	721	8.7	1,417	17.1
Fixed neck posture									
No	34,212	3,741	10.9	2,112	6.2	1,370	4.0	2,550	7.5
Yes	48,794	5,677	11.6	4,462	9.1	3,409	7.0	7,993	16.4
Frequent repetitive lower limb/ankle movements									
No	49,758	5,885	11.8	3,833	7.7	2,584	5.2	4,167	8.4
Yes	33,248	3,533	10.6	2,741	8.2	2,195	6.6	6,376	19.2
Lifting heavy loads (>20 kg)									
No	45,236	5,296	11.7	3,664	8.1	2,638	5.8	4,602	10.2
Occasionally	24,911	2,720	10.9	1,848	7.4	1,408	5.7	3,510	14.1
Frequent	8,840	929	10.5	691	7.8	479	5.4	1,488	16.8
Very frequent	4,019	473	11.8	371	9.2	254	6.3	943	23.5
Trunk bending and twisting									
No	47,513	5,305	11.2	3,597	7.6	2,393	5.0	3,918	8.2
Yes	35,493	4,113	11.6	2,977	8.4	2,386	6.7	6,625	18.7
Wrist bending									
No	47,700	5,500	11.5	3,497	7.3	2,300	4.8	3,650	7.7
Yes	35,306	3,918	11.1	3,077	8.7	2,479	7.0	6,893	19.5
Prolonged fixed back posture									
No	34,620	3,902	11.3	2,310	6.7	1,458	4.2	2,523	7.3
Yes	48,386	5,516	11.4	4,264	8.8	3,321	6.9	8,020	16.6
Work organizational factors									
Frequent overtime									
No	41,660	4,527	10.9	3,027	7.3	2,152	5.2	4,119	9.9
Yes	41,346	4,891	11.8	3,547	8.6	2,627	6.4	6,424	15.5
Insufficient rest									
No	41,799	4,383	10.5	2,649	6.3	1,635	3.9	2,721	6.5
Yes	41,207	5,035	12.2	3,925	9.5	3,144	7.6	7,822	19.0
Staff shortages									
No	47,181	5,179	11.0	3,368	7.1	2,273	4.8	4,098	8.7

Continued

Work related variables	N	Single-site (1 body part)		Dual-site (2 body parts)		Triple-site (3 body parts)		Over-3-site (>3 body parts)	
		n	Proportion (%)	*n*	Proportion (%)	*n*	Proportion (%)	*n*	Proportion (%)
Yes	35,825	4,239	11.8	3,206	8.9	2,506	7.0	6,445	18.0
Do same working									
No	9,271	920	9.9	617	6.7	338	3.6	662	7.1
Yes	73,735	8,498	11.5	5,957	8.1	4,441	6.0	9,881	13.4
Job rotation									
No	38,913	4,471	11.5	3,250	8.4	2,396	6.2	5,316	13.7
Yes	44,093	4,947	11.2	3,324	7.5	2,383	5.4	5,227	11.9

Abbreviation: WMSDs=work-related musculoskeletal disorders.



SUPPLEMENTARY FIGURE S1. Implementation Process of the Study.

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