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Prevalence of Occupational Diseases caused by vibration, 1975 to 2022: National baseline survey

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Objective: Prolonged occupational vibration exposure can cause neurological, musculoskeletal, and connective tissue disorders. Establishing a national baseline in Mongolia is essential to determine the prevalence of vibration-related occupational diseases and to guide evidence-based policy interventions. To establish baseline evidence on the point prevalence and characteristics of vibration-related occupational diseases among individuals diagnosed with work-related disabilities in Mongolia. **Methods:** A descriptive desk review was conducted using data from 10,219 registered occupational disease cases between 1975 and 2022. Vibration-related cases (ICD codes: G54, G54.1, T75, T75.2, M21) were identified in two stages. A total of 952 cases were analyzed using STATA 12.0. **Results:** Of the 10,219 cases, 952 (9.3%) were vibration-related, including 895 (94.1%) whole-body vibration (WBV) and 57 (5.9%) hand-arm vibration (HAV) cases. The mean age at loss of work ability due to vibration-related disease was 43.38 ± 6.32 years, with an average exposure duration of 17.62 ± 5.63 years. The mining sector showed the highest prevalence, at 224.86 cases per 100,000 working-age population. Among WBV-related diseases, nerve root and plexus disorders (G54) were most common (38.26 per 100,000), while acquired limb deformities (M21) predominated in HAV cases (1.98 per 100,000). **Conclusion:** Vibration-induced occupational diseases mainly affect the mining sector. The frequent neurological and musculoskeletal disorders highlight the need for accurate differential diagnosis to ensure effective prevention and management.

Keywords: Whole-body vibration, Occupational disease, Industry, Vibration exposure, Hand-arm vibration

Introduction

Vibration is a physical factor that affects the human body through the transmission of mechanical energy from a source. Whole-body vibration is commonly experienced by operators of heavy machinery or individuals working while sitting or standing on vibrating surfaces, whereas hand–arm vibration occurs when using handheld tools such as power drills, graders, breakers, and sledgehammers.[1] Prolonged occupational exposure to vibration can lead to neurological, musculoskeletal, and connective tissue disorders.

The progression of vibration-related disorders is typically slow. Without early detection and timely intervention, these conditions may result in long-term disability, functional limitations, and reduced quality of life. International studies have demonstrated that whole-body vibration not only contributes to bone, muscle, and nervous system disorders but may also increase the risk of cardiovascular disease, gastrointestinal disorders, and certain cancers.[2,3]

The health effects of vibration depend on its type, acceleration, and duration of exposure.[4] For example, a study of underground rock drillers in British Columbia reported that 25% of workers with 1–5 years of experience and 80% of those with more than 16 years of experience developed hand–arm vibration disorders.[5] In another investigation, four-hour weighted vibration acceleration levels measured from 26 vehicle lift legs and 13 drill rods in mining workplaces ranged from 15 to 32 m/s^2, exceeding the limits recommended by the International Organization for Standardization.[6] Similarly, vibration levels in South African gold mines, where rock drills have been in use since 1907, averaged 24–31 m/s^2—five to six times higher than the European Union exposure limit of 5 m/s^2. Despite longstanding knowledge of these risks, vibration remains a common occupational hazard. It is estimated that 1.7–3.6% of heavy industry workers in Europe and the United States are exposed to vibration at levels considered harmful.[7]

Between 1999 and 2013, France reported 400–500 cases of vibration-related disorders annually in heavy industry and over 280 cases in agriculture.[8] Across North America and Europe, an estimated 4–7% of the workforce is exposed to whole-body vibration each year, corresponding to approximately 7 million workers in the United States and 9 million workers (7.2 million men and 1.8 million women) in the United Kingdom.[9] In Singapore, musculoskeletal disorders account for 42.2% (337 cases) of all occupational diseases, and their prevalence continues to rise.[10]

In Mongolia, the working-age population was 2,119,515 in 2024, with 288,400 employed in mining, construction, road transport, and energy sectors.[11] A study by Altansukh, et al. found that operators of heavy machinery, including excavators, drill drivers, and BelAZ haul trucks in large mining operations, were exposed to whole-body vibration levels exceeding the permissible threshold of 50 dB. Moreover, 29.5 cases of nerve root and plexus disorders due to vibration exposure were reported per 100 workers between 2009 and 2019.[12] Mining workers in Mongolia face elevated risks of premature disability, occupational diseases such as pneumoconiosis, hearing loss, and concussion, as well as work-related accidents and fatalities.[13]

Occupational health practice must therefore prioritize the protection of workers from vibration exposure and develop effective strategies to monitor, control, and reduce associated risks. In Mongolia, vibration-related diseases are classified according to the ICD-10 system. However, since 1975, no comprehensive study has calculated the national prevalence or proportion of work-related disability attributable to vibration. Furthermore, specific policies and regulations addressing vibration hazards remain underdeveloped, with only two standards currently in force (MNS 6769 and MNS 6770).[14] Therefore, the present study sought to provide baseline data on the point prevalence and characteristics of vibration-related illnesses among workers diagnosed with occupational diseases or work-related disabilities in Mongolia, aiming to fill the existing knowledge gap in this area.

Materials and Methods

Study Design

This study employed a descriptive desk review design. A total of 10,219 occupational disease cases registered at the Center for Occupational Safety and Health of Mongolia between 1975 and 2022 were analyzed.

In the first stage, cases diagnosed with ICD-10 codes G54, G54.1, T75, T75.2, G62.8, G56.0, M70.0, M65.4 and M21 +Z57.7 were identified (Table 1).[15] In the second stage, 167 cases were excluded from the 1,119 vibration-related diagnoses due to either non-vibration-related occupations or missing information on job position. The final dataset included 952 cases of workers employed in vibration-related conditions who were diagnosed with vibration-related diseases (Figure 1).

Table 1. ICD-10 codes and procedure codes used in the data search.

ICD-10 code	Diagnosis
G54	Nerve root and plexus disorders
G54.1	Lumbosacral plexus disorders
T75	Effects of other external causes
T75.2	Effects of vibration
M21	Other acquired deformities of limbs
G62.8	Other specified polyneuropathies
G56.0	Carpal tunnel syndrome
M70.0	Chronic crepitant synovitis of hand and wrist
M65.4	Radial styloid tenosynovitis
Z57.7	Occupational exposure to vibration

ICD - International Classification of Diseases ICD - International Classification of Diseases

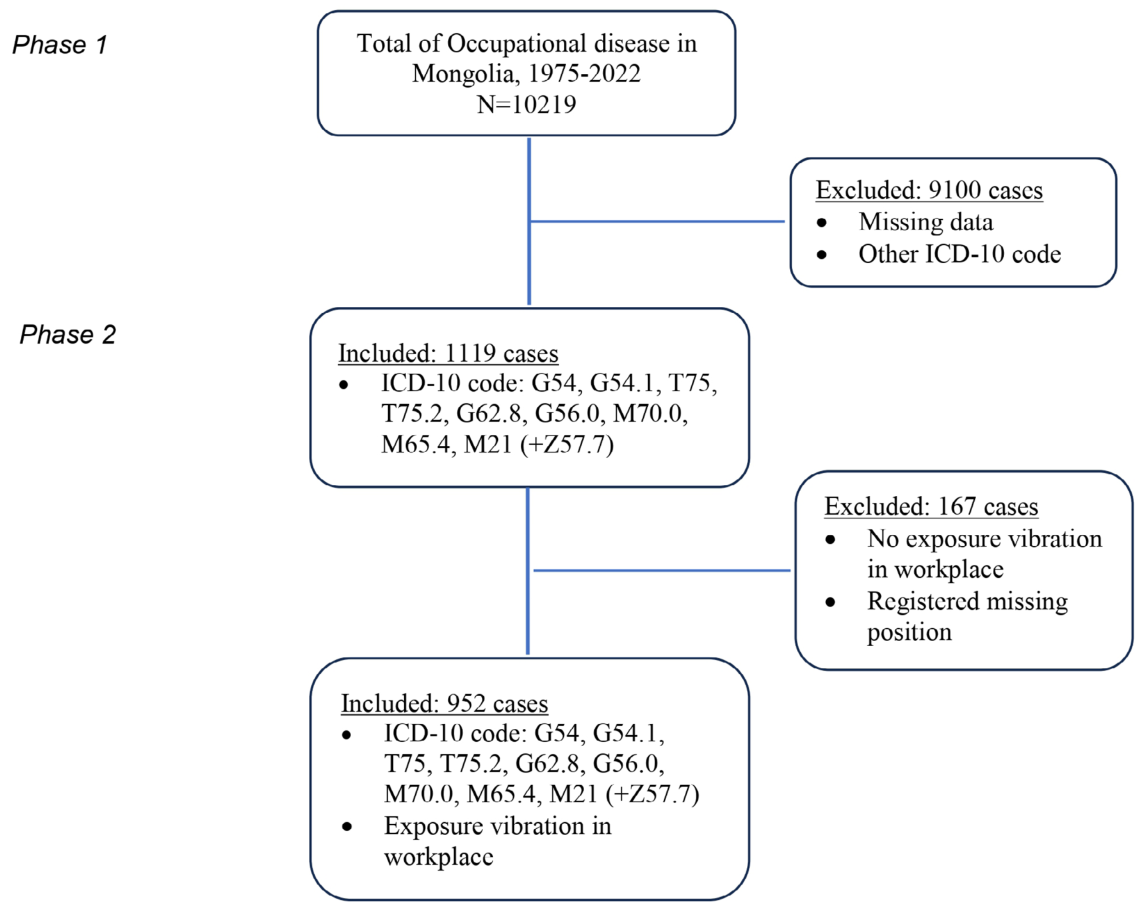

Figure 1. Study flowchart. Sample flowchart has described process of selecting participants eligible for study.

To estimate the prevalence of occupational diseases caused by vibration, eight variables were extracted: (I). Year of diagnosis of vibration-related occupational disease, (II). International Classification of Diseases (ICD-10) code, (III). Sector of employment, (IV). Organization, (V). Total years of work, (VI). Years of work in vibration-related conditions, (VII). Age, (VIII). Gender.

Additionally, data on the working-age population and the number of employees in each sector of the Mongolian labor market were obtained from the National Statistics Office of Mongolia.

Statistical Analysis

The data were categorized into industrial sectors according to Joint Order No. 319/A/160 of the Minister of Finance and the Director of the National Statistics Office, issued on December 31, 2018.(16) All records were converted into a Stata dataset and analyzed using STATA software (version 12.0; StataCorp LLC, College Station, TX, USA).

The prevalence of vibration-related occupational diseases in Mongolia was calculated using Formula 1, defined as the number of whole-body vibration–related occupational disease cases diagnosed in a given year per 100,000 working-age population in that year. The proportion of whole-body vibration diseases among all occupational diseases was calculated using Formula 2, expressed as the number of whole-body vibration disease cases diagnosed in a given year divided by the total number of occupational disease cases, multiplied by 100%.

(Formula 1)

$$\text{Point prevalence} = \frac{\begin{array}{c}(Number\ of\ cases\ of\ occupational\\ diseases\ caused\ by\ whole-body\ vibration\ in\ a\ given\ year)\end{array}}{Working\ age\ population} * 100\ 000$$

(Formula 2)

$$\text{Vibration related disease proportion} = \frac{\begin{array}{c}Number\ of\ occupational\ diseases\\ caused\ by\ vibration\ recorded\ in\ a\ given\ year\end{array}}{\begin{array}{c}Total\ number\ of\ occupational\ disease\\ cases\ registered\ in\ a\ given\ year\end{array}} * 100\%$$

Based on the number of employees in the manufacturing sector in Mongolia, the incidence of vibration-related diseases among workers in this industry was calculated using Formula 3. This was expressed as the number of diagnosed vibration-related cases per 100,000 working-age population.

(Formula 3)

$$\text{Point prevalence of vibration related disease by sector} = \frac{\begin{array}{c}Number\ of\ cases\ of\ vibration-related\\ illnesses\ registered\ in\ the\ sector\end{array}}{Number\ of\ employees\ in\ the\ sector} * 100\ 00$$

The distribution of the years of working in whole-body vibration (WBV) conditions variable was evaluated for normality using graphical methods and the Shapiro–Wilk test. As the data did not meet the assumptions of normality, non-parametric statistical methods were applied. Differences in years of working in vibration conditions across industry sector categories were initially examined using the Kruskal–Wallis test.

Following a statistically significant Kruskal–Wallis result, post hoc pairwise comparisons between industry sectors were performed using Dunn's test, which is appropriate for multiple comparisons of independent groups in non-parametric settings. Dunn's test calculates pairwise z-statistics based on rank differences between groups.

To maintain consistency with the Stata output used in this study, *p*-values were not adjusted for multiple comparisons. For each pairwise comparison, both the z-statistic and the corresponding unadjusted *p*-value were reported. Statistical significance was defined as $p < 0.05$.

Point prevalence of WBV and HAV per 100,000 working-age population were calculated, and trends were presented in Figure 3.

Study Ethics

The study protocol was reviewed and approved by the Academic Council of the School of Public Health, Mongolian National University of Medical Sciences, and subsequently by the Institutional Review Board of the Mongolian National University of Medical Sciences (Approval No. 2023/3-04). Permission to access occupational disease data was obtained from the Center for Occupational Safety and Health (Approval No. 2023/3-04). All data were anonymized prior to analysis, and no confidential personal information was used.

Results

A total of 10,219 occupational disease cases were registered at the Hospital of Occupational Diseases, Center for Occupational Safety and Health in Mongolia between 1975 and 2022. Of these, 952 cases (9.3%) were vibration related.

Among vibration-related illnesses, 895 (94.1%) were whole-body vibration disorders and 57 (5.9%) were hand–arm vibration disorders. The mean age at diagnosis was 43.5 ± 6.3 years (95% CI: 42.9–43.3). Male workers had a mean age of 43.4 ± 6.4 years (95% CI: 43.1–43.9), while female workers had a mean age of 41.7 ± 5.1 years (95% CI: 40.3–43.1). The mean age at diagnosis was 43.4 ± 6.3 years (95% CI: 43.0–43.8) for whole-body vibration and 42.9 ± 6.3 years (95% CI: 41.2–44.6) for hand–arm vibration disorders.

Regarding duration of exposure, male workers developed vibration-related disease after an average of 17.6 ± 5.6 years (95% CI: 17.2–17.9) and female workers after 18.2 ± 4.5 years (95% CI: 16.9–19.4). The mean exposure duration was 17.7 ± 5.6 years (95% CI: 17.3–18.1) for whole-body vibration and 16.9 ± 5.3 years (95% CI: 15.5–18.3) for hand–arm vibration (Table 2).

The proportion of occupational diseases attributed to vibration increased over time. In 1975, 15 of 377 cases (3.9%) were vibration-related, while in 1991 the proportion rose to 47 of 625 (23.1%). In 2009, vibration-related cases accounted for 17 of 56 (30.4%), and by 2022, 42 of 93 cases (45.2%) were due to vibration. Although the absolute number of cases declined, the relative proportion of vibration-related diseases increased (Figure 2).

The point prevalence of vibration-related diseases per 100,000 working-age population peaked between 1989 and 2011. The highest prevalence of whole-body vibration was recorded in 2000 (5.4 cases per 100,000), while hand–arm vibration peaked in 2002 (0.51 cases per 100,000) (Figure 3).

Table 1. ICD-10 codes and procedure codes used in the data search.

Variables	n	mean	SD	95% CI	min	max
Age	952	43.3	6.32	42.98 - 43.32	22	62
Male	897	43.4	6.37	43.07 - 43.90	22	62
Female	55	41.7	5.14	40.31 – 43.10	28	52
WBV	895	43.4	6.32	43.00 – 43.83	22	62
HAV	57	42.8	6.34	41.21 – 44.57	32	60
Total years worked	952	21.17	6.42	19.77 - 20.59	3	41
Male	897	21.22	6.52	20.79 – 21.65	3	41
Female	55	20.4	4.54	19.17 – 21.62	10	34
WBV	895	21.14	6.44	20.71 – 21.56	3	41
HAV	57	21.75	6.07	20.14 – 23.36	11	35
Years worked under vibration	952	17.65	5.57	16.40 - 17.11	3	38
Male	897	17.62	5.63	17.25 – 17.99	3	38
Female	55	18.21	4.52	16.99 – 19.44	8	28
WBV	895	17.70	5.59	17.33 – 18.07	3	38
HAV	57	16.91	5.26	15.51 – 18.30	6	28

WBV- Whole body vibration; HAV -Hand arm vibration; SD- Standard deviation; CI- Confidence interval

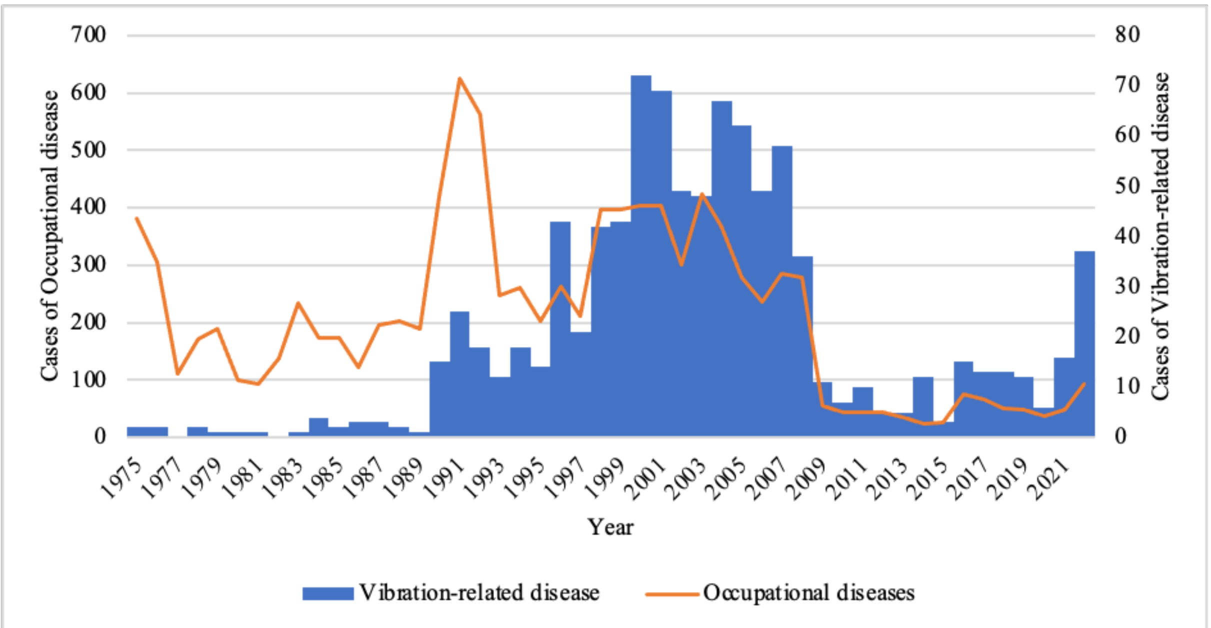

Figure 2. Cases of occupational diseases caused by vibration by year

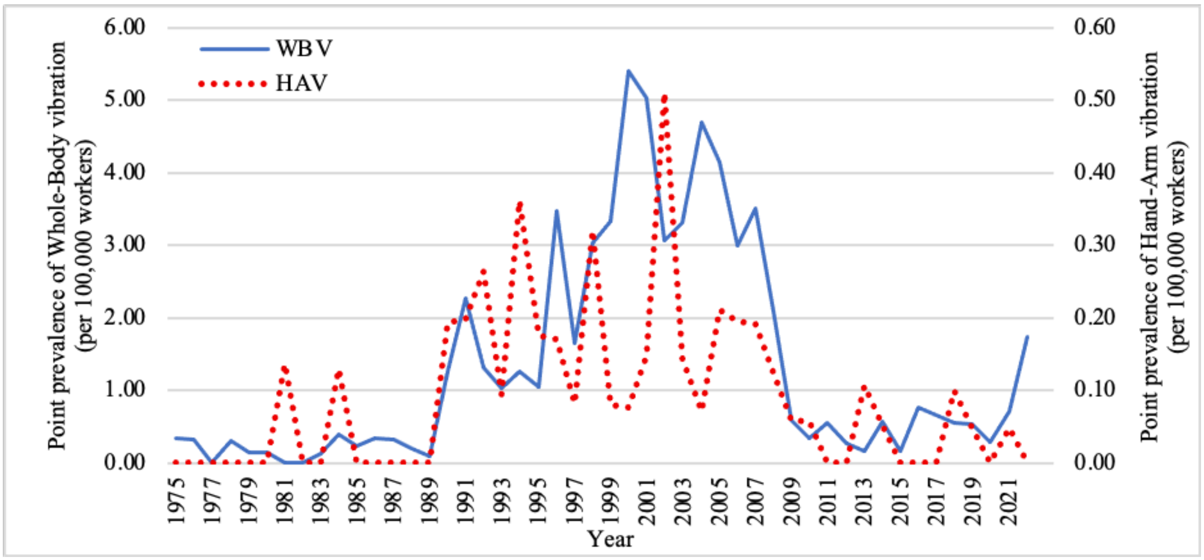

Figure 3. Point prevalence of vibration related disorders per 100,000 working-age population

By age group, the highest prevalence occurred among workers aged 35–44 years, with 23.9 cases per 100,000 working-age population. Within this group, 481 cases (53.7%) were whole-body vibration, and 26 cases (45.6%) were hand–arm vibration disorders; however, this difference was not statistically significant ($\chi^2 = 3.76$, $p = 0.44$) (Table 3).

The mining and quarrying sector had the highest prevalence of vibration-related diseases, with 224.9 cases per 100,000 working-age population, followed by the energy sector (25.2 cases per 100,000) (Table 4). The average time to disease onset in the mining and quarrying sector was 17.3 ± 5.5 years, while the road and transport sector showed the longest latency period, averaging 20.9 ± 5.9 years. The Kruskal Wallis test showed a significant difference in the median duration (years) to the development of vibration related disease across sectors (H= 28.93, df=5, p <0.001) (Table 4).

Table 3. Point prevalence of diseases caused by vibration, by age group

Age group	N	Point prevalence (per 100,000 workers)	WBV n (%)	HAV n (%)
>24	1	0.05	1 (0.11)	-
25-34	63	2.97	56 (6.26)	7 (12.28)
35-44	507	23.92	481 (53.74)	26 (45.61)
45-54	337	15.90	316 (35.31)	21 (36.84)
55<	44	2.08	41 (4.58)	3 (5.26)
Total	952	21.17	6.42	57 (100)

WBV- Whole body vibration; HAV -Hand arm vibration

Table 4. Point prevalence of diseases caused by vibration, by sector

Sectors	N (%)	Point prevalence (per 100,000 workers)	Mean (years) ±SD	Median*	Max	Min
Mining	814 (86)	224.86	17.3±5.4	17	3	38
Processing factory	12 (1)	16.00	19.4±4.8	20	12	27
Construction	34 (4)	3.40	19.1±4.8	19.5	10	29
Power	40 (4)	25.16	18.5±6.0	18	6	35
Transportation	52 (5)	8.62	20.9±5.9	20	6	34
Total	952 (100)	44.92	17.6±5.5	17	3	38

** Kruskal–Wallis test, p=0.0001*

Dunn's post hoc pairwise comparison (without adjustment) revealed statistically significant differences in median vibration exposure between the mining and construction sectors ($z = -2.38$, $p = 0.0086$) and between the mining and transportation sectors ($z = -4.50$, $p < 0.001$) (Table 5). When analyzed by ICD-10 classification, the highest incidence of whole-body vibration disorders was recorded for G54 (nerve root and plexus disorders), at 38.3 cases per 100,000 working-age population. For hand–arm vibration, the highest incidence was for M21 (other acquired deformities of limbs), at 2.0 cases per 100,000 working-age population (Table 6).

Discussion

The sharp increase in the proportion of vibration-related occupational diseases from 1991 to 2008 is likely attributable to the establishment of the Center for Occupational Diseases in 1991, which expanded surveillance and diagnostic capacity. Conversely, the decline in incidence since 2009 may be related to Mongolia's transition to a market economy in the 1990s, which led to the privatization and stagnation of many factories and mines, the closure of industrial enterprises, and a shift of the working-age population toward trade. Additionally, in the mid-1990s, more than 50,000 Mongolian citizens migrated to Kazakhstan under employment contracts, many of whom acquired Kazakhstani citizenship. This internal and external migration further reduced the industrial labor force.[17]

In recent years, the number of vibration-related illnesses has risen again, coinciding with the rapid expansion of the mining sector following the enactment of the 2006 Minerals Law of Mongolia. The proportion of young workers entering the mining sector increased by 1.25 percentage points compared with previous years.[11] Since 2006, occupational disease incidence has risen markedly, with 90.7% of new cases linked to mining, underscoring the urgent need for policy measures to improve working conditions in this sector.[18]

A study by Altansukh, et al. reported that, at the Erdenet Mining Company between 2009 and 2019, 49.4% of whole-body vibration measurements exceeded the permissible limit of 50 dB, while 27.5% of hand–arm vibration measurements

Table 5. Dunn's pairwise comparison of median vibration exposure by sector (no adjustment)

Sectors	z-value	*p*-value	Significance
Mining vs Processing factory	–1.52	0.0642	Not significant
Mining vs Construction	–2.38	0.0086	Significant
Mining vs Power	–1.39	0.0818	Not significant
Mining vs Transportation	–4.50	<0.001	Significant

Values represent z-statistics and unadjusted p-values from Dunn's post hoc test following a significant Kruskal–Wallis test. Statistical significance was defined as $p < 0.05$.

Table 6. Vibration caused disease, by diagnosis

ICD (Diagnosis)	WBV			HAV		
	n	%	Point prevalence (per 100,000 workers)	n	%	Point prevalence (per 100,000 workers)
G54 (Nerve root and plexus disorder)	811	90.61	38.26	1	1.75	0.05
G54.1(lumbosacral plexus disorders)	74	8.27	3.49	-	-	-
M21 (Other Acquired Deformities of Limbs)	-	-	-	42	73.68	1.98
M21.2 (Flexion deformity)	-	-	-	1	1.75	0.05
T75 (Effect of other external causes)	10	1.12	0.47	11	19.3	0.52
T75.2 (Effect of vibration)	-	-	-	2	3.51	0.09

ICD - International Classification of Diseases; WBV- Whole body vibration; HAV -Hand arm vibration

exceeded 76 dB. This indicates that one in every two to three employees is exposed to hazardous vibration levels.[12]

Our findings are consistent: from 1975 to 2022, 814 cases (86%) of vibration-related occupational diseases were recorded among mining workers. Given that the mining sector contributes 22.8% of Mongolia's gross domestic product and 93.7% of its exports, the high prevalence of vibration-related disorders is closely tied to long working hours, often 12-hour shifts, with more than 90% of time spent operating vehicles.[19] As the mining sector continues to expand, the burden of vibration-related occupational diseases is expected to increase.

International evidence supports these findings. In an Australian coal mine, Wolfgang and Burgess-Limerick, et al. measured vibration exposure among 32 truck drivers over an 8-hour shift; 94% were found to be at risk of vibration-induced health effects.[20] Similarly, Kumar, et al. demonstrated that heavy dump truck operators exposed to whole-body vibration had significantly higher rates of low back pain, with a 2.52-fold increased prevalence compared with unexposed controls.[21]

In our study, the mining and quarrying sector accounted for 86% of all vibration-related cases. Among these, nerve root and plexus disorders (G54) represented 90.6% (811 cases), while lumbosacral plexus disorders (G54.1) accounted for 8.3% (74 cases). This pattern aligns with previous reports and likely reflects the widespread use of heavy vibrating machinery, inadequate occupational health practices, reliance on outdated equipment, and limited access to spare parts for repair.

Long-term exposure to whole-body vibration has been shown to cause damage to bones and joints, particularly in the lumbar spine. Bovenzi, et al. reported vibration exposure levels of 0.79–1.04 m/s^2 among tractor, forklift, and heavy vehicle drivers, concluding that prolonged exposure increases the risk of low back disorders. These findings highlight the importance of implementing preventive measures, including proper maintenance of equipment, adherence to occupational health guidelines, and targeted interventions for workers in high-exposure sectors.[22]

The Society of Occupational Medicine (UK) has estimated that 10% of the working-age population will develop Raynaud's disease after 12 years of exposure at the exposure action value

(EAV) of 2.5 m/s^2.[23] In our dataset, 57 cases (5.9%) of vibration-related diseases were attributed to hand–arm vibration, diagnosed after an average of 16.9 ± 5.3 years of exposure. According to the international classification, 3.5% (2 cases) were recorded as T75.2 (effects of vibration).

However, under Joint Order No. A/152 and A/388 of the Minister of Labor and Social Security and the Minister of Health (November 7, 2023), compensation for disability cannot be granted under a T75.2 diagnosis[24] Instead, T75 has been applied in practice for disability determinations, which may explain why 19.3% (11 cases) in our study were diagnosed with T75.

Internationally, occupational physicians use diagnostic tools such as nailfold capillaroscopy, laser Doppler flowmetry, photoplethysmography, and biomarker analysis to detect vascular changes associated with vibration-induced Raynaud's disease.[23] In Mongolia, however, diagnoses are made largely on the basis of sensory testing and workplace assessments due to the lack of specialized equipment.

In Mongolia's regulatory framework, vibration-related diseases are listed under ICD-10 code T75 in the "List, Degree, and Duration of Occupational Diseases" regulation. However, in the ICD-10-CM system, T75 encompasses "other and unspecified effects of external causes," including lightning (T75.0), drowning (T75.1), vibration (T75.2), motion sickness (T75.3), and electric current (T75.4). This classification makes it difficult to distinguish occupational vibration-related diagnoses. In our study, 22 workers (1.12%) were classified under T75 10 with whole-body vibration syndrome and 12 with hand–arm vibration syndrome suggesting potential misclassification.

The International Labour Organization (ILO) guidelines classify hand–arm vibration under ICD-10 T75.2 (effects of vibration) and G62.8 (other specified polyneuropathies), while whole-body vibration can be recorded as M54.5 (low back pain), M54.4 (lumbago with sciatica), or Z57.7 (occupational exposure to vibration).[15]

In Mongolia, however, there is no legal or regulatory framework for disability compensation under these codes. This gap prevents accurate diagnosis and registration of vibration-related diseases. Moving forward, it is a priority to improve occupational disease registration systems, establish a unified database, and revise disability determination procedures in accordance with international standards.

Limitations of the Study

A key limitation of this study is that statistical records of occupational diseases registered in Mongolia before 2006 were only available in paper form. These records lacked essential variables such as age, sex, and degree of work-related disability. As a result, it was not possible to conduct subgroup analyses of vibration-related diseases by demographic characteristics or disability level.

Conclusion

On average, disability due to vibration-related conditions is diagnosed after 17 years of occupational exposure. Whole-body vibration most frequently results in nerve root and plexus disorders, while hand–arm vibration is primarily associated with acquired deformities of the limbs. The highest incidence of vibration-related occupational diseases was observed in the mining and quarrying sector, with 224.9 cases per 100,000 working-age population.

In recent years, nerve root and plexus disorders have become increasingly common, highlighting the urgent need to strengthen differential diagnosis of vibration-induced neurological diseases and to improve Mongolia's national occupational disease registration system. Future studies should focus on early detection and precise classification of vibration-related disorders to enhance diagnostic accuracy and guide the development of effective preventive measures and evidence-based policy interventions.

Conflict of interest

The authors declare that there is no conflict of interest.

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