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This week's issue was organized by Xin Sun

Foreword

Occupational Noise Exposure and Worker's Health in China

The World Health Organization (WHO) released the *World Report on Hearing* on March 2, 2021. The WHO estimated that by 2050, nearly 2.5 billion (1 in 4 people) would be living with some degree of hearing loss, and at least 700 million of whom would require rehabilitation services (*1*). The risk factors that cause hearing loss not only include occupational but also non-occupational factors, such as, high-level exposure of noise and ototoxic chemicals at workplaces, age, excessive noise exposure in living environments or listening to loud music through personal listening devices, and ototoxic drug intake during childhood, etc. It was estimated that 16% of hearing loss might be contributed by exposure to high-levels of noise at the workplace (*2*). In occupational settings, high levels of noise are still the most focused issue all over the world. It was estimated that more than 30 million workers were exposed to hazardous noise in the United States of America (USA) (*3*). In Germany, 4–5 million people (12%–15% of the workforce) were exposed to noise levels defined as hazardous by the WHO (*4*). It is estimated that approximately 80 million workers in the total of 574 million workers in industrial and service settings in China are exposed to hazardous noise, and it is estimated that 14% of the workers in industrial and service settings in USA exposed to hazardous noise (*5*).

The exposure level for hearing loss in occupational setting was calculated as an A-weighted equivalent sound pressure level, averaged over the time of an 8-hours working day ($L_{EX,8h}$), or 40 hours per working week ($L_{EX,week}$) (*3*). The exposure limit of 85 dBA for occupational noise exposure recommended by the National Institute of Occupational Safety and Health (NIOSH) was reevaluated by incorporating the 4,000-Hz audiometric frequency into the definition of hearing impairment in the risk assessment (*3*). Current noise standards of hearing loss are based on the equal-energy hypothesis, especially for Gaussian (G) noise, e.g. ISO 1999:2013 (*6*), but not for complex noise. A statistic metric, kurtosis (β) had been developed for quantifying the complex temporal structure of a non-Gaussian (non-G) noise with measuring the peak (P), interval (I), and duration (D) histograms of the transients in the noise signal (*7*). Figure 1 showed the numbers of new cases of occupational noise-induced deafness diagnosed and reported from 2001 to 2019 in China. Although the numbers of new cases diagnosed and reported were dramatically increased after 2010, there is a huge gap between the numbers of cases diagnosed and the numbers of workers exposed to hazardous noise at workplace. The data from a cross-sectional survey with 6,557 workers of automotive industry showed that 28.8% of workers were found to have high-frequency noise-induced hearing loss (*8*). A meta-analysis with a total of 71,865 workers from transportation, mining, and typical manufacturing industries revealed that the prevalence of suspected occupational noise induced hearing loss in China was 21.3%, of which 30.2% was related to high-frequency noise-induced hearing loss, 9.0% was related to speech-frequency noise-induced hearing loss, and 5.8% was related to noise-induced deafness (*9*). In USA, a total of 15,900 new cases of recordable standard threshold shifts in 2017 that representing a rate of 1.4 cases per 10,000 workers were reported from the US Bureau of Labor Statistics annual Survey of Occupational Injuries and Illnesses (*10*).

Current studies found that noise exposure was not the only risk factor for hearing loss at the workplace as some chemicals used, either alone or in combination with noise or other chemicals, in industrial processes have been shown to have ototoxic effects (*11*). Current evidence demonstrates that some aromatic solvents have confirmed associations with exposure in the workplace and increased prevalence of hearing loss, including the following: toluene, styrene, ethylbenzene, p-xylene, methylstyrenes, allylbenzene, and n-propylbenzene; some non-aromatic solvent such as trichloroethylene, nitrile, and asphyxiants; and some metals or its compounds such as lead or its compounds (*11*). Our research investigated the hearing loss of workers by combined exposure of ototoxic organic solvents and noise in wood furniture manufacturing factories and printing factories. The results of our study indicated that hearing loss of workers caused by combined exposure of organic solvents and noise was serious as high frequency hearing loss and speech frequency hearing loss were affected. Noise is a physical factor that causes mostly mechanical and metabolic damage to the peripheral auditory receptor, cochlea, and the auditory neural pathways (*12–14*). Ototoxic chemicals in the bloodstream go through either the blood-labyrinth barrier into the cochlea or the blood–brain barrier to the eighth cranial nerve and central nervous system (*14–15*). As a result, chemical-

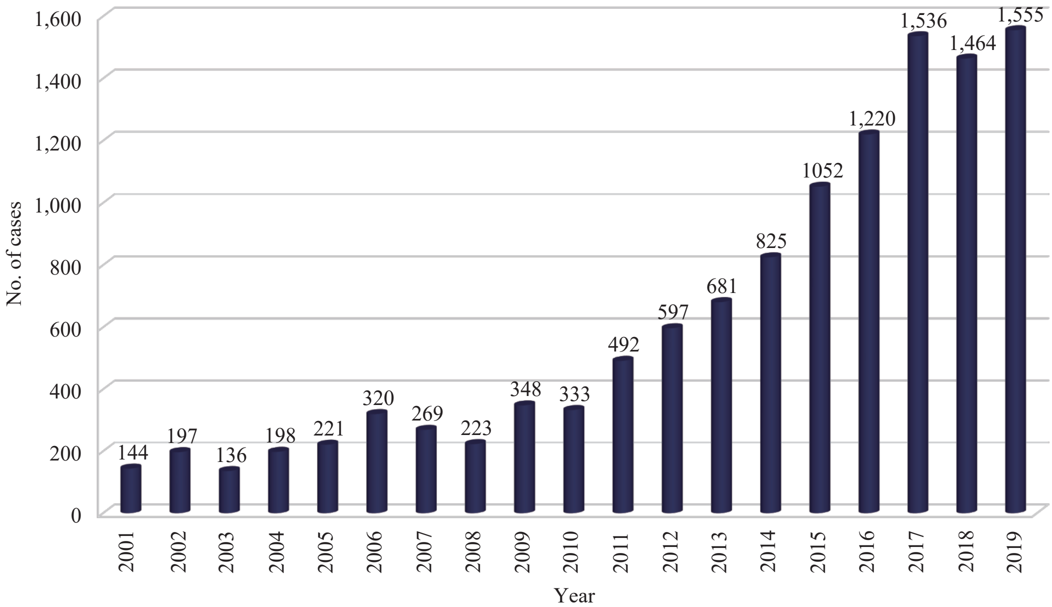

FIGURE 1. Number of occupational noise induced deafness cases diagnosed and reported during 2001–2019 in China.
Note: Data from National Occupational Disease Report.

induced hearing loss can result from the effects on several sites in the hearing system. Ototoxic chemicals may affect the structures and/or the function of the inner ear (auditory and vestibular apparatus) and the connected neural pathways.

The workers exposed to hazardous noise may experience multiple adverse health outcomes, including communication difficulties, social isolation, stress, and fatigue (*16*), and these adverse health outcomes are probably associated with depression, cognitive decline, dementia, fall, increased hospitalization, and health care costs (*17*–*18*). High levels of noise are associated with tinnitus, hyperacusis, cardiovascular disease, annoyance, performance decreases, and sleep disturbances (*16*–*18*). High levels of noise exposure during pregnancy may be associated with adverse reproductive outcomes, including low birthweight and preterm birth (*19*). In China, the huge numbers of workers exposed to hazardous noise will increase the burdens in diagnosis and economic costs of disease. The best approach is to improve a comprehensive strategy to control and reduce the exposure level of noise in workplaces and improve health promotion of workers.

We are currently establishing a prospective cohort to investigate the impact on workers of hearing loss and related adverse outcomes due to exposure of noise and combined exposure to noise and ototoxic chemicals at workplace. Data from this ongoing study will provide evidence for better understanding of health impacts and mechanisms of hearing loss and related diseases and for revision of occupational health and occupational diagnosis standards, e.g. occupational exposure limits for noise in the workplace and the diagnosis of occupational noise-induced deafness.

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Preplanned Studies

The Role of the Kurtosis Metric in Evaluating the Risk of Occupational Hearing Loss Associated with Complex Noise — Zhejiang Province, China, 2010–2019

Meibian Zhang[1,#]; Xiangjing Gao[1]; Wei Qiu[2]; Xin Sun[3]; Weijiang Hu[3]

Summary

What is already known about this topic?

Occupational noise-induced hearing loss (NIHL) has been the second most common occupational disease in China. Noise energy is the main risk factor for occupational NIHL. Evidence shows the temporal structure of noise (as indicated by kurtosis metric) contribute to the development of NIHL. However, the role of the kurtosis metric in evaluating the risk of occupational NIHL associated with complex noise has been rarely reported.

What is added by this report?

Noise temporal structure (as indicated by kurtosis) is an important risk factor for occupational NIHL in addition to noise energy. Kurtosis can be used to quantify complex noise exposure. A combination of noise kurtosis and noise energy can effectively evaluate the risk of occupational hearing loss associated with complex noise.

What are the implications for public health practice?

Considering the effect of noise temporal structure on occupational NIHL, the existing international noise exposure standards (e.g. measurement method and noise exposure limit) for complex noise should be modified based on noise temporal structure. More effort is needed to reduce noise exposure, improve health screening, and monitor occupational NIHL.

Occupational noise-induced hearing loss (NIHL) is one of the most prevalent occupational diseases worldwide, and it ranks the second occupational disease in China (*1*). Complex noise, also known as non-Gaussian noise, is the main type of industrial noise in the workplaces, which is composed of transient high-energy impulsive/impact noise superimposed on Gaussian background noise (*2*). The previous animal experiments and epidemiological studies showed that in addition to noise energy, the temporal structure of noise was a necessary metric to assess the hearing loss caused by complex noise (*3*). These findings indicated that the existing international noise exposure standards (e.g. ISO 1999:2013) might not be adequate for complex noise, in which the noise energy (e.g. the A-weighted equivalent sound pressure level, L_{Aeq}) served as the only metric to assess NIHL based on the equal energy hypothesis (EEH) (*4*). The EEH assumes that the hearing loss caused by noise exposure is proportional to the exposure duration multiplied by the energy intensity, thus implying that the hearing loss is not related to the acoustic energy temporal distribution. In addition, due to the peak clipping effect of impulse noise, traditional noise measurement techniques are not suitable for measuring complex noise (*5*).

Recently, the evidence has shown that the kurtosis (β), as defined as the ratio of the fourth-order central moment to the squared second-order central moment of a distribution, can provide an "indirect" measure of sensitivity to the presence of impulse noise in complex noise exposure (*5*). There was little epidemiological data reporting whether the kurtosis metric could be used to quantify complex noise exposure and in combination with noise energy to assess the occupational hearing loss associated with complex noise (*3*).

In this study, a cross-sectional study was designed to investigate the role of kurtosis in evaluating the risk of occupational hearing loss associated with complex noise. A total of 2,898 manufacturing workers in the Zhejiang Province were recruited from 6 industries in 2010–2019. Findings of this study showed that the kurtosis metric could be used to quantify complex noise exposure, indicating the existing international noise exposure standards for complex noise should be modified based on noise temporal structure.

The inclusion criteria for these subjects were as follows: 1) a minimum of 1-year noise exposure with fixed work tasks; 2) no history of drug-related hearing loss, ear diseases, and military service; 3) either no use of hearing protection devices (HPDs) or use of them only within the last 1 year at the time of data collection; and 4) no exposure to organic solvents or heavy metals. A digital recorder (ASV5910-R, Aihua) was used to record the shift-long personal noise waveform for each participant. The noise waveform was analyzed using the MATLAB software (The MathWorks, R2017, Natick, USA) to obtain the A-weighted sound-pressure level ($L_{Aeq,8h}$) and kurtosis (β) value. Noise with a mean $\beta \geq 10$ was defined as complex noise, and that with a mean $\beta < 10$ was defined as continuous steady-state noise. The cumulative noise exposure (CNE) was calculated using a combination of $L_{Aeq,8h,}$ and exposure duration for quantifying total noise energy of exposure, then the CNE was adjusted by kurtosis based on a model used in Xie et al. (*6*) The kurtosis-adjusted CNE is calculated as Adjusted-CNE=$L_{Aeq,8h}$+[(In β +1.9)÷log2×logT], where T is exposure time.

At least 16 hours after the last occupational noise exposure, the participants' pure-tone hearing threshold levels (HTL) at frequencies 0.5, 1.0, 2.0, 3.0, 4.0, 6.0, and 8.0 kHz for each ear were measured using an audiometer (Madsen OB40, Denmark). The HTLs were adjusted by subtracting the age- and sex-specific HTL according to Annex B, Table B.3, of the ISO 1999:2013. High-frequency noise-induced hearing loss (HFNIHL) was defined as adjusted HTL≥30 dB in either ear at 3.0, 4.0, and 6.0 kHz. The noise-induced permanent threshold shift ($NIPTS_{346}$) at 3.0, 4.0, and 6.0 kHz was calculated using the formulas in the ISO 1999:2013. Binary logistic regression analysis was used to analyze the odds ratios (ORs) of key factors affecting HFNIHL.

Table 1 showed that 72.3% of manufacturing workers were male. The average age and exposure duration were 35.81±9.36 and 9.00±7.60 years, respectively. The mean $L_{Aeq,8h}$ was 88.82±5.73 dB(A), of which 80.8% exceeded the occupational exposure limit (OEL) of 85 dB(A), and 21.0% exceeded 95 dB(A). Mean kurtosis values of steady-state noise in textile and paper-making industries were less or equal to 10, while mean kurtosis of complex noise in other industries was greater than 10. On average, 26.9% of manufacturing workers suffered from HFNIHL. The logistic regression analysis for key factors affecting HFNIHL% showed the OR of kurtosis was 1.37, which was similar to that for $L_{Aeq,8h}$ or exposure duration.

Figure 1A demonstrated the scatter plot between

TABLE 1. Prevalence of noise-induced hearing loss and its risk factors among manufacturing workers, Zhejiang province, China, 2010−2019.

Noise type	Industry	General information on workers			$L_{Aeq,8h}$ [dB(A)]				Kurtosis	HFNIHL (%)
		Sex (male %)	Age (y)	Exposure duration (y)	Mean	>85 (%)	>90 (%)	>95 (%)	Mean	
Steady-state	Textile	346 (47.4)	33.44 ± 8.00	8.00 ± 7.00	93.02 ± 6.57	85.5	76.3	57.2	9.98 ± 9.28	27.7
	Paper making	99 (64.7)	47.74 ± 9.92	11.70 ± 8.63	88.54 ± 4.35	85.9	36.4	4.0	10.82 ± 9.74	26.3
	Average	445 (51.2)	36.62 ±10.62	8.83 ± 6.76	92.02 ± 6.42	85.7	56.4	30.6	10.16 ± 9.38	27.4
Complex	Furniture	428(87.6)	34.91 ± 10.24	5.35 ± 5.56	88.09 ± 4.86	77.6	36.0	5.4	165.85 ± 153.99	35.3
	Automobile	996 (81.1)	35.07 ± 8.07	10.19 ± 8.35	88.43 ± 4.49	79.7	34.6	7.4	25.88 ± 37.38	24.4
	Metal product	351 (70.4)	37.27 ± 9.69	7.71 ± 7.24	90.42 ± 5.98	80.9	61.3	23.9	33.80 ± 43.70	24.8
	General equipment	678 (64.7)	36.18 ± 9.35	10.33 ± 7.39	86.91 ± 6.19	65.5	32.4	8.3	34.81 ± 43.77	26.0
	Average	2,453 (76.1)	35.66 ± 9.11	9.03 ± 7.74	88.24 ± 5.40	75.9	41.1	11.3	53.90 ± 90.35	26.8
Total		2,898 (72.3)	35.81 ± 9.36	9.00 ± 7.60	88.82 ± 5.73	80.8	48.8	21.0	47.19 ± 84.69	26.9
Binary logistic regression analysis of key factors influencing HFNIHL%										
OR* (95% CI)		1.28† (1.04–1.57)	1.22§ (1.10–1.36)	1.14§ (1.06–1.22)	1.41§ (1.30–1.53)				1.37§ (1.23–1.52)	-

Abbreviation: HFNIHL=high-frequency noise-induced hearing loss.

* The selected variables including age, gender, exposure duration, $L_{Aeq,8h}$, and kurtosis, were fitted in the binary logistic regression model using the "enter" method; Age (years): <30, 40–, 50–, 60–, 70–, ≥70; Exposure duration (years): <5, 10–, 15–, 20–, >20; $L_{Aeq,8h}$ [(dB(A)]: <80, 85–, 90–, 95–, 100–, ≥100; Sex: male/female; Kurtosis: <10, 5–0, 100–, >100.

† *P*<0.05.

§ *P*<0.01.

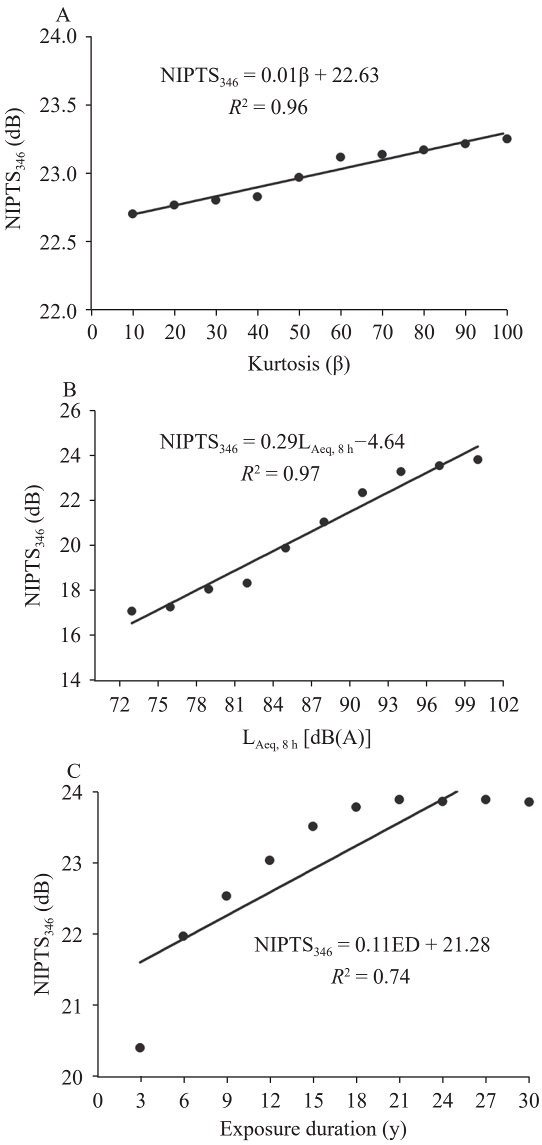

FIGURE 1. Linear regression equation between $NIPTS_{346}$ and kurtosis, $L_{Aeq,8h}$, or exposure duration in the scatter plot, Zhejiang province, China, 2010−2019. (A) The linear relationship between mean $NIPTS_{346}$ and mean kurtosis (β) in 10-β bin collapse; (B) The linear relationship between mean $NIPTS_{346}$ and mean $L_{Aeq,8h}$ in 3-dB(A) bin collapse; (C) The linear relationship between mean $NIPTS_{346}$ and mean exposure duration in 3- year bin collapse.
Abbreviation: NIPTS=noise-induced permanent threshold shift.

mean $NIPTS_{346}$ and mean kurtosis (β) in 10-β bin collapse, and their linear regression equation was: $NIPTS_{346}$=0.01β+22.63, R^2=0.96. Figure 1B showed the linear regression equation between mean $NIPTS_{346}$ and mean $L_{Aeq,8h}$ in 3-dB(A) bin collapse (i.e. $NIPTS_{346}$=0.29$L_{Aeq,8h}$−4.64, R^2=0.97). Figure 1C also demonstrated a linear relationship between $NIPTS_{346}$ and exposure duration, in which the R^2 value of exposure duration was relatively lower than that of kurtosis or $L_{Aeq,8h}$.

Figure 2A illustrated dose-response relationship between HFNIHL% and CNE for complex noise or steady-state noise. The average HFNIHL% (22.4%) for complex noise was significantly higher than that (15.04%) for steady-state noise (P<0.05). Figure 2B demonstrated that after CNE was adjusted by kurtosis, the 2 regression lines were nearly overlapped, and the difference of HFNIHL% between complex noise and steady-state noise was significantly reduced from 7.40% to 1.28%.

DISCUSSIONS

Table 1 illustrated an epidemiological feature of occupational NIHL in China. The high prevalence of occupational NIHL in young male workers was associated with the wide distribution of noise in manufacturing industries, high noise levels, and long-term exposure duration. Relevant data showed that at least 10 million workers in China were assumed to be exposed to harmful noise levels, and the prevalence of occupational NIHL was estimated to be more than 20% (*1*). Approximately 600 million workers were estimated to be exposed to harmful levels of noise globally, and the prevalence of occupational NIHL in developed countries and developing countries were >10% and 18%–67%, respectively (*1*).

Binary logistic regression analysis in Table 1 showed that the order of ORs for risk factors of occupational NIHL was $OR_{LAeq,8h}$>$OR_{kurtosis}$>OR_{sex}>OR_{age}>$OR_{duration}$, which suggests that $L_{Aeq,8h}$ has the greatest contribution to NIHL, and kurtosis is an important factor affecting NIHL, as is exposure duration, age, and sex. Figure 1 demonstrated that the relationships between $NIPTS_{346}$ and these factors of kurtosis, $L_{Aeq,8h}$, and exposure duration were linear, indicating there was a clear dose-response relationship between each of these factors and occupational NIHL.

Figure 2A further illustrates the role of kurtosis is a risk factor. The HFNIHL% among manufacturing workers exposed to complex noise with mean kurtosis ≥10 was significantly higher than that in those exposed to steady-state noise with mean kurtosis <10, which suggested that workers exposed to complex noises had worse hearing loss than those exposed to steady-state noise. These results also indicated that the kurtosis metric could quantify complex noise exposure. These findings emphasize that, in addition to noise energy (as indicated by CNE, noise intensity, or exposure

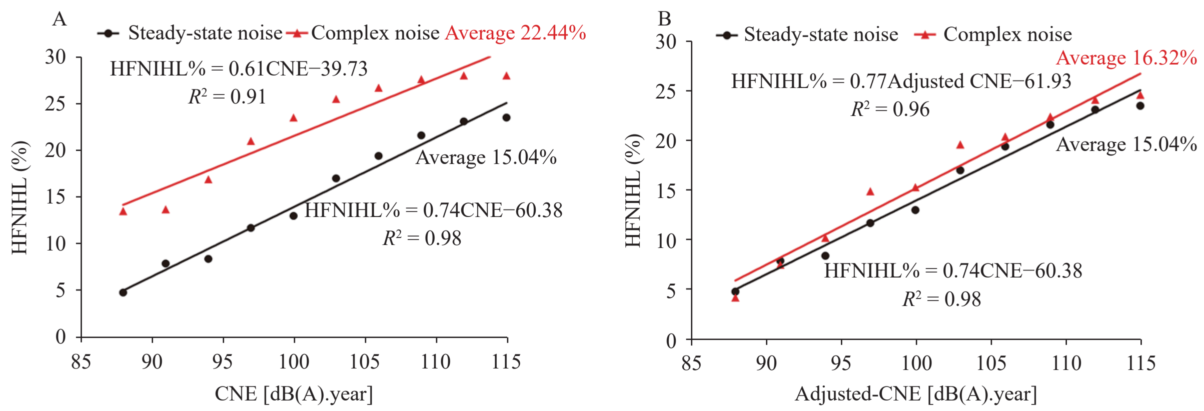

FIGURE 2. Dose-response relationship between HFNIHL% and CNE or kurtosis-adjusted CNE, Zhejiang province, China, 2010−2019. (A) A significant difference in average HFNIHL% between complex noise and Gaussian noise; (B) The two linear regression equations of complex noise and Gaussian noise were almost overlapped after CNE was adjusted by kurtosis.

Abbreviations: HFNIHL=high-frequency noise-induced hearing loss; CNE=cumulative noise exposure.

duration), the temporal structure of noise (as indicated by kurtosis) is also an important risk factor for occupational NIHL (*7*). This result was supported by studies that have reported that hearing loss caused by complex noise was underestimated using current international noise exposure standards. Noise energy is a necessary metric, but the structural characteristics of noise were also an important risk factor for the hearing loss induced by complex noise (*8*–*9*).

Figure 2B demonstrated the role of kurtosis combined with noise energy (i.e., CNE) in the evaluation of NIHL. After CNE was adjusted by kurtosis, the regression line between HFNIHL% and kurtosis-adjusted CNE for complex noise almost overlapped the line between HFNIHL% and CNE for steady-state noise. This demonstrates the ability of kurtosis to adjust CNE based on the equal energy hypothesis to provide a consistent estimate of hearing loss across varied noise environments using a single metric. This result is in agreement with related human investigations that reported kurtosis combined with noise energy could be used as a single metric to evaluate the risk of NIHL in different noise environments (*6*,*10*).

Considering the effect of noise temporal structure on NIHL, it is necessary to re-evaluate the appropriateness of the current international noise exposure standards (e.g. measurement method and OEL) for complex noise. Traditional noise measurement methods using dosimeters or sound level meters should be improved by a kurtosis metric to compensate for the lack of ability to capture the peak clipping effect of impulse noise. The role of kurtosis as the additional risk factor for the occupational NIHL suggests that the noise OEL of 85 dB(A) may be unsafe for the hearing of workers exposed to noise exposure with a complex temporal structure. The American College of Occupational and Environmental Medicine (ACOEM) also concludes that although the Occupational Safety and Health Administration (OSHA) action level for noise exposure is 85 dB(A), there is evidence that the NIHL risk increases with long-term exposure to noise above 80 dB(A) and that the risk increases significantly as the exposure rises above 85 dB(A) (*11*). Therefore, the OEL for noise should be modified based on the noise temporal structure.

This study was subject to at least two limitations. First is that the sample size for some types of work was insufficient. Second was that the kurtosis measure was a proxy measure for quantifying noise complexity and may be limited to quantifying certain aspects of a complex signal.

Based on these findings above, conclusions could be drawn as follows: 1) noise temporal structure was an important risk factor for occupational NIHL in addition to noise energy; 2) the kurtosis metric could be used to quantify complex noise exposure; and 3) as a combination of noise temporal structure and noise energy, the kurtosis-adjusted CNE could be used to evaluate the risk of occupational hearing loss associated with complex noise.

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Preplanned Studies

Epidemiological Data of Work-Related Musculoskeletal Disorders — China, 2018–2020

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Summary

What is already known about this topic?

In recent decades, work-related musculoskeletal disorders (WMSDs) have become increasingly prominent and have become an important issue that is of universal concern and an urgent need to be solved in all countries of the world.

What is added by this report?

The top three industries or occupational groups with the highest standardized prevalence rate of WMSDs were flight attendants, medical staff, and vegetable greenhouses in that order. Women workers were 1.5 times more likely to suffer from WMSDs than men workers.

What are the implications for public health practice?

This study has found the prevalence and distribution characteristics of WMSDs in key industries in China. It is urgent to draw up relevant measures to prevent and control occupational populations with WMSDs.

With the development of science and technology and the process of industrialization, the working conditions of workers have changed greatly. During their work, workers frequently undergo local muscle tension such as repetitive operation, poor working posture, excessive force load, continuous muscle tension, vibration contact, and other health effects caused by adverse working conditions. Work-related musculoskeletal disorders (WMSDs) caused by adverse ergonomics are becoming increasingly prominent. As early as 2002, the International Labor Organization (ILO) added WMSDs in the international list of occupational diseases and refined it in the latest edition of occupational diseases catalogue approved in 2010, including seven categories and an open clause (*1*). Currently, WMSDs are not included in the list of statutory occupational diseases in China. Rather, it is only perceived as work-related diseases, so there is no legal basis for preventing and controlling WMSDs among occupational groups. In 2019, China put forward in the Healthy China Action (2019–2030) that the prevention and control of WMSDs should be included in the national health action goal. Therefore, a large sample of people in key industries in different regions of China were investigated and studied to determine the prevalence and distribution characteristics of WMSDs in key industries of China and explore related epidemiological characteristics.

The scope of this study covers seven regions of North, East, Central, South, Southwest, Northwest and Northeast China. Selection of key industries is based on representative industries closely related to WMSDs, i.e., involving 15 industries such as automobile manufacturing, footwear industry, biological medicine manufacturing, electronic equipment manufacturing, ship and related equipment manufacturing, petrochemical industry, construction industry, furniture manufacturing, coal mining and cleaning industry, animal husbandry, medical staff, automobile 4S shops, vegetable greenhouses, civil aviation flight attendants, and toy manufacturing. In this study, a cluster sampling method was adopted, and all workers on duty who met the inclusion criteria were selected as research objects from the representative enterprises in the key industries and above areas. The inclusion criteria was workers with more than one year's service, and the exclusion criteria was congenital spinal deformity and non-WMSD patients due to trauma, infectious diseases, and malignant tumors.

In the study, the epidemiological cross-sectional survey method and the electronic questionnaire system of Chinese version of musculoskeletal disorders questionnaire were used to investigate the prevalence of WMSDs among occupational groups in key industries in different regions of China. This electronic questionnaire system was based on Nordic

Musculoskeletal Questionnaires (NMQ) (*2*), and after proper modification, the adapted NMQ proved to have good reliability and validity for use for Chinese occupational groups. The criteria of the US National Institute for Occupational Safety and Health (NIOSH) for musculoskeletal injury was used to determine WMSDs (*3*). The survey was conducted by an investigator using face-to-face survey on N respondents, and the respondents answered questions online by mobile phone or by tablet after scanning Quick Response (QR) codes. Up to now, 57,501 valid questionnaires have been received, and the effective rate of questionnaires was 100%. There were 37,240 male workers and 20,261 female workers. The age of the investigated population was (32.3±9.2) years and the length of service was (7.5±7.2) years.

The standardized prevalence rate of WMSDs among the population in key industries in China was 41.2% (all patients suffering from WMSDS at any position are regarded as one patient). The standardized prevalence rate of WMSDs varied from 7.3% to 24.8%. The 3 parts with the highest prevalence were the neck (24.8%), shoulders (20.8%), and lower back (16.8%). Female workers had 1.5 times the risk of WMSDs compared to male workers. A significant difference in the prevalence of WMSDs was observed between different age groups and different working age groups (P<0.05). The prevalence rate of WMSDs increased gradually and decreased with age, and the highest prevalence rate was between 35 and 45 years old. The prevalence of WMSDs increased with increased length of service. Regular physical exercise could reduce the risk of suffering from WMSDs. The risk of neck, shoulders, and lower back of people with different demographic characteristics was shown in Table 1.

The results showed statistical differences in the prevalence of WMSDs among occupational groups in different industries (P<0.05). The standardized prevalence rate of WMSDs in various industries from high to low was: flight attendants (55.7%), medical staff (54.2%), vegetable greenhouse (50.7%), toy manufacturing (49.0%), biopharmaceutical manufacturing (48.4%), automobile manufacturing (43.5%), electronic equipment manufacturing (40.4%), shipbuilding and related equipment manufacturing (40.1%), animal husbandry (39.7%), 4S automobile store (38.6%), coal mining and cleaning industry (38.4%), footwear industry (34.2%), furniture manufacturing (28.5%), construction industry (23.4%), and petrochemical industry (11.5%) (Table 2).

In this study, 56.5%–88.7% of the occupational population chose the pain scores for the neck, shoulders, upper back, lower back (waist), elbow, wrist/hand, hip/thigh, knee, ankle/foot, etc., as 0, which means no pain occurred. Therefore, this study used 10–90 percentile to express the distribution of pain scores. The results demonstrated that the pain scores of female workers were higher than those of male workers except for elbow and knee, which were statistically significant (P<0.05). The pain scores of different age groups, different working age groups, smoking history, and physical exercise habits were statistically significant (P<0.05) (Table 3).

DISCUSSION

The epidemiological characteristics of WMSDs in key industries in China from January 2018 to June 2020 were investigated in this study. On the basis of data published last year (*4*), this paper continues to expand the sample size, reaching data of nearly 60,000 people, which is the largest population survey on WMSDs in China so far. The results of this study showed that the prevalence rate of WMSDs in any body part was 41.2%, and the most common parts were neck, shoulders, and lower back. The risk of WMSDs among female workers was 1.5 times that of male workers. With increases in age, the prevalence rate of WMSDs increased gradually and then decreased. A study on the burden of 354 diseases in 195 countries and regions demonstrated that from 1990 to 2017, lower back pain was the first disease leading to years lived with disability (YLD), and the prevalence rate of musculoskeletal disorders, lower back pain, and neck pain was 38.4% (36.4% to 40.2%), 30.0% (27.9% to 31.9%), and 44.4% (41.9% to 47.0%), respectively (*5*). According to the data, in 2017, the spot prevalence rate of neck pain in women was higher than that in men, although the results were not significant at P=0.05. It was also found that the prevalence rate of pain in the neck increased up to age 70–74 years and then decreased (*6*), which was similar to the results obtained from this study.

The results showed that biopharmaceutical manufacturing, vegetable greenhouses, medical personnel, civil aviation flight attendants, toy manufacturing, automobile manufacturing, and shipbuilding and related equipment manufacturing were industries or occupational groups with high prevalence rate of WMSDs exceeding 40%.

TABLE 1. WMSD prevalence and risk for different demographic groups among key industries or occupational groups in China, 2018–2020.

Characteristic	Number	Any body part			Neck		Shoulders		Lower back	
		No. of cases	Rate, %	OR (95%CI)	No. of cases	OR (95%CI)	No. of cases	OR (95%CI)	No. of cases	OR (95%CI)
Gender										
Male	37,240	14,057	37.7	1	7,774	1	6,419	1	5,514	1
Female	20,261	9,612	47.4	1.5 (1.4−1.5)*	6,713	1.9 (1.8−2.0)*	5,647	1.9 (1.8−1.9)*	3,935	1.4 (1.3−1.5)*
Age (years)										
<25	12,085	4,426	36.6	1	2,389	1	2,027	1	1,462	1
25–	26,139	11,196	42.8	1.3 (1.2−1.4)*	6,967	1.5 (1.4−1.6)*	5,741	1.4 (1.3−1.5)*	4,577	1.5 (1.4−1.6)*
35–	12,301	5,294	43.0	1.3 (1.2−1.4)*	3,486	1.6 (1.5−1.7)*	2,888	1.5 (1.4−1.6)*	2,238	1.6 (1.5−1.7)*
45–	5,802	2,271	39.1	1.1 (1.0−1.2)*	1,385	1.2 (1.2−1.4)*	1,187	1.3 (1.2−1.4)*	964	1.4 (1.3−1.6)*
55–	1,174	482	41.1	1.2 (1.1−1.4)*	260	1.2 (1.0−1.3)*	223	1.2 (1.0−1.4)*	208	1.6 (1.3−1.8)*
Working age (years)										
<2	16,061	5,498	34.2	1	2,955	1	2,536	1	1,886	1
2–	12,072	4,989	41.3	1.3 (1.3−1.4)*	3,011	1.5 (1.4−1.6)*	2,509	1.4 (1.3−1.5)*	1,857	1.4 (1.3−1.5)*
4–	7,299	3,106	42.6	1.4 (1.3−1.5)*	1,966	1.6 (1.5−1.7)*	1,654	1.6 (1.5−1.7)*	1,292	1.6 (1.5−1.7)*
6–	9,717	4,361	44.9	1.6 (1.5−1.6)*	2,805	1.8 (1.7−1.9)*	2,302	1.7 (1.6−1.8)*	1,853	1.8 (1.7−1.9)*
8–	12,352	5,715	46.3	1.7 (1.6−1.7)*	3,750	1.9 (1.8−2.0)*	3,065	1.8 (1.7−1.9)*	2,561	2.0 (1.8−2.1)*
Education										
Junior high school	15,369	5,543	36.1	1	3,230	1	2,815	1	2,225	1
Senior high school	21,901	8,636	39.4	1.2 (1.1−1.2)*	4,990	1.1 (1.1−1.2)*	4,174	1.1 (1.0−1.1)*	3,399	1.1 (1.0−1.2)*
University degree	19,231	8,949	46.5	1.5 (1.5−1.6)*	5,841	1.6 (1.6−1.7)*	4,729	1.5 (1.4−1.5)*	3,626	1.4 (1.3−1.5)*
Graduate degree	1,000	541	54.1	2.1 (1.8−2.4)*	426	2.8 (2.4−3.2)*	348	2.4 (2.1−2.7)*	199	1.5 (1.2−1.7)*
BMI										
<18.5	6,006	2,459	40.9	1	1,487	1	1,217	1	908	1
18.5–	39,328	16,130	41.0	1.0 (0.9−1.1)	9,973	1.0 (0.9−1.1)	8,389	1.1 (0.9−1.1)	6,414	1.1 (1.0−1.2)*
25–	12,167	5,080	41.8	1.0 (1.0−1.1)	3,027	1.0 (0.9−1.1)	2,460	1.0 (0.9−1.1)	2,127	1.2 (1.1−1.3)*
Smoking										
No	36,527	15,496	42.4	1	9,895	1	8,227	1	6,074	1
Occasionally	10,111	3,616	35.8	0.8 (0.7−0.8)	2,049	0.7 (0. 6−0.7)*	1,708	0.7 (0.6−0.7)*	1,453	0.8 (0.8−0.9)*
Frequently	10,863	4,557	41.9	1.0 (0.9−1.0)	2,543	0.8 (0. 8−0.9)*	2,131	0.8 (0.8−0.9)*	1,922	1.1 (1.0−1.1)*
Sporting										
No	17,947	7,859	43.8	1	4,772	1	4,038	1	3,375	1
Occasionally	32,797	13,272	40.5	0.9 (0.8−0.9)*	8,147	0.9 (0.8−0.9)*	6,749	0.9 (0.8−0.9)*	5,116	0.8 (0.7−0.8)*
Frequently	6,757	2,538	37.6	0.8 (0.7−0.8)*	1,568	0.8 (0.8−0.9)*	1,279	0.8 (0.7−0.8)*	958	0.7 (0.6−0.7)*

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

* P<0.05.

TABLE 2. Prevalence of WMSDs in key industries or occupational groups in China, 2018–2020.

Industry	Number (n)	Any body part			Neck			Shoulders			Upper back			Lower back			Elbows			Wrists/Hands			Hips/Thighs			Knees			Ankles/Feet		
		n	p_i	p'	n	p_i	p'	n	p_i	p'	n	p_i	p'	n	p_i	p'	n	p_i	p'	n	p_i	p'	n	p_i	p'	n	p_i	p'	n	p_i	p'
Total	57,501	23,669	41.2	40.9	14,487	25.2	24.8	12,066	21.0	20.8	8,399	14.6	14.2	9,449	16.4	16.8	4,169	7.3	7.3	7,553	13.1	12.9	6,065	10.5	10.6	6,184	10.8	11.0	8,002	13.9	12.8
Automobile manufacturing	21,560	8,969	41.6	43.5	5,047	23.4	25.2	4,214	19.5	20.6	3,148	14.6	15.3	3,460	16.0	18.1	1,571	7.3	7.3	3,210	14.9	14.0	2,219	10.3	11.1	2,584	12.0	12.3	3,883	18.0	16.8
Electronic equipment manufacturing	8,116	3,158	38.9	40.4	2,060	25.4	25.2	1,758	21.7	22.4	1,156	14.2	14.2	1,129	13.9	13.9	515	6.3	6.4	889	11.0	10.9	701	8.6	8.4	572	7.0	8.1	800	9.9	10.9
Footwear industry	7,106	2,616	36.8	34.2	1,701	23.9	21.6	1,368	19.3	17.9	846	11.9	11.5	943	13.3	12.4	507	7.1	7.1	1,058	14.9	14.4	603	8.5	8.5	524	7.4	7.0	595	8.4	8.2
Medical staff	6,766	3,794	56.1	54.2	2,749	40.6	39.7	2,224	32.9	32.5	1,490	22.0	21.9	1,712	25.3	24.5	462	6.8	7.6	782	11.6	12.1	1,126	16.6	16.2	922	13.6	14.0	1,072	15.8	15.0
Furniture manufacturing	4,471	1,320	29.5	28.5	701	15.7	15.0	623	13.9	13.7	481	10.8	10.6	459	10.3	9.9	410	9.2	9.0	556	12.4	12.1	429	9.6	9.6	418	9.3	9.6	612	13.7	12.9
Shipbuilding and related equipment manufacturing	3,488	1,432	41.1	40.1	787	22.6	21.6	672	19.3	18.8	491	14.1	13.5	658	18.9	18.4	326	9.3	8.9	452	13.0	12.3	418	12.0	11.7	488	14.0	13.0	413	11.8	11.5
Coal mining and cleaning industry	1,500	586	39.1	38.4	362	24.1	23.7	311	20.7	20.2	223	14.9	13.0	259	17.3	15.6	133	8.9	7.6	168	11.2	10.2	188	12.5	11.6	244	16.3	15.0	200	13.3	0.1
Construction industry	1,379	332	24.1	23.4	134	9.7	9.5	147	10.7	10.5	102	7.4	7.1	165	12.0	11.6	55	4.0	3.9	89	6.5	5.9	63	4.6	4.6	50	3.6	3.5	63	4.6	4.5
Flight attendants	1,356	696	51.3	55.7	504	37.2	38.2	387	28.5	33.7	203	15.0	20.1	275	20.3	88.4	52	3.8	4.8	98	7.2	7.0	121	8.9	10.0	143	10.5	11.7	156	11.5	11.2
4S automobile store[11]	544	177	32.5	38.6	88	16.2	23.1	78	14.3	16.8	70	12.9	15.4	92	16.9	23.2	27	5.0	8.5	50	9.2	14.5	47	8.6	12.3	50	9.2	15.2	61	11.2	16.2
Toy manufacturing	333	167	50.2	49.0	119	35.7	34.2	116	34.8	31.6	84	25.2	24.2	91	27.3	25.3	71	21.3	20.1	97	29.1	28.3	55	16.5	14.9	63	18.9	18.9	64	19.2	19.4
Animal husbandry	246	96	39.0	39.7	62	25.2	27.3	41	16.7	17.7	20	8.1	8.6	64	26.0	27.1	19	7.7	8.3	47	19.1	20.6	23	9.3	10.1	35	14.2	14.2	15	6.1	6.3
Biopharmaceutical manufacturing	243	157	64.6	48.4	110	45.3	34.1	77	31.7	24.7	65	26.7	20.9	53	21.8	17.7	13	5.3	5.0	34	14.0	88.4	36	14.8	11.3	29	11.9	9.2	52	21.4	18.0
Vegetable greenhouse	243	147	60.5	50.7	51	21.0	18.7	43	17.7	15.0	16	6.6	4.5	79	32.5	27.1	5	2.1	1.5	16	6.6	4.2	30	12.3	10.3	57	23.5	16.6	13	5.3	3.7
Petrochemical industry	150	22	14.7	11.5	12	8.0	7.0	7	4.7	3.5	4	2.7	1.6	10	6.7	6.5	3	2.0	1.4	7	4.7	2.7	6	4.0	4.5	5	3.3	1.9	3	2.0	1.4
Chi-square test			1,336.7									1,525.7									992.4									550.4	
P value			0									0									0									0	

Note: Pi: Actual prevalence rate, P': Standardized prevalence rate.
Abbreviation: WMSDs=work-related musculoskeletal disorders.

TABLE 3. Analysis of pain scores of WMSDs with different demographic characteristics in China, 2018–2020.

Characteristic	Neck		Shoulders		Upper back		Lower back		Elbows		Wrists/Hands		Hips/Thighs		Knees		Ankles/Feet	
	M (Q10, Q90)	Z/χ^2	M (Q10, Q90)	Z/χ^2	M (Q10, Q90)	Z/χ^2	M (Q10, Q90)	Z/χ^2	M (Q10, Q90)	Z/χ^2	M (Q10, Q90)	Z/χ^2	M (Q10, Q90)	Z/χ^2	M (Q10, Q90)	Z/χ^2	M (Q10, Q90)	Z/χ^2
Gender																		
Male	0(0, 6)	−40.5**	0(0, 6)	−37.8**	0(0, 5)	−16.9**	0(0, 6)	−15.8**	0(0, 2)	−0.7	0(0, 5)	−6.0**	0(0, 5)	−10.6**	0(0, 5)	−9.1	0(0, 6)	−10.9**
Female	3(0, 7)		0(0, 6)		0(0, 6)		0(0, 6)		0(0, 3)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 5)	
Age (years)																		
<25	0(0, 6)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 0)		0(0, 5)		0(0, 4)		0(0, 4)		0(0, 6)	
25–	0(0, 6)		0(0, 6)		0(0, 6)		0(0, 6)		0(0, 2)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 6)	
35–	0(0, 6)	888.4**	0(0, 6)	619.5**	0(0, 6)	287.3**	0(0, 6)	684.8**	0(0, 4)	97.7**	0(0, 5)	38.3**	0(0, 5)	152.5**	0(0, 5)	182.4**	0(0, 5)	262.3**
45–	0(0, 6)		0(0, 6)		0(0, 5)		0(0, 5)		0(0, 4)		0(0, 5)		0(0, 4)		0(0, 5)		0(0, 4)	
55–	0(0, 6)		0(0, 6)		0(0, 5)		0(0, 5)		0(0, 1)		0(0, 4)		0(0, 4)		0(0, 5)		0(0, 4)	
Working age (years)																		
<2	0(0, 6)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 0)		0(0, 5)		0(0, 4)		0(0, 4)		0(0, 5)	
2–	0(0, 6)		0(0, 6)		0(0, 5)		0(0, 6)		0(0, 3)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 5)	
4–	0(0, 6)	1740.3**	0(0, 6)	1225.6**	0(0, 6)	667.1**	0(0, 6)	1300.8**	0(0, 2)	86.9**	0(0, 5)	36.5**	0(0, 5)	343.5**	0(0, 5)	664.9**	0(0, 5)	102.2**
6–	0(0, 7)		0(0, 6)		0(0, 6)		0(0, 6)		0(0, 3)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 6)	
8–	2(0, 7)		0(0, 6)		0(0, 6)		0(0, 6)		0(0, 4)		0(0, 5)		0(0, 5)		0(0, 6)		0(0, 6)	
BMI																		
<18.5	0(0, 6)		0(0, 6)		0(0, 5)		0(0, 6)		0(0, 1)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 5)	
18.5–	0(0, 6)	6.4*	0(0, 6)	10.3**	0(0, 5)	15.5*	0(0, 6)	76.6**	0(0, 3)	8.4	0(0, 5)	2.5	0(0, 5)	3.6	0(0, 5)	49.2**	0(0, 5)	49.7**
25–	0(0, 6)		0(0, 6)		0(0, 6		0(0, 6)		0(0, 3)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 6)	
Smoking																		
No	0(0, 6)		0(0, 6)		0(0, 5)		0(0, 6)		0(0, 2)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 5)	
Occasionally	0(0, 6)	421.9**	0(0, 6)	327.2**	0(0, 5)	102.3**	0(0, 5)	214.1**	0(0, 2)	38.3**	0(0, 5)	53.0**	0(0, 4)	62.9**	0(0, 5)	104.9**	0(0, 5)	268.6**
Frequently	0(0, 6)		0(0, 6)		0(0, 6)		0(0, 6)		0(0, 4)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 6)	
Sporting																		
No	0(0, 7)		0(0, 6)		0(0, 6)		0(0, 6)		0(0, 3)		0(0, 5)		0(0, 5)		0(0, 5)		0(0, 6)	
Occasionally	0(0, 6)	26.6**	0(0, 6)	39.8**	0(0, 5)	56.7**	0(0, 6)	128.5**	0(0, 2)	10.9**	0(0, 5)	84.4**	0(0, 5)	41.5**	0(0, 5)	28.4**	0(0, 5)	72.0**
Frequently	0(0, 6)		0(0, 6)		0(0, 5)		0(0, 6)		0(0, 1)		0(0, 5)		0(0, 4)		0(0, 5)		0(0, 5)	

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

* P<0.05.

** P<0.01.

Differences in the occurrence position of WMSDs depended on features of occupational activities. WMSDs of shipbuilding and related equipment manufacturing industry, construction industry, coal mining and cleaning industry, civil aviation flight attendants, automobile 4S shops, automobile manufacturing industry, petrochemical industry, and medical personnel were mainly concentrated in the neck, shoulders, and lower back. WMSDs in electronic equipment manufacturing and biopharmaceutical manufacturing occurred mainly in the upper back, and WMSDs in the furniture manufacturing industry occurred mainly in the ankles. However, in toy manufacturing, animal husbandry, and footwear industry, WMSDs not only occurred in the neck and shoulders but also the wrist. WMSDs occurred in the knees of vegetable greenhouse workers except for the lower back and neck. The disparity in results may be related to differences in affected parts, labor intensity, working conditions, and working methods. The prevalence rate of WMSDs in vegetable greenhouse workers was very high, which exceeded that of most workers in industrial and mining enterprises.

The pain scores in many parts of the female population were higher than those of the male population, which might be related to the fact that women were more sensitive to pain than men and were more willing to report pain (*7*). This study also found that the pain scores of those with BMI above 25, those who smoke, and those without physical exercise were higher than those of the corresponding low-dose groups. A prospective population study investigated the relationship between chronic pain and lifestyle factors and a correlation was found between pain and lifestyle such as smoking and infrequent physical exercise (*8*).

The study was subject to some limitations. First, research objects came from workers of 15 industries in China and some key industries related to WMSDs were not investigated, so the generalizability of the results was limited. Second, because of the nature of cross-sectional studies, making causal inference between risk factors and WMSDs was impossible. Finally, because the questionnaire survey was used in this study and the time period of the questionnaire survey was limited to past year, the resulting reporting bias and recall bias could influence the results.

In conclusion, the prevalence rate of WMSDs in key industries or occupations in China was relatively high. The most affected body parts were in the neck, shoulders, and lower back, and the results showed increases with increasing age and length of service. Women were more likely to suffer from WMSDs than men. The top three industries or occupational groups with the highest prevalence of WMSDs were pharmaceutical manufacturing, vegetable greenhouses, and medical staff. As a result, it is necessary to strengthen the publicity and education of ergonomics knowledge and improve the awareness of the occupational population on the basis of this study of WMSDs to promote effective intervention and control measures among the occupational population in order to reduce the impact of WMSDs. WMSDs in key industries should also be considered to be included in China's list of statutory occupational diseases.

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Perspectives

Application of the Kurtosis Metric to the Assessment of Hearing Loss Associated with Occupational Noise Exposure

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It is well known that high-level noise exposure can lead to hearing loss. Noise-induced hearing loss (NIHL) continues to be one of the major occupational health hazards. An underlying assumption in current noise standards, e.g., ISO 1999:2013 (*1*), is that hearing loss is related to the total energy of the exposure. Thus, the risk of NIHL can be predicted according to the ISO 1999 prediction model. Unfortunately, the validity of the prediction model to correctly predict the NIHL for all types of noise exposure is still under question, especially for complex noise of impulsive character. The basis of current noise guidelines is the equal-energy hypothesis (EEH) approach, i.e., equivalent effects on hearing for a 3-dB increase or decrease in exposure intensity with a halving or doubling of the exposure duration, respectively. This approach is generally considered appropriate for steady-state noise but not for complex noise.

Steady-state continuous noise exposure has a Gaussian amplitude distribution. Therefore, the temporal characteristics of steady-state noise do not change over time. However, noise exposures often vary in the temporal pattern in many work environments. A complex noise is a non-Gaussian noise consisting of a Gaussian background noise punctuated by a temporally complex series of randomly occurring high-level noise transients. These transients can be brief high-level noise bursts or impacts. Industrial workers are often exposed to complex noise environments. Noises of the same or similar acoustic energies and spectra can have very different effects on hearing because of their different temporal structures.

The fundamental problem with current noise standards, e.g., ISO 1999 (*1*), is their reliance on an acoustic energy metric to quantify noise exposure. An acoustic energy metric completely ignores the effects of the temporal characteristics of noise exposure known to be important in affecting complex noise-induced hearing loss. Many published papers have shown that exposure to complex noise produces more hearing loss and sensory cell loss than an equivalent energy exposure to steady-state noise does in both animal and human models (*2–5*). It is reasonable that a metric that would incorporate and reflect the temporal structure of exposure might be a useful adjunct to the equivalent sound pressure level (L_{eq}) metric. One such metric is the kurtosis of a noise exposure (*3*,*5*). Kurtosis (β) is a statistical measure of extreme values or outliers of a distribution. Kurtosis can be used to describe the amplitude "peakedness" of noise waveforms. It is worth mentioning that the Gaussian distribution has a kurtosis of 3. A complex non-Gaussian noise, $\beta>3$, can be effectively modeled as a combination of Gaussian noise, $\beta=3$, with various high-level transients superimposed.

THE KURTOSIS METRIC AS AN ADJUNCT TO ENERGY IN THE EVALUATION OF NIHL

A team of researchers conducted a series of animal (chinchilla) experiments to investigate whether kurtosis can differentiate the NIHL for a fixed Leq (*2–3*,*6–7*). The results showed that: i) non-Gaussian noise exposures are more hazardous than continuous Gaussian noise exposures of equivalent energy, and noise kurtosis explains much of this increased hazard; ii) NIHL increase as kurtosis increases for a fixed L_{eq}; and iii) both kurtosis and energy (L_{eq}) are necessary to evaluate the hazard posed to hearing by complex noise exposure.

Recently, large-scale epidemiological studies have been carried out in Chinese industries, and the data have been fully analyzed (*5*). The results were in general agreement with the above-mentioned animal models showing that: i) an acoustic energy metric is necessary but not sufficient to evaluate the hazard of noise to hearing; ii) the temporal distribution of energy of noise (i.e., kurtosis) is an important factor in assessing noise-induced hearing loss; iii) for a fixed energy level, the noise-induced hearing loss increased as the kurtosis of the noise increased; and iv) non-

Gaussian complex noises are more hazardous than Gaussian noise exposures of equivalent energy, and the hazard is identified by the kurtosis value of the noise.

CALCULATION METHOD AND ADJUSTMENT MODELS USING NOISE KURTOSIS

Calculating the Kurtosis of Noise Exposure

If, based on existing data, one accepts the proposition that kurtosis should be routinely measured in all industrial noise exposures, then the question of how best to measure the kurtosis metric should be considered. The kurtosis of the noise sample is dependent upon not just the probability of a high amplitude event to occur within the sample window, but also the length of the sample window. Recently, two algorithms were designed by Tian and colleagues (*8*) to investigate the correlation between window duration for kurtosis computation and the accuracy of NIHL prediction using a Chinese industrial database. They found that 60 seconds is the optimal window length for kurtosis calculation. Therefore, the kurtosis of noise exposure should be computed over consecutive 60-second time windows without overlap over the shift-long noise record using a sampling rate of 48 kHz. The mean of the measured kurtosis values is calculated and used as the kurtosis metric.

The Kurtosis Adjustment Models

So far, two kurtosis adjustment models have been proposed as follows:

Model 1 — kurtosis adjustment through exposure time:

This model was used in Zhao et al. (*4*) and Xie et al. (*9*). The adjustment formula is listed below:

$$CNE_{kurtosis-adjusted} = L_{Aeq.8h} + \frac{\ln(\beta) + 1.9}{\log(2)}\log(T) \qquad (1)$$

This form was chosen for calculating the kurtosis-adjusted cumulative noise exposure (CNE) because Gaussian noise has a kurtosis of $\beta=3$, and the term $[(\ln(\beta)+1.9)/\log(2)]$ is close to 10. Thus, for Gaussian noise, the kurtosis-adjusted CNE equals the unadjusted CNE. According to Equation (1), for a fixed $L_{Aeq,8h}$, the kurtosis adjusted CNE of the non-Gaussian noise ($\beta>3$) is larger than that of the Gaussian noise ($\beta=3$), which is equivalent to prolonging the noise exposure duration.

Model 2 — kurtosis adjustment through L_{Aeq}

Goley et al. (*10*) presented another way to use kurtosis in NIHL evaluation. Goley and colleagues proposed a scheme that uses kurtosis to adjust the A-weighted equivalent sound pressure level (L_{Aeq}) directly. The basic form of the kurtosis-adjusted L'_{Aeq} was determined as follows:

$$L'_{Aeq} = L_{Aeq} + \lambda log_{10}\frac{\beta_N}{\beta_G} \qquad (2)$$

where λ is a positive constant to be determined from the dose-response correlation study, β_N is the kurtosis of the noise, and $\beta_G=3$ is the kurtosis of the Gaussian noise. Taking noise-induced permanent threshold shift as the dependent variable and L_{Aeq} and $\log(\beta_N/3)$ as independent variables, the coefficient λ was calculated by multiple linear regression model. Based on the animal (chinchilla) model, Goley obtained $\lambda=4.02$. If the model is applied to humans, the value needs to be re-estimated using human data. Using Goley's model is equivalent to adding an increment determined by the second term of the formula to the resulting total sound pressure level.

APPLICATION OF THE KURTOSIS METRIC IN INDUSTRIAL SETTINGS

Zhao et al. (*4*) published the first preliminary study of using kurtosis in industrial settings. Using kurtosis-adjustment Equation (1), they evaluated the prevalence of adjusted high-frequency NIHL (AHFNIHL) in workers exposed to Gaussian (N=163) and non-Gaussian noise (N=32). The prevalence of AHFNIHL in workers was defined as having one or more hearing thresholds, in either ear, at 3, 4, 6 kHz equal to or higher than 30 dB HL. A dose-response relation for the Gaussian and non-Gaussian noise-exposed groups was then constructed. By introducing the kurtosis variable into the temporal component of the CNE calculation, the two dose-response curves were made to overlap, essentially yielding an equivalent noise-induced effect (i.e., AHFNIHL) for the two study groups. Thus, the kurtosis metric was used to quantify the deviation of the non-Gaussian noise environment from the Gaussian noise environment. The results showed that the kurtosis metric could more accurately assess the risk of developing AHFNIHL in workers exposed to high-level Gaussian and non-Gaussian noise. Xie et al. (*9*) conducted another study, including 178 workers exposed to complex non-Gaussian noise and 163 participants exposed to Gaussian noise. The result showed that using a kurtosis-adjusted CNE, the AHFNIHL-CNE relationship curves of the complex noise and G noise overlapped. This result supported the work from Zhao et al. (*4*).

Fuente et al. (*11*) conducted a pilot study in China to determine the synergistic effect of solvents combined with non-Gaussian noise in humans. The kurtosis metric was calculated to quantify the temporal structure of the noise. The CNE was used to quantify the noise exposure for each participant. This index was also adjusted by the kurtosis metric using Equation (1). The change in slope for the relationship between CNE and kurtosis-adjusted CNE and hearing thresholds in each exposure group was analyzed to determine whether there was a significant effect in the interaction. The results showed that the interaction term between CNE and exposure group on hearing thresholds (1–8 kHz) was not statistically significant. However, the interaction term between kurtosis-adjusted CNE and the exposure group showed a statistically significant effect at 6 kHz. Therefore, an interaction between noise and solvent exposure on the pure-tone threshold at 6 kHz was observed only when the temporal structure of noise was considered. This pilot study provides evidence that using a kurtosis metric that incorporates the impulsiveness of noise combined with solvent exposure can allow the detection of their effects on the hearing threshold.

There is a growing interest in using kurtosis as a metric for examining the effects of anthropogenic noise on the hearing of marine mammals, fishes, and other marine organisms. Kurtosis was recommended as one of the marine mammal noise exposure criteria, and kurtosis was used as one of the quantitative metrics to describe the underwater soundscape. Muller et al. (*12*) demonstrated how the kurtosis of underwater sounds could be measured unambiguously. They provided practical formulas for evaluating the kurtosis of impulsive sounds.

THE APPLICATION PROSPECT OF KURTOSIS IN NIHL EVALUATION

Researchers have long been aware that under the same energy and spectrum conditions, complex noise with impulsive components is more hazardous to hearing than steady-state noise. Therefore, using the equal energy rule is not sufficiently protective against noise exposures other than continuous or Gaussian noise. The 1971 version of the ISO 1999 document mentioned an increase of 10 dB for noise with impulsive components, while the 1990 version mentioned a correction of 5 dB. However, since there is no specific quantitative standard, such a correction method is arbitrary. The above studies have shown that kurtosis can effectively evaluate the temporal characteristics of noise exposure for hearing conservation purpose. Correspondingly, animal and epidemiological studies have demonstrated that NIHL increases monotonically with the increase of kurtosis. With the development of the human kurtosis database, the kurtosis-adjustment model can provide us with more accurate NIHL prediction, thus providing a reliable basis for establishing more effective hearing protection programs for the workers exposed to occupational noise.

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Profiles

Chengye Sun, China CDC's Chief Expert of Poison Control

Yu Chen[1]; Peter Hao[1]; Nankun Liu[1]; Zhenjun Li[1]; Jingjing Xi[1,#]; Feng Tan[1,#]

In July 1985, Chengye Sun graduated from Henan Medical University and became a physician in a hospital. In 1988, he entered the Chinese Academy of Preventive Medical Sciences for postgraduate studies on occupational medicine, which helped him become a public health professional. The shift from being a clinician to a public health worker helped him realize how external factors could act as strong drivers on human health.

In 1993, Sun noticed that the diversity of poisons and the complexity of people's exposure to poisons were far beyond the ability of physicians to control as even experts in this field had difficulty providing appropriate treatments for poisoned patients, and disposal plans for poisons were based on personal perspectives. To address this issue, Sun applied information technology to collating and analyzing toxicological data with his colleagues. They developed toxicological databases and data sharing platforms, which greatly facilitated poison treatment and poison research. The toxicology database has been under continuous development since the mid-1990s. At present, more than 2,000 hospitals or professional medical institutions have been included in this platform. It has become the world's largest Chinese toxicology database with users all over the country.

With the expansion of poison control tasks, the Poison Control Center of the Chinese Academy of Preventive Medical Sciences was established in January 1999. Sun has contributed greatly to the establishment and effective operation of this center. The poison control center has been in operation for 22 years, providing 24/7 telephone and Internet-based services to medical professionals and the public across the country.

After the severe acute respiratory syndrome (SARS) epidemic in 2003, China's public emergency management has attracted more and more attention. As a domestic expert on poison control, Sun has participated in drafting and modifying several relevant laws, regulations, and policies, and emergency poisoning accidents were included in the category of public health emergencies.

Since 2005, the Poison Control Center of China CDC has undertaken the task of building a national level chemical poisoning treatment base and emergency response team for sudden poisoning incidents and coordinating the national professional forces, and is responsible for the organization and technical guidance of national poisoning health emergency work. As the leader of poison control, Sun has devoted himself to the national health emergency work for poisoning such as the establishment of national remote consultation system for emergency poisoning in 2008, the drafting of the *Health emergency plan of the Ministry of Health for poisoning emergencies* and *Health Emergency Response Technical Plan for Acute Poisoning on 14 Types of Common Toxicants* in 2011, the exploration of network service models on health emergency work for poisoning and the Platform of Health Emergency for Poisoning in 2012, etc.

In addition to the great contribution to poison information and emergency management, Sun has also been engaged in poison control research. In the mid-1990s, several "sudden deaths of unknown causes" occurred in many provinces in China. After a series of field investigations, experiments, and clinical studies led by Sun, the disease was confirmed to be caused by the highly toxic rodenticide tetramine. Sun's team then developed rapid diagnostic methods and treatment plans and promoted the banning of tetramine at the national level. With their effort, tetramine poisonings were brought under control. The case was compiled into textbooks, and the research won the Science and Technology Award of the Chinese Preventive Medical Association.

After 2000, Sun noticed that the frequent occurrence and high mortality of mushroom poisonings became a public health problem in some areas of China. He carried out difficult exploration and research and established a toxic biological specimen bank in China CDC, which has now become the largest poisonous biological entity specimen bank in China. United with experts in public health, clinical medicine, biological identification, and other fields, he established a network work model and carried out a series of studies on toxins detection methods, pathogenesis, toxicology, and standard clinical therapy of mushroom poisoning prevention and control. Currently, China is a leader in mushroom poisoning prevention and control worldwide.

Being highly recognized in the field of poison control, Professor Sun is also known as a member of the Public Health Emergencies Expert Group of the China National Health Commission (NHC) (Leader of Poison Disposal Team), expert of the World Health Organization (WHO) International Health Regulations on Chemical Safety, Advisory Expert of National Chemical Terrorist Incident Response Team, an Expert of National Food Safety Risk Assessment Expert Committee, the Director of Chinese Preventive Medical Association, the Chair of Occupational Disease Committee of Chinese Preventive Medical Association, Director of Chinese Medical Association, and the Deputy Leader of Toxicology Group of Chinese Medical Association for Emergency, etc.

China is now in a period of rapid development, and Sun had maintained his focus on the poisoning rescue in chemical industrial parks in the past three years. He will continue to devote himself to promote production safety, public health, and social development.

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