# Assessment of Worker Exposure to Noise and Vibrations in a Car Body Shop and a Construction Site

## Valutazione dell'esposizione dei lavoratori a rumore e vibrazioni in una carrozzeria e in un cantiere edile

**Alessandro Gelardi [1], Andrea Bisco [2], Francesca Borghi [3], Rocco Loris Del Vecchio [4,5], Andrea Spinazzè [4*], Domenico Maria Cavallo [4]**

[1] *Department of Theoretical and Applied Sciences, University of Insubria, via O. Rossi 9, 21100, Varese, Italy*
[2] *Artser S.r.l., Viale Milano 5, 21100, Varese, Italy*
[3] *Department of Medical and Surgical Sciences, University of Bologna, via P. Palagi 9, 40138, Bologna, Italy*
[4] *Department of Science and High Technology, University of Insubria, Via Valleggio 11, 22100, Como, Italy*
[5] *Department of Medicine and Surgery, University of Insubria, Via Guicciardini 9, 21100, Varese, Italy*

***Corresponding author**: andrea.spinazze@uninsubria.it

**DOI**: https://doi.org/10.36125/ijoehy.16i2.564

Occupational exposure to noise and mechanical vibration is a significant health and safety problem in many work environments. Prolonged exposure can cause several adverse health effects, including hearing loss, disorders affecting the lumbar spine (vibrations transmitted to the whole body) and neurological, vascular and musculoskeletal disorders affecting the upper limbs (vibrations transmitted to the hand-arm system). This study aims to investigate occupational exposure to noise and mechanical vibration through two case studies, relating to scenarios in different sectors (car body shop and construction company). For the exposure assessment, phonometric and vibrometric measurements were carried out in different operating scenarios, using a sound level meter and two vibration analysers, respectively. Exposure levels were compared to the action and exposure limit values established by Italian occupational health and safety legislation (Legislative Decree 81/2008). The results showed high risk levels for exposure to vibrations transmitted to the hand-arm system in both case studies, particularly during the use of tools such as grinders, drills and demolition hammers. As regards noise risk levels, the levels associated with these tools are equally high. Based on the findings, the study makes recommendations to improve risk management and protection strategies, including the use of low-emission equipment, the adoption of organisational and procedural measures, and the pro-vision of information and training to workers.

**Keywords**: Risk assessment; Occupational health; Occupational safety; Phonometric measurements; Vibrometric measurements

L'esposizione occupazionale a rumore e vibrazioni meccaniche rappresenta un rilevante problema di salute e sicurezza in molti ambienti di lavoro. Un'esposizione prolungata può causare diversi effetti avversi sulla salute, tra cui perdita dell'udito, disturbi a carico del tratto lombare del rachide (vibrazioni trasmesse al corpo intero) e di carattere neurologico, vascolare e muscoloscheletrico a carico degli arti superiori (vibrazioni trasmesse al sistema mano-braccio). Il presente studio si propone di indagare l'esposizione occupazionale a rumore e vibrazioni meccaniche attraverso due casi studio, relativi a scenari in diversi settori (carrozzeria e impresa edile). Per la valutazione dell'esposizione sono state effettuate misurazioni fonometriche e vibrometriche in differenti scenari operativi, utilizzando rispettivamente un fonometro e due analizzatori di vibrazioni. I livelli di esposizione sono stati confrontati con i valori di azione e limite stabiliti dalla normativa italiana in materia di salute e sicurezza sul lavoro (D.Lgs. 81/2008). I risultati hanno evidenziato livelli di rischio alti per l'esposizione a vibrazioni trasmesse al sistema mano-braccio in entrambi i casi studio, in particolare durante l'uso di utensili come smerigliatrici, trapani e martelli demolitori. Per quanto riguarda i livelli di rischio da rumore, i livelli associati a questi ultimi utensili sono ugualmente alti. Sulla base delle evidenze raccolte, lo studio formula raccomandazioni per migliorare la gestione del rischio e le strategie di protezione, tra cui l'impiego di attrezzature a basse emissioni, l'adozione di misure organizzative e procedurali, nonché la fornitura di informazioni e formazione ai lavoratori.

**Keywords**: Valutazione del rischio; Salute occupazionale; Sicurezza sul lavoro; Misurazioni fonometriche; Misurazioni vibrometriche

## Introduction

### *Background*

Occupational exposure to mechanical noise and vibration is a significant health and safety problem in several occupational settings [Istate et al., 2014, Olasum et al., 2009]. Prolonged occupational exposure to noise and vibration can lead to a range of adverse health effects, including hearing loss [Maynts et al., 2024; Stocks et al., 2015; Masterson et al., 2025; Wu et al., 2024]. The World Health Organisation (WHO) has identified noise-induced hearing loss as one of the most widespread occupational hazards, affecting millions of workers worldwide [WHO, 2024; WHO, 2029]. Prolonged exposure to high noise levels can cause permanent hearing damage, tinnitus and other auditory dysfunctions as well as non-auditory effects, significantly impairing quality of life [WHO, 2024; Pretzsch et al., 2021; Le et al., 2017; Themann et al., 2019; Lie et al., 2016a]. Similarly, exposure to mechanical vibrations can lead to lumbar spine disorders (from whole-body vibrations) and neurological, vascular, and musculoskeletal conditions of the upper limbs (from hand–arm vibration exposure), further compounding the health risks for exposed workers [Sheppard et al., 2020; Lie et al., 2016b]. The International Labour Organisation (ILO) emphasises the risks associated with mechanical vibrations, noting their contribution to disorders such as hand-arm vibration (HAV) syndrome and whole-body vibration (WBV) disorders [Krajnak et al., 2018; Johanning, 2015; Gerhardsson et al., 2020; Mendes et al., 2021; Budd et al., 2018; Aarhus et al., 2019].

### *Problem statement*

Noise and vibration exposures may occur in many occupational settings. As expected, noise exposure is particularly problematic in environments where machinery, tools, and equipment operate at high decibel levels. Further, mechanical vibrations, often produced by handheld tools and heavy machinery, pose additional risks. Obviously, various international and national bodies dealing with occupational health and safety have proposed exposure action and limit values and procedures for risk assessment associated with occupational exposure to noise and mechanical vibration. Despite regulatory efforts, the reduction of occupational noise and vibration occupational exposure remain challenging, especially in high-risk sectors like automotive industry, car body repair [Chen et al., 2019; Alimohammadi et al., 2018; Jayjock et al., 1984] and construction [Fernández et al., 2009; Lewkowski et al., 2018; Li et al., 2016]. Accurate assessment and mitigation of these hazards are essential for preventing long-term health consequences and ensuring workplace safety and protection of workers' health. Moreover, many small and medium-sized enterprises (SMEs) lack the resources to implement comprehensive monitoring.

### *Aims of the study*

This study aims to investigate occupational exposure to noise and mechanical vibration through two detailed case studies from the body repair and construction sectors. By analysing exposure levels in these specific contexts, the study aims to quantify the levels of noise and mechanical vibration to which workers are exposed in typical operating contexts.

## Materials and methods

### *Case studies and scenarios*

Two different industrial indoor environments have been taken into consideration: a car body shop (C1), and a construction company (C2). For each case study, three diverse scenarios have been considered (Table 1). In C1, in the first scenario (C1.S1), the operator has prepared the bodywork to be repainted, with the aid of a polisher which, due to the friction between the surfaces, scrapes the worn paint by performing an orbital movement. The bodywork without paint was then taken to the paint booth where the operator removed the impurities present with an abrasive brush (C1.S2). In the third scenario (C1.S3), the operator performed the last polishing phase using a classic polisher.

In C2, three scenarios were evaluated depending on the degree of severity expected in terms of acoustic impact: (i) mild, in which the operator only uses the concrete mixer for the production of mortar necessary for the construction activity (C2.S1); (ii) medium, in which the operator uses a set of instruments such as the drill and the demolition hammer to make tracks in the wall for the installation of electrical or plumbing systems (C2.S2); and finally (iii) severe, in which the number of instruments of the same type used is higher (C2.S3). Across all case studies, daily noise exposure (L_EX,8h) was computed from task-specific active durations excluding breaks and non-operational intervals. We considered representative profiles for a generic body shop worker and a construction worker, each defined by the main tasks performed during a typical high-demand shift. To address day-to-day and week-to-week variability in machine use, we considered scenario ranges for task durations (low/typical/high) derived from field logs and supervisor interviews.

 

**Table 1.** Scenarios evaluated per each case study.

| Case study(C) Scenarios(S) | Type of works | Type of instruments |
|---|---|---|
| Case study 1 (C1): car body shop | | |
| C1.S1 | First polishing | Polisher |
| C1.S2 | Removal of impurities | Abrasive brush |
| C1.S3 | Final polishing | Polisher |
| Case study 2 (C2): construction company | | |
| C2.S1 | Production of mortar | Concrete mixer |
| C2.S2 | Demolition and installation activities | Drill, Demolition hammer |
| C2.S3 | Demolition and installation activities | Grinder, Drill, Demolition hammer |

***Monitoring set-up of phonometric measurements***

Noise measurements were performed with a Class 1 sound level meter (LD-831, Larson Davis, USA) equipped with a ½" measurement microphone (PCB 377A02, PCB Piezotronics, USA). Given the proximity of hand-held tools to the operator, the microphone was positioned 10 cm from the more exposed ear by means of a shoulder mount. Instruments were field-calibrated pre/post using a CAL200 acoustic calibrator (Larson Davis, USA), with deviations within tolerance. The results of the series of measurements carried out in the interval between one calibration and another were considered valid only if the deviation of the calibration level was not greater than 0.5 dB(A).

Sound Pressure Level (SPL) measurements were carried out on all identified noise sources indicated above as well as for all work carried out by the worker. When carrying out the measurements, no interference was made in any way with the characteristics of the activity (e.g., postures, distances of the worker from sound sources, use of hearing protection devices, exposure times, etc.). Each SPL measurement was taken on a variable interval, the duration of which was evaluated based on the experience of the survey technician considering the information and the noisiest operating condition reported by the Employer, and in any case for an acquisition time sufficient to allow a stable reading of the instrument.

To evaluate the exposure to noise for workers, the personal noise exposure level ($L_{ex}$), (weighted on an 8-hour period) were calculated according to Eq. 1:

$$L_{ex,i}\big(dB(A)\big) = L_{Aeq,i} + 10\log(T_e\, T_0^{-1}) \qquad (1)$$

Where $T_e$ and $T_0$ represent the duration of daily exposure to the i-th source and the duration of the working day (8 h), respectively. LAeq,i is the level of exposure to the i-th source. When multiple tasks or sources were present, daily noise exposure ($L_{ex}$) was derived via energetic summation of task-specific $L_{ex,i}$ values according to equation 2:

$$\text{Lex} = 10 \log \Sigma\, 10^{\text{Lex,i}/10} \qquad (2)$$

To characterize the level of risk from exposure to noise for the workers in the selected scenarios, the calculated occupational exposure values were compared with the current threshold values reported in the Italian Occupational Safety and Health legislation (Legislative Decree 9 April 2008, n. 81). In line with Directive 2003/10/EC (as implemented in D.Lgs. 81/2008), we refer to two exposure action values - a lower action value of 80 dB(A) and an upper action value of 85 dB(A) - and to the daily exposure limit value standardised to an eight-hour reference period of 87 dB(A) for the daily noise exposure level (L_EX,8h). Importantly, action values apply to the unprotected worker (i.e., without hearing protection worn), whereas the exposure limit value applies with hearing protection worn (i.e., after attenuation). According to the Italian legislation, a worker exposed below 80 dB(A) is considered not occupationally exposed to noise. For the purposes of this discussion, a weighted average exposure below this value is considered to correspond to a "low" risk level. For exposure above 80 dB(A), the risk can be considered significant, whereas it may be deemed high above 85 dB(A). A 'control banding' approach is applied to define a gradually increasing risk level, as shown in Table 2.

**Table 2.** Level of risk to noise exposure at workplace for the operators. The values are referred to the current Italian Legislation; Lex Value above 87 dB(A) are unacceptable.

| Level of risk | Noise |
|---|---|
| Low | < 80 |
| Medium | $80 < L_{ex,i} < 85$ |
| High | $85 < L_{ex,i} < 87$ |

*Monitoring set-up of vibration measurements*

The vibration measurements carried out are aimed at evaluating the exposure of workers to the risk of vibrations transmitted to the hand-arm system and the whole body, for which two distinct types of analyzers were used. A HVM 200 vibration analyzer (Larson Davis, NY, U.S.A.) was used to perform the vibrometric measurements concerning the whole body. A HVM 100 vibration analyzer (Larson Davis, NY, U.S.A.) was used to perform the vibration measurements concerning the hand-arm system. In both cases, an ICP Triaxial Micro-Accelerometer (PCB Piezotronics, NY, U.S.A.) has been used. Whole-body vibration (WBV) was measured by installing accelerometers at the vibration transmission interface. Hand–arm vibration (HAV) was measured using a tri-axial accelerometer rigidly coupled to the tool handle via dedicated mounting adaptors. A HVM100 vibration analyzer (Larson Davis, NY, USA) was used for acquisition. Mounting locations and orientations were recorded for each task; measurements excluded non-operational periods. In both cases, to limit triboelectric phenomena, the connection cables were fixed with adhesive tape. The personal vibrations exposure level for the hand-arm system and the whole body has been calculated following Eq. 3.

$$A(8)\left(m\,s^{-2}\right)= \left[\frac{1}{8}\sum_{i=1}^{N} a_i^2 T_i\right]^{\frac{1}{2}} \quad (3)$$

Where $a_i$ represents the the value determining the risk of frequency-weighted acceleration relating to the i-th activity (sum vector in the case of vibrations transmitted to the hand-arm system, higher acceleration than the set of values after multiplying by a factor of 1.4 for longitudinal and transverse accelerations in the case of vibrations transmitted to the whole body), and $T_i$ is the duration of the i-th activity.

To characterize the level of risk from exposure to HAV and WBV for the workers in the selected scenarios, the calculated occupational exposure values were compared with the action and limit values reported in the Italian Occupational Safety and Health legislation (Legislative Decree 9 April 2008, n. 81). The legislation provides limit values for both HAV (5 $m/s^2$) and WBV (1 $m/s^2$). In addition, 'action values' are defined for HAV (2.5 $m/s^2$) and WBV (0.5 $m/s^2$). All values are intended as personal exposure levels, calculated as 8-hour weighted average values. According to the Italian legislation, a worker exposed below the action level is considered not occupationally exposed to vibration. For this discussion, a weighted average exposure below the action level is considered to correspond to a 'low' risk level. For exposures above the action level, a 'control band' approach is applied to define a gradually increasing risk level, as shown in table 3.

**Table 3.** Level of risk to vibrations exposure at workplace for the operators. The values are referred to the current Italian Legislation.

| Level of risk | Vibrations ($m/s^2$) | |
|---|---|---|
| | Hand-arm | Whole body |
| Low | < 2.5 | < 0.5 |
| Medium | 2.5 < A(8) < 5 | 0.5 < A(8) < 1 |
| Unacceptable | > 5 | > 1 |

## Results

The results obtained from monitoring occupational exposure to noise and vibration in the two case studies presented in the previous chapters and the resulting risk characterizations are shown in Table 4.

**Table 4.** Level of daily personal exposure to noise and to vibrations in the scenarios investigated and case studies. Risk Characterization is also reported.
*Note: n.e.: not evaluated considering that the machinery considered in these scenarios are not source of vibrations.*

| Scenarios | $L_{ex}$ [dB(A)] (Risk) | A(8) [m $s^{-2}$] (Risk) | |
|---|---|---|---|
| | | Hand-arm | Whole body |
| C1.S1 | < 80 (Low) | 3.45 ± 0.69 (Medium) | 0.18 ± 0.04 (Low) |
| C1.S2 | < 80 (Low) | | |
| C1.S3 | < 80 (Low) | | |
| C2.S1 | < 80 (Low) | n.e. | n.e. |
| C2.S2 | 86 (High) | 4.88 ± 0.98 (High or unacceptable) | < 0.5 (Low) |
| C2.S3 | > 87 (very high) | 6.07 ± 1.21 (Unacceptable) | < 0.5 (Low) |

In the case of a medium or high risk due to exposure to vibrations, the following equation was used to evaluate Raynaud's phenomenon ($R_p$), i.e., the average exposure time for the onset of white finger syndrome pathology in a fraction of 10% of exposed operators (Eq. 4):

$$R_P\,(y)= 31.8\,A(8)^{-1.06} \quad (4)$$

The vibrations to the hand-arm system were the only ones related to a medium and high risk.
Should the average A(8) values be considered, in C1, the $R_p$ was equal to 8.56 y. In the case of C2.S2 and C2.S3 was lower (5.93 y and 4.70 y, respectively), indicating a higher risk of developing occupational diseases (Raynaud syndrome).
Concerning Noise exposure, for scenario C2.S2 and C2.S3, it is also necessary to consider intervening with risk management measures and/or calculating the exposure level considering the attenuation of personal protective equipment for hearing.

## Discussion

Following the analysis carried out, in C1, C2.S2 and C2.S3 the risk level due to exposure to vibrations for the hand-arm system is considered very high. In the car body shop sector, specific literature is lacking; some investigations about metal polishers could be found in Xiao et al. [Xiao et al., 2019] focusing on diagnostic strategies more than risk assessment.
Regarding the construction industry a larger proportion of workers are exposed to hand–arm vibration from vibrating equipment than in other industries; it's also crucial to highlight that, in this working sector, the risk of incurring a vibration injury is often overshadowed by more prominent risks on construction sites [Fisk et al., 2023].
On the other hand, Scenarios C2.S2 and C2.S3 are those that were found to be of interest in noise exposure and possibly require risk management measures to be taken. This was somewhat expected, as construction workers are generally known to be one of the occupational groups at high risk of noise-induced hearing loss [Lie et al., 2016b; Movahed et al., 2022]. On a practical level, the authors recommend taking technical, organizational, and procedural measures to reduce the levels of exposure to vibrations transmissible to the hand-arm system. Regarding the risk of occupational exposure to noise and vibration, in addition to specific health surveillance for exposed workers (according to current legislation) and specific training and information relating to these types of risks, the authors recommend as a further risk management measure the need to:

- Reducing noise and vibrations at source: use quieter machinery or install sound insulation systems. Regular maintenance to ensure that equipment functions properly and does not generate excessive noise. Check in advance the vibrations and noise emissions declared by the manufacturer and prefer equipment equipped with an anti-vibration handle or noise abatement systems, when applicable.
- Organizational changes: limit workers' exposure time to noise and vibrations through staff rotation. Schedule regular breaks in quiet environments.
- Personal protection: provide appropriate protection devices, such as earplugs or earmuffs, which are certified and comfortable to wear or anti-vibration handle and/or anti-vibration gloves to make available to the employees.

Interpreting the present findings requires consideration of several limitations. Due to the sample size, this project should be regarded as exploratory rather than confirmatory. Moreover, car body shops and construction sites are characterized by indirect exposures arising from noisy equipment operated by nearby co-workers. It is also difficult to disentangle noise exposure from vibration, since a portion of the noise originates from vibrating tools, and circulation disorders (e.g., vibration-induced white finger) are recognized risk factors for hearing loss among noise-exposed workers [Lie et al., 2016b; House et al., 2010].

## Conclusions

The results of the measurements showed high levels of risk for hand-arm vibrations in both scenarios C1 and C2, and for noise in scenario C2, with potential long-term health consequences for workers. It is therefore essential to take effective prevention and control measures, such as using low-emission equipment, implementing organizational and procedural measures, and training workers on specific risks. It is only through careful risk management that the health and safety of workers can be ensured, and the incidence of illnesses related to noise and vibration exposure reduced.

***Acknowledgments***

*The authors would like to express their sincere gratitude to Alberto Pietro Damiano Baltrocchi, Dr. Marco Carnevale Miino, Prof. Dr. Elena Cristina Rada, and Prof. Dr. Vincenzo Torretta, all from the University of Insubria, for their valuable support to the study, for providing the case study and overseeing its experimental part, as well as for their contribution to the first draft of the manuscript.*

***Disclosure Statement***

*The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.*

***IRB- Declaration of Helsinki***
*Not applicable*

***Declaration of funding***
*No funding was received.*

***Data availability statement***
*All data generated or analysed during this study are included in this published article.*

## References

Aarhus, L., Veiersted, K.-B., Nordby, K.-C., et al., 2019. *Neurosensory component of hand-arm vibration syndrome: a 22-year follow-up study*. Occup. Med. (Lond.), 69 (3), 215–218.

Alimohammadi, I., Ahmadi Kanrash, F., Abolghasemi, J., et al., 2018. *Effect of chronic noise exposure on aggressive behavior of automotive industry workers*. Int. J. Occup. Environ. Med., 9 (4), 170–175.

Budd, D., Holness, D.L., House, R., 2018. *Functional limitations in workers with hand-arm vibration syndrome (HAVS)*. Occup. Med. (Lond.), 68 (7), 478–481.

Chen, Y., Zhang, M., Qiu, W., et al., 2019. *Prevalence and determinants of noise-induced hearing loss among workers in the automotive industry in China: A pilot study*. J. Occup. Health, 61 (5), 387–397.

Fernández, M.D., Quintana, S., Chavarría, N., et al., 2009. *Noise exposure of workers of the construction sector*. Appl. Acoust., 70 (5), 753–760.

Fisk, K., Nordander, C., Ek, Å., 2023. *Hand-arm vibration: Swedish carpenters' perceptions of health and safety management*. Occup. Med. (Lond.), 73 (2), 85–90.

Gerhardsson, L., Ahlstrand, C., Ersson, P., et al., 2020. *Vibration-induced injuries in workers exposed to transient and high frequency vibrations*. J. Occup. Med. Toxicol., 15 (1), 18.

House, R.A., Sauvé, J.T., Jiang, D., 2010. *Noise-induced hearing loss in construction workers being assessed for hand-arm vibration syndrome*. Can. J. Public Health, 101 (3), 226–229.

Istrate, I.A., Oprea, T., Rada, E.C., et al., 2014. *Noise and air pollution from urban traffic*. WIT Trans. Ecol. Environ., 191, 1381–1389.

Jayjock, M.A., Levin, L., 1984. *Health hazards in a small automotive body repair shop*. Ann. Occup. Hyg., 28 (1), 19–29.

Johanning, E., 2015. *Whole-body vibration-related health disorders in occupational medicine—an international comparison*. Ergonomics, 58 (7), 1239–1252.

Krajnak, K., 2018. *Health effects associated with occupational exposure to hand-arm or whole body vibration*. J. Toxicol. Environ. Health B, 21 (5), 320–334.

Le, T.N., Straatman, L.V., Lea, J., et al., 2017. *Current insights in noise-induced hearing loss: a literature review of the underlying mechanism, pathophysiology, asymmetry, and management options*. J. Otolaryngol. Head Neck Surg., 46 (1), 41.

Lewkowski, K., Li, I.W., Fritschi, L., et al., 2018. *A systematic review of full-shift, noise exposure levels among construction workers: Are we improving?* Ann. Work Expo. Health, 62 (7), 771–782.

Li, X., Song, Z., Wang, T., et al., 2016. *Health impacts of construction noise on workers: A quantitative assessment model based on exposure measurement*. J. Clean. Prod., 135, 721–731.

Lie, A., Skogstad, M., Johannessen, H.A., et al., 2016a. *Occupational noise exposure and hearing: a systematic review*. Int. Arch. Occup. Environ. Health, 89 (3), 351–372.

Lie, A., Skogstad, M., Johnsen, T.S., et al., 2016b. *Noise-induced hearing loss in a longitudinal study of Norwegian railway workers*. BMJ Open, 6 (9), e011923.

Masterson, E.A., Themann, C.L., 2025. *Prevalence of hearing loss among noise-exposed U.S. workers within the construction sector, 2010–2019*. J. Safety Res., 92 (1), 158–165.

Mayntz, S.P., Rosenbech, K.E., Mohamed, R.A., et al., 2024. *Impact of air pollution and noise exposure on cardiovascular disease incidence and mortality: a systematic review*. Heliyon, 10 (21), e39844.

Mendes, H.G., de Moraes Tomaz, B., Coelho-Oliveira, A.C., et al., 2021. *The consequences of mechanical vibration exposure on the lower back of bus drivers: A systematic review*. Appl. Sci., 11, 1–15.

Movahed, N., Ravanshadnia, M., 2022. *Noise exposure assessment in construction equipment operators in Tehran, Iran*. J. UOEH, 44 (1), 43–52.

Olaosum, A., Ogundiran, O., Tobih, J., 2009. *Health hazard of noise: A review article*. Res. J. Med. Sci., 3 (3), 115–122.

Pretzsch, A., Seidler, A., Hegewald, J., 2021. *Health ef-*

 

*fects of occupational noise*. Curr. Pollut. Rep., 7 (3), 344–358.

Sheppard, A., Ralli, M., Gilardi, A., et al., 2020. *Occupational noise: auditory and non-auditory consequences*. Int. J. Environ. Res. Public Health, 17 (23), 1–15.

Stocks, S.J., McNamee, R., van der Molen, H.F., et al., 2015. *Trends in incidence of occupational asthma, contact dermatitis, noise-induced hearing loss, carpal tunnel syndrome and upper limb musculoskeletal disorders in European countries from 2000 to 2012*. Occup. Environ. Med., 72 (4), 294–303.

Themann, C.L., Masterson, E.A., 2019. *Occupational noise exposure: A review of its effects, epidemiology, and impact with recommendations for reducing its burden*. J. Acoust. Soc. Am., 146 (5), 3879–3905.

World Health Organization (WHO), 2004. *Occupational noise: assessing the burden of disease from work-related hearing impairment at national and local levels*. Environmental Burden of Disease Series, No. 9, Geneva.

WHO Regional Office for Europe, 2009. *Night noise guidelines for Europe*. WHO, Copenhagen.

Wu, Z., Liang, Y., Khan, A., et al., 2024. *Is occupational noise associated with arthritis? Cross-sectional evidence from US population*. BMC Public Health, 24 (1), 371.

Xiao, B., Zhang, D., Yan, M., et al., 2019. *Cold water immersion test (10 °C, 10 min) for diagnosing vibration-induced white finger among a group of polishers in a subtropical environment*. Int. Arch. Occup. Environ. Health, 92 (6), 865–872.

 