

Evaluation of Exposure to Noise and Vibration and Its Effect on Work-related Fatigue

Somayeh Rahimimoghadam

Department of Occupational Health Engineering,
Neyshabur University of Medical Sciences, Neyshabur,
Iran.

Safoora Javan

Department of Occupational Health Engineering,
Neyshabur University of Medical Sciences, Neyshabur,
Iran.

Saeed Yari

Ph.D. of Environmental Engineering-Air Pollution, Tehran
University, Tehran, Iran.

Atefeh Kheyrikhah

Department of Health, Safety and Environment, School of
Public Health and Safety, Sahid Beheshti University of
Medical Science, Tehran, Iran.

Mohammad Nourmohamadi

Occupational Health Engineering, Department of
Occupational Health Engineering, Mashhad University of
Medical Sciences, Mashhad, Iran.

Introduction: Exposure to vibration and noise has been identified to potentially contribute to work-related fatigue, consequently causing a range of adverse effects on job performance.

Method: In this study, a sample of 62 city bus drivers underwent examination to evaluate noise levels through the utilization of a TES dosimeter. Additionally, vibration measurements were conducted using an SV 106 vibration meter. Furthermore, the level of occupational fatigue was determined through the utilization of a Swedish fatigue questionnaire.

Results: In the conducted study, it was observed that bus drivers were subjected to an average exposure level of 82.18 dB and 0.99 m/s² for noise and whole-body vibration, respectively, throughout their work shifts. Additionally, their average job fatigue score was measured to be 26.21 out of a total of 200. To comprehensively evaluate the influence of various factors on (WRF), both single-variable and multi-variable analyses were conducted. The result of the univariate tests exhibited a notable association between job fatigue and the Lon life of the vehicle, the type of car seat (spring or inflatable), as well as the level of exposure to vibration and job satisfaction. Moreover, when considering the influencing factors concurrently in the multivariate test, a significant correlation between occupational fatigue and exposure to vibration, as well as the type of chair, was established.

Conclusion: Improving the quality of buses by implementing modernized features that minimize vibrations and reduce noise levels can greatly contribute to mitigating fatigue among urban bus drivers.

Introduction

The prevalence of pressure and stress resulting from exposure to diverse environmental pollutants among the driver population has garnered significant attention in recent decades [1]. According to numerous studies, noise pollution emerges as a prevalent issue across a wide range of occupations and industries, with particularly high emission rates [2,3].

Noise refers to the presence of irregular waves that are universally disliked, unwelcome, and often impossible to avoid. It is important to note that there is no discernible correlation between the pressure ranges, frequencies, and wavelengths associated with noise. This undesirable auditory

phenomenon is extensively generated and dispersed across numerous industries, leading to its abundant presence in various settings [4,5]. Extended exposure to noise levels surpassing standard thresholds within work environments can give rise to detrimental outcomes. These may include hearing loss, compromised blood circulation, sleep disorders, reduced concentration and alertness, physiological issues, impeded verbal communication and learning, mental disorders, heightened stress levels, hormonal imbalances, and diminished work performance [6-8].

Another occupational stressor that poses health risks alongside noise is vibration. Long-term exposure to vibration can have various adverse effects on individuals in different job roles, particularly when the entire body is consistently exposed. This prolonged exposure can result in skeletal and muscular pains. One notable consequence is the reduction in disc height within the lumbar spine, which leads to an increased spinal load. In addition, exposure to vibration can contribute to the development of cardiovascular, cardio-pulmonary, metabolic, endocrine disorders, neurological problems, and digestive system issues. Previous studies have highlighted these health concerns as significant side effects of prolonged exposure to vibration [9,10].

It is important to note that prolonged exposure to vibrations can have negative effects on individuals, including distractions and decreased Centralization [11]. Moreover, individuals working in environments where their hands are continuously subjected to vibrations may experience a decline in hand strength and potentially develop a condition known as white finger disease [12,13]. One of the most widely utilized modes of transportation globally is public transportation, which holds significant significance in facilitating the mobility of individuals. Buses, in particular, represent a dominant form of public transportation adopted by countless commuters. Throughout their regular duties, bus drivers encounter notable levels of vibrations and noise, which are recognized as occupational hazards [14-16].

Occupational risk factors, such as exposure to noise and vibration, have been identified as potential contributors to driver fatigue. Furthermore, it is well established that occupational fatigue itself is a significant risk factor for skeletal and muscular disorders [17]. One of the primary impacts of fatigue is physiological sleepiness, leading to reduced consciousness and compromised task performance. This decline in cognitive and psychomotor abilities can also be observed [18]. Fatigue creates a pervasive condition of physical and mental strain, impeding an individual's work productivity and natural capabilities [19,20]. Given these implications, it is crucial for businesses and industries to prioritize fatigue management as a key concern. Until now, extensive research has been conducted on the impact of noise and vibration on fatigue. One such study by Melamed et al.[16] examined the influence of noise on cortisol levels in urine and its correlation with fatigue and irritability among textile factory workers. Additionally, Khani Jazni [19] investigated the effect of noise and air pollution on fatigue in traffic officers. Another noteworthy research conducted by R. Robinson revealed a compelling causal connection between overall body vibration and driver drowsiness [15].

Fatigue is a crucial determinant affecting driver performance, warranting comprehensive investigation into the underlying factors, associated signs and symptoms, and its profound implications. Additionally, it is imperative to develop effective strategies aimed at mitigating fatigue-related factors. Remarkably, the influence of noise and vibration on the fatigue experienced by urban bus drivers remains largely unexplored. Hence, this study aims to shed light on this critical aspect, potentially uncovering valuable insights for further consideration.

Materials and Methods

In the present study, according to the inquiry of the bus company of Neishabur city, the number of all city bus drivers in Neishabur city, there were 37 buses and 76 drivers, were studied. Informed consent to participate in the study was obtained from the participants and finally 62 people entered

the study with their consent.

Noise and vibration assessment

The Taiwanese-made TES dosimeter model 660 was employed to assess the individual noise exposure levels. The measurements were conducted on each driver based on ISO 5128:1980 standards (noise measurement inside motor vehicles). The measurements were taken at the driver's seat and in close proximity to the drivers' auditory system. In this study, the evaluation of vibration exposure was conducted using the SV 106 vibration meter, Svantek, Poland. The instrument has a sensitivity of 10 ms²/mv. The measurement of vibration was performed by placing the accelerometer plate at the center of the seat, capturing data under the actual daily work conditions of the drivers. This approach adhered to the criteria specified by the ISO 2631 standard [21].

In order to assess the potential health risks to individuals, the root mean square (RMS) frequency weighted accelerations in the x, y, and z axes were combined, denoted as ax, ay, az respectively. Additionally, the total equivalent acceleration (aeq(t)), representing the overall acceleration, was calculated using the following relationship [22].

Work-related fatigue questionnaire

work-related fatigue (WRF) was evaluated with the Swedish Occupational Fatigue Inventory (SOFI), an established assessment tool. The 24-item version of this questionnaire encompasses five distinct dimensions: "lack of energy," "physical effort," "physical discomfort," "lack of motivation," and "drowsiness." Each dimension is evaluated through four specific questions, with each question being rated on an 11-point Likert scale. This scale ranges from 0, representing complete disagreement, to 10, indicating a high level of agreement. It is pertinent to note that a higher score on this Likert scale indicates a more unfavorable occupational fatigue situation [22].

The data collected for the study were analyzed using SPSS 23 software. To assess normality, the Kolmogorov-Smirnov test was employed. The correlation test was utilized to examine the relationship between quantitative variables, including age, work experience, and working hours, with the job fatigue score. Additionally, the impact of qualitative variables such as education level and job satisfaction on job fatigue was evaluated. Statistical tests employed included the one-way ANOVA and independent t-test. Finally, a linear regression analysis was conducted to determine the impact of individual variables on job fatigue. The significance of results was assessed using p-values.

Results

In this particular study, a sample of 62 bus drivers was examined, all of whom were married males. The mean age of the drivers was found to be 40.06 years, while their average body mass index (BMI) was 26.72 kg/m². On average, the drivers had accumulated 13.71 years of driving experience. moreover, they reported spending an average of 59.93 hours per week on driving tasks, with an additional 78.72 hours of overtime per month. The study also assessed the extent of noise and vibration exposure experienced by the bus drivers during their work shifts, recording average values of 82.18 dB and 0.99 m/s², respectively. Notably, 62% of the drivers expressed satisfaction with their work, as depicted in Table 1.

	Minimum	Maximum	Mean	Std. Deviation
Age (years)	29	51	40.06	5.57

Height (cm)	150	187	173.72	6.54
(kg)	53	105	80.75	11.41
BMI	18.78	34.6	26.72	3.25
Experience (years)	1	30	13.71	6.91
The number of children	1	6	2	0.9
Working hours per week	42	98	59.93	19.61
Overtime hours per month	0	210	78.72	83.79
Noise exposure (dB)	72	88	82.18	4.49
Exposure to vibration (meters per square second)	0.56	1.03	0.99	0.13
Qualitative variables			Frequency	Percent
level of Education	High school		18	29.2
	Community Verified icon Verified			
	Diploma & associate		37	59.6
	Higher		7	11.2
Job satisfaction	Yes		39	62
	No		23	38
Seat type	Spring seat		27	45
	Inflatable chair		34	55
Bus type	Benz		39	62
	Scania		23	37

Table 1. Demographic Characteristics of City Bus Drivers.

The study reported an average WRF score of 26.21 out of a possible 200, with the highest recorded score for job fatigue reaching 108. among the five dimensions encompassing WRF, sleepiness exhibited the highest average score of 10.88, followed by physical effort with a score of 8.48. The findings pertaining to the different dimensions of WRF are presented in Table 2.

Descriptive Statistics				
	Minimum	Maximum	Mean	Std. Deviation
lack of energy	0	33	2.2	5.04
physical effort	0	18	8.48	3.3
physical discomfort	0	24	2.75	4.25
Lack of motivation	0	11	2.66	3.29
Drowsiness	0	22	10.88	5.04
Overall job fatigue score	0	108	26.21	16.07

Table 2. Scores Related to Different Dimensions of Job Fatigue.

The study aimed to assess the impact of various factors on job fatigue by examining them individually as well as in combination. Univariate tests revealed a significant correlation between job fatigue and car lifespan, type of car seat (spring or inflatable), exposure to vibration, and job satisfaction. However, in the multivariable analysis, while accounting for other influencing factors, a noteworthy association was observed between occupational fatigue and exposure to vibrations as well as the type of chair used (Table 3).

	Correlation test		Regression test	
	p-value	r	t	p-value

Year of operation of the car	*0.03	-0.01	0.04	0.77
Number of engine repairs	0.64	0.061	0.4	0.68
Number of bus stops	0.5	-0.086	0.09	0.92
Driver's age	0.28	0.14	0.58	0.56
Driver's height	0.57	0.07	0.36	0.72
Driver's weight	0.85	0.02	-0.26	0.79
Body mass index of the driver	0.86	-0.02	0.28	0.77
Number of services	0.11	0.2	0.77	0.44
Number of children	0.68	0.056	0.53	0.59
Working hours per week	0.17	0.177	-1.03	0.3
Overtime hours per month	0.04	0.23	1.36	0.18
Exposure to noise	0.92	0.013	-0.2	0.83
Exposure to vibration	*0.03	0.97	0.04	*0.02
work experience	0.54	0.08	0.02	0.97
Seat type (inflatable, spring)	*0.04	0.73	-0.5	*0.01
Bus type (Benz, Scania)	0.29	0.25	-0.33	0.73
Job Satisfaction (yes-no)	0.05	-2.21	0.04	0.96

Table 3. The Effect of Variables on Job Fatigue (single variable/multivariable).

Discussion

Fatigue refers to the reduction in the body's capacity to generate force or perform at its maximum performance [23]. This phenomenon is exclusive to living organisms and is universally experienced by individuals in their everyday lives. Consequently, fatigue is commonly regarded as an enigmatic sensation and an undesirable manifestation of ennui [24]. WRF can arise due to the prolonged exposure of individuals in the workplace to a wide range of physical and chemical factors. In instances where job fatigue manifests, individuals often express a reduced willingness to sustain their focus and attention towards the tasks delegated to them [25].

This study was undertaken to examine the impact of noise and vibration on inducing fatigue among a sample of 62 drivers. The findings of this investigation demonstrated that city bus drivers were exposed to noise levels of 82 dB, which is below the occupational exposure thresholds set by both the European ACGIH standards and the Occupational Health Committee of Iran (85 dB) [21].

In the study conducted by ebrahimi et al., the researchers examined the level of noise exposure experienced by bus drivers in Tehran city. The study revealed that the bus drivers were exposed to noise levels ranging from 75 to 81 decibels. The investigation also identified several significant factors influencing the extent of noise exposure among the drivers. These factors included the longevity of the bus, the placement of the bus engine, and the working hours of the drivers. The study sample consisted of 25 drivers whose exposure to noise was assessed. Despite the fact that the achieved results regarding noise levels fall below the standard, it is important to acknowledge the variability of drivers' travel locations within the city. Those drivers who frequently navigate through crowded areas are more susceptible to noise-related complications [26]. In the present study, the research investigated the magnitude of whole body vibration experienced by drivers, which was found to be 0.99 m/s^2 . This measurement exceeds the predetermined daily occupational exposure limits set by industry standards (0.58 m/s^2 for an 8-hour work shift). Notably, Nasiri et al. conducted a study on the vibration exposure among bus drivers in Tehran, wherein they recorded a vibration level of 0.71 m/s^2 , surpassing the established occupational limit [21]. The study findings

revealed that drivers' WRF exhibited an average score of 26.7 out of a total of 200, indicating a relatively favorable overall rating. Notably, the highest level of job fatigue was found to be associated with experiences of sleepiness and physical discomfort. Additionally, several factors were identified as influencing job fatigue, including exposure to vibrations, the lifespan of the bus, and levels of job satisfaction.

In a study by Hassanzadeh et al. on the sleep quality of drivers held accountable for severe road accidents resulting in injuries and fatalities, it was demonstrated that the sleep quality of Iranian drivers responsible for fatal traffic accidents was significantly disrupted. The study indicated that these drivers experienced sleep disorders which led to difficulties and drowsiness owing to inadequate sleep quality and reliance on sleeping medications to carry out their daily activities. Additionally, drivers encountered physical and digestive ailments due to improper dietary habits and consumption of fast food items [27]. In contemporary times, businesses have recognized the significant role played by human resources in enhancing productivity, thereby placing emphasis on enhancing their overall well-being. Specifically, organizations are increasingly focusing on addressing mental health issues. Notably, one such factor that poses a risk to the mental health of workers, ultimately resulting in a decline in individual and organizational performance, is job fatigue. Hence, it is imperative for organizations to prioritize the development of strategies aimed at mitigating the contributing factors associated with job fatigue.

In conclusion, the study revealed that city bus drivers were exposed to noise levels within the permissible limit. However, their exposure to vibration exceeded the acceptable threshold. While the average job fatigue score among drivers indicated a satisfactory level, a percentage of drivers experienced high levels of job fatigue. Factors such as the lifespan of buses, seat type, and vibration exposure were identified as contributors to job fatigue. Therefore, it is imperative for the municipal organization to consider taking appropriate measures, such as procuring new buses and equipping them with ergonomic seats, to address this issue effectively.

References

References

1. Hamidi Y, Fayazi N, Soltanian A, Heidari G, Ahmadpanah M, Nazari N, Javaheri M. Relationship between Occupational Stress and the Performance of Health Care Units in Hamadan Health Center, Iran. *Journal of Occupational Hygiene Engineering*. 2017; 4(3)[DOI](#)
2. Asivandzadeh E, Jamalizadeh Z, Mohebi A, Yari P, Fazeli SP. Evaluation of Noise Exposure and the Relationship between Job Stress and Sleep Disturbance in Workers of an Iranian Construction Industry. *Occupational Hygiene and Health Promotion*. 2019. [DOI](#)
3. Fallah Madvari R, Malakoutikhah M, Abbasi balochkhane F, Rabiei H, Jalali Ardekani M. Relationship between Workplace Noise Exposure and Worker's Communication Skills among Miners in Iran: A Cross-Sectional Study. *Journal of Occupational Hygiene Engineering*. 2021; 7(4)[DOI](#)
4. Golmohamadi R. Noise and vibration engineering 2th ed. hamedan. daneshjo publications; 1999.
5. Tajic R, Ghadami A, Ghamari F. The Effects of Noise Pollution and Hearing of Metal Workers in Arak. *Zahedan Journal of Research in Medical Sciences*. 2008; 10(4)
6. Ketabi D, Barkhordari A. Noise Induced Hearing Loss among Workers of an Iranian Axial Parts Factory, 2009. *International Journal of Occupational Hygiene*. 2010; 2(2)
7. Polajnar A, Herzog NV, Buchmeister B, Jevsnik S. Strains and stresses of workers caused by exposure to noise. *Collegium Antropologicum*. 2012; 36(3)
8. Pourabdian S, Mahmoudi A, Forouhar Majd F, Mansourian M, Ziayi N. Laboratory Study of the Effect of Exposure Time to Noise and Sound Pressure Level on Mental Fatigue and Release of Noradrenaline the in Human Body. *Journal of Health System Research*. 2019;

- 15(1)[DOI](#)
9. Fritz M. Description of the relation between the forces acting in the lumbar spine and whole-body vibrations by means of transfer functions. *Clinical Biomechanics (Bristol, Avon)*. 2000; 15(4)[DOI](#)
10. Lewis CA, Johnson PW. Whole-body vibration exposure in metropolitan bus drivers. *Occupational Medicine (Oxford, England)*. 2012; 62(7)[DOI](#)
11. Krajnak K. Health effects associated with occupational exposure to hand-arm or whole body vibration. *Journal of Toxicology and Environmental Health. Part B, Critical Reviews*. 2018; 21(5)[DOI](#)
12. Figueiredo MADM, Silva LF, Barnabé TL. Transporte coletivo: vibração de corpo-inteiro e conforto de passageiros, motoristas e cobradores. *Journal of Transport Literature*. 2016; 10[DOI](#)
13. Rahmani R, Aliabadi M, Golmohammadi R, Babamiri M, Farhadian M. Body physiological responses of city bus drivers subjected to noise and vibration exposure in working environment. *Heliyon*. 2022; 8(8)[DOI](#)
14. Aliabadi M, Darvishi E, Farhadian M, Rahmani R, Motlagh M, Mahdavi N. An investigation of musculoskeletal discomforts among mining truck drivers with respect to human vibration and awkward body posture using random forest algorithm. *Human Factors and Ergonomics in Manufacturing & Service Industries*. 2022; 32[DOI](#)
15. Bhuiyan MHU, Fard M, Robinson SR. Effects of whole-body vibration on driver drowsiness: A review. *Journal of Safety Research*. 2022; 81[DOI](#)
16. Melamed S, Bruhis S. The effects of chronic industrial noise exposure on urinary cortisol, fatigue and irritability: a controlled field experiment. *Journal of Occupational and Environmental Medicine*. 1996; 38(3)[DOI](#)
17. Karimi A, Honarbakhsh M. Dimensions of Occupational Fatigue in Heavy Vehicle Drivers. *Journal of Mazandaran University of Medical Sciences*. 2016; 26(140)
18. Liu YC, Wu TJ. Fatigued driver's driving behavior and cognitive task performance: Effects of road environments and road environment changes. *Safety Science*. 2009; 47[DOI](#)
19. Jazani RK, Saremi M, Rezapour T, Kavousi A, Shirzad H. Influence of traffic-related noise and air pollution on self-reported fatigue. *International journal of occupational safety and ergonomics: JOSE*. 2015; 21(2)[DOI](#)
20. Sharpe M, Wilks D. ABC of psychological medicine-fatigue. *BMJ : British Medical Journal*. 2002; 325(7362)
21. Ebrahimi H, Nasiri P, Alimohammadi I, Mousavi S, Abedi K, Danesh F. Modeling of Sound Exposure in Bus Drivers of Tehran Branch by Neural Network Method. *Rahavard Salamat Journal*. 2017; 3(1)
22. Åhsberg E. Dimensions of fatigue in different working populations. *Scandinavian Journal of Psychology*. 2000; 41(3)[DOI](#)
23. Vøllestad NK. Measurement of human muscle fatigue. *Journal of Neuroscience Methods*. 1997; 74(2)[DOI](#)
24. Winwood PC, Winefield AH, Lushington K. Work-related fatigue and recovery: the contribution of age, domestic responsibilities and shiftwork. *Journal of Advanced Nursing*. 2006; 56(4)[DOI](#)
25. Damrad-Frye R, Laird JD. The experience of boredom: The role of the self-perception of attention. *Journal of Personality and Social Psychology*. 1989; 57(2)[DOI](#)
26. Pedersen E. City Dweller Responses to Multiple Stressors Intruding into Their Homes: Noise, Light, Odour, and Vibration. *International Journal of Environmental Research and Public Health*. 2015; 12(3)[DOI](#)
27. Hasanzadeh M, Alavi K, Ghalehbandi MF, Yadollahi Z, Gharraee B, Sadeghikia A. Sleep quality in Iranian drivers recognized as responsible for severe road accidents. *Journal of Research in Behavioural Sciences*. 2008; 6(2)