Original Article

The Effect of Exposure to Noise and Vibration and Ergonomic Factors on Sleep Quality and Musculoskeletal Disorders in Bus Drivers in Iran

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Abstract

Aim: City bus drivers are exposed to various harmful factors such as noise and vibration, which may cause adverse health effects. This study was conducted with the aim of investigating the impact of exposure to noise, vibration, and ergonomic factors on the quality of sleep and the prevalence of musculoskeletal disorders (MSDs) among city bus drivers in Neyshabur, Iran. **Methods:** Sixty-two city bus drivers from Neyshabur, Iran, participated in this study. Their level of exposure to noise was measured according to the ISO 5128:1980 standard, and the level of exposure to vibration was measured according to the ISO 2631 standard. Sleep quality (SQual) was evaluated with the Pittsburgh SQual Index, and the prevalence of MSDs was surveyed with the Nordic questionnaire. Data were analyzed with R version 4.3.2. **Results:** The average ± standard deviation (SD) exposure to noise was 83.25 ± 4.12 dB, and the average ± SD exposure to vibration was 0.14 ± 0.04 m/s^2. The SQual of 46.77% of drivers was bad, and 69.35% of drivers suffered from MSDs in at least one of their body parts. The results of this study showed as drivers' age increased, the chance of having good SQual decreased (odds ratio [OR]: 0.9, 95% confidence interval [CI]: 0.81–0.99). Sleep disorders were more common among drivers whose buses had spring seats (OR =3.17, 95% CI: 1.07–9.40). **Conclusion:** Almost half of the drivers had unfavorable SQual and suffered from MSDs. The type and quality of the seats, the age of the bus driver, and the bus type were among the most important factors affecting the quality of sleep and the presence of MSDs.

Keywords: Ergonomics, musculoskeletal disorders, noise, sleep quality, vibration

Introduction

Driving a bus is stressful due to factors such as noise, vibration, temperature changes, and ergonomic issues, leading to musculoskeletal disorders (MSDs).[1] Long-term exposure to these stresses can exacerbate MSDs, with sitting alone not increasing low back pain risk, but combined with vibration and poor posture, the risk is significantly higher.[2] Key risk factors for MSDs include prolonged sitting, poor seat ergonomics, whole-body vibration, vehicle type, and overall driver health.[3,4] However, the impact of individual factors such as age, sex, and body mass index (BMI) varies and remains controversial.[5] Studies show a high prevalence of low back pain, particularly among city bus drivers.[6]

Another harmful exposure among bus drivers is noise. According to the World Health Organization, noise is the third most important environmental pollutant in big cities.[7] According to the statistics of the occupational and environmental health center in 2015, out of a total of 22,604,718 people working in Iran, nearly 11 million people are in the service and administrative sectors with low sound levels (<75 dBA) and more than 2 million workers are in direct contact with the levels moderate and high

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sound levels (above 75 dBA) are exposed.[8] Exposure to noise intensities of more than 85 decibels in 8 h can cause tinnitus or a temporary or permanent change in humans' hearing threshold. The effects of noise on humans include damage to the hearing system, interfering with conversation, adverse effects on balance, neurological and psychological effects, and adverse effects on electrolytes. City buses are both a source of environmental noise (traffic) for city residents and a source of occupational noise for drivers.[9] According to studies, the amount of noise exposure for drivers is different based on the age and model of the bus.[10]

One of the most important nonauditory effects of noise is its impact on sleep quality (SQual). It can cause sleep interruptions and reduce the continuity and time of sleep.[11,12] In the study conducted by Jiang *et al*., about 30% of people who were exposed to noise above the permissible limit in the work environment had bad SQual.[13] Researchers have shown that exposure to vibration and noise above the recommended occupational limits can cause higher degrees of sleep disturbance when compared to exposure to noise alone.[14]

This study aims to evaluate the impact of exposure to noise, vibration, and ergonomic factors on SQual and the prevalence of MSDs among city bus drivers in Neyshabur, Iran. By identifying the key factors affecting drivers' health, this study seeks to provide insights and recommendations for improving working conditions and reducing health-related issues among bus drivers.

Materials and Methods

In the present study, conducted in 2023, based on an inquiry from the Neyshabur city bus company, there were 37 buses in the city, and the total number of city bus drivers was 76. To determine the sample, the census method was used, and all drivers who agreed to participate in the study were selected. Of the 76 drivers, 62 were ultimately included in the study. Informed consent was obtained from all participants.

Assessment of exposure to noise

A Touch Embedded Solutions (TES) dosimeter model 660 made in Taiwan was used to measure individual noise exposure. Measurements were made for each driver during driving on the road and based on the ISO 5128:1980 standard. Noise measurement was done inside the bus, at the driver's seat, and near to the drivers' ears.[10]

Assessment of exposure to vibration

Exposure to vibration was evaluated using an SV 106 vibration meter made by SVANTEK, Poland, with a sensitivity of 10 ms^2/mv. The vibration measurement was done by placing the accelerometer plate on the center of the seat, under the actual daily work conditions of the drivers, and in accordance with the criteria mentioned by the ISO 2631 standard.[15] To predict human health risk, the root mean square frequency-weighted accelerations in X, Y, and Z axes with the symbols of ax, ay, and az are combined, and the total equivalent acceleration (Aeq [T]) is calculated from Equation 1.

Equation (1) $$A_{q(T)} = \sqrt{(1.4ax)^2 + (1.4ay)^2 + (az)^2}$$

Assessment of sleep quality

The Pittsburgh SQual Index (PSQI) was used to assess SQual. The validity of the Persian PSQI is confirmed with a Cronbach's alpha coefficient of 0.83.[16] The PSQI includes seven scales: overall SQual, sleep-onset delay, sleep duration, sleep sufficiency, sleep disturbances, medication use, and daytime performance. Each component is scored from 0 (normal) to 3 (severe), with total scores ranging from 0 to 21. A score of 5 or less indicates good SQual, while 6 or more indicates poor SQual. To enhance the accuracy of the results, the questionnaires were administered through face-to-face interviews with the drivers.

Assessment of musculoskeletal disorders

The prevalence of MSDs was investigated using the Nordic questionnaire. This questionnaire is one of the most common tools for determining the symptoms of MSDs in workplace. This questionnaire evaluates the prevalence of MSDs in 9 areas including neck, shoulders, low back, waist, hands and wrists, thighs, legs, feet, and ankles in the two time periods of the last 7 days and the last 12 months.[17]

Data analysis

Categorical variables were summarized as frequency and percentage, while continuous variables were expressed as median and interquartile range due to asymmetry. Normality was assessed using histograms, Q-Q plots, and the Kolmogorov–Smirnov test. Differences in continuous variables (e.g. age and BMI) were analyzed with Mann–Whitney *U* or *t*-tests, and categorical differences were evaluated using Chi-squared and Fisher's exact tests. Logistic regression models tested associations between SQual and other variables. Analyses used R version 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria), with significance set at $P < 0.05$.

Ethical Approval

Ethical approval for this study (IR.NUMS.REC.1400.047) was provided by the Research Ethics Committees of Neyshabur University of Medical Sciences, Neyshabur, IRAN, on 22 February 2022.

Results

In this study, 62 male, married, nonsmoking bus drivers were assessed. The average age was 40.06 ± 5.57 years, with a BMI of 26.72 ± 3.26 kg/m^2 and 13.71 ± 6.92 years of driving experience. They were exposed to an average noise level of 83.25 dB and whole-body vibration of 0.14 m/s^2. Drivers averaged 5.30 h of sleep per day, with a SQual score of 5 out of 21. About 32.2% had poor SQual, 67.74% had good quality, and 19.7% used sleeping pills. Table 1 details the participants' SQual index.

Table 2 presents the prevalence of MSDs among participants. Over the last week, 37.10% of drivers experienced MSDs in at least one limb, while 69.35% reported MSDs in the past

Table 1: The results of the Pittsburgh Sleep Quality Index questionnaire in different items

PSQI components	Frequency (%)
SQual	
Very good	21 (33.90)
Fairly good	21 (33.90)
Fairly bad	14 (22.60)
Very bad	6 (9.70)
Latency in sleep (min)	
<15	51 (82.30)
16–30	6 (9.70)
31–60	3 (4.80)
>60	2 (3.20)
Sleep duration (h)	
>7	6 (9.70)
≥6–≥7	22 (35.50)
≥5–>6	23 (37.11)
<5	11 (17.70)
Sleep efficiency (%)	
>85	34 (36.20)
75–84	9 (14.50)
65–74	10 (16.10)
<65	9 (14.50)
Sleep disturbances	
None	0
1–9	52 (83.90)
10–18	10 (16.10)
19–27	0
Sleep medication use	
No use	50 (81.30)
Once a week	0
Once or twice a week	0
Three times or>3 times a week	12 (19.70)
Inappropriate performance	
Never	55 (88.70)
Once or twice a week, very little	6 (9.70)
Once or twice a week, some	1 (1.60)
Three or more times a week, serious	0

SQual: Sleep quality, PSQI: Pittsburgh SQual Index

12 months. Additionally, 17.74% were unable to perform daily tasks due to MSDs. The most common disorders in the past year were low back (45.16%) and neck (41.93%). Other prevalent issues included back (19.35%), shoulder (17.74%), hands and wrists (14.52%), and knees (11.29%).

There was no statistically significant relationship between the prevalence of MSDs over the past 7 days or 12 months and bus drivers' SQual ($P > 0.05$). The study investigated various factors, including education level, bus type, seat type, job satisfaction, and exposure to noise and vibration, but only the type of seat (spring vs. inflatable) and drivers' age were significantly related to SQual ($P = 0.03$ for both) [Table 3]. Backward multivariate logistic regression revealed that drivers with spring seats were 3.17 times more likely to experience poor sleep (95% confidence interval [CI]: 1.07–9.40), and each additional year of age decreased the likelihood of good

Table 2: Prevalence of musculoskeletal disorders in city bus drivers

	Discomfort during the past 7 days?, *n* (%)	Discomfort during the past 12 months, *n* (%)
Neck	11 (17.74)	26 (41.93)
Shoulder	6 (9.68)	11 (17.74)
Arm	0	1 (1.61)
Hands and wrists	2 (3.23)	9 (14.52)
Back	5 (8.07)	12 (19.35)
Low back	15 (24.19)	28 (45.16)
Thighs	1 (1.61)	4 (6.45)
Knees	4 (6.45)	7 (11.29)
Feet and ankles	1 (1.61)	1 (1.61)

SQual by 10% (odds ratio: 0.9, 95% CI: 0.81–0.99). There was no significant relation between other variables and MSD prevalence in the past 12 months [Table 4].

Discussion

In this study, the average noise exposure was 83.25 dB, which is lower than the permissible occupational exposure limit for 8 h which is 85 dB, and the average exposure to vibration was 0.14 m/s^2, which is lower than the permissible exposure limit for 8 h which is 0.58 m/s^2. In a study by Ebrahimi *et al*., noise exposure among Tehran bus drivers was 81.74 dB,[15] while Nassiri *et al*. reported a vibration exposure of 0.78 m/s^2.[10]

In this study, the average SQual score among Neyshabur city bus drivers was 5 out of 21, with 32.2% experiencing poor SQual. Comparatively, Emkani and Khanjani reported an average score of 6.98 in Kerman,[11] and Kakui *et al*. found a score of 7.2 in Tehran.[12] Qaraei Banafsheh *et al*.,[18] noted an average score of 6.3 ± 2.8 among Iranian drivers after severe road accidents. Poor SQual was more prevalent in Kerman (61%) and Tehran (78.2%) than in Neyshabur, likely due to larger populations and higher noise pollution in those cities.[11,12] In this study, 32.2% of drivers rated their SQual as bad, compared to only 11% in Kerman,[11] 14.8% in Qaraei Banafsheh *et al*.'s study on Iranian drivers,[18] and 12.8% in Tehran.[12] This suggests that many drivers are unaware of their poor SQual despite experiencing related issues.

In this study, 69.35% of drivers experienced MSDs in the past 12 months, with low back and neck pain being the most common. Other prevalent pains included the shoulder, hand, wrist, and knee. A review about the prevalence of MSDs in drivers of different vehicles and in different countries (Iran, Nigeria, India, China, Ghana, Malaysia, South Africa, and England) found similar patterns, with 41.6% of drivers suffering from low back pain, 26.9% from neck pain, and 18.7% from shoulder pain.[19]

Studies highlight that low back pain is the most prevalent MSD among drivers, primarily due to prolonged sitting, insufficient rest, road bumps, and poor seat design, particularly in developing countries.[20] Lis *et al*. found that sitting for long periods, combined with whole-body vibration

Table 3: The effect of different variables on the sleep quality of bus drivers

Qualitative variables				
	Good SQual, frequency (%)	Poor SQual frequency (%)	Total frequency (%)	*P*
Education level				
Under diploma	9 (27.27)	9 (31.03)	18 (29.03)	0.99
Diploma and postgraduate diploma	22 (66.67)	19 (65.52)	41 (66.13)	
Bachelor's degree and higher	2 (6.06)	1 (3.45)	3 (4.84)	
Type of car				
Benz	19 (57.58)	20 (68.97)	39 (62.9)	0.35
Scania	14 (42.42)	9 (31.03)	23 (37.10)	
Seat type				
Spring	10 (30.30)	17 (58.62)	27 (43.55)	0.03*
Inflatable	23 (69.70)	12 (41.38)	35 (56.45)	
Job satisfaction				
Yes	10 (30.30)	13 (44.83)	23 (37.10)	0.26
No	6 (18.18)	7 (24.14)	13 (20.97)	
Almost	17 (51.51)	9 (31.03)	26 (41.93)	
The number of engine repairs				
0	10 (30.30)	7 (24.14)	17 (27.42)	0.90
1	17 (51.51)	15 (51.72)	32 (51.61)	
2	4 (12.12)	4 (13.79)	8 (12.90)	
≥3	2 (6.06)	3 (10.34)	5 (8.06)	
Number of stops				
≤40	9 (27.27)	11 (37.93)	20 (32.26)	0.37
>40	24 (72.73)	18 (62.07)	42 (67.74)	
Work experience (years)				
≤15	23 (69.70)	16 (55.17)	39 (62.90)	0.24
>15	10 (30.3)	13 (44.83)	23 (37.10)	
Number of services per shift				
≤10	23 (69.7)	21 (72.44)	44 (70.97)	0.81
>10	10 (30.30)	8 (27.59)	18 (29.03)	
Work time (week)				
≤60 h	16 (48.48)	18 (62.07)	34 (54.84)	0.28
>60 h	17 (51.51)	11 (37.93)	28 (45.16)	
Overtime (month)				
≤40 h	13 (39.39)	18 (62.07)	31 (50)	0.07
>40 h	20 (60.61)	11 (37.93)	31 (50)	
Quantitative variables				
	Mean (Range)	**Mean (Range)**		***P***
Year of bus manufacture	14 (14–18)	16 (14–19)		0.15
Age	38.64±5.54	41.69±5.23		0.03
Height	175 (171–178)	173 (169.5–177)		0.24
Weight	80 (75–89.50)	82 (70–85)		0.59
BMI	26.57 (25.30–28.53)	26.83 (24.93–28.91)		0.82
Noise exposure	83 (77.90–86.35)	84 (78.60–85.30)		0.86
Vibration exposure	0.14±0.04	0.13±0.04		0.83

BMI: Body mass index, SQual: Sleep quality

and poor posture, increases the risk of low back pain or sciatica.[4] In this study, neck pain was the second most common MSD. Mansfield and Marshall reported that 54% of rally drivers in England experienced neck pain, and 47% had shoulder pain.[21] Drivers often maintain static neck positions for extended periods, exacerbating MSDs in this area. Adhering to ergonomic standards, proper seat design, and avoiding long work hours can help mitigate these issues.[20]

This study found no significant correlation between noise or vibration exposure and SQual or MSDs. Frei's study in Basel indicated a significant link between urban traffic noise and reduced SQual.[22] Xu *et al*. showed that higher noise levels significantly shortened rapid eye movement sleep and worsened subjective SQual.[23] Jamalizadeh *et al*. found a significant relationship between vibration exposure and MSDs in construction machinery drivers,

Table 4: The effect of different variables on musculoskeletal disorders of bus drivers

	Qualitative variables			
	MSDs		Total frequency, *n* (%)	*P*
	Yes, frequency (%)	No, frequency (%)		
Education level				
Under diploma	10 (23.26)	8 (42.11)	18 (29.03)	0.23
Diploma and postgraduate diploma	31 (72.09)	10 (52.63)	41 (66.13)	
Bachelor's degree and higher	2 (4.65)	1 (5.26)	3 (4.84)	
Type of car				
Benz	28 (65.12)	11 (57.89)	39 (62.90)	0.39
Scania	15 (34.88)	8 (42.11)	23 (37.10)	
Seat type				
Spring	18 (41.86)	9 (47.37)	27 (43.55)	0.45
Inflatable	25 (58.14)	10 (52.63)	35 (56.45)	
Job satisfaction				
Yes	14 (32.56)	9 (47.37)	23 (37.10)	0.52
No	10 (23.26)	3 (15.79)	13 (20.97)	
Almost	19 (44.19)	7 (36.84)	26 (41.93)	
The number of engine repairs				
0	11 (25.58)	6 (31.58)	17 (27.42)	0.90
1	23 (53.49)	9 (47.37)	32 (51.61)	
2	5 (11.63)	3 (15.79)	8 (12.90)	
≥3	4 (9.30)	1 (5.26)	5 (8.06)	
Number of stops				
≤40	16 (37.21)	4 (21.05)	20 (32.26)	0.21
>40	27 (62.79)	15 (78.95)	42 (67.74)	
Work experience (years)				
≤15	28 (65.12)	11 (57.89)	39 (62.90)	0.59
>15	15 (34.88)	8 (42.11)	23 (37.10)	
Number of services per shift				
≤10	30 (69.77)	14 (73.68)	44 (70.97)	0.75
>10	13 (30.23)	5 (26.31)	18 (29.03)	
Amount of work per week (h)				
≤60	24 (55.81)	10 (52.63)	34 (54.84)	0.82
>60	19 (44.19)	9 (47.37)	28 (45.16)	
Overtime per month (h)				
≤40	22 (51.16)	9 (47.37)	31 (50)	0.78
>40	21 (48.84)	10 (52.63)	31 (50)	
	Quantitative variables			
	Mean (Range)	**Mean (Range)**		***P***
Year of bus manufacture	16 (14–19)	14 (14–19)		0.53
Age	40.21±5.92	39.74±4.81		0.76
Height	173 (170–176)	176 (171–180)		0.09
Weight	80 (72–87)	85 (80–90)		0.15
BMI	26.45 (25.06–28.73)	27.68 (25.35–28.41)		0.67
Noise exposure	83 (79–86)	84 (77.30–86)		0.63
Vibration exposure	0.14±0.04	0.13±0.05		0.35

BMI; Body mass index, MSDs: Musculoskeletal disorders

with higher vibration levels correlating with increased MSD prevalence.[24]

Multivariate analysis revealed that seat type (spring vs. inflatable) and age impacted SQual, with older drivers and those in buses with spring seats reporting worse SQual. Studies by Emkani and Khanjani,[11] Hojjati Hamid *et al*.,[25] and Kakui *et al*.[12] also noted age-related declines in SQual among bus drivers. Efatpanah *et al*. found no significant age-related effect on SQual in Tehran.[26] Yarmohammadi *et al*.[19] showed that increased age was linked to a higher prevalence of ankle and knee pain, likely due to prolonged use of pedals. Arghami *et al*. similarly noted that increased age correlated with foot and

ankle pain among Zanjan intercity bus drivers.[27] Nassiri *et al*. identified bus type (Ikaroos, Man, and Shahab) and age as factors influencing vibration exposure, with older buses and Ikaroos buses showing higher vibration levels.[10] Ebrahimi *et al*. found that older buses and engine position affect noise exposure in city bus drivers, with mid-mounted engines producing more noise due to engine wear and cabin deterioration.[15]

The relationship between MSDs and SQual is bidirectional; poor sleep can exacerbate MSDs, and vice versa. Auvinen *et al*.'s longitudinal study found that poor SQual and quantity were related to increased neck, shoulder, and low back pain.[28] Sleep is one of the basic physiological needs of the body in order to relieve daily fatigue, and if this need is not met, it leads to increased fatigue and decreased physical ability, which is probably related to MSDs.[29]

This study found no significant links between height, weight, bus age, job satisfaction, work history, or education level with SQual or MSD prevalence. However, factors such as shorter height, lower education, longer bus life, lower job satisfaction, more service calls per shift, and frequent engine repairs correlated with higher MSD prevalence and worse SQual. Emkani and Khanjani and Kakui *et al*. found job dissatisfaction related to poorer SQual.[11,12] Sadeghi and Habibi noted that driver anthropometric parameters were linked to musculoskeletal discomfort.[30] Taghizadeh *et al*. found a significant correlation between working hours and upper limb MSDs.[31]

This study has several limitations that should be considered. These include focusing solely on inner-city bus drivers, which limits comparisons with other types of drivers. Additionally, drivers reported other risk factors, such as exposure to smoke, temperature extremes, and glare, which affect body position and MSDs. Future research should explore these factors to better understand their impact on driver health.

Conclusion

In this study, the exposure of drivers to noise and vibration was lower than the permissible exposure limits. Almost half of the drivers had bad SQual and suffered from MSDs. Factors such as the type and quality of seats and the age of the bus were among the most important factors affecting the quality of sleep. The use of new buses with suitable seats is recommended by municipal organizations.

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Ethics Code

IR.NUMS.REC.1399.048.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Contributions

Narges Khanjani and Mahdi Jalali: Design and implementation of the research; Fatemeh Khorashadizadeh and Ayda Shahmohammadi: Data gathering and analysis of the data; Somayeh Rahimimoghadam and Mahdi Jalali: Writing of the manuscript.

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