



Original article

Body physiological responses of city bus drivers subjected to noise and vibration exposure in working environment

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ABSTRACT

Background: The city bus drivers have critical roles in public transport and are occupationally exposed to different environmental stressors. This study aimed to investigate body physiological responses of city bus drivers subjected to noise and vibration exposure while crossing city routes.**Methods:** This cross-sectional study was conducted on 103 city bus drivers working in the governmental transportation system in Hamadan city. The subjects' exposures to noise and body vibration were measured during driving activities. Their blood pressure (BP), as well as heart rate (HR), were measured before and after driving. Multivariate regressions (MLR) were employed to analyze the effect size of the stimulus on body physiological responses using SPSS 22.**Results:** Exposure levels to noise, whole-body vibration (WBV), and hand-arm vibration among drivers were 79.50 ± 3.51 dB, 0.620 ± 0.159 m/s², and 0.438 ± 0.064 m/s², respectively which were lower than the exposure limits. Heart rate as main physiological response before and after driving were 74.22 ± 4.11 and 79.23 ± 8.59 bpm, respectively. The developed MLR models statistically showed that noise exposure could only affect the HR ($\beta = 0.193$ and $p < 0.001$); while WBV exposure affected both BP ($\beta = 0.360$ and $p < 0.001$) and HR ($\beta = 0.367$ and $p = 0.020$). The statistical analysis represented that exposure to noise and vibration in the presence of other possible covariates have significant effects on body physiological responses.**Conclusion:** The study empirically confirmed the possibility of body physiological changes influenced by physical stimulus during real driving activities. It is highly recommended that occupational health surveillance should continuously be implemented to maintain and promote the safety and health of drivers throughout their careers.

1. Introduction

Noise and vibration are two physical agents which exist in various occupational settings. Regardless of how they appeared in the workplace, human exposure to these agents can be harmful and threatening. Literature indicated that noise exposure has two main effects called "auditory and non-auditory effects" [1]. In the last decade, the non-auditory effects of noise exposure have attracted a lot of attention. These effects include the mental and physiological effects such as affecting cognitive performance [2] and sleep quality [3] as well as its impacts on job stress [4] and

changes in physiological parameters (i.e. blood pressure and heart rate) [5]. The health effects of exposure to vibration are another interesting issue from the perspective of occupational health experts. Despite some beneficial effects of vibration-based exercises reported by Bembem et al. [6] such as enhancing the muscles strength as well as alleviating pain in musculoskeletal system, long-term exposure to vibration can lead to some adverse health effects in different occupations. The previous research showed that whole-body vibration (WBV) is one of the most responsible causes of musculoskeletal pains [7]. Moreover, it can distract human attention and impair their performance [8]. Hand-arm vibration

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(HAV) is also one of the main risk factors for white finger disease or Reynaud's phenomenon [7, 9]. HAV also can reduce individuals' hand-grip strength as well as their hand dexterity [10].

The drivers of heavy vehicles (i.e. truck and bus) have the potential to be exposed to amounts of noise and vibration [11, 12]. The bus drivers have an important role in public transport and are most useful for alleviating the traffic load as well as air pollution [13]. They transfer people across various routes and help them get to their routines. The bus drivers are subjected to both noise and vibration raised from the bus engine, traffic, and passengers. Previous studies proved that in heavy vehicles (i.e. truck and bus) noise and vibration can be induced due to their diesel-based fuel as well as their heavy and powerful engines. Ebrahimi et al. [14] using neural network modeling identified that bus engine age and its location (i.e. located in the back or middle of the bus) are the most influential factors that affect the noise exposure of bus drivers. Also, some pieces of evidence suggest that another important factor for inducing vibration is related to the route which they are driving across it [15].

It is worth mentioning that psychological and physiological balances of professional drivers impaired by several environmental and organizational factors. For example, it was well documented by Useche et al. [16] that job stress in professional drivers can cause by variables such as job demands, influence and development, interpersonal relationships, leadership, job insecurity, strain effects and outcomes. According to Liamazares et al., in addition to environmental harmful agents (such as noise and vibration), working experience, time of the day, and gender were known to be associated with the performances among professional drivers [17]. Generally, complications caused by the mentioned factors can lead to crashes and other commuting road accidents during driving activities.

There are some descriptive studies evaluating the exposure of bus drivers to noise and vibration. Nadri et al. [18] showed that bus drivers were exposed to noise ranging from 65.9 dB to 79.0 dB. Golmohammadi et al. [19] stated that the average exposure of bus drivers to noise was 76.4 dB. Nasiri et al. [20] observed that the WBV exposures of studied bus drivers were between 0.70 m/s² and 0.78 m/s² within different models of buses. The findings of Khavanin et al. [21] pointed out that exposure to WBV reaches 0.95 m/s² among some bus drivers.

Various health impacts from exposure to these agents were discussed in previous researches [7]. Moreover, the simultaneous exposures of drivers to noise and vibration and the possible interaction is the other challenges. The majority of previous studies investigated merely one of these two agents (i.e. noise or vibration). Golmohammadi et al. [19] showed that the higher the noise exposure, the higher the probability of unsafe acts and accidents. Mendes et al. [22] conducted a systematic review and concluded that daily exposure to vibration may increase the risk of low back pain among bus drivers. Bhuiyan et al. stated that there are causal relationships between WBV and drowsiness of drivers which can lead to accidents [11].

It is reported that continuous exposure to noise and vibration may lead to changing the body's physiological responses and causes hypertension [23]. Hypertension is one of the most well-known and obvious risk factors of cardiovascular diseases which is responsible for one-third of deaths over the world [24]. Previous studies reported that the prevalence of hypertension among bus drivers has a range from lower than 20% to higher than 53% over the world [23, 25, 26]. Some findings suggested that the heart rate of individuals increased after exposure to noise and vibration [5]. It seems that tracing the physiological symptoms of bus drivers can be valuable to prevent cardiovascular diseases and to get an early diagnosis of other related outcomes.

Although there are a lot of studies investigating the noise and vibration exposures and their health effects in different occupational settings, up to our knowledge, only a limited studies focused on the body physiological responses among bus drivers exposed to physical agents or stimulus in the real work conditions. There is a shortage of accurate empirical evidences in this topic and therefore, this study empirically

aimed to investigate the body physiological responses of city bus drivers exposed to noise and vibration in their working environment.

2. Methods

2.1. Study design and participants

The present study was carried out with the participation of 103 city bus drivers working in governmental transportation system (Hamadan, western province of Iran). As the population size was limited, all drivers have been invited to participate in the study. It is worth mentioning that having at least one year of experience, not having severe mental disorders as well as not having a second job were considered as initial criteria to include drivers in the study. Moreover, the study protocol has been confirmed by the Ethics Committee (ethics code: IR.UM-SHA.REC.1398.905), and drivers who met the inclusion criteria, signed informed consent before participating in the study.

In this study, data collection has been conducted in several phases. As the primary phase, the information related to bus drivers' demographic and job characteristics as well as baseline job stress were obtained. Then, physiological parameters included systolic blood pressure (BP), diastolic blood pressure, and heart rate (HR) were measured twice; the first measurements were done before driving, in a situation in which the drivers were exposed to the minimum levels of environmental stressors. Then, the measurements were repeated as soon as a whole cycle of driving was completed. The differences between the values of BP and HR in the two measurements were registered and considered for the next analysis. The last phase of the study included of measurement the environmental stressors such as noise, whole-body vibration (WBV), and hand-arm vibration (HAV) which bus drivers were exposed to in their working day. These data were assessed between the two measurements of the above-mentioned physiological parameters.

2.2. Job stress

Previous studies introduced several tools to assess the job stress among various occupational settings such as the job demand-control model [27] and the effort-reward imbalance model [28]. Another well-known model for the assessment of job stress has been developed by Philip L. Rice [29], which was used in a previous related research to study the job stress among drivers. In the present study, we applied the Philip L. Rice occupational stress assessment method, which individuated three dimensions of stress among drivers. These dimensions include "interpersonal relationships", "physical conditions", and "job interests". The questionnaire has 57 items with five choices Likert-based scoring system (from 1 for "rarely" to 5 for "most of the time"). The questionnaire was developed in 1992 by Philip L. Rice [29] and translated to Persian with psychometric analysis by Hatami et al. in 1999. They reported its validity as 0.92 and its reliability as 0.89 [19]. It should be noted that the Persian version of this tool has been used frequently by Iranian researchers which indicates that it has good reliability for the Iranian working population [30]. Also, it has been used among a relatively same sample of bus drivers by Golmohammadi et al. in 2014 [19].

2.3. Body physiological responses

The two parameters including blood pressure and heart rate were measured using a digital device named Pulse GALA X model TD-3124 (Figure 1). The mentioned device was portable and have an arm cuff that can measure both BP and HR. The results were depicted on the device's monitor as soon as the cuff was filled with air (it takes a time between 10 to 15 s). As mentioned, these data were recorded twice for each driver (before driving and after a whole cycle of passenger transportation). The cuff was put on the left arm for all drivers both at time 1 (before driving) and time 2 (after driving).



Figure 1. a) Pulse GALA X for measuring BP and HR; b) Svantek 104 for measuring noise exposure; c) Svantek 106A for measuring WBV and HAV.

2.4. Noise and vibration exposures

To measure the city bus drivers' exposures to noise and vibration, their work schedule of them was investigated for two weeks. Based on our investigation, the majority of bus drivers work one shift in a day (morning or afternoon), with a weekly rotation. They worked 8 h a day and six days a week. The working plan of the studied city bus drivers is in this way: they move through certain routes to transfer the passengers. Their routes can be considered as a circle. They repeat this circular passenger movement six times in their shifts. The only parameter which changes between their circular movements is the load of traffic. Therefore, one of the circular passenger movements was selected, randomly. The traffic load was measured using a traffic police monitoring database and the loads were categorized into three groups: low, moderate, and heavy. Then, the exposures of the driver to noise and vibration were measured as follow:

As shown in Figure 1, to measure the noise exposure, a noise dosimeter (Svantek, SV104) was applied. This device is small and attached to the left side of drivers' collar within their hearing zone. The noise dosimeter was measuring the exposure of the driver in a whole cycle of passenger movement.

At the same time, using the human vibration meter (Svantek, SV106A), the driver exposures to both WBV and HAV were measured (Figure 1). There are useful guidelines in the fields of WBV which were considered in this study [31, 32]; it should be noted that WBV was measured through the driving chair, and HAV was measured through the bus steering wheel (Figure 2). The vibration meter has two ports that can be used for measuring WBV and HAV, simultaneously. This device was active in the whole selected cycle of passenger movement. It should be noted that the doses of noise were recorded, then, the doses were converted to the equivalent levels (Leq) in dB using Eq. (1), which is based on the national noise exposure limit (85 dB for 8h, noise dose of 100%) [33]. Most countries set the occupational exposure limit (OEL) of 85 dBA for an 8-hour time-weighted average exposure. It is observed that an 8h

time-weighted exposure limit of 85 dBA, which corresponds to a dose of 100% of the OEL is recommended for occupational exposure.

The vibration accelerations were measured for each axis (X, Y, and Z) in m/s^2 , separately. Thus, using Eqs. (2) and (3), the equivalent accelerations were calculated for WBV and HAV, respectively, and then extended to the entire shift [34, 35].

$$Leq(dB) = 10 \text{Log} \left(\frac{Dose (\%)}{\frac{100}{480} \times t} \right) + 85 \tag{1}$$

$$a_{hw-WBV} = \sqrt{1.4(a_{hwX}^2) + 1.4(a_{hwY}^2) + a_{hwZ}^2} \tag{2}$$

$$a_{hw-HAV} = \sqrt{a_{hwX}^2 + a_{hwY}^2 + a_{hwZ}^2} \tag{3}$$

where t is the work exposure time (in minutes), Dose (%) is the value recorded by a noise dosimeter during exposure time, a_{hw-WBV} is the equivalent vibration acceleration of WBV and a_{hw-HAV} is the same value for the HAV. Also, a_{hwX} , a_{hwY} , and a_{hwZ} are the effective acceleration rates for X, Y, and Z axes respectively.

The daily exposure limit value (ELV) for HAV, 8-hour equivalent vibration is $5 m/s^2$ which represents situations under which most workers may be exposed frequently without health risks. The exposure action value (EAV) for HAV, 8-hour equivalent vibration is $2.5 m/s^2$ which indicates a situation where the risk is very low for most workers (ISO 5349-2: 2001). The daily ELV for WBV, 8-hour equivalent value is $0.9 m/s^2$ which indicates situations that the majority of workers may be exposed frequently without health risks. The EAV for WBV, 8-hour equivalent value is $0.45 m/s^2$ indicates a situation under which the risk of signs is quite low for most workers (ISO 2631-1 1997).

2.5. Analysis of data

The mean and the standard deviation (SD), as well as number and percentage, were reported to describe the data. Then, the normality of data was tested by means of the Kolmogorov-Smirnov tests. Using the independent-samples T-tests and One-way ANOVA tests, the mean of variables were compared within various groups. Also, the before and after changes for BP and HR were studied using the paired samples T-tests. Moreover, the multivariate linear regression (MLR) models were applied to determine the relation between the predictive variables, such as the noise and WBV and HAV exposure levels, and the physiological parameters. All statistical analyses were performed using the SPSS 22.

3. Results

The mean (\pm SD) age and work experience of the studied bus drivers were $44.48 (\pm 6.73)$ and $11.85 (\pm 5.01)$ years, respectively. All

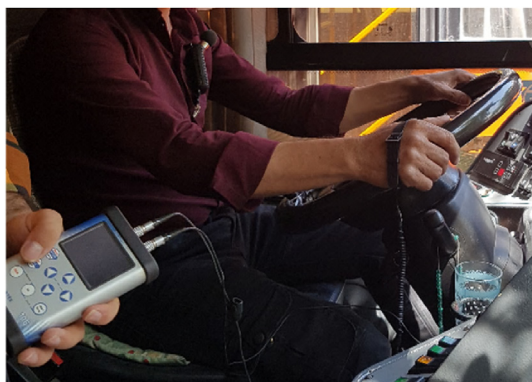


Figure 2. Set up for measuring drivers' exposure to noise, WBV and HAV.

participants were men and married. More than half of them (54.4 %) had a diploma or higher education. Only 14 drivers (13.6 %) were cigarette smokers. Fifty-three drivers (51.5 %) have been occupied governmentally. The mean (\pm SD) BMI was 26.09 (\pm 2.91) Kg/m². Totally, 4 types of buses were individuated: type 1 (N = 50), type 2 (N = 18), type 3 (N = 22), and type 4 (N = 13). Moreover, based on the engine ages, the buses were categorized into 3 groups: up to 5 years (N = 20), 6–10 years (N = 53), and more than 10 years (N = 30).

3.1. Exposure to noise and vibration

The drivers' exposure to noise, WBV, and HAV across these categories of buses are shown in Figure 3. As it can be seen, despite the noise exposure being higher in type 1 and those buses that had the engines age more than 10 years, no significant differences were observed within both bus types and bus engine ages categories ($p = 0.148$ and $p = 0.174$, respectively). In the case of vibration, the same results were obtained. But, the differences

of WBV and HAV within both types and engine ages categories were statistically significant ($p < 0.001$). Using the Scheffee post hoc test, it was found that the WBV in type 1 with type 3 and type 4 had significant differences ($p < 0.001$ and $p = 0.008$, respectively). Also, the HAV in type 1 was statistically different from those of type 3 and type 4 ($p < 0.001$ and $p = 0.004$, respectively). Moreover, the differences between the buses with engine ages up to 5 years and those with engine ages more than 10 years in terms of both WBV and HAV were statistically significant ($p < 0.001$).

The measurement of noise and vibration were under the three different levels of the traffic load. Almost half of the measuring cases (49.5 %) were in the light level, 34.0 % were in the moderate level and the rest were in the heavy level of the traffic load. The one-way ANOVA tests showed that there were no significant differences between these groups in terms of noise exposure. For both WBV and HAV exposures, there were statistically significant differences within the traffic load categories. The higher the traffic load resulted in the higher the exposure to WBV and HAV ($p < 0.001$).

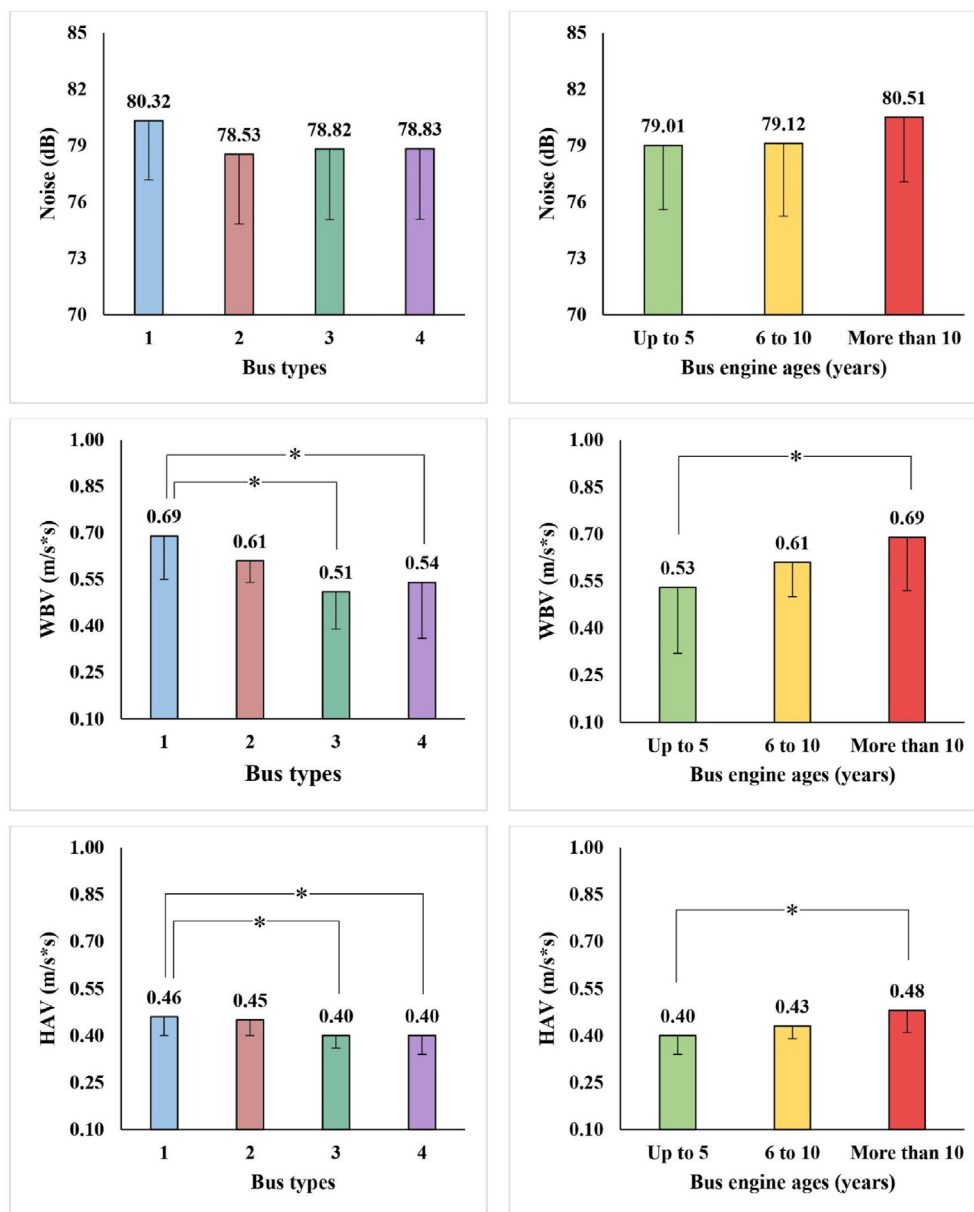


Figure 3. Bus drivers' exposure to noise, WBV, and HAV according to bus types and bus engine ages note: asterisk shows $p < 0.01$.

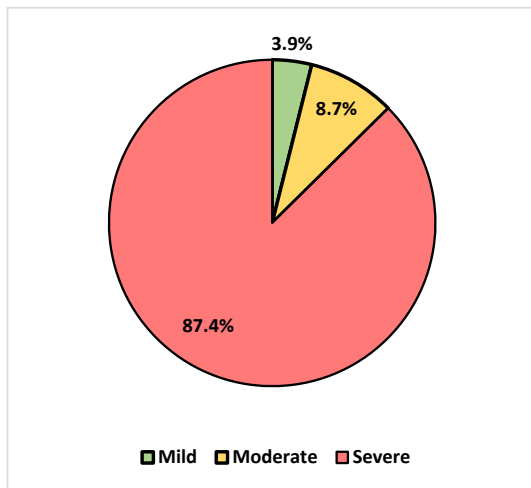


Figure 4. Distribution of bus drivers across different levels of job stress.

3.2. Drivers' job stress

Using the Philip L. Rice questionnaire, the scores less than 117 are considered as mild, the scores between 117 and 140 are considered as moderate, and the scores above 140 are considered as severe job stress. In this regard, our results showed that most drivers (87.4 %) had severe job stress (Figure 4). Within the three dimensions of job stress, the most effective dimension was a physical condition which showed the highest correlation coefficient with the total score of the questionnaire ($r = 0.922$ and $p = 0.006$). The correlation coefficients for interpersonal relationships and job interests were lower ($r = 0.902$, $p = 0.007$ and $r = 0.549$, $p = 0.009$).

3.3. Blood pressure and heart rate

The BP and HR of bus drivers were measured twice, to investigate how they change after individuals drive through a certain route. The obtained data were summarized in Table 1. It was found that significant increases occurred both in BP and HR after driving compared to before driving ($p < 0.001$). Mean (\pm SD) systolic BP before and after driving were $118.34 (\pm 2.31)$ and $126.07 (\pm 7.72)$ mmHg, respectively.

To investigate the predictors of changes in BP and HR of bus drivers, the MLR models were developed. After examination of various approaches, the backward approach was selected because it has the greater fit. It should be noted that in the backward approach, firstly, all relevant independent variables included in the model, then the weakest variable which has no noteworthy association with the dependent variable excluded from the model; Subsequently, the regression was re-calculated and the next weakest variable excludes from the model. This cycle will be continued till just the most useful predictors remain in the model. To summarize the results, the last steps of MLR models were reported (Table 2). It is worth mentioning that the included variables were age, experience, BMI, education levels, type of occupied, smoking, traffic load, job stress, noise, WBV, and HAV. Based on MLR models, the final remaining variables which had dramatic roles in BP changes were noise,

WBV, job stress, and drivers' age. Except for the noise, significant positive associations were observed between these variables and BP. Moreover, there were positive associations between noise, WBV, and job stress with increasing HR.

Using the scatter charts (Figure 5), the predicted value compared with the measured values of BP and HR were investigated. It can be seen in Figure 5, increasing the measured values is associated with increases in the predicted values both in BP and HR.

4. Discussion

Although some effects of noise and vibration on body physiological responses were well-reported in the previous studies, there were few field results on the effects of these two harmful occupational agents on the bus drivers in real working condition. This study tried to trace body physiological responses among city bus drivers related to occupationally noise and vibration exposures.

The daily exposures of the studied bus drivers to noise, WBV, and HAV were 79.50 ± 3.51 dB, 0.62 ± 0.16 m/s², and 0.44 ± 0.06 m/s², respectively. The results showed that both for noise and human vibrations, the drivers' exposures on average were lower than the national occupational exposure limits (OEL). Likewise, Golmohammadi et al. [19], Nasiri et al. [20], and Khavanin et al. [21] studies showed that the bus drivers' exposures to noise and vibration were lower than the exposure limits; however, preventive measures should be taken in order to reduce the bus drivers' exposure to noise and vibration, and consequently, its side effects on their health. It is should be noted that OEL is based on some important body response to stimulus dose and it is not definite borderline between safe and dangerous exposures to stimulus.

One of the most important sources for generating noise and vibration is related to the aging of the bus engines. Despite no significant differences observed within different groups of engine ages in terms of noise exposure, based on Ebrahimi et al. study [14], the location of the engine and its age were the most influential factors affecting the noise levels in buses. Moreover, in terms of vibration, Nasiri et al. [20] reported that bus type and engine age were two important factors affecting the levels of the bus drivers' exposure to vibration. In the same way, our results verified that both bus type and engine age affected the vibration exposures of the bus drivers. Thus, periodic services as well as switching the older buses with the new ones can reduce their exposures to noise and vibration.

The current findings showed that most drivers (87.4 %) had severe job stress. The physical condition is the most responsible factor that caused job stress. The bus drivers' job stress may be due to several sources such as improper ergonomics situations, long working time, and shift work as well as their noise exposure [4, 36]. Abbasi et al. [4] showed that noise has both direct and indirect effects on job stress. The direct effects of noise on job stress happens by means of increasing the levels of Cortisol as well as Adrenaline and Noradrenaline hormones. Besides, the indirect effects of noise on job stress are related to noise annoyance and job satisfaction. Noise exposure is causes to an increase in annoyance as well as a decrease in job satisfaction. Abbasi et al. showed the effect of noise on job satisfaction was higher than noise annoyance. There are a lot of studies showing that lower job satisfaction is associated with higher job stress [37, 38].

Table 1. Descriptive statistics of blood pressure and heart rate of bus drivers before and after driving.

Variables	Measurement condition	Mean	SD	Min	Max	Difference of means	SE	P value
Systolic BP (mmHg)	Before driving	118.34	2.31	111	128	7.73	0.56	<0.001
	After driving	126.07	7.72	110	149			
Diastolic BP (mmHg)	Before driving	78.09	1.96	73	84	4.65	0.52	<0.001
	After driving	84.72	5.98	72	101			
HR (bpm)	Before driving	74.22	4.11	65	85	5.01	0.50	<0.001
	After driving	79.23	8.59	63	103			

Table 2. Multivariate linear regression models for predicting the changes in BP, and HR among bus drivers.

Predicted Variable	Independent variables	Unstandardized Coefficients		Standardized Coefficients	P value
		B	S.E	Beta	
BP	(Constant)	-18.597	4.203	-	<0.001
	Age	0.135	0.066	0.153	0.045
	Job stress	0.072	0.016	0.204	<0.001
	Noise	2.025	1.063	0.408	0.060
	WBV	11.783	2.835	0.360	<0.001
HR	(Constant)	-14.403	3.219	-	<0.001
	Experience	0.163	0.087	0.160	0.067
	Job stress	0.073	0.015	0.444	0.032
	Noise	2.143	1.041	0.193	<0.001
	WBV	11.735	2.765	0.367	0.020

Note: The models determination coefficients for BP, and HR were $r^2 = 0.299$, and $r^2 = 0.298$, respectively.

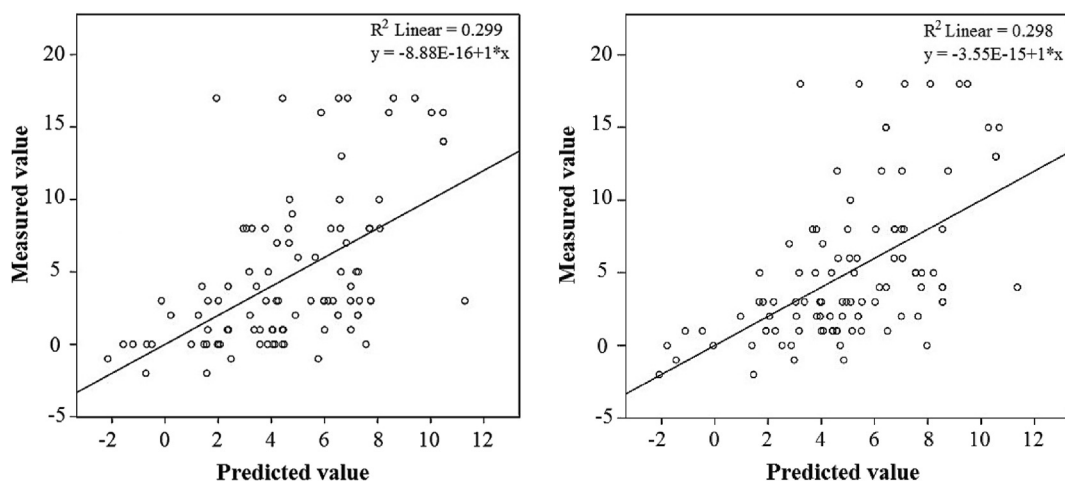


Figure 5. The predicted values compared with the measured values of blood pressure and heart rate.

It should be noted that some advantageous of short-term exposure to vibration is documented by Bemben et al. [6]. It seems that, vibration has both positive and negative effects on human body based on the amount of dose received in a certain period of time. Dionello et al. and Sá-Caputo et al., showed that the positive effects are related to the curative role of vibration in certain frequencies as a rehabilitation approach to subside the musculoskeletal pains as well as other adverse effects in people suffering from metabolic syndrome [39, 40, 41]. In terms of occupational exposures, long term exposure to vibration can induce some adverse effects on human body. Based on the developed MLR models, it was found that exposure to WBV can affect the drivers' BP and HR. Previous studies also discussed the possibility of cardiovascular diseases due to chronic exposure to WBV [7]. According to a study done by Bhalchandra [42], exposure to vibration is associated with an increase in workload and leads to mental stress; consequently, the parasympathetic nervous system is affected by stress and its activity declined; therefore, the HR increases. Moreover, some pieces of evidence suggest that exposure to vibration can be responsible for vasospasm, and through this mechanism, the physiological parameters would be changed [7, 9].

Along with WBV, drivers' age and their job stress also affect the changes of BP. By increasing the individuals' age, the blood pressure increased due to higher vascular resistance and formation of atherosclerotic plaques [43]. Moreover, previous studies confirmed that the job stress has significant correlation with physiological parameters and reported as a risk factor for cardiovascular diseases [44, 45].

The MLR models showed that the final predictors of changes in drivers' HR were their exposures to noise and WBV as well as their job stress. Noise can lead to stress and an increase in HR by increasing some above-mentioned hormones such as cortisol [4]. In terms to WBV, in addition to previous mechanistic explanation, by increasing vibration exposure, the cortisol level is also increased. In fact increased absorption of vibration has an impact on muscles activity. Therefore, by increasing vibration exposure, muscle activity increases and leads to a higher rate of metabolism, and in this way, the HR also increases [42].

It worth mentioning that noise and vibration are not the only risk factors affecting health of bus drivers. Useche et al. [16] and Lamazares et al. [17] confirmed that another risk factors such as gender, job strain, job security as well as work experience and time of the day are known to be associated with psychological and physiological balance of bus drivers, and consequently, have significant roles in driving performance.

The present study was an attempt to identify some physiological effects of exposure to noise and vibration among city bus drivers. One of the strengths of the study was providing field observations and creating experimental data of exposure – response.

As one of the limitation of the study, due to conducting the study in real driving conditions, it was not possible to determine the separate effect of noise and vibration factors on body responses. The second important limitation is related to the sample size, which due to the number of working drivers, it was not possible to increase the number of samples. The third limitation is related to the collaboration of participants; while in simulation studies, more tests and also more physiological parameters can be measured, in the field studies, the number of variables is one of the limitations. Therefore, the changes in BP and HR of the participants were the only measured parameters. Moreover, due to the small size of the cigarette smokers in this study, the effects of smoking on physiological parameters were not observed. Also, the effects of traffic load may be masked by other variables such as WBV. It is highly recommended to design more comprehensive studies in laboratories as well as fields with large sample sizes to identify the causes and predictors of changes in the physiological parameters.

5. Conclusion

This study aimed to explore empirical evidences about body physiological responses among bus drivers due to noise and vibration exposure. It was found that the exposures of bus drivers to noise, WBV, and HAV were lower than the exposure limits. The finding verified that exposure to noise and vibration in the presence of other possible covariates has significant effects on body physiological responses. It is highly

recommended that occupational health surveillance, as well as continuous physiological health monitoring, be done for bus drivers concerning their noise and vibration exposures levels. Moreover, regarding the adverse effects of bus ages on producing more noise and vibration, it is highly recommended that periodic investigations and maintenance services were established for buses as well as replace worn-out buses with new ones.

Declarations

Author contribution statement

Ramin Rahmani: Performed the experiments.
 Mohsen Aliabadi & Rostam Golmohammadi: Conceived and designed the experiments.
 Ramin Rahmani & Mohsen Aliabadi: Wrote the paper.
 Mohammad Babamiri: Contributed reagents, materials, analysis tools or data.
 Maryam Farhadian: Analyzed and interpreted the data.

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Data availability statement

The data that has been used is confidential.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at <https://doi.org/10.1016/j.heliyon.2022.e10329>.

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