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ORIGINAL ARTICLE

Exposure to Vibration and Its Relationship with the Low-back Pain in the Drivers of Mining Heavy Vehicles

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ABSTRACT

Vibration can disrupt comfort, decrease effective labour and adversely affect peoples' health and safety. This study aimed to evaluate vibration and its relationship with lower-back pain in drivers of heavy vehicles in the mines of Sirjan Gol Gohar Complex. This cross-sectional study was conducted on drivers of heavy vehicles in mines of Sirjan Gol-e-Gohar Complex, Kerman Province, Iran in 2013. The statistical population consisted of 432 (216 cases and 216 controls) people. Data were collected using Nordic questionnaire. Data were analyzed using SPSS20 software and statistical tests including t-test, ANOVA, chi-square and logistic regression test. Moreover, $P<0.05$ was considered significant. The prevalence of musculoskeletal disorders was significantly different in all three study aspects: in the past 12 months, in the past 12 months which resulted in limited activities and in the past 7 d in waist and back of drivers and non-drivers ($P<0.05$) (the incidence was more in drivers). Moreover, vibration was the main factor causing musculoskeletal disorders in the back ($P=0.01$).Vibration is a major factor causing musculoskeletal disorders in the back. Therefore, some suitable preventive measures must be taken to reduce exposure to vibration and to control it.

KEYWORDS: *Vibration, Low back pain, Musculoskeletal disorders, Vehicle, Drivers*

INTRODUCTION

All mechanical equipment (land, air, sea) used in industry, agriculture, and transportation causes humans to be exposed to vibrations that can disrupt comfort, decrease effective labour and adversely affect peoples' health and safety.

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In addition to causing vibration, such machines are the main source of noise in industries [1]. Vibration may be periodic and non-periodic. Periodic vibration can be either simple or complex. Non-periodic vibrations are oscillations that have no regular period. Most of the important mechanical vibrations have the frequency of 1-2000 Hz. Vibrations produced in industries are mainly non-periodic [2].

Like other elastic environments, the human body is able to accept and produce a vibration; human remarkable vibration is frequencies less than 2000 Hz, but the vibrations which include the normal range are between 1 to 80 Hz [1]. Frequent and prolonged exposure to high levels of vibrations can have deleterious effects on the health of organs [3-4]. Severe vibrations and oscillations can reduce the efficiency of labor. In addition, disruptive vibrations and oscillations are stressful, tiring and sometimes dangerous [5].

The most common complaints of workers exposed to harmful occupational factors are musculoskeletal pains. Several factors such as gender, age, smoking and metabolic disorders have a role in musculoskeletal disorders, but the relationship between these disorders and occupation is mainly based on ergonomic and physical factors of the work environment. Doing routine and static jobs, unfavorable conditions of the work environment, poor physical conditions, using muscles more than their power and vibration are some of these factors [6]. Some of the complications of vibration including hand-arm syndrome, low back pain, prostate, hemorrhoids and cardiovascular disorders are reported [6]. Moreover, neurological, digestive and respiratory disorders and decreased gastric motility are other disorders caused by vibration [7, 9].

Driving (especially as a profession) is one of the factors which cause the people and especially the drivers to be exposed to considerable vibrations [1]. Professional drivers are at higher risk of backaches and other disorders related to the spine [10]. Demographic studies conducted in the United States of America [11] and Canada [12] have reported that the prevalence of back pain among drivers is 1.6 and 2 times more than the standard prevalence [13]. Gastrointestinal, venous, musculoskeletal and respiratory diseases were more prevalent in bus drivers than in non-drivers [14].

Truck drivers constitute a large population exposed to whole body vibration for a long time; it is associated with low back pain [12]. Thus, it is very difficult to consider only one risk factor as the main cause of low back pain in truck drivers.

Since vibrations can disrupt peoples' normal activities, daily life and health and since many Iranian people working in industries including mines are exposed to this harmful factor, it is necessary to take some measures to control and improve working conditions and health conditions of people exposed to vibrations.

The aim of this study was to evaluate vibration and its relationship with lower-back pain among heavy vehicle drivers in the mines of Sirjan Gol Gohar Complex.

MATERIALS AND METHODS

This cross-sectional study was conducted on heavy vehicle drivers in the mines of Sirjan Gol-e-Gohar Complex, Kerman Province, Iran. Samples were selected through the census. Totally, 288 drivers with 92 cars worked in four 8-h shifts. About 72 drivers were excluded from the study due to skeletal diseases, inflammatory and metabolic disorders, spinal trauma, congenital disorders, driving less than a year and unwillingness to cooperate; the remaining 216 drivers who were willing to participate in the study were examined. Moreover, 216 people (from other jobs in the same industry) not exposed to the vibration (sale section, telecommunications, etc.) were randomly selected from the control group in compliance with all the inclusion criteria.

The evaluation basis for musculoskeletal disorders in the back and waist areas of the drivers was the standard Nordic questionnaire. This questionnaire provides information about whether there has been a problem in 9 anatomical areas of the body over the past 12 months, whether these problems have caused them to quit their job or to be unable to work or whether there have been problems in the past 7 d in one of these areas [15, 17].

To measure whole body vibration, a calibrated SVAN 958 vibration meter and SV 39 A/L whole body disc sensor (with a 10 mV/ms^{-2} sensitivity rate) was used in order to measure WBV. Concerning the work cycle of each vehicle and the related secondary cycles, the vibration was measured in a way that all cycle steps of each vehicle were covered. The measurement time of vibrations and the position of the sensor of the vibration meter were in accordance with the ISO 2631-1-(1997) standard [18]. All measurements were taken in normal working conditions of the vehicles; the average measurement was used to eliminate the impact of existing interventions including road surface and tire type, etc. as much as possible. Results related to vibration measurements were published by the authors in a study entitled "evaluating vibration in heavy vehicles in Sirjan Gol-e-Gohar Complex [19].

Data were analyzed using SPSS 20 (Chicago, IL, USA). Descriptive and statistical tests such as *t*-test and chi-square were used to compare frequencies; in addition, logistic regression test was used to examine the relationship between musculoskeletal disorders over the past 12 months and limited personal activities and other variables. In all statistical tests, $P<0.05$ was considered significant.

All issues related to ethical considerations including obtaining informed consents, clarifying the objectives of the study and confidentiality of the information were observed.

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RESULTS

Overall, 432 people (216 subjects and 216 the control group) with an average age of 34.29 yr (subjects) and 32.34 yr (the control group) and an average work experience of 52.78 months (subjects) and 71.87 months (the control group) participated in this study. Table 1 showed demographic features and the comparison between these two groups.

The prevalence of musculoskeletal disorders in the waist area in the past 12 months was 56.9% in the drivers and 38% in the non-drivers. Moreover, the prevalence of musculoskeletal disorders in the low-back area was 49.5% and 31% in drivers and non-drivers, respectively. Musculoskeletal disorders in the back (P<0.001) and the waist (P<0.001) were significantly different in both groups, and they were higher in drivers than in non-drivers (Table 2). The prevalence of musculoskeletal disorders in the back (over the past 12 months) which decreased daily activities was 17.1% and 10.6% in drivers and non-drivers respectively; concerning the low-back area, it was 17.6% and 9.3% in drivers and non-drivers respectively. Concerning musculoskeletal disorders which caused occupational restrictions, there was a significant difference between both groups (P=0.01 in the back and P=0.049 in the low back) (Table 2).

Concerning musculoskeletal disorders in the back over the past 7 d, the prevalence was 31.9% and 13% in drivers and non-drivers respectively; in the low back area, it was 29.2% and 14.4% in drivers and non-drivers respectively. There was a significant difference between both groups (P<0.001 in the back and P<0.001in the low back) (Table 2).

Table 1. Describe the demographic variables and factors affecting at musculoskeletal disorders in case and control groups

Variable		Case	Control	*P*-Value
		Mean (SD)	**Mean (SD)**	
Age (yr)		34.29 (7.85)	32.34 (6.50)	∗0.005
Work Experience (month)		52.78 (47.03)	71.87 (64.84)	∗0.001
Daily working hours (hour)		8.56 (1.38)	8.44 (0.85)	0.260
Height (cm)		175.55 (7.07)	175.45 (8.4)	0.890
Weight (kg)		78.88 (11.26)	77.28 (11.67)	0.150
BMI		25.60 (3.36)	25.09 (3.64)	0.130
Work Experience:10 past yr (month)		80.05 (56.98)	24.05 (35.02)	∗<0.001
		Frequency (percent)	**Frequency (percent)**	***P*-Value**
Exercise	Yes	114 (52.8)	140 (64.8)	∗0.014
	No	102 (47.2)	76 (35.2)	
Smoking	No	190 (88)	199 (92.1)	0.056
	Casual	18 (8.3)	16 (7.4)	
	Regular	8 (3.7)	1 (0.5)	
Alcohol Consumption	Yes	6 (2.8)	0 (0.0)	∗0.030
	No	210 (97.2)	216 (100.0)	
Non-occupational disease	Yes	6 (2.8)	6 (2.8)	1.000
	No	210 (97.2)	210 (97.2)	

***Significant**

Table 2. Frequency of Musculoskeletal disorders based on Back and Low-Back organs in Cases and control groups

Organs	Status	Musculoskeletal disorder during the past 12 months			Musculoskeletal disorder during the past 12 months with restriction			Musculoskeletal disorder during the past 7 d		
		Case	Control	*P*-Value	Case	Control	*P*-Value	Case	Control	*P*-Value
Back	Yes	107	67	∗<0.001	38	20	∗0.010	63	31	∗<0.001
	No	109	149		178	196		153	185	
Low Back	Yes	123	82	∗<0.001	37	23	0.049	69	28	∗<0.001
	No	93	134		179	193		147	188	

***Significant**

Musculoskeletal disorders in the previous 12 months associated with restrictions in activities were the most prominent musculoskeletal disorders, and the relationship between them and different variables including whole body vibration, age, work experience, body mass index, smoking and exercise was examined.

In the univariate regression test, whole body vibration had a significant relationship with the musculoskeletal disorders on the back (P=0.003) and on the low back (P=0.021); as vibration increased by one unit, the risk of

musculoskeletal disorders increased by 82.6% and 58.1% in the low back and in the back.

Moreover, age had a significant relationship with musculoskeletal disorders in the back (P<0/001); as age increased by one year, the risk of musculoskeletal disorders increased by 7.1% in the back. A significant relationship was observed between work experience and musculoskeletal disorders in the back (P=0.003). As work experience increased by one month, the risk of musculoskeletal disorders increased by 0.6% in the back. Moreover, smoking had a significant relationship with musculoskeletal disorders in the back (P=0.033). The risk of musculoskeletal disorders in the back was 86.6% more in smokers than in non-smokers. In addition, exercise had a significant relationship with musculoskeletal disorders in the back (P=0.021). The risk of musculoskeletal disorders in the back was 47.7% less in people who exercised than in those who did not exercise. No significant difference was observed between body mass index and musculoskeletal disorders in different parts of the body (Table 3).

In multivariate logistic regression test, there was a significant relationship between vibration and musculoskeletal disorders (P=0.011) by entering the variables "vibration, age, work experience, body mass index, smoking, and exercise" together into the model. Examining the ratio between vibration and musculoskeletal disorders in different areas of the body, it was observed that as vibration increased by one unit, the risk of musculoskeletal disorders in the back increased by 71.5%. The variables "age, work experience, smoking, body mass index, and exercise" had no significant relationship with musculoskeletal disorders in the back and low back (Table 3).

Table 3. Regression logistic Affection of variable on MSDS in past 12 months with activity restriction on Back and low back organs

Organs			Variable					
			Vibration	**Age**	**Work Experience**	**BMI**	**Smoking**	**Exercise**
Back	Crude	*P*-Value	*0.003	0.15	0.42	0.146	*0.033	0.145
		CI %95	1.24-2.70	0.99-1.06	0.99-1.01	0.98-1.14	1.05-3.31	0.38-1.15
		OR	1.826	1.026	1.002	1.059	1.868	0.662
	Adjusted	P-Value	*0.011	0.937	0.478	0.215	0.066	0.284
		CI %95	1.13-2.6	0.95-1.05	0.99-1.009	0.97-1.14	0.96-3.15	0.41-1.3
		OR	1.715	0.998	1.002	1.052	1.743	0.729
Low Back	Crude	P-Value	*0.021	*<0.001	*0.003	0.197	0.177	*0.021
		CI %95	1.07-2.33	1.03-1.11	1.002-1.01	0.97-1.13	0.82-2.76	0.3-0.9
		OR	1.581	1.071	1.006	1.051	1.513	0.523
	Adjusted	P-Value	0.129	0.071	0.322	0.300	0.378	0.115
		CI %95	0.91-2.12	0.99-1.09	0.99-1.009	0.96-1.13	0.71-2.49	0.35-1.12
		OR	1.390	1.043	1.003	1.044	1.329	0.630

***Significant**

DISCUSSION

Examining the average whole-body vibration in different types of the vehicles revealed that the highest overall equivalent acceleration of the whole body was found in Graders with 2.179 ms2, and bulldozers were next with 1.738 ms2; the lowest overall equivalent acceleration was found in drills with 0.479 ms2. Comparing the overall equivalent acceleration of the vehicles with the related standards, the overall equivalent acceleration was higher than the 8-hour care standard limit in all vehicles except for drills [19]. The prevalence of musculoskeletal disorders in the back and low back area was significantly different between drivers and non-drivers, with drivers having the highest incidence. Moreover, the vibration was a major factor causing musculoskeletal disorders in the back.

Musculoskeletal disorders were evaluated in both groups in three aspects including the last 12 months, the last 12 months with limited activities and the last 7 days. Concerning musculoskeletal disorders in the last 12 months, there was a significant difference between both groups in the low-back area (P<0.001) and the back (P<0.001); these disorders were higher in the drivers than in non-drivers. Certainly, many factors were involved in musculoskeletal disorders, but vibration was one of the main factors causing these disorders.

Concerning musculoskeletal disorders in the last 7 d, there was a significant difference between both groups in the low back area (P<0.001) and the back (P<0.001); these disorders were higher in the drivers than in non-drivers.

Concerning other studies which examined musculoskeletal disorders in the last 12 months with limitations in the activity [20], this study mainly interpreted the results and compared them with the results of other studies.

Musculoskeletal disorders caused some problems for the people including pain, discomfort or fatigue in different areas of the body and limited their everyday work activities in the last 12 months. These disorders were significantly different in both

groups in the low back area (P=0.01) and in the back (P=0.049).

The prevalence of back disorders was 56.9% in drivers in the last 12 months. The whole body vibration was evaluated and its relationship with a backache in professional drivers and reported that the prevalence of a cumulative backache, severe back pains and disability of the low-back area were 36.3%, 24.6% , and 19.2%, respectively in the last 12 months [21]. Back area disorders were 60% of professional truck drivers in the last 12 months [22]. The prevalence of a backache was 84% in bus drivers; it was higher than the results of another study [23]. It could be due to some factors including high levels of bending and twisting, long working hours and psychological factors which had less important roles in other studies [23].

The relationship between smoking and backaches was meaningful in most of the epidemiological studies; however, it is only risk factor [24]. Examining individual risk factors in the prevalence of backaches, age and smoking along with a history of injury, the relative power and gender were the most important variables [25]. Concerning smoking and back disorders, there were various pathogenic hypotheses including accelerated degeneration in all parts of the spinal column due to reduced blood flow nicotine and coughs resulted from the smoke that caused mechanical stress on the back [24-26].

In the present study, whole body vibration was the only significant factor in back disorders. Vibration played a major role in causing back disorders. There is a significant relationship between exposure to whole-body vibration in a sitting position and back pain [21, 27-28]. Although backaches increase in some jobs which cause people to be exposed to whole body vibration, vibration cannot be considered the only factor increasing the backache [29].

Another result of this study was the effect of exercise on musculoskeletal disorders; that is, physical activity decreased musculoskeletal disorders by 47.7%. However, the fact that exercise could affect musculoskeletal disorders was investigated in none of the articles searched and referred to in the present study.

In the present study, back disorders in drivers were 49.5% in the last 12 months, and 17.6% of back disorders caused limitations in the activities of the drivers in the last 12 months. Back disorders were much less than those found in the present study (12%); it could be because the vehicles examined in the present study were more powerful and had higher capacities, while vehicles with the capacity of 3.5 tones were examined. In addition, relatively high levels of back pain among tractor drivers observed in a study were related to greater levels of vibration, shock, bending and twisting mainly observed in operators of agricultural machinery [30].

In this study, a significant relationship was observed between the body mass index and back disorders in the last 12 months. This relationship was also observed in another study [22].

Most studies conducted on the relationship between vibration and its complications and health status are of cross-sectional and case-control types that are less valid than prospective cohort studies. Cohort studies must be carried out to obtain more detailed information about the impact of effective factors and risk factors in this field.

Limitations of this study included technical damages and defects of mining machinery; after repairing and fixing the machinery, the vibration was measured and the questionnaires were completed.

CONCLUSION

Vibration was a factor causing musculoskeletal disorders in the back area. Thus, appropriate control measures must be taken to reduce exposure to vibration and to control it such as regular screening to identify susceptible people with musculoskeletal disorders, replacing old vehicles, maintaining vehicles regularly, checking the conditions of seats, making use of vibration insulating materials and springs in vehicle seats and flattening the traffic routes.

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The authors declare that there is no conflict of interests.

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