ORIGINAL ARTICLE

Health Effects of Long-term Occupational Exposure to Whole Body Vibration: A Study on Drivers of Heavy Motor Vehicles in Iran

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Abstract

Background: Drivers of heavy motor vehicles are occupationally exposed to intense whole body vibration (WBV) for several hours per day over their working lifetime. Therefore, they are at risk of WBV-induced occupational disorders. This study aimed to investigate health effects of long-term exposure to whole body vibration among a group of heavy vehicle drivers in Fars province, southwestern Iran.

Methods: Data on vibration-induced health effects were gathered through a checklist specifically devised for this purpose, interview and medical records of 155 male heavy vehicle drivers as well as 70 referent subjects. Signs and symptoms were classified into 6 categories of neuropsychological, gastrointestinal, ocular, auditory and metabolic and cardiovascular disorders.

Results: Symptoms such as neuropsychological, musculoskeletal, metabolic, visual and hearing disorders were significantly more prevalent among drivers than in referent individuals. Additionally, logistic regression analysis revealed that there were statistically significant associations between exposure to WBV and several outcomes.

Conclusion: Findings of the study indicate that long-term occupational exposure to WBV is a risk factor for neuropsychological, musculoskeletal, metabolic, visual and hearing disorders.

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Introduction

Whole-body vibration (WBV) is a form of mechanical vibration transferred to the whole body with the frequency ranging from 2 to 100 HZ.[1] Its long term effects mainly affect the musculoskeletal system.[2] Exposure to WBV is common in industry. For instance, truck and bus drivers, operators of industrial machineries and miners have intense occupational exposure to WBV. It has been estimated that in the United Kingdom alone nearly 7.2 million males and 1.8 million females are occupationally exposed to WBV.[3] Similarly, it has been reported that in the European Union about 40 million workers (more than 30% of the work force) suffer from WBV-induced musculoskeletal disorders.

Reduced visual acuity, gastrointestinal and musculoskeletal disorders, ischemic heart disease, obesity, autonomic nerve dysfunction, prostatitis and decreased peripheral nerve conduction velocity have been reported in male heavy vehicle drivers as a result of exposure to WBV. Additionally, spontaneous abortion and congenital malformations have been observed in the offspring of female motor vehicle drivers.[1,4-7] It is estimated that the total expenses of work-related musculoskeletal disorders in Nordic countries is about 2-5% of gross national product.[8]

Similarly, the annual national cost of musculoskeletal disorders in the United States of America is estimated to be between 45 to 54 billion dollars.[9] Heavy vehicle drivers are exposed to various and complicated vibrations which are transferred to their bodies through different directions. Occupational fatigue, reduced performance and concentration are the direct consequences of working under these conditions, resulting in accidents and injuries.[10-12] Nearly all clinical symptoms of WBV are related to frequencies below 20 Hertz (Hz).[13] Cyclic forces act over a range of frequencies, typically between 0.5 and 80 Hz in forklift truck (forklift) drivers working in UK industries.[14] Epidemiological studies in the US and Canada have indicated that professional drivers are at high risk of International Standardization Organization (LBP) and various spinal disorders and these symptoms are twice as much prevalent as in a group of unexposed referent population.[15] Dupuis and Zerlett in their study on bus and truck drivers reported high prevalence rates of degenerative spinal changes due to exposure to WBV.[16] In 2010, Massimo Bovenzi and colleagues in a study on professional drivers observed that the prevalence of LBP, intense pain and severe disability was 38.6%, 16.8%, and 14.4%, respectively.[17] Milosevic showed significant changes in the diastolic blood pressure, body temperature and visual accommodation time after long-term exposure to WBV.[18] Furthermore, vertebral disorders, in the cervical, thoracic and lumbar regions, chest pain and stomach complaints have been reported by Rosegger and colleagues among tractor drivers with a history of long-term exposure to WBV.[10] Interestingly, the vibration levels of heavy equipment and machineries coincide with those of sensitive body organs and are higher than the ISO[2] standards and permissible levels of WBV.[19-22] To the best of the authors' knowledge, so far, the effects of long term occupational exposure to WBV have not been studied in Iran. Additionally, apart from some case reports, no conclusive epidemiological evidence exists to convincingly demonstrate the possible health effects of long term occupational exposure to WBV. This study was, therefore, undertaken to investigate these issues more thoroughly.

Methods

This was a cross-sectional study in which data were gathered through a checklist designed for this purpose, interview and medical records of male heavy vehicle drivers exposed to WBV. To devise the checklist, the authors conducted a comprehensive search in the literature regarding disorders reported to be associated with exposure to WBV. These were then extracted and classified into 6 categories of neuropsychological, gastrointestinal, ocular, auditory and metabolic and cardiovascular disorders.[4,6,23]

The studied population consisted of 155 male heavy vehicle drivers, all of whom had medical records files and were under active surveillance of a private Industrial Medicine Company in Shiraz for their compulsory annual periodic examinations, when the study was conducted in 2015.

Referent group consisted of all clerical staff (70 healthy males) of an industrial plant in Shiraz. They were similar to the exposed group in terms of age and gender. *Inclusion criterion was history of at least one year of continuous driving experience for exposed and one year of service for referent individuals; the exclusion criteria included history of pre-existing medical conditions such as low back pain and other musculoskeletal disorders, hearing loss, metabolic disorders, and dyslipidemia.* One of the coauthors who is an experienced Occupational Medicine specialist derived the information from the medical records of the drivers.

Chi-square or Fisher's exact test and independent sample t-test were used to analyze the qualitative (low back pain, gastrointestinal symptoms, etc.) and demographic parameters, respectively. Association between exposure to WBV and different outcomes was evaluated by logistic regression analysis. This study was approved by ethics committee of Shiraz University of Medical Sciences. All subjects voluntarily participated in the study. They filled out an informed consent form before participating in the study. Additionally, they were assured that their medical information will be used solely for the sake of research purposes and will remain confidential.

Logistic regression analysis was used to control the effects of potential confounders. The statistical analyses were performed using SPSS statistical software, version 20.

Results

Demographic characteristics of the studied population are shown in Table 1. Apart from weight, BMI, family size and mean value of cigarettes smoked per day, no significant differences were noted between both groups as far as other variables were concerned. Table 2 displays the prevalence of neuropsychological disorders among the studied population.

As shown in Table 2, neurasthenia, nervousness and impatience were significantly more prevalent in heavy vehicle drivers than in referent subjects (P=0.001, P=0.01 and P=0.01, respectively).

Table 3 displays the prevalence of symptoms of musculoskeletal disorders. LBP, disc herniations, sciatica and muscular fatigue were significantly more common among WBV-exposed subjects than in referent population (P=0.001, P=0.01 and 0.001, respectively).

Table 1: Demographic characteristics of the studied population

Variable	Exposed (n=155)		Non-exposed (n=70)		P value†
	Mean	SD	Mean	SD	
Age (yrs)	41.31	7.85	39.56	7.61	0.11
Height (cm)	173.41	4.88	174.73	6.02	0.08
Weight (kg)	81.64	12.56	74.14	10.61	0.001
BMI £	27.39	3.97	24.27	3.19	0.001
Number of children	2.86	1.67	1.31	1.16	0.001
Length of employment (yrs)	15.8	7.99	13.17	7.01	0.06
Number of cigarettes smoked per day	4.58	1.68	5.56	1.33	0.001

† Independent sample t-test; £ Body mass index

Table 2: Prevalence of neuropsychological disorders among the exposed and non-exposed subjects

Variable	Exposed (n=155) N (%)	Non- exposed (n=70) N (%)	P value*
Headache	36 (23.2)	18 (25.7)	0.73
Neurasthenia	137 (88.4)	28 (40)	0.001
Nervousness	85 (54.8)	26 (37.1)	0.01
Aggressive behavior	36 (23.2)	14 (20)	0.72
Impatience	80 (51.6)	23 (32.9)	0.01

*Chi square or Fisher's exact test; P<0.05

Table 3: Prevalence of symptoms of musculoskeletal disorders among the exposed and non-exposed subjects.

Variable	Exposed (n=155) N (%)	Non-exposed (n=70) N (%)	P value*
LBP	83 (53.6)	15 (21.4)	0.001
disc herniations‡	46 (29.7)	10 (14.3)	0.01
Sciatica	47 (30.3)	11 (15.7)	0.02
Knee pain	47 (30.3)	14 (20)	0.14
Neck pain	49 (31.6)	20 (28.6)	0.75
Shoulder pain	42 (27.1)	16 (22.9)	0.62
Muscular fatigue	145 (93.5)	26 (37.1)	0.001

*Chi-square or Fisher's exact test, P<0.05; ‡ Based on medical records

The prevalence of gastrointestinal disorders is shown in Table 4. Prevalence rates of chronic constipation, heartburn and hemorrhoid were significantly higher among heavy vehicle drivers (P=0.007, P=0.001 and P=0.007, respectively).

Results on the prevalence of metabolic and cardiovascular disorders are presented in Table 5. The prevalence rates of hypertriglyceridemia, overweight, hypercholesterolemia and hypertension were significantly higher among heavy vehicle drivers (P=0.02, P=0.001, P=0.03 and P=0.006, respectively).

The prevalence of visual and hearing disorders is displayed in Table 6. Decreased visual acuity, hearing loss and tinnitus among the exposed individuals were significantly higher than those in the non-exposed individuals (P=0.02, 0.002 and P=0.04, respectively).

Figure 1 illustrates the overall prevalence rates of different WBV-related disorders. As shown, the highest and lowest rates were related to neuropsychological and hearing disorders, respectively.

The association between exposure to WBV and the prevalence of different disorders is displayed in Table 7. Logistic Regression Analysis including independent variables of age, BMI, smoking habits, marital status and years of employment in the model showed that after adjusting for these confounders, there were statistically significant associations between exposure to WBV and the prevalence of all sign and symptoms.

Discussion

As shown in Table 1, drivers were, on average, 7 kg heavier than their referent counterparts. This difference which is statistically significant indicates that drivers are more prone to overweight presumably due to the lack of movement and non-sufficient physical activities (P=0.001). Additionally, drivers' family size was significantly larger than that of the non-exposed individuals (P=0.001). No significant difference was

Table 4: Prevalence of Gastrointestinal disorders among the exposed and non-exposed subjects

Variable	Exposed (n=155) N (%)	Non-exposed (n=70) N (%)	P value*
Chronic Constipation	33 (21.3)	5 (7.1)	0.007
Diarrhea	18 (11.6)	6 (8.6)	0.64
Indigestion	21 (13.5)	6 (8.6)	0.37
Abdominal pain	25 (16.1)	9 (12.9)	0.68
Heartburn	68 (43.9)	13 (18.6)	0.001
Hemorrhoids ǂ	33 (21.3)	5 (7.1)	0.007

*Chi square or Fisher's exact test; P<0.05; ǂ Based on medical records

Table 5: Prevalence of Metabolic disorders and cardiovascular diseases among the exposed and non-exposed subjects

Variable	Exposed (n=155) N (%)	Non- exposed (n=70) N (%)	P value*
Hypertriglyceridemia ǂ	35 (22.6)	7 (10)	0.02
Hypercholestrolemia ǂ	37 (23.9)	8 (11.4)	0.03
Elevated fasting blood sugar ǂ	22 (14.2)	8 (11.4)	0.67
Overweight ǂ	89 (57.4)	17 (24.3)	0.001
Hypertension ǂ	28 (18.1)	3 (4.3)	0.006

*Chi square or Fisher's exact test; P<0.05; ǂ Based on medical records

Table 6: Prevalence of visual and hearing disorders among the exposed and non-exposed subjects

Variable	Exposed (n=155) N (%)	Non-exposed (n=70) N (%)	P value*
Decreased visual acuity	71 (45.8)	21 (30)	0.02
Cataract ǂ	14 (9)	2 (2.9)	0.15
Tinnitus	28 (18.1)	5 (7.1)	0.04
Hearing loss ǂ	22 (14.20	1 (1.4)	0.002

*Chi-square or Fisher's exact test; P<0.05; ǂ Based on medical records

found between the exposed and non-exposed groups with respect to age, height and length of employment.

According to Table 2, significant differences were noted between the exposed and non-exposed individuals as far as symptoms of neuropsychological disorders such as neurasthenia, nervousness and impatience were concerned. In line with these findings, in some studies, psychological fatigue, irritability and headache have been reported as a result of exposure to WBV.[24]

Concerning the symptoms of musculoskeletal disorders, significant differences were noted between the prevalence rate of LBP, muscular fatigue and disc hernitation among the exposed and non-exposed groups (Table 3).

Consistent with this finding, Kumar and colleagues showed that WBV and occupational posture were two crucial causal factors of musculoskeletal disorders.[25] In contrast, Battié MC and colleagues[26] noted that disc degeneration did not differ between occupational drivers and their twin brothers. They also did not identify any overall tendency for greater degeneration or pathology in occupational drivers than their twin brothers.

While the exact reasons of these discrepancies are not known, factors such as differences in the drivers' age, frequency and intensity of WBV to which they were exposed, length of their exposure to WBV as well as the model of the vehicles they drove may explain, at least in part, these inconsistencies.

Table 4 shows that symptoms of gastrointestinal disorders such as hemorrhoids, heartburn and chronic constipation were significantly more common in drivers than in referent subjects.

Although similar observations have been reported by others,[27,28] the authors maintain that gastrointestinal disorders may not necessarily be causally linked with WBV and the role of other contributing factors such as irregular sleeping time and shift work should not be neglected in this scenario.[27]

Table 6 shows the results of metabolic and cardiovascular disorders. As shown, the prevalence of hypertriglyceridemia, overweight, hypertension and hypercholestrolemia was significantly higher in the exposed group.

In line with this finding, Morris and colleagues have also shown that cardiovascular and coronary

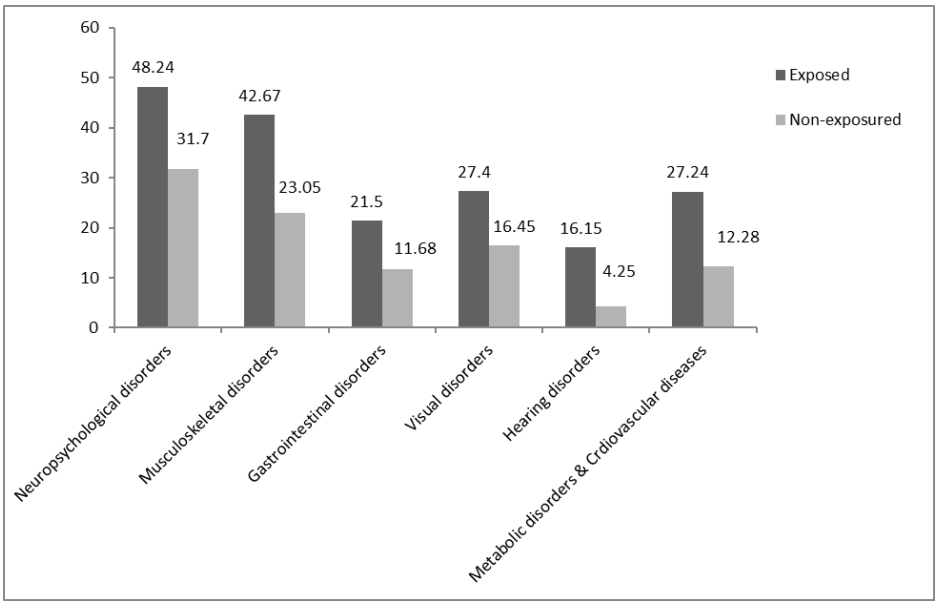

Figure 1: Frequency (%) of health effects associated with occupational exposure to WBV.

Table 7: Association between occupational exposure to WBV and prevalence of different disorders

Variable	Odds ratio	95% CI	P value ą
Nervousness	2.05	0.27-0.86	0.015
Neurasthenia	11.41	0.04-0.17	0.001
Impatience	2.18	0.33-1.04	0.01
LBP	4.22	0.12-0.45	0.001
disc herniations	2.53	0.18-0.83	0.01
Sciatica	2.33	0.20-0.88	0.02
Muscular fatigue	22.15	0.01-0.09	0.001
Chronic Constipation	3.51	0.10-0.76	0.01
Heartburn	3.42	0.14-0.57	0.001
Hemorrhoids	3.51	0.10-0.76	0.01
Hypertriglyceridemia	2.62	0.16-0.90	0.02
Hypercholestrolemia	2.43	0.18-0.93	0.03
Overweight	4.20	0.12-0.44	0.001
Hypertension	4.85	0.16-0.90	0.01
Decreased visual acuity	1.97	0.27-0.92	0.02
Tinnitus	2.86	0.12-0.94	0.03
Hearing loss	11.41	0.01-0.66	0.01

ą Logistic regression analysis; CI: Confidence Interval

diseases are considerably higher among drivers than in the non-exposed individuals.[29] Reduced blood flow to the heart has been reported as a result of exposure to WBV.[30] Vukas and colleagues exposed an isolated rabbit's heart to WBV with frequencies of 50, 80 and 100 HZ and noticed that as vibration range increases, cardiac output and aortic blood flow decreases.[31]

Table 6 shows that the prevalence of decreased visual acuity, hearing loss and tinnitus is significantly higher among drivers. Reduced visual acuity has been demonstrated as a consequence of exposure to WBV at 5 HZ frequency.[23]

The results of logistic regression analysis (Table 7), where the role of potential confounders was controlled, provided further evidence in favor of a significant causal association between exposure to WBV and the prevalence of symptoms of multi-organ/system disorders.

Conclusion

The findings of this study provide circumstantial evidence to support the notion that long term exposure to WBV is associated with increased prevalence of neuropsychological, musculoskeletal, gastrointestinal, visual, hearing, metabolic and cardiovascular disorders among heavy vehicle drivers. Engineering (ergonomic interventions and designing appropriate chairs to reduce the drivers' exposure to WBV), managerial (reduction of exposure time to WBV), and medical controls (early diagnosis of vibration-induced disorders in periodic

examinations) are recommended to reduce the exposure to WBV and/or to prevent its long term medical and health problems.

This study is subject to a number of limitations. First referent subjects were office staff. Second, quantitative data on drivers' exposure to WBV are not available. Therefore, additional studies in which both exposed and referent subjects are selected from working populations and their exposure are quantified appropriately are strongly recommended to further substantiate these preliminary observations.

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Conflict of Interest: None declared.

References

1 Levy BS, editor. Occupational and environmental health: recognizing and preventing disease and injury. Lippincott Williams & Wilkins; 2006.

2 Directive EU, Provisions GE. Directive 2002/44/EC of the European Parliament and the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration)(sixteenth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC). Official Journal of the European Communities, L 2002; 117(13): 6-7.

3 Palmer KT, Griffin MJ, Bendall H, Pannett B, Coggon D. Prevalence and pattern of occupational exposure to whole body vibration in Great Britain: findings from a national survey. Occup Environ Med 2000; 57(4): 229-36.

4 Harrison RJ. Current occupational & environmental medicine. LaDou J, editor. New York: McGraw-Hill; 2007.

5 Zenz C, Dickerson OB, Horvath 3rd EP. Occupational Medicine 3rd ed. St. Louis: Mosby-Year Book.

6 Rom WN, Markowitz SB, editors. Environmental and occupational medicine. Lippincott Williams & Wilkins; 2007.

7 Sharif Nia H, Doost H, Akbar A, Haji Hoseini F, Hojati H, Javan Amoli M. Effect of Occupational and Psychological Factors in Back Pain Nurses in AMOL City. J Rehabil Med 2012; 12(4): 93-101.

8 Ringelberg JA, Koukoulaki T. Risk estimation for musculoskeletal disorders in machinery design: Integrating a user perspective. European Trade Union Technical Bureau for Health and Safety; 2002.

9 Carayon P, Smith MJ, Haims MC. Work organization, job stress, and work-related musculoskeletal disorders. Human factors 1999; 41(4): 644.

10 Rosegger R, Rosegger S. Health effects of tractor driving. Journal of Agricultural Engineering Research 1960; 5(3): I960.

11 Grandjean E, Kroemer KH. Fitting the task to the human: a textbook of occupational ergonomics. CRC press; 1997 Jul 31.

12 Goglia V, Gospodarić Z, Kosutić S, Filipović D. Hand transmitted vibration from steering wheel to drivers of a small four-wheel drive tractor. Appl Ergon 2002; 34: 45-9.

13 Levy BS, editor. Occupational and environmental health: recognizing and preventing disease and injury. Lippincott Williams & Wilkins; 2006.

14 Hoy J, Mubarak N, Nelson S, De Landas MS, Magnusson M, Okunribido O, et al. Whole body vibration and posture as risk factors for low back pain among forklift truck drivers. J Sound Vib 2005 Jun 21; 284(3): 933-46.

15 Guo HR, Tanaka S, Cameron LL, Seligman PJ, Behrens VJ, Ger J, et al. Back pain among workers in the United States: national estimates and workers at high risk. Am J Ind Med 1995; 28(5): 591-602.

16 Dupuis H, Zerlett G. The effects of whole-body vibration. Springer Science & Business Media; 2012 Dec 6.

17 Bovenzi M. A longitudinal study of low back pain and daily vibration exposure in professional drivers. Ind Health 2010; 48(5): 584-95.

18 Milosevic S. Drivers' fatigue studies. Ergonomics 1997; 40(3): 381-9.

19 International Organization for Standardization. Mechanical vibration and shock-Evaluation of human exposure to whole-body vibration-Part 1: General requirements. The Organization; 1997.

20 Wasserman DE, Doyle JE, Asburry WC. Whole-body vibration exposure of workers during heavy equipment operation. InWhole-body vibration exposure of workers during heavy equipment operation 1978. Department of Health, Education, and Welfare. NIOSH.

21 Hansson JE, Wikström BO. Comparison of some technical methodes for the evaluation of whole body vibration. Ergonomics 1998; 24: 953-63.

22 Crolla D, Horton D, Dale A. C131/84. Vehicle noise and vibration. 1984; 5: 55.

23 Baxter PJ, Aw TC, Cockcroft A, Durrington P, Harrington JM, editors. Hunter's diseases of occupations. CRC Press; 2010 Oct 29.

24 Stellman JM. The ILO Encyclopedia of Occupational Health and Safety: A Multidisciplinary Challenge. International Labour Review 1998; 137(3): 410.

25 Kittusamy NK, Buchholz B. Whole-body vibration and postural stress among operators of construction equipment: A literature review. J Safety Res 2004; 35(3): 255-61.

26 Battié MC, Videman T, Gibbons LE, Manninen H, Gill K, Pope M, et al. Occupational driving and lumbar

disc degeneration: a casecontrol study. Lancet 2002; 360(9343): 1369-74.

27 John LM, Flin R, Mearns K. Bus driver well-being review: 50 years of research. Transportation Research Part F: Traffic Psychology and Behaviour 2006 Mar 31; 9(2): 89-114.

28 Balmes J. Occupational exposures as a cause of chronic airway disease. Environmental and occupational medicine. USA: Lippincott Williams & Wilkins. 2007; 517.

29 Morris J, Kagan A, Pattison D, Gardner MJ, Raffle P. Incidence and prediction of ischaemic heart-disease in London busmen. Lancet 1966; 288(7463): 553-9.

30 Vukas M, Malek I, Hjalmarson A. Myocardial depressant effect of vibrations in the isolated rabbit heart. Scand J Clin Lab Invest 1978; 38(5): 421-4.

31 Futatsuka M, Maeda S, Inaoka T, Nagano M, Shono M, Miyakita T. Whole-body vibration and health effects in the agricultural machinery drivers. Ind Health 1998; 36(2): 127-32.