ORIGINAL ARTICLE

# Low Back Pain and Association with Whole Body Vibration Among Military Armoured Vehicle Drivers in Malaysia

A Rozali, MCommMed (Occup Health)*, K G Rampal, PhD**, M T Shamsul Bahri, MMed Sc***, M S Sherina, MMed (Fam Med) ***, S Shamsul Azhar, MCommMed (Epid) **, H Khairuddin, MMed(Occup Med)*, A Sulaiman, MPH*

*Health Services Division of Malaysian Armed Forces, Kuala Lumpur, **Department of Community Health, Faculty of Medicine, Universiti Kebangsaan Malaysia (UKM), Cheras, ***Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia (UPM), Serdang, Selangor, Malaysia

## SUMMARY

**A cross sectional study was conducted among military armoured vehicle drivers in the two largest mechanized battalions with the objective to determine the prevalence of low back pain (LBP), and its association with whole body vibration (WBV) and other associated factors. A self-administered questionnaire and Human Vibration Meter were used in this study. A total of 159 respondents participated in this study and 102 (64.2%) of them were subjected to WBV measurement. One-hundred-and–seventeen respondents complained of LBP for the past 12 months giving a prevalence of 73.6%. The prevalence of LBP among tracked armoured vehicle drivers was higher (81.7%) as compared to wheeled armoured vehicle drivers (67.0%). The mean acceleration at Z–axis in tracked armoured vehicles (1.09 ± 0.26 $ms^{-2}$) and wheeled armoured vehicles (0.33 ± 0.07 $ms^{-2}$) were the dominant vibration directions. The mean estimated vibration dose value (eVDV) for eight-hour daily exposure at Z–axis (19.86 ± 4.72 $ms^{-1.75}$) in tracked armoured vehicles showed the highest estimation. Based on the European Vibration Directive (2002), the mean eVDV at Z–axis in tracked armoured vehicles exceeded exposure action value (EAV) (> 9.1 $ms^{-1.75}$), but did not exceed exposure limit value (ELV) (<21.0 $ms^{-1.75}$). Logistic regression analysis revealed that only driving in forward bending sitting posture (OR=3.63, 95% CI 1.06–12.42) and WBV exposure at X-axis (OR=1.94, 95% CI 1.02–3.69) were significant risk factors to LBP. Preventive measures should be implemented to minimize risk of WBV and to improve ergonomic postures among drivers.**

**KEY WORDS:**
*Low-back pain, Whole-body vibration, Military armoured vehicle drivers, Tracked armoured vehicles, Wheeled armoured vehicles, Estimated vibration dose value (eVDV)*

## INTRODUCTION

Low back pain (LBP) is defined as back pain or discomfort in the lower back region between the twelfth rib and gluteal folds, with or without radiating pain down one or both legs, lasting one day or longer in the previous seven days (7 day LBP) or the previous 12 months (12-month LBP) [1, 2]. Whole body vibration (WBV) is the mechanical vibration transmitted to a person's entire body via contact with a vibration source, usually through sitting or standing on a vibrating surface [3]. Many epidemiological studies on LBP among occupational drivers and its association with WBV exposure in high vibration vehicles have been published such as in agricultural tractors [4, 5], rally cars [6], helicopters [7], forklift trucks [8], railroad locomotives [9], buses [10] as well as military vehicles [11].

Military vehicles comprise a wide range of types of vehicles from track laying tanks and armoured vehicles to on/off highway trucks and jeeps. Military armoured vehicles are equipped with armour protections which include weapons against hostile attacks and equipments for driving in rugged terrain. It can be categorized into tracked armoured vehicles and wheeled armoured vehicles. Tracked armoured vehicles are superior to wheeled armoured vehicles on soft ground, crossing ditches and have greater mobility performances. Wheeled armoured vehicles are for reconnaissance and peace keeping missions due to their higher road speeds and can be deployed in larger numbers [12, 13]. Exposure to WBV is one of the physical hazards that give rise to long-term adverse health effects; particularly musculoskeletal disorders (MSD) among the army personnel handling the armoured vehicles. Consequences of these MSD particularly LBP are frequently related to absenteeism, disability, hospitalization and poor performances in active army personnel[14, 15].

Beevis and Forshaw[11] and Dupuis and Zerlett[16] reported their observations on the health of military armoured vehicle drivers. Beevis and Forshaw[11] reported 88.0% of tracked armoured personnel carrier (APC) drivers complained of LBP as compared to 55.0% of slow moving battle tank drivers in the U.S. Army. Dupuis and Zerlett[16] reported 68.7% out of 353 operators of earth-moving machines which included military armoured vehicle operators complained of spinal discomfort in the lumbar region.

In Malaysia, military armoured vehicle drivers are qualified drivers who are specifically trained to drive and handle armoured vehicles. They must be medically healthy, fit and ready to be deployed at all times [17]. Any MSD related to long-term WBV exposure such as LBP might affect their strength, loss of active duty time and capability as well as occupational performance. However, studies done among military drivers in Malaysia related to WBV and its adverse health effects are few. Therefore, the objective of this study was to determine the prevalence of LBP, and its association with WBV and

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*Corresponding Author: Rozali Ahmad, Health Services & Division of Malaysian Armed Forces, Kuala Lumpur, Malaysia*
*Email: rozaliqhmad@yahoo.com*

other associated factors among military armoured vehicle drivers. There was a prediction that the prevalence of LBP among armoured vehicle drivers was high and WBV was one of the main risk factor to develop LBP.

## MATERIALS AND METHODS

### Study background and design

This cross sectional study was conducted among military armoured vehicle drivers in the two largest mechanized battalions in an army camp in Malaysia. It was carried out from June 2006 until mid-August 2006. The sampling frame consisted of the name list of qualified armoured vehicle drivers provided by the selected mechanized battalion's administration office. Sampling units consisted of military drivers qualified as armoured vehicle drivers fulfilling the selection criteria. Universal sampling was used to select the study sample using inclusion and exclusion criteria during the study period.

Inclusion criteria involved: (1) respondents who qualified as armoured vehicle drivers, (2) respondents who drove armoured vehicles (tracked or wheeled) for a duration of three months and more, (3) respondents who were present in the camp during the data collection period, and (4) the availability of the armoured vehicles assigned to the respondents. Respondents were excluded if they had: (1) history of LBP before joining the armed forces, (2) history of LBP before qualifying as armoured vehicle drivers, (3) history of trauma or surgical procedure to the lower back; (4) not present in the camp during the data collection period (this involved drivers who were attending courses, involved in military exercise (local or oversea), on-leave or medical leave) and (5) been assigned to armoured vehicles categorized as 'not operational'.

### Instruments

A validated self-administered questionnaire adopted from Magnusson *et al.*[18], Nordic Questionnaire[19] and General Health Questionnaire (GHQ 12)[20,21] were used to determine the demographic information, working environment, previous occupational history information, MSD complaints and mental health status.

The Human Vibration Meter (MAESTRO, 0.4 – 1000Hz) was used to assess the level of WBV measurement, which has been designed and compatible according to the ISO 2631 – 1(1997) standard[22]. Calibration and pre-testing was done based on standard procedure to ensure the accuracy of the equipments prior to actual measurements.

### Data collection techniques

The interview was conducted in a hall or rooms at the respective mechanized battalions. The selected armoured vehicle drivers were gathered, and the purpose of the study and method of answering the questionnaire was explained by the researcher. Written consent was obtained from all respondents.

Measurement of WBV was conducted among the selected respondents based on appointed schedules during the data collection period. The WBV measurement was based on standard of procedure of the ISO 2631-1 (1997)[22]. The MAESTRO was used to measure WBV in 30 minutes exposure for each driver. Measurements were done by qualified personnel in handling the equipment. The process of WBV measurement was explained to each respondent. The transducer was placed at the centre of the seat and plastered to avoid any movement between the transducer, the seat and the respondent's back. The arrow of X-axis on the transducer was placed directly to the vehicle steering. The transducer was connected to the MAESTRO via a connection optic wire. All selected respondents were required to sit and drive for 30 minutes duration on selected tar-road-surface designs. Speed was maintained within the range of 35 km/hour to 40 km/hour. Duration of time was monitored using a digital watch.

The acceleration of WBV at X, Y, Z-axes and sum of all axes (XYZ) was recorded in the MAESTRO and the data was transferred to the researcher's personal lap top using the MAESTRO software. The acceleration of the vibration was interpreted in average of 30 minutes exposure in meter per second squared root means square ($ms^{-2}$ r.m.s). Estimated vibration dose value (eVDV) was then calculated and it was based on estimation in eight-hour daily exposure in meters per second to the power of 1.75 ($ms^{-1.75}$). Mean or median eVDV in each axis (X, Y and Z) was obtained and the axis giving the highest reading or dominant direction was used in the assessment of exposure severity. The result was then compared to the vibration dose value (VDV) standardized for exposure action value (EAV) (9.1 $ms^{-1.75}$) and exposure limit value (ELV) (21.0 $ms^{-1.75}$) according to the European Vibration Directive (2002)[23].

### Statistical analysis

All data from the questionnaire and MAESTRO software were then analysed using the SPSS (Statistical Package for Social Science) 11.5 version. Descriptive analysis was used to determine mean, standard deviation, frequency and percentage. Bivariate analysis was used to determine the association of the dependent and independent variables. The p-value was considered significant if less than 0.05 ($p<0.05$). Logistic regression analysis was used to determine the strength of WBV and other associated factors.

### Ethics Committee Approval

Ethical approval was obtained from the Ethics Committee of the Universiti Kebangsaan Malaysia (UKM), Malaysia. Permission to conduct the study at the field was obtained from the Brigade Mechanized Commander and Commanding Officers-in-charge of the respective mechanized battalions.

## RESULTS

One-hundred-and-fifty-nine out of 175 respondents participated in this study, giving a response rate of 90.8%. Sixteen respondents were excluded from this study due to (a) incomplete data in the questionnaires (n=6), (b) driving of armoured vehicles less than three months duration (n=4), (c) history of LBP before joining the armed forces (n=3), and (d) history of LBP before qualifying as armoured vehicle drivers (n=3).

Out of these 159 respondents who completed the questionnaires, 102 respondents (64.2%) had WBV measurements taken while driving their armoured vehicles. Forty-six of these respondents (45.1%) drove tracked armoured vehicles and 56 respondents (54.9%) drove wheeled armoured vehicles. The remaining 57 respondents (35.8%) did not have any WBV measurements due to the inavailability of the respondents themselves or their vehicles during the data collection period.

Socio-demographic, mental health status, occupational background and ergonomic factors of respondents

The mean age of the 159 respondents was 29.8± 4.9 years old, and ranged between 20 and 42 years old. The mean basic income per month was RM1213.60 ± 274.50 and ranged between RM790.00 to RM1810.00. All respondents were male (100.0%). Majority were Malays (80.5%). More than half of the respondents were married (59.7%) and completed upper secondary education (55.3%). Forty-five out of 159 respondents had GHQ 12 scores of 3 and above, giving the prevalence of 28.3% of 'poor mental health status' (Table I).

Forty-point-nine percent out of 159 respondents had ranks of Lans Corporals, followed by Privates (36.4%), Corporals (18.9%) and Sergeants (3.8%). Seventy–one out of 159 respondents (44.7%) were tracked armoured vehicle drivers and 88 (55.3%) were wheeled armoured vehicle drivers. Mean duration of service in armed forces was 10.2 ± 4.7 years and the mean duration of service as armoured vehicle drivers was 5.9 ± 3.6 years. The mean duration for daily routine driving was 106.6 ± 75.2 minutes (1.8 hours), while the mean duration for daily driving during military exercise was 8.5 ± 3.8 hours respectively (Table I).

Other than driving, respondents had to do other work related to the maintenance of their armoured vehicles such as carrying batteries, firearms, bullets, maintenance tools as well as replacing armoured plates, tyres and band track. These included manually lifting, pushing and pulling heavy apparatus. One-hundred-and fifty-six (98.1%) respondents did manual lifting and 112 (70.4%) did pushing and pulling of equipments in their daily work. One-hundred-and-four out of the 159 respondents claimed that their armoured vehicles had backrest support (65.4%). There were several awkward postures adopted by each respondent while driving. Most respondents drove their armoured vehicles in forward bending sitting posture (74.8%). Majority of respondents (88.1%) had experienced their vehicles jerking or jolting during driving (Table I).

Prevalence of LBP

One-hundred-and-seventeen out of 159 respondents complained of LBP for the past 12 months, giving a prevalence of 73.6%. The prevalence of LBP among tracked armoured vehicle drivers was higher (81.7%) as compared to wheeled armoured vehicle drivers (67.0%). Out of these 117 respondents, 50 (42.8%) sought medical treatment from government and private clinics, while the rest sought traditional treatment. Only 38 respondents (32.4%) had been given medical leave due to LBP (Table II).

WBV measurement and evaluation

One-hundred-and-two measurements of WBV for 30 minutes exposure were carried out among drivers of tracked armoured vehicles (n=46) and wheeled armoured vehicles (n=56). The study found that the mean acceleration of WBV at each X ($0.32\ ms^{-2}$), Y ($0.25\ ms^{-2}$) and Z ($1.09\ ms^{-2}$) - axes and the mean sum acceleration of all axes (XYZ) ($1.17\ ms^{-2}$) in tracked armoured vehicles was higher as compared to wheeled armoured vehicles. The mean sum acceleration of all axes (XYZ) in tracked armoured vehicles was 2.7 times higher as compared to wheeled armoured vehicles. The mean acceleration at Z–axis in tracked armoured vehicles ($1.09 \pm 0.26 ms^{-2}$) and wheeled armoured vehicles ($0.33 \pm 0.07\ ms^{-2}$) were the dominant vibration directions (Table III).

It was found that mean eVDV for an eight-hour daily exposure at X ($5.87\ ms^{-1.75}$), Y($4.53\ ms^{-1.75}$) and Z ($19.86\ ms^{-1.75}$) –axis and the mean sum of eVDV in all axes (XYZ) ($21.26\ ms^{-1.75}$) in tracked armoured vehicles was higher as compared to wheeled armoured vehicles. The mean eVDV for an eight-hour daily exposure at Z–axis ($19.86\ ms^{-1.75}$) showed the highest estimation as compared to other axis (X-axis = $5.87\ ms^{-1.75}$, Y-axis = $4.53\ ms^{-1.75}$) in tracked armoured vehicles as well as in wheeled armoured vehicles. The result shows that the mean eVDV for an eight-hour daily exposure in Z–axis exceeded EAV of the European Vibration Directive (> $9.1\ ms^{-1.75}$). However, mean eVDV for an eight-hour daily exposure in Z-axis did not exceed ELV (<$21.0\ ms^{-1.75}$) (Table IV).

Association between socio-demographic, mental health status, occupational background and ergonomic factors with LBP

As shown in Table V, there was significant association between age and LBP ($\chi^2$ =6.430; p=0.011), and marital status and LBP ($\chi^2$ =4.997; p=0.025). Significant association was also observed between mental health status and LBP ($\chi^2$=9.918; p=0.002). There was significant association between certain occupational background factors and LBP such as duration of service in armed forces ($\chi^2$ =8.812; p=0.003), duration of service as armoured vehicle drivers ($\chi^2$=7.403; p=0.007) and category of armoured vehicle drivers ($\chi^2$=4.336; p = 0.037). There was significant association between certain ergonomic factors and LBP such as the use of backrest support ($\chi^2$=4.371; p=0.037), driving in forward bending sitting posture ($\chi^2$=5.074; p=0.024) and experience of vehicle jerking or jolting during driving ($\chi^2$=14.987; p=0.001).

Comparison between WBV and LBP among armoured vehicle drivers

This study found that there was a significant difference between respondents who complained of LBP and respondents who did not complain of LBP in the WBV (eVDV) at X-axis (p<0.05, difference=1.081, 95% CI 0.46-1.71) and Z-axis (p<0.05, difference = 3.348, 95% CI 0.22-6.74). There was also a significant difference in the WBV (eVDV) at the sum of all axes (XYZ) between the respondents with LBP and the respondents without LBP (p<0.05, difference=3.562, 95% CI 0.37-6.75). This showed that the armoured vehicle drivers who complained of LBP were exposed to higher WBV at X-axis, Z-axis and sum of all axes (XYZ) for an eight-hour daily exposure as compared to the armoured vehicle drivers who did not complain of LBP (Table VI).

**Association between selected associated factors and LBP using multivariate logistic regression analysis**
All significant findings in this study were grouped together and multivariate logistic regression analysis was done. This analysis found that there was significant association between two selected associated factors and LBP which were; (1) driving in forward bending posture, and (2) exposure to WBV at X-axis for eight-hour daily exposure ($p<0.05$). Respondents who drove their armoured vehicles in forward bending posture were at risk of LBP almost 4 times higher (OR=3.63, 95% CI 1.06-12.42) as compared to respondents who did not drive in forward bending posture. Respondents who were exposed to WBV at X- axis were almost twice at risk of LBP (OR=1.94, 95% CI 1.02–3.69) (Table VII).

**Table I: Socio-demographic profile, mental health status, occupational background and ergonomic factors of the respondents (n=159)**

| | Mean | SD | Frequency (n) | Percentage (%) |
|---|---|---|---|---|
| **Age (year)** | 29.8 | 4.9 | | |
| **Basic income per month (RM)** | 1213.60 | 274.50 | | |
| **Race** | | | | |
| Malays | | | 128 | 80.5 |
| Indians | | | 2 | 1.3 |
| Others | | | 29 | 18.2 |
| **Marital status** | | | | |
| Single | | | 63 | 39.7 |
| Married | | | 95 | 59.7 |
| Divorced/Separated | | | 1 | 0.6 |
| **Educational level** | | | | |
| SRP / PMR | | | 71 | 44.7 |
| SPM | | | 88 | 55.3 |
| **Mental Health Status** | | | | |
| Normal | | | 114 | 71.7 |
| Poor | | | 45 | 28.3 |
| **Rank** | | | | |
| Private | | | 58 | 36.4 |
| Lans Corporal | | | 65 | 40.9 |
| Corporal | | | 30 | 18.9 |
| Sergeant | | | 6 | 3.8 |
| **Category of armoured vehicle drivers** | | | | |
| Tracked | | | 71 | 44.7 |
| Wheeled | | | 88 | 55.3 |
| **Duration of services in armed forces (year)** | 10.2 | 4.7 | | |
| **Duration of services as armoured vehicle drivers (year)** | 5.9 | 3.6 | | |
| **Average daily routine driving (minute)** | 106.6 | 75.2 | | |
| **Average daily driving during military exercise (hour)** | 8.5 | 3.8 | | |
| **Manual lifting(equipment)** | | | | |
| Yes | | | 156 | 98.1 |
| No | | | 3 | 1.9 |
| **Pushing and pulling(equipment)** | | | | |
| Yes | | | 112 | 70.4 |
| No | | | 47 | 29.6 |
| **Backrest support** | | | | |
| Yes | | | 104 | 65.4 |
| No | | | 55 | 34.6 |
| **Driving in forward bending sitting posture** | | | | |
| Yes | | | 119 | 74.8 |
| No | | | 40 | 25.2 |
| **Vehicle jerking or jolting during driving** | | | | |
| Normal | | | 140 | 881. |
| Poor | | | 19 | 11.9 |

SD = Standard Deviation

**Table II: Prevalence and characteristics of LBP among the respondents for the past 12 months**

| | Frequency (n) | Percentage (%) |
|---|---|---|
| **LBP among armoured vehicle drivers (n=159)** | | |
| Yes | 117 | 73.6 |
| No | 42 | 26.4 |
| **LBP among tracked armoured vehicle drivers (n=71)** | | |
| Yes | 58 | 81.7 |
| No | 13 | 18.3 |
| **LBP among wheeled armoured vehicle drivers(n=88)** | | |
| Yes | 59 | 67.0 |
| No | 29 | 33.0 |
| **Types of treatment received for LBP (n=117)** | | |
| Medical treatment | 50 | 42.8 |
| Traditional treatment | 67 | 57.2 |
| **Medical leave due to LBP (n=117)** | | |
| Yes | 38 | 32.4 |
| No | 79 | 67.6 |

**Table III: WBV acceleration ($ms^{-2}$ r.m.s) measurements for 30 minutes exposure in tracked armoured vehicles (n=46) and wheeled armoured vehicles (n=56).**

| | Tracked (n=46) | | | | Wheeled (n=56) | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Minimum | Maximum | Mean | SD | Minimum | Maximum |
| **X-axis ($ms^{-2}$ r.m.s)** | **0.32** | 0.09 | 0.12 | 0.51 | **0.17** | 0.04 | 0.10 | 0.34 |
| **Y-axis($ms^{-2}$ r.m.s)** | **0.25** | 0.05 | 0.17 | 0.38 | **0.19** | 0.06 | 0.09 | 0.35 |
| **Z-axis ($ms^{-2}$ r.m.s)** | **1.09** | 0.26 | 0.51 | 1.92 | **0.33** | 0.07 | 0.21 | 0.55 |
| **Sum of all axes (XYZ)($ms^{-2}$ r.m.s)** | **1.17** | 0.26 | 0.62 | 1.96 | **0.43** | 0.08 | 0.30 | 0.63 |

**Table IV: WBV measurement in eVDV ($ms^{-1.75}$) for an eight-hour daily exposure in tracked armoured vehicles (n=46) and wheeled armoured vehicle drivers (n=56).**

| | Tracked (n=46) | | | | Wheeled (n=56) | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Minimum | Maximum | Mean | SD | Minimum | Maximum |
| **X-axis eVDV T= 8 hours ($ms^{-1.75}$)** | 5.87* | 1.55 | 3.00 | 9.27 | 3.19* | 0.80 | 1.81 | 6.27 |
| **Y-axis eVDV T= 8 hours ($ms^{-1.75}$)** | 4.53* | 0.83 | 3.17 | 6.93 | 3.41* | 1.13 | 1.61 | 6.31 |
| **Z-axis eVDV T= 8 hours ($ms^{-1.75}$)** | **19.86**** | 4.72 | 9.33 | 35.03 | **6.10*** | 1.22 | 3.88 | 10.08 |
| **XYZ- sum eVDV T= 8 hours ($ms^{-1.75}$)** | 21.26*** | 4.71 | 11.35 | 35.80 | 7.77* | 1.42 | 5.55 | 11.40 |

SD = Standard Deviation
The Physical Agents (Vibration) Directive of European Union (2002))
* Below exposure action value (< 9.1 $ms^{-1.75}$)
** Between exposure action value (9.1 $ms^{-1.75}$ and 20.9 $ms^{-1.75}$)
*** Above exposure limit value (21.0 $ms^{-1.75}$ and above)

**Table V: Association between socio-demographic profile, mental health status, occupational background and ergonomic factors with LBP among the respondents (n=159)**

| | Low Back Pain | | | | | |
|---|---|---|---|---|---|---|
| | Yes (%) | No (%) | Total | $\chi^2$ | p-value | POR (95% Confident Interval) |
| **SOCIO-DEMOGRAPHIC** | | | | | | |
| **Age (year)** | | | | | | |
| 35 year old and above | 30(90.9) | 3(9.1) | 33 | 6.430 | 0.011* | 4.48(1.29 – 15.58) |
| Less than 35 year old | 87(69.0) | 39(31.0) | 126 | | | |
| **Race** | | | | | | |
| Malays | 97(75.80 | 31(24.2) | 128 | 1.629 | 0.202 | 1.72(0.74 – 3.99) |
| Non-Malays | 20(64.5) | 11(35.5) | 31 | | | |
| **Marital Status** | | | | | | |
| Married | 76(80.0) | 19(20.0) | 95 | 4.997 | 0.025* | 2.24(1.10 – 4.70) |
| Single/Divorced/Separated | 41(64.1) | 23(35.9) | 64 | | | |
| **Educational level** | | | | | | |
| SRP/PMR and below | 51(71.8) | 20(28.2) | 71 | 0.203 | 0.652 | 0.85(0.42 – 1.72) |
| SPM and above | 66(75.0) | 22(25.0) | 88 | | | |
| **MENTAL HEALTH STATUS** | | | | | | |
| Poor | 41(91.1) | 4(8.9) | 45 | 9.918 | 0.002* | 5.13(1.71 – 15.37) |
| Normal | 76(66.7) | 38(33.3) | 114 | | | |
| **OCCUPATIONAL BACKGROUND** | | | | | | |
| **Duration of services in armed forces** | | | | | | |
| 15 years and above | 35(92.1) | 3(7.9) | 38 | 8.812 | 0.003* | 5.55(1.61-19.16) |
| Less than 15 years | 82(67.8) | 39(32.2) | 121 | | | |
| **Duration of services as an armoured drivers (years)** | | | | | | |
| 7 years and above | 53(85.5) | 9(14.5) | 61 | 7.403 | 0.007* | 3.04(1.34-6.91) |
| Less than 7 years | 64(66.0) | 33(34.0) | 97 | | | |
| **Category of armoured vehicle drivers** | | | | | | |
| Tracked | 58(81.7) | 13(18.3) | 71 | 4.336 | 0.037* | 2.20(1.04-4.63) |
| Wheeled | 59(67.0) | 29(33.0) | 88 | | | |
| **ERGONOMIC FACTORS** | | | | | | |
| **Backrest support** | | | | | | |
| Yes | 71(68.3) | 33(31.7) | 104 | 4.371 | 0.037* | 0.42(0.18-0.96) |
| No | 87(69.0) | 39(31.0) | 55 | | | |
| **Driving in forward bending posture** | | | | | | |
| Yes | 93(78.2) | 26(21.8) | 119 | 5.074 | 0.024* | 2.39(1.11-5.14) |
| No | 24(60.0) | 14(40.0) | 40 | | | |
| **Vehicle jerking or jolting** | | | | | | |
| Yes | 110(78.6) | 30(21.4) | 140 | 14.987 | 0.001* | 6.27(2.28-17.36) |
| No | 7(36.8) | 12(63.2) | 19 | | | |

Significant at p-value < 0.05*; Chi-square test; POR = Prevalence Odds Ratio

**Table VI: Comparison of WBV (eVDV) and LBP at X, Y, Z-axes and sum of all axes (XYZ) for an eight-hour daily exposure among the armoured vehicle drivers (n=102)**

| | Low Back Pain | | | | |
|---|---|---|---|---|---|
| | Yes (Mean ± SD) (n=74) | No (Mean ± SD) (n=28) | Mean differ (95% Confident Interval) | t - test | p-value |
| X-axis (eVDV $ms^{-1.75}$) | 4.69 ± 1.89 | 3.61 ± 1.18 | 1.08 (0.46-1.71) | 3.440 | 0.001* |
| Y-axis (eVDV $ms^{-1.75}$) | 4.01 ± 1.17 | 3.67 ± 1.05 | 0.34 (-0.16-0.85) | 1.357 | 0.178 |
| Z-axis (eVDV $ms^{-1.75}$) | 13.26 ± 7.60 | 9.78 ± 7.20 | 3.49 (0.22-6.74) | 2.145 | 0.037* |
| Sum of all axes (XYZ) (eVDV $ms^{-1.75}$) | 14.83 ± 7.50 | 11.27 ± 7.02 | 3.56 (0.37-6.75) | 2.243 | 0.029* |

Significant at p-value < 0.05*; Independent t test; SD = Standard Deviation

**Table VII: Association between selected associated factors and LBP among the respondents (n = 102)**

| Selected Associated Factors | Regression Coefficient (β) | OR (95% Confident Interval) | p-value |
|---|---|---|---|
| Constant value | -0.328 | | 0.930 |
| **Age (year)** | -0.109 | 0.90 (0.62-1.30) | 0.563 |
| **Mental health status** | | | |
| Poor** | 0.679 | 1.97 (0.51-7.57) | 0.322 |
| Normal | | | |
| **Category of armoured vehicle drivers** | | | |
| Tracked** | -1.171 | 0.31(0.020-5.12) | 0.413 |
| Wheeled | | | |
| **Duration of services in armed forces (year)** | 0.322 | 1.38 (0.88-2.18) | 0.166 |
| **Duration of services as armoured vehicle driver (year)** | -0.258 | 0.77(0.58-1.04) | 0.084 |
| **Back rest support** | | | |
| Yes** | -1.482 | 0.23(0.04-1.41) | 0.111 |
| No | | | |
| **Driving in forward bending sitting posture** | | | |
| Yes** | 1.288 | 3.63(1.06-12.42) | **0.040*** |
| No | | | |
| **Jerking or jolting of armoured vehicles** | | | |
| Yes** | 1.229 | 4.42(0.76-15.30) | 0.108 |
| No | | | |
| **X-axis eVDV $ms^{-1.75}$ (8 hours)** | 0.663 | 1.94(1.02-3.69) | **0.043*** |
| **Y-axis eVDV $ms^{-1.75}$ (8 hours)** | 0.013 | 1.01(0.59-1.73) | 0.961 |
| **Z-axis eVDV $ms^{-1.75}$ (8 hours)** | -0.050 | 0.95(0.77-1.17) | 0.637 |

Significant at p-value < 0.05*; Reference category**; OR = Odds Ratio

## DISCUSSION

Prevalence of LBP among military armoured vehicle drivers was found to be very high (73.6%). This study revealed that tracked armoured vehicle drivers were more likely to complain of LBP as compared to wheeled armoured vehicle drivers. This study is similar to the finding of Beevis and Forshaw[11] among tracked APC drivers and Amad Mahmud Muslim[24] among military truck drivers. The two studies found prevalences of LBP at 88.0% and 92.5% respectively. The prevalence in this study was higher as compared to a study by Dupuis and Zerlett[16], which reported that only 68.7% of their earth-moving operators which included military armoured vehicle operators complained of spinal discomfort. Beevis and Forshaw[11] also reported a lower prevalence of LBP among slow moving battle tank drivers (55.0%) as compared with this study.

The prevalence of LBP in this study was higher as compared to other ground moving vehicle drivers in civilian populations, namely taxi drivers (45.8%)[25], rally drivers and co-rally drivers (70.0%)[6], power shovel drivers (38.0%), bulldozer drivers (36.2%) and forklift drivers (50.0%)[26] as well as tractor drivers (31.3% to 40.0%)[4, 5]. However, studies by Magnusson *et al.* (1996)[27] and Mohd Ropti Abdullah (2003)[28] among bus drivers found higher prevalences of LBP 81.0% and 80.0% respectively.

Another finding in this study was that eVDV at Z-axis among tracked armoured vehicles was the dominant direction (19.86 ± 4.72 $ms^{-1.75}$). This value exceeded the EAV of the European Vibration Directive (2002) which stated that any reading above 9.1 $ms^{-1.75}$ is above the EAV and therefore action needs to be taken by the management to reduce the vibration level to a minimum[23, 29].

Tracked armoured vehicle drivers were also found to have twice the risk of developing LBP as compared to wheeled armoured vehicle drivers (POR = 2.20; 95% CI 1.04 – 4.63). This study found that tracked armoured vehicle drivers were exposed to higher WBV in all the axes as compared to wheeled armoured vehicle drivers. In addition, WBV mean sum acceleration of all axes (XYZ) in tracked armoured vehicles was 2.7 times higher as compared to wheeled armoured vehicles. The difference in the WBV measurement among tracked armoured vehicles and wheeled armoured vehicles can be explained based on the design of the vehicles. In tracked armoured vehicles, vibration is produced mainly from the drive sprocket, idler and other elements through polygonal action as well as impact between sprocket and moving tracks [30]. It was observed that the wheeled armoured vehicles used rubber tyres which produced less vibration due to the reduction of friction between the tyres and the road.

In tracked armoured vehicles, it was observed that the friction between the moving steel tracked and hard surface ground (tar-road) significantly produced excessive vibration. This study found that the drivers drove their vehicles almost fifty-percent on tar- road as compared to other ground surfaces during routine driving and exercises. Therefore the friction between the moving steel tracked and hard surface ground (tar road) may have significantly produced excessive vibration and noise in the tracked armoured vehicles. The friction came worse if the vehicles had poor maintenance such as delay in replacement of rubber pads (which were used to reduce friction between ground surface and the moving steel tracks), ageing of the vehicles as well as low speed during driving.

It was found that the armoured vehicle drivers who complained of LBP were exposed to a higher level of WBV (eVDV) at X-axis and Z-axis for an eight-hour daily exposure as compared to the armoured vehicle drivers who did not complain of LBP. However, further analysis showed that only WBV at X–axis (OR=1.94, 95% CI 1.02-3.69) was significantly associated with LBP.

This study found that driving with forward bending sitting posture was the most important and significant risk factor of LBP as compared to other risk factors of LBP (OR=3.63, 95% CI 1.06-12.42). This finding is consistent with a study by Bovenzi *et al.* [31] among port machinery drivers and by Hoy *et al.* [8] among forklift truck drivers where LBP was more prevalent among drivers who drove in forward bending posture. Beevis and Forshaw [11] also concluded that poor posture was one of the risk factors among tracked APC drivers; however, their study did not specify what posture was adopted by the drivers. It was also observed that while driving in military exercises or in bad weather, the drivers had to close the hatches, adjust their seats and drive in forward bending sitting postures to have better vision through the front glass. This occurred mainly in tracked armoured vehicles. This could explain the significant association between driving in forward bending sitting posture and LBP among armoured vehicle drivers.

There was significant association between respondents who experienced their armoured vehicles jerking or jolting during driving and LBP (POR=6.27, 95% CI 2.28–17.36). There is increasing evidence which indicates that jerking and jolting or repetitive shock events may cause an increased risk of LBP [10, 32, 33, 34]. This jerking and jolting or repetitive shock depends on ground surface conditions caused by uneven terrain surfaces, style of driving or suspension design of the vehicles[34]. However, further analyses found that this was not a significant risk factor in this study (OR=4.42, 95% CI 0.76-15.30).

## CONCLUSION

This study found that prevalence of 12-months LBP among military armoured vehicle drivers was high (73.6%). The prevalence of LBP was higher among tracked armoured vehicle drivers (81.7%) as compared to wheeled armoured vehicle drivers (67.0%). WBV exposure in tracked armoured vehicles was higher as compared to wheeled armoured vehicles. The WBV (Z-axis) in tracked armoured vehicles exceeded the EAV set by the European Vibration Directive (2002). Further analysis found that driving in forward bending sitting posture and WBV exposure at X-axis were significant risk factors of LBP among military armoured vehicle drivers.

It is recommended that preventive measures should be set up by the respective mechanized battalions to reduce to a minimum the exposure to vibration among armoured vehicle drivers, particularly among tracked armoured vehicle drivers. The main recommendations that need to be addressed are providing appropriate measures to minimize vibration exposure to the drivers (e.g. appropriate maintenance scheduling, replacing rubber pad, improving the suspension system) as well as improvement of ergonomic postures during driving and provision of backrest support in the vehicles. Adequate information and training should be provided as well as conduct of health surveillance programmes to detect vibration-related ill heath among the drivers.

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