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Ergonomic Risk Assessment of the Impact of Road Terrain and Vehicle Conditions on Commercial Bus Drivers' Health and Safety

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ABSTRACT

Commercial bus drivers in Nigeria are exposed to a variety of road irregularities and vibrations, including smooth, bumpy, harsh and poor terrain conditions, as part of their daily commute. The study examines the economic risk assessment of road terrain and vehicle impact on commercial bus drivers, focusing on health, and safety aspects. The degree of vibration experienced by seated bus drivers was assessed by utilizing a tri-axial accelerometer to study the dynamic effects of whole-body vibration (WBV) on drivers in south western Nigeria. The findings demonstrated that the (z) vertical displacement was more noticeable than the x and y directions, suggesting that lower-spine diseases, weariness, and musculoskeletal illnesses are brought on by the vibrations. A survey of 200 commercial bus drivers revealed that 70.5% experienced musculoskeletal disorders (MSDs), while 62% experienced one or more forms of disorders in their lower back, shoulder, neck, legs, and wrists. The increasing years of active commercial bus driving is linked to a higher likelihood of developing body pain in drivers. Drivers in professional bus driving experience discomfort in their back, neck, wrists, and ankles, which increases with years of driving. Newer buses with sophisticated suspension systems and a strong maintenance culture are recommended to minimize WBV transmission.

1. INTRODUCTION

Driving conditions have gotten worse over time, mostly due to whole body vibration (WBV), road conditions, and vehicle conditions. The driver takes the brunt of the transport system's malfunctions, which leads to higher stress levels, customer conflict, and the intensification of a variety of work pressures in a hostile traffic environment. These conditions have an adverse effect on drivers' health (Wiatrowski, 2015; Biggs et al., 2019). These complex and varied vibration conditions are experienced by commercial bus drivers. Driving a commercial bus expose one to WBV over an extended period of time. The bodily components of drivers can withstand different frequencies before reacting to the WBV's effects. The drivers should choose a comfortable and ergonomic seating posture in a well-designed space to maintain their health (Okuribido et al., 2017).

For an ergonomic seating position, the size and mounting locations of the steering wheel, pedals, and driver's seat must be carefully considered. A motorist who adopts a relaxed and healthy posture is less agitated and can concentrate better on what is going on the road. Worldwide, occupational drivers are prone to repetitive trauma disorder and other musculoskeletal issues associated to their employment. Transportation vibration is linked to fatigue, driving-related risks, motion sickness (0.5 and 100 Hz), work-related brain damage, hand-arm vibration (HAV) (5 and 10,000 Hz), sound vibration (10-11,000 Hz), and ultra-sound vibration (10,000-100 Hz) (Paschold and Mayton, 2011)

Work-related injuries due to work-related vibration (WBV) in vehicles are increasing, exposing workers to awkward postures, repetitive motions, and sustained postures. This can lead to various conditions such as Carpal Tunnel Syndrome, trigger finger, golfer's or tennis elbow, and cervical and lumbar disorders. Low back pain, a common musculoskeletal disorder, is linked to WBV exposure, especially in commercial bus driving. Ergonomics principles focus on safety and productivity after work. Proper sitting posture is crucial to avoid backaches, strain, and stress on the neck and back. Factors influencing posture include vibration, aging, poor vehicle suspension, and poor road conditions (Tiemessen et al., 2007). Fatigue measurement is achieved through subjective study of seat types and designs using participatory ergonomic intervention (PEI) approach, focusing on the interaction, use, and combination of driver's seat, pedals, and steering column (Naeini and Mosaddad, 2013; Ayodeji et al., 2015).

Vibration is the oscillation of a mass around a fixed point, produced by periodic movements of tools or vehicles that displace the human body. It can be internal or external, depending on the source and human activity. Internal sources include mechanical and human-induced excitation. Exposure to vibration depends on frequency, amplitude, period, direction, location, mass, and external support. Human responses to vibration can be mechanical or psychological, with mechanical responses including fractures, damages, and MSDs, while psychological responses involve cognitive aspects of ergonomics like perception, morality, mood, and fatigue. Motor vehicle operators experience acceleration of vertical oscillations between 0.5 and 5 m/s^2, with the highest values recorded for earth moving machines and tractors. Road bumps cause up-and-down vibration along the spine. Human vibration is measured at interfaces between the body and the source of vibration, with accelerometers placed on seat surfaces, seat backs, feet, and hands (Wolfgang and Burgess-limerick, 2014).

Musculoskeletal Disorders (MSDs) are injuries and disorders affecting soft tissues and the nervous system, often affecting the arms and back. Low Back Pain (LBP) is a common MSD in developed countries, often linked to occupational exposure to Whole-body Vibration Symptoms include numbness, difficulty moving, stiff joints, and back pains (Darby, 2018, Bovenzi, 2019, Gallais and Griffin, 2009).

Driver fatigue is a significant safety concern in the road transport industry, causing fatigue and falling asleep at the wheel. Factors such as working time, evening work, and inadequate rest contribute to fatigue. In Nigeria, commercial bus drivers face prolonged whole-body vibration, leading to musculoskeletal disorders like low back pain. Unlike Europe, Australia, and other western countries, Nigeria lacks legislative exposure action and limit values for WBV exposures. It is crucial to check if exposure values exceed ISO and EU limits due to terrain, climatic conditions, and soil texture differences (Rasmussen, 2019; Smets et al., 2010). The study examines the economic risk assessment of road terrain and vehicle conditions on commercial bus drivers in Nigeria, focusing on health and safety aspects.

2. MATERIALS AND METHODS

The study assessed the impact of WBV exposure on 200 bus drivers in Ado, Akure, and Lagos, Nigeria. An anthropometric datasheet was created to compare drivers' anthropometric parameters with their working space, determining percentile ranges. The study used Toyota and Mazda buses for selection. The age of the buses and the type of terrain they are being driven on are by the drivers of bus types B1, B2, and B3's exposure to WBV were considered. Equations 1 was used to determine the percentiles that can accommodate the minimum and maximum commercial bus driver.

$$LP = \frac{\mathrm{P}}{100}\,(N+1) \qquad (1)$$

The research measured bus drivers' whole-body vibration using an accelerometer, comparing it to a standard seat pad accelerometer. The accelerometer evaluated WBV parameters, bus years of usage and conditions, road terrain and e-bikes were tested for their impact on health. The study categorized buses into smooth, rough, bumpy, and combination of the three groups, with exposure durations of 5-10 minutes. Using a tri-axial consumer device accelerometer, the commercial bus drivers' WBV was quantified. This included measuring the buses' average acceleration (Arms), vibration dose values (VDV), eight-hour energy equivalent acceleration (A (8), and the time it took to reach the health guidance caution zone (HGCZ) in the x, y, and z directions. Prior to real measurement, the accelerometer's biocentric axes were experimentally aligned in relation to the human body.

The fourth-power vibration dose value (VDV) shock factor in vibration of exposure and the average root means square accelerator (Arms) data of the WBV from the time-acceleration domain are expressed in Equations 2 and 3, respectively (McPhee et al., 2009). The eight-hour energy equivalent acceleration was 8.5 $m/s^{1.75}$ and related vibration dose value (VDV) was 17 $m/s^{1.75}$, respectively. The interval between the lower and upper bounds of the health guidance caution zone (HGCZ) are 0.47 m/s^2 and 0.93 m/s^2, respectively.

$$\mathrm{A_{rms}} = \left(\frac{1}{\mathrm{T}}\int_0^{\mathrm{T}} \mathrm{a_w}^2(\mathrm{t})\mathrm{dt}\right)^{\frac{1}{2}} \qquad (2)$$

$$\mathrm{VDV} = \left(\int_0^{\mathrm{T}} \mathrm{a_w}^4(\mathrm{t})\,\mathrm{dt}\right)^{\frac{1}{4}} \qquad (3)$$

The demographic information of bus drivers and specific body parts was integrated into surveys and a musculoskeletal disease questionnaire in order to collect data and identify any changes that may be linked to an educational program. A standardized questionnaire was given to 200 drivers of commercial buses. The questionnaire's development took into account the following factors: the age range of the buses; the types of roads (rough, smooth, bumpy, and a combination of terrains); the number of trips made each day; the distance traveled on each trip; the degree of education; driving instruction; the acceptability of government policies; anthropometric parameters; the demographics; and the type of pain felt while driving. MATLAB was utilized to analyze data and assess pain zones in respondents' bodies using analysis of variance to strengthen the connection between WBV and LBPs.

3. RESULTS AND DISCUSSION

3.1. Anthropometric Parameters Dimensions of the Drivers

Figure 1 shows various anthropometric parameters of all the respondents i compared with the available working space in the buses used in the study. The results showed no significance that is linked with the discomfort felt based on the available working space in the buses justified by Tarabini *et al.,* (2018).

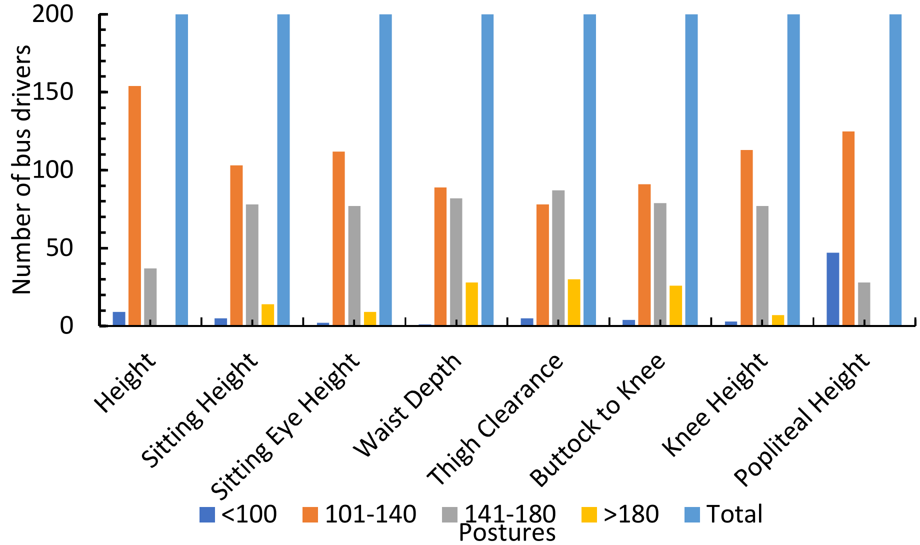

Figure 1: Anthropometric parameters dimensions of the drivers

3.2. Whole-body Vibration Assessment

Figures 2 to 5 show the values root mean square (RMS), VDV, Time to reach HGCZ and A (8) on the corresponding roads selected for the study (smooth road, rough road, and bumpy road and combined). The results revealed that shocks were not present in the RMS acceleration in all cases, hence; RMS acceleration is sufficient to evaluate the WBV in the study. The bumpy road is characterized by intermittent bumps while the combined road is the combination of other road terrains. The evaluation of the WBV on the combined road was carried out for a low time (period of travel).

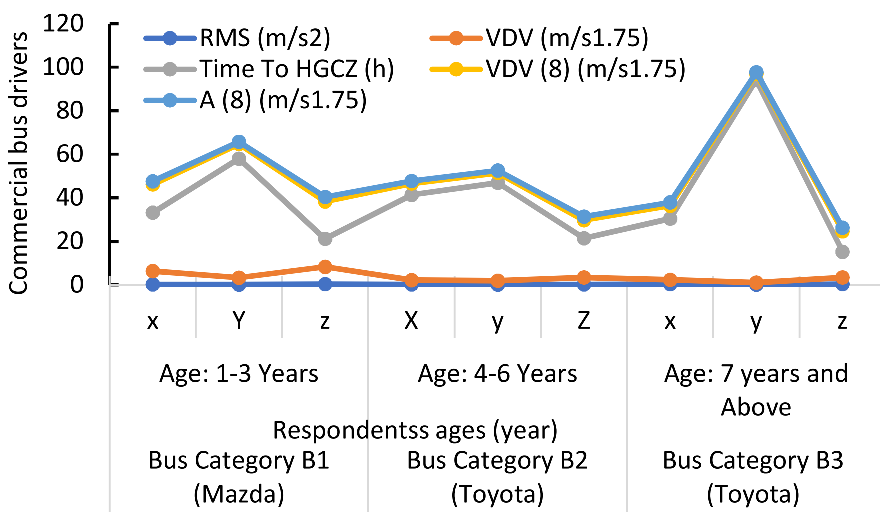

Figure 2: Experimental measurement of WBV on smooth road

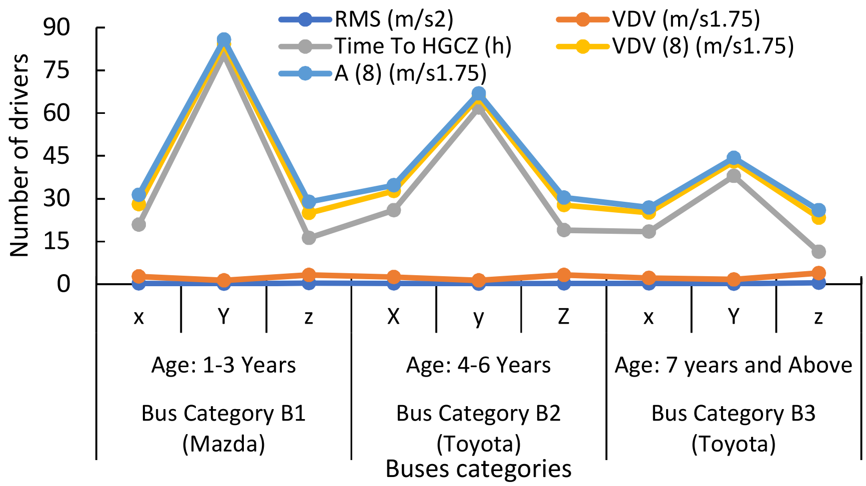

Figure 3: Experimental measurement of WBV on rough road

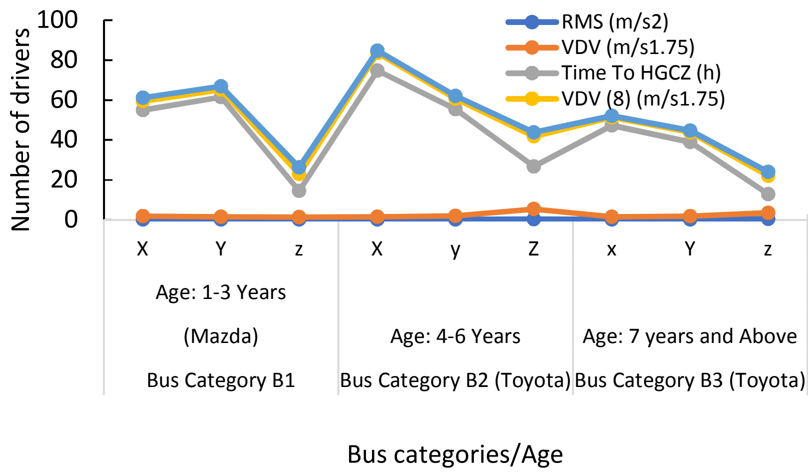

Figure 4: Experimental measurement of WBV on bumpy road

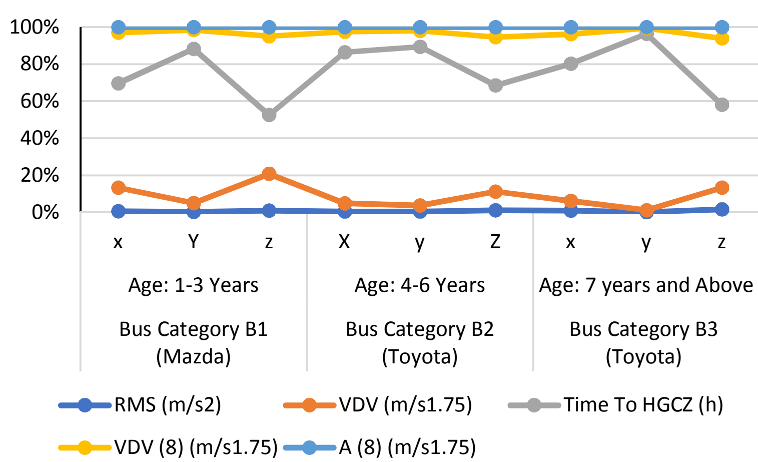

Figure 5: Experimental measurement of WBV on the combined roads

3.3. Average RMS Acceleration

The values of the average root-mean-square accelerations on the seat was determined and tabulated using the GCDC consumer device accelerometer and results are shown in Figure 2 and 5 for smooth, rough, bumpy and combined roads respectively. The RMS value along the z (vertical) axis acceleration less than its corresponding values on the x and y axes respectively; this is as a result of the road terrain. The vertical acceleration appears greater than the lateral acceleration. Buses B2 and B3 are not similar and this difference could be attributed to the buses' age range as contained in Button *et al.,* (2017).

3.4. Vibration Dose Value

The vibration dose value uses the fourth-power value of the acceleration is used to evaluate vibration that includes multiple shock. Just like the average RMS acceleration, the 8.5 $m/s^{1.75}$ VDV exposure action and 17 $m/s^{1.75}$ limit values are testaments. It implies that, as VDV exposure action increases, the more injured the driver's health attack and unsafe.

3.5. Buses and Road Terrain

Table 1 shows that the RMS, VDV, and HGCZ values are all greatest along the z axis and that the time surpassed the suggested levels. The RMS, VDV, and HGCZ values in the x, y, and z axes assumed the largest values in the case of bus B3, confirming that all these parameters are strongly related to the age range of the buses and the trip terrain, with the exception of buses. This is because of the topography, which increases the buses' longitudinal and transverse accelerations as well as their magnitude as contained in Button, (2017).

Table 1: Experimental measurement of whole-body vibration and buses on rough road terrain

	Bus category B1 (Mazda) Age: 1-3 Years			Bus category B2 (Toyota) Age: 4-6 Years			Bus category B3 (Toyota) Age: 7 years and above		
	X	Y	Z	X	Y	Z	X	Y	Z
RMS (m/s^2)	0.35	0.42	0.76	0.20	0.40	0.41	0.29	0.47	0.68
VDV ($m/s^{1.75}$)	1.95	2.51	4.62	1.22	2.47	2.49	1.69	2.70	3.89
Time To HGCZ (h)	16.73	11.22	3.43	49.07	12.56	12.13	24.45	8.92	4.39
VDV (8) ($m/s^{1.75}$)	6.13	7.90	14.55	3.84	7.78	7.85	5.38	8.58	12.38
A (8) ($m/s^{1.75}$)	3.76	4.51	8.16	1.52	3.04	3.12	2.73	4.42	6.40

3.6. Eight-hour Energy Equivalent Acceleration

Bus drivers' eight-hour energy equivalent acceleration exposure surpasses the exposure limit values (ELV) in all terrains, with highest values on rough roads and vertical axis attributed to irregular properties as shown in Figure 6. The health guidance caution zone (HGCZ) is crucial for reaching the recommended effective amplitude of vibration (EAV), affecting drivers' health and comfort.

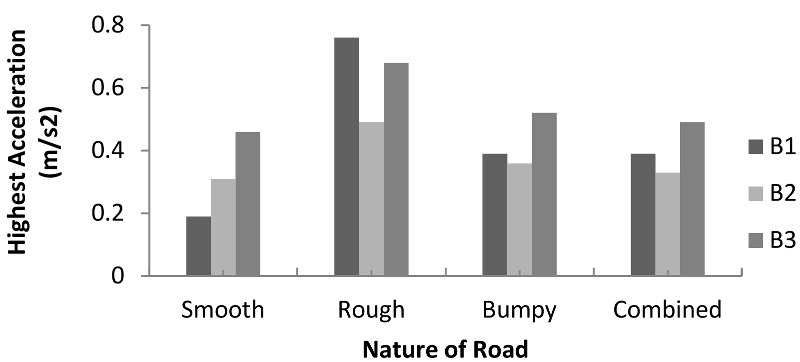

Figure 6: Highest acceleration of buses on different road terrains

3.7. Musculoskeletal Disorders

The survey analysis of 200 commercial bus drivers revealed that 70.5% experienced MSDs. Factors like marital status, smoking, and driving years were not significant. There was no correlation between MSDs and height. However, 62% of the respondents experienced disorders in their lower back, shoulder, neck, legs, and wrists. The increasing years of active commercial bus driving is linked to a higher likelihood of developing body pain in drivers.

3.8. Human Safety

The likelihood of experiencing pain rises in direct proportion to factors such as road terrain, posture, and year of driving experience. Driver comfort and health are impacted by WBV. The precise frequency spectrum density of Nigerian roadways is closely related to the WBV exposure level. The bus seats need be upgraded to lessen vibrations that reach the sitting driver because the survey's roads are unmanageable in their current state. In order to lessen the impact of whole-body vibration (WBV) on seated commercial bus drivers, as whole-body vibration cannot be completely eliminated from buses, buying newer, more technologically advanced buses; maintaining the buses on a regular basis; training bus drivers; and having all levels of government repair roads to allow for safe operating conditions and appropriate speed are essential.

4. CONCLUSION

The whole-body vibration that commercial bus drivers experienced in Nigerian terrain was assessed in this study, along with the precise implications for the degree of discomfort felt in relation to MSDs and the prevention of future hazard. The age of the buses in issue and the type of terrain they are being driven on are major factors that determine the drivers of bus types B1, B2, and B3's exposure to WBV. The degree of exposure to extremely high whole-body vibration magnitudes is associated with the indicated difficulty. The results showed that WBV levels above the ISO-recommended effective amplitude of vibration (EAV) and exposure limit values (ELV) are encountered by commercial bus drivers. The amplitude of average RMS vibration utilizing the worst axis enhances the influence of WBV on perception and comfort. The bus seats need be upgraded to lessen vibrations that reach the sitting driver because the survey's roads are unmanageable in their current state.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Ayodeji, S.P., Idada, O.R. and Akinnuli, B.O. (2015). Ergonomic evaluation of post biomechanical effects of lifting maximum loads using male subjects. *British Journal of Applied Science and Technology*, 7(3), pp. 295-301.

Biggs, H., Dingsdag, D. and Stenson, N. (2019). Fatigue factors affecting metropolitan bus drivers: a qualitative investigation. *Clinical Physiology*, 21(3), pp. 377-382.

Bovenzi, M. (2019). A longitudinal study of low back pain and daily exposure in professional drivers. *Conference proceeding*: 4th International conference on whole-body vibration injuries, Montreal, Canada. June 2-4th: pp. 3-4.

Button, C., Anderson, N.C., Bradford, C., Cotter J.D. and Ainslie, P.N. (2017). The Effect of Multidirectional Mechanical Vibration on Peripheral Circulation of Humans. *Clinic Physiology Function Imagin*, 27(4), pp. 211–216.

Darby, A.M. (2018). Whole-body vibration and ergonomics toolkits. health and safety laboratory. health and safety executives. Retrieved from www.hse.gov.uk/research/rrpdf/rr612.pdf on 16th February, 2015.

Gallais, L. and Griffin, M.J. (2009). Low back pain and risk factors for low back pain in taxi drivers. *Conference Proceeding,* 4th International Conference on Whole body Vibration Injuries, Montreal, Canada. June 2-4th: pp 5-6.

McPhee, B.; Foster, G. and Long, A. (2009). Bad vibrations. coal services health & safety trust, Sydney. 2nd Edition.

Naeini, H.S. and Mosaddad, S.H. (2013). The role of ergonomics issues in engineering education. *Conference Proceeding: 6th International Forum of Engineering Education (IFEE),* Malaysia. 20th November, 2012: pp 587-590.

Okuribido, O.O.; Shimble, S. J.; Magnusson, M., and Pope, M. (2017). City bus driving and low back pain: a study of the exposures to posture demands manual materials handling and whole-body vibration. *Applied Ergonomics*, 38, pp. 29-38.

Paschold, H.W., and Mayton, A.G. (2011). Whole-body vibration: building awareness in safety, health and environment. professional safety. Peer reviewed, 56(4), pp. 30- 35

Rasmussen, G. (2019). Human body vibration and its measurement. *Journal of the Acoustic Society of America,* 73(6), pp. 97-1

Smets, M.P., Eger, T.R., and Grenier, S.G. (2010). Whole-body vibration experienced by haulage truck operators in surface mining operations: a comparison of various analysis methods utilized in the prediction of health risks. *Applied Ergonomics*, 41(6), pp. 763–770.

Stephen, J.B. (2008). Long driving hours and health of truck drivers: presented on noisier student/resident research day, Cullimore lecture hall -1, *New Jersey Institute of Technology*, Newark.

Tarabini, M.; Moschioni, G. and Saggin, B. (2019). Long Term WBV Measurements on vehicles travelling on urban paths. Conference Proceeding: 4th International Conference on Whole body Vibration Injuries, Montreal, Canada. June 2-4th: pp. 107- 108.

Tiemessen, I.; Hulsof, C. and Frings-Dresen, M. (2007). An overview of strategies to reduce whole-body vibration exposure on drivers: a systematic review. *Industrial Ergonomics,* 37(3), pp. 245-256.

Wiatrowski, W. (2015). Occupational safety and health statistics: monthly labor review. *Applied Ergonomics*, 46(2), pp. 119-124.

Wolfgang, R. and Burgess-Limerick, R. (2014). Whole-body vibration exposure of haul truck drivers at a surface coal mine. *Applied Ergonomics*, 45(6), pp. 1700-1704.