ORIGINAL ARTICLE

The Use of Coconut Fiber Padded Seat in Reducing Vibration and Fatigue of Bus Drivers

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ABSTRACT

Introduction: Environmental factors such as vibration can affect work fatigue. The previous research results showed that there was a relationship between vibration and fatigue, with the use of ergonomic seats by bus drivers. Experimental research was conducted on making ergonomic seat padding from coconut fiber to reduce the level of vibration and driver fatigue. The purpose of this research was to analyze the differences in seating vibrations and fatigue for bus drivers who used or did not use a padded seat. **Methods:** The research design was experimental and the subjects were 42 bus drivers. The vibration intensity was measured using a vibrometer and work fatigue was measured using a reaction timer, then the data were analyzed using the t-test. **Results:** Based on the research results, the vibration experienced by bus drivers who did not use seat padding was greater than by those who did (p=0.001). Those who used seat padding had lower mean fatigue than drivers who did not use it (p=0.001). **Conclusion:** The vibration and work fatigue in bus drivers who did not use a padded seat were greater than those who used it and the difference was statistically significant. The use of ergonomic seating for bus drivers was very useful for reducing vibration.

Keywords: bus driver, coconut fiber, seat cushion, vibration, work fatigue

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INTRODUCTION

Many workers are exposed to vibration every day at work, including construction workers, agricultural, heavy equipment operators, and vehicle operators (Johanning, 2015; Krajnak, 2018). The health standards for the work environment include physical factors, and physical factors that cause occupational diseases include vibration (Presidential Regulation of The Republic of Indonesia, 2019). The vibration source comes from the engine when the vehicle is running. Engine vibration is caused by combustion excitation and unbalanced inertia forces on it, then vibrations are transmitted from the engine to the vehicle, eventually causing the vehicle's seat to vibrate (Charles *et al*., 2018).

The limit for hand and arm vibrations (HAVs) for daily exposure is $5 m/s^2$, while for whole-body vibrations (WBVs) the threshold for daily exposure is 0.50 m/s (Ministry Regulation of The Republic of Indonesia, 2018). Physical hazards such as vibration are categorized as potentially posing a long-term risk to health when viewed from the potential for occupational safety and health hazards based on their impact on victims (International Labor Organization, 2018). Vibration can interfere with work comfort and accelerate fatigue, causing health problems, which include work-related musculoskeletal disorders (WRMSDs) (Chaudhary *et al*., 2020). A driver seated for too long and exposed to full body vibration is prone to fatigue and back problems (Wang *et al*., 2017; Park *et al*., 2020) Fatigue is one of the factors causing accidents in the transportation sector (Zuraida and Abbas, 2020). It can affect the safety behavior of bus drivers and their cognitive abilities and is associated with occupational safety factors (Fan and Smith, 2020). Adam and Jalil argued that the main point of contact for the WBV transmission to the driver is via the vehicle seat, originating from the engine when the vehicle is running. Reducing vibrations while driving can be done by designing seats that serve to minimize their transmission and reduce the level of discomfort experienced by the driver (Adam and Jalil, 2017).

An ergonomic seating system plays an important role in reducing vibration (Chi *et al*., 2017; Kim, Marin and Dennerlein, 2018). Based on this, the researchers conducted an experiment in making bus driver seats using coconut fiber to reduce vibration

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and fatigue. The purpose of this research was to compare the differences in seating vibrations and bus driver fatigue between those who did and did not use a padded seat.

METHODS

Subject

This was an experimental study design, with exposed and non-exposed groups. The study population was intercity bus drivers in West Kalimantan. The inclusion criteria for the sample were: an intercity bus driver, who was driving the bus during this study, aged 20–55 years; not currently suffering from chronic diseases and degenerative diseases such as diabetes, hypertension, heart disease, cancer, stroke, osteoporosis, hyperuricemia, and rheumatoid arthritis (Nandi *et al*., 2019) ; and willing to participate, adhere to research procedures and sign an informed consent.

Exclusion criteria were bus drivers who were not driving when the study was conducted. Based on the criteria set, 42 drivers were included in the study. A total of 21 respondents who drove the bus without using the padded seat were in the control group, while 21 respondents who drove the bus using a padded seat were in the treatment group. Both groups had the same characteristics, and the only difference was in the provision of intervention/ exposure using seat cushions in the treatment group.

Determination of the control and the treatment group was done using simple random sampling, allowing each respondent an equal chance of being selected into the respective groups. The lottery method was used to randomly sample the respondents into the two groups, where respondents who received odd numbers were assigned to the control group and even numbers to the treatment group. Then the two groups were observed, measurements taken and results compared (Elfill and Negida, 2017; Verma *et al*., 2017). This research was conducted in May–October 2017, according to the guideline of the Declaration of Helsinki, and approved by the Polytechnic of Ministry of Health, Pontianak, Indonesia (152/KEPK-PTKMKS/ IV/2017).

Procedure

Research activities were carried out in the following steps: Preparation stage: The author collaborated with the Occupational Health and Safety unit of West Kalimantan Province, Indonesia, to measure vibration and fatigue among bus drivers. Ethical clearance was obtained from the Health Research Ethics Commission, for the companies and Transportation Department of West Kalimantan Province. In the implementation stage, the following materials and tools were prepared: 1) coconut coir that was split into fiber, 2) a layer of foam, 3) permon cloth, 4) glue, 5) bias tape, 6) rubber strap, 7) nylon thread, 8) car seat sewing machine.

Padded seat construction: 1) The research team prepared 2 cm and 3 cm thick foam layers, 2) stacked the coconut fibers on it up to 2 cm and 3 cm thickness, 3) applied glue between layers (to avoid them shifting), 4) placed 2 cm and 3 cm foam layers on the coconut fiber, till the seat padding was 6 cm and 8 cm thick, 5) used the permon fabric and tape to make the edging, 6) and added the rubber strap and sewed it on the bus drivers' padded seat.

Field activities: 1) The research team held a meeting with the tasks division, to collect data in the field, and 2) held a meeting with officers from the Occupational Safety and Health Unit, who measured the vibration and fatigue. 3) Research subject determination: from the drivers who met the inclusion criteria, 4) a random selection was made of drivers into the control and treatment groups, 5) meeting the bus drivers to explain the purpose and objectives of the research, as well as the procedures in the research activities. 6) Research subjects who were willing to take part in this research signed an informed consent form, and 7) enumerators collected data using interview questionnaires, with respondent demographic variables including: age, length of work and status. 8) Initial fatigue data (pre-test): fatigue measurement before work was carried out on bus drivers in the control group and the treatment group. 9) Conducting experiments, namely with the Control Group (CG) of bus drivers who did not use a padded seat, and the Experimental Group (EG) of drivers who used a coconut fiber padded seat. 10) Vibration measurements on bus drivers in the control and experimental groups were carried out 15 minutes after the bus left for its destination. The distance from Pontianak to the destination was approximately 150 km. The mean speed of the buses was 80–120 km per hour. The time taken by the bus driver after departure was 4–5 hours, as also was the time to return from outside the city to the starting place. The total traveling time was thus >8 hours, and the driver's working hours were >8 hours.

During the working hours, the driver would be exposed to engine vibration. Vibration measurement was done using a vibration meter Svantek/SV 106. The unit of vibration measurement was calculated by displacement (m), velocity (m/s), or acceleration (m/s2). The vibration measurement procedure was in accordance with ISO 2631-1: 1997 20. 11) Final data collection (post-test; the fatigue measurement after work was carried out on the bus drivers in the control group and the treatment group). The officer who took the measurements came from the Occupational Safety and Health (OSH) unit to measure vibration and fatigue and was a trained Occupational Safety and Health examiner. Post-vibration measurements were carried out by different people to avoid observational bias. The vibration intensity was obtained based on measurements taken using a vibration meter at each driver's seat, in both the control group and the treatment group.

Work fatigue data were obtained by using the reaction timer measurement L 77 tool to determine the time needed between the stimulation and the response generated by stimuli in the form of sound and light, which are displayed digitally. In this research, the authors used light stimulation. This tool was a standard tool for measuring fatigue used by the government in West Kalimantan Province. The instrument was regularly calibrated so that the validity and reliability of the measuring instrument could be assured. The unit of measurement was milliseconds (ms). The measurement results were further classified according to several criteria according to Mustofani and Dwiyanti (2019) and Maurits (2010): criterion for normal work fatigue with a reaction time of 150.0–239.0 ms, criterion for mild work fatigue with a reaction time of 240.0 – < 409.0 ms, criterion for moderate work fatigue with a reaction time of 410.0–580.0 ms, and criterion for heavy work fatigue with a reaction time > 580.0 ms. The work fatigue measurement used a reaction timer because the results were measured objectively and digitally displayed, unlike the use of a questionnaire which was subjective.

Statistical Analysis

The research data analysis consisted of descriptive analysis (univariate analysis) to determine the distribution characteristics of each dependent and independent variable. Inferential analysis was done through statistical calculations to test the hypothesis based on the estimation theory. The research hypothesis test used a t-test to test the difference in the mean of the two sample groups on vibration and fatigue against soft seats. The chi-square test was used to determine the association between sociodemographic characteristics and the use of soft seats. The test was carried out at the significance level ($\alpha = 0.05$); test results with $p < 0.05$ were considered significant.

RESULT

Table 1 shows the association between the socio-demographic characteristics and the use of padded seats. Most of the respondents in the treatment group are in the age category of 31–40 years, namely 12 respondents (57.14%), while in the control group most are in the category of 20–30 years, with 9 respondents (42.86%). Most of the respondents in the treatment group, 10 (47.62%), have worked for 6–10 years, while in the control group 9 (42.86%) have worked for a period of 1–5 years. Twenty (20) respondents (95.23%) in the treatment group were married, while 19 respondents (90.48%) in the control group were married. The statistical test results showed no difference between the age group and the use of the soft seat, p = 0.077, and there was no difference between the length of working hours and the use of the soft seat, p = 0.429.

Table 1. Association between Socio- demographic Characteristic and Use of Padded Seats

Variable	Group				c^2	p
	Treatment		Control			
	N	%	N	%		
Age						
20-30	4	19.05	9	42.86		
31-40	12	57.14	5	23.81	5.139	0.077
≥ 41	5	23.81	7	33.33		
Length of Working						
1-5 years	6	28.57	9	42.86		
6-10 years	10	47.62	6	28.57	1.691	0.429
>10 years	5	23.81	6	28.57		
Married Status						
Married	20	95.23	19	90.48	-	-
Unmarried	1	4.77	2	9.52		

Note: n = Number samples c2 = Chi Square p = p value

Coconut Fiber Padded Seat in Reducing Vibration

Test to determine the thickness of the seat pad to reduce vibration: To determine the thickness of the seat padding, vibration measurements were made with 5 bus drivers, before and after using 6 cm and 8 cm thickness padding. Each vibration measurement was carried out 3 times and averaged, as pre- and post-vibration measurements on using the fiber padded seats. The vibrations produced from padding with the two thicknesses were compared and the measurement results are shown in Table 2 and Table 3. Based on Table 2, the mean whole-body vibration of the bus driver before using the padding was 0.620 m/s^2, exceeding the threshold value (> 0.50 m/s^2). After using 6 cm thick padding, the mean vibration became 0.453 m/s^2, less than the threshold value. There was thus a decrease in vibration of 0.167 m/s^2 when using the 6 cm think seat padding (Table 2). Based on Table 3, the whole-body vibration of the bus driver before using the padding was 0.626 m/s^2, exceeding the threshold value (>0.50 m/s^2). When using the 8 cm thickness padding, the vibration became 0.427 m/s^2, less than the threshold value. There was thus a decrease in vibration of 0.199 m/s^2 when using the 8 cm thick padding.

These reductions in vibration for drivers who used seat padding with thicknesses of 6 cm and 8 cm show that the decrease that occurred was 0.32 m/s^2 greater with the 8 cm thickness compared to the 6 cm padding. Based on the interviews with five bus drivers who took the preliminary test, they stated that the 6 cm thick padding was more suitable because it matched the seat and steering wheel height, making it more comfortable to use. Moreover, the upholstery tailors suggested making pads with a thickness of 6 cm, as sewing would be easier and more economical because less coconut fiber would be used. Based on this, the seat cushion made for the subsequent activities was 6 cm thick.

Table 2. The Results of Vibration Measurements Before and After Using a 6 cm Thickness Padded

Measurement	Results		Details
	Before	After	
1st driver mean measurement	0.632	0.459	
2nd driver mean measurement	0.611	0.449	
3rd driver mean measurement	0.621	0.454	TLV whole body vibration is < 0.50m/s^2
4th driver mean measurement	0.622	0.453	
5th driver mean measurement	0.616	0.451	
Mean measurement	0.620	0.453	

Table 3. The Results of Vibration Measurements Before and After Using an 8 cm Thickness Padded

Measurement	Results		Details
	Before	After	
1st driver mean measurement	0.635	0.444	
2nd driver mean measurement	0.611	0.447	
3rd driver mean measurement	0.623	0.434	TLV whole body vibration is < 0.50m/s^2
4th driver mean measurement	0.629	0.413	
5th driver mean measurement	0.632	0.401	
Mean measurement	0.626	0.427	

Table 4. The results of whole body vibration measurement in each drive

No	Do not use seat padded	Use seat padded
1.	1.03	0.46
2.	1.06	0.36
3.	1.93	0.4
4.	1.8	0.56
5.	1.1	0.6
6.	0.8	0.7
7.	1.5	0.5
8.	1.23	0.46
9.	1.36	0.36
10.	1.3	0.46
11.	0.8	0.7
12.	0.86	0.66
13.	1.7	0.5
14.	0.7	0.56
15.	1.6	0.86
16.	1.46	0.56
17.	1.4	0.86
18.	1.4	0.83
19.	0.5	0.36
20.	1.1	0.43
21.	1.33	0.46
Mean	1.23	0.55

The Intensity of Whole-body Vibration Measurement Results for Bus Drivers

The vibration measurement results in the driver group who did not use a pad (control group) were 0.50–1.93 m/s^2 with a mean of 1.23 m/s^2, and in the driver group who used a pad (experimental group) were 0.36–0.86 m/s^2 with a mean of 0.55 m/s^2. This showed that the vibration for bus drivers who used coconut fiber seat padding was less than for those who did not. Also, based on the results of the statistical test p = 0.001 (<0.05), there was a significant difference in the level of vibration for bus drivers who used seat padding compared to those who did not (Tables 4 and 5).

Fatigue Measurements on Bus Drivers

The mean work fatigue in the respondent group who did not use a padded seat (control group) before work was 224.72 ms and after work was 361.21 ms. The mean difference of work fatigue before and after work therefore increased by 136.49 ms. The mean work fatigue in the experimental group before work was 228.27 ms and after work was 268.53 ms, a mean difference increase of 40.26 ms. The difference in fatigue levels after work between the bus drivers in the control group and the experimental group was thus 92.68 ms (p<0.05). The mean difference in the fatigue levels between the two groups was 96.23 ms, which was found to be statistically significant at p<0.05. This showed that providing coconut fiber seat padding could reduce fatigue by 96.23 ms in the experimental group (Table 6).

Table 5. The Intensity of Whole-body Vibration Measurement Results for Bus Drivers

Group	Vibration Intensity				
	n	Mean	SD	Statistical Test	
				T	p
Do not use seat padding	21	1.23	0.37	12.225	0.001
Use seat padding	21	0.55	0.16		

Figure 1. Whole body vibration measurement on bus drivers

DISCUSSION

Coconut Fiber Padded Seat in Reducing Vibration

The research results on the vibration of the bus drivers who used seat padding reported a mean of 0.55 m/s^2, while those who did not use it reported a mean of 1.23 m/s^2, meaning that the vibration of the seats with padding was less and the difference was statistically significant. Zhang, Qiu and Griffin (2015) reported that using 60 mm foam padding reduced vibration transmission. Sitting on foam material, because of the pressure, will decrease its thickness. For the seat cushions made of coconut fiber in tightly arranged layers, with pressure, the thickness decreased, although not as much as with foam material. Modifying the ergonomic design of the driver's seat can increase the comfort experienced by the driver (Manohar, Krishnan and Kumar, 2020). Occupational health problems for bus drivers can be prevented by repairing bus seats, on which the driver spends most of his time. Improvements or modifications to the design of the driver's seat including the provision of padding, which has been shown to reduce vibration, will reduce driver fatigue (Sekulić *et al*., 2018; Manohar, Krishnan and Kumar, 2020). The function of the seat in the vehicle plays an important role, contributing to the rider's comfort.

Vibrations caused by a vehicle running in poor road conditions are transmitted through the suspension into the vehicle chassis. The moving wheels of the vehicle also produce acceleration, which is channeled along with vertical vibrations to the seat. A driver's seat should meet the threshold requirements set for reducing vibration (Du *et al*., 2018). The driver's seat must be ergonomically designed to ensure quality, comfort, safety, and health while driving. Road accidents are mostly caused by driver fatigue. Driver comfort is important in the design of the driver's seat in order to reduce vibration and fatigue. The components that must be considered include the padding (Du *et al*., 2018; Cardoso *et al*., 2019; Heidarian and Wang, 2019). Materials used to dampen vibrations in vehicle seats include natural materials such as rubber, banana fiber, bamboo, and coconut (Kerywan and Coles, 2018; Nandi *et al*., 2019; Loganathan *et al*., 2020). Requirements for car seat cushions that meet ergonomic requirements must be adjusted to the needs of users, paying attention to the seat height, cushion length, backrest, cushion width, armrests, and headrests (Muhammad, Abdullah and Faris, 2018). The addition of suspension to the driver's seat to dampen vibrations can reduce the risk of danger felt by the driver, increase comfort, reduce driver fatigue and save costs for the company (Alfadhli, Darling and Hillis, 2018).

The Intensity of Whole-body Vibration Measurement Results for Bus Drivers

Vibration is a physical factor in the workplace resulting from equipment used in work activities that can cause adverse health effects (Du *et al*., 2018; Johnson *et al*., 2018). Vibration can come from various sources and can be caused, among others, by tools or work equipment in various sectors, including transportation (Moloney, 2021). Publications have revealed that the source of vibration when the bus is on the move comes from the engine, which is then transmitted to the driver's body through the vehicle seat, vehicle body, rotating tire vibrations, and road conditions (Chi *et al*., 2017). although undamaged road conditions can reduce the amplitude of the vibration. It has been reported that the vehicle size affects the level of vibration, where larger vehicles are associated with lower vibration levels than smaller ones (Harikrishnan and Gopi, 2017). Vehicle speed can increase the vibration level of both the chassis and seat. The vibration can also be influenced by various factors, including load conditions, vehicle load capacity and vehicle age, suspension size, seat design, and vehicle maintenance (Kim, Marin and Dennerlein, 2018; Rikaz, Abeysinghe and Perera, 2019). Vehicles including buses that vibrate greatly affect the health and comfort of both drivers and passengers (Kilikevičius, Kilikevičienė and Matijošius, 2018; Mendes *et al*., 2021). The vibrations of each frequency transmitted to the body are called whole-body vibrations (WBVs). A person who is exposed to vibrations for a long time is susceptible to health problems, namely injuries, spinal disorders, cardiovascular disorders and peripheral disorders (Krajnak, 2018). WBVs can affect health because they can cause fatigue and injury, through vibrations transmitted to the human body at the natural frequency of the body as a whole or parts of the body through vehicle seats. The body or body parts will vibrate during resonance, muscles will react by contracting voluntarily or unintentionally, resulting in fatigue or decreased motor performance capacity (Yung *et al*., 2017; Krajnak, 2018; Johnson *et al*., 2019; Mondal and Arunachalam, 2019). Workers exposed to vibration every day for years can experience health problems. Vibration causes intestinal, circulatory, muscle, and back disorders in bus drivers, exacerbated by the combined accumulation of effects consisting of vibration, non-ergonomic posture and fatigue (CCOHS, 2017).

The difference in average fatigue of bus drivers who use and do not use padded seats

The difference in the mean fatigue level between bus drivers who did not use padding and those who used it was 136.49 ms and 40.26 ms. The mean fatigue levels were therefore 96.23 ms greater for bus drivers who did not use padding and the difference was statistically significant. Driver fatigue is one of the biggest health and safety problems in the transportation sector (Phillips *et al*., 2017). Workplace or workstation exposure to vibration can cause fatigue, which can lead to deterioration of driver performance and increase the risk of accidents. The resulting impaired information processing can also reduce the ability of the driver to respond in emergencies or unusual situations (Alonso *et al*., 2017; Manuputty, 2021).

It can affect driving performance by increasing the frequency, amplitude, and variability of errors (Pelders and Nelson, 2019). The length of working hours, and health and fitness conditions are the most frequently reported cause of fatigue (Hulme *et al*., 2018; Irwanto, 2020). The impact of bus transportation is vibration that causes fatigue in bus drivers, so it is necessary to prevent vibration in order to reduce fatigue, by implementing occupational health and safety measures at work. This is in line with the opinion of Çalış and Büyükakıncı (2019) that occupational health and safety management must be carried out in order to prevent health problems that adversely affect the driver. This study has shown that padding seats with coconut fiber can reduce it. In addition to physical environmental factors, in this case, vibration, the age and length of work of bus drivers also need attention, although in this study these did not show a relationship. Contrary to the opinion of Adytama and Muliawan (2020), age factors can affect workers' endurance and physical strength, making them more prone to work fatigue. Likewise, the length of work is contrary to the opinion of Juliana *et al*. (2021) opinion. even though the length of work significantly results in the length of time for which the bus driver is exposed to vibration. But the results of Wahyuni and Indriyani (2019) on age and length of work are not related to work fatigue. It is possible that the research sample is small, so future research to add data through adding further research objects needs to be done.

CONCLUSION

In general, this study examined the differences in bus drivers' vibrations and fatigue when they did or did not use seat pads made of coconut fiber. Based on the research findings, vibration and work fatigue in bus drivers who did not use a padded seat were greater than in those who did, and the difference was statistically significant. It is necessary to design a seat that incorporates a pad so that it is more ergonomic for the bus driver, reducing the vibrations so as to avert work fatigue.

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