Development and Initial Testing of Lumbar Support for Traffic Police Motorcycle Seat With Built-In Massager System: A Preliminary Study In The View of Ergonomics

Nur Athirah Diyana Mohammad Yusof, Karmegam Karuppiah, Putri Anis Syahira Mohamad Jamil, Irniza Rasdi, Vivien How, Sivasankar Sambasivam
Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
athirahd@hotmail.com, megam@upm.edu.my, putrianissyahira@gmail.com, irniza@upm.edu.my, vivien@upm.edu.my, sivasankar@hotmail.com

Kulanthayan KC Mani
Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
kulan@upm.edu.my

Abstract
Traffic police riders are exposed to prolonged static posture, causing significant angular deviation of body muscles, including lumbar angle (L1-L5). This postural alteration contributes to muscle discomfort, especially low back pain (LBP), since it is one of the most severe modern diseases nowadays. This study aims to develop a prototype (lumbar support with built-in massager system) of motorcycle seat for traffic police riders to precisely transform riders' need with comfort. There are three stages (Stage 1: Problem identification, Stage 2: Prototype development, and Stage 3: Prototype testing) involved in this study. A 100 mm visual analogue scale rating was used to assess the discomfort ratings of this prototype. The prototype testing showed good indicators in reducing riders' discomfort (31%) compared with the existing motorcycle seat. The majority of the items were statistically significant difference between the existing seat and prototype seat, namely the seat length, seat contour, vibration, physical design, tendency to slide, with/without lumbar support as well as massager, the pressure under the buttock, lower back, middle back, upper back, side of the body, buttock, and overall discomfort ($p<0.05$). A prototype (lumbar support with built-in massager system) does offer an alternative solution to improve motorcycle seat design ergonomically. It enhances the reduction of overall body discomfort on police riders. However, a further evaluation of the in-depth field, laboratory and clinical testing should be carried out to support the effectiveness of the prototype.

Keywords
Adjustable, lumbar support, massage system, product design specification

1. Introduction
Low back pain has been affecting the world with a high recurrence rate and caused the loss of function and disability (Hartvigsen et al., 2018). This disorder usually affects vehicle users, especially motorcyclists, as the current feature of a motorcycle seat still lacks in providing good posture support for the riders (Arunachalam et al., 2019). Sitting discomfort of a motorcycle has become a crucial issue and needs to be distinguished due to the limited space, more restriction to posture, prolonged riding, and multiple tasks, which can lead to muscle discomfort and musculoskeletal disorders (MSD) (Yusof et al., 2016). Previous studies found that approximately 50% of the traffic police officers use motorcycles as their main vehicle while on duty (Diyana et al., 2019; Yusof et al., 2016). The traffic police force in Malaysia is under the Department of Investigation and Traffic Enforcement which is one of the main components of the Malaysian Royal Police (MRP). Traffic police riders represent one of the most critical subcomponents in this department. They are responsible for escorting, patrolling selected locations, and fine any offence of road users in their eight to 12-hours working shift. From a previous research

study on the CBX 750P21 motorcycle among traffic police riders, it was found that 88.3% of them suffered from MSD, with 34.3% of them suffering from lower back pain due to static posture and prolonged sitting while riding the motorcycle (Diyana et al., 2019). Another previous study also revealed that more than half (54.7%) of the traffic police riders rode high-powered motorcycles for an average of 5.64 hours per day with a fixed posture leading to increased discomfort from prolonged sitting that enhanced muscle fatigue (Yusof, 2016). This showed that most of their working time involves riding motorcycles. Previous studies have shown that car seats with a lumbar support and massager system are capable of reducing MSD among drivers during long-distance drives (Durkin et al., 2006; Franz et al., 2011). Hence, it will also benefit motorcycles to have similar features, which will help motorcyclists during long-distance rides, especially traffic police riders who use a motorcycle for work purposes.

Besides that, vehicle ride comfort has recently become one of the most prominent factors affecting purchase decision and customer satisfaction. Meeting customer comfort requirements, which is a significant issue, plays a vital role in vehicle marketing (Shende, 2014; Jahanshashi et al., 2011). Therefore, in recent years, the number of studies that focused on developing techniques to optimise vehicle ride comfort characteristics has gradually increased to meet customer requirements (Tatsuno et al., 2020; Ibusuki, U., and Kaminski, P. C., 2007; Sturgeon et al., 2009). Mohanty (2015) stated that ergonomically designed equipment or machines are highly desirable and essential because the interaction between user and product leads to enhanced comfort, performance, and user satisfaction as well as minimised health risks. Although functionality, cost, and quality are crucial factors of a product design, ergonomics emphasise other design elements, including comfort, safety, image, emotion, and attractiveness (Vink et al., 2006). According to Donnelly et al. (2009), the inability to fully accommodate the seat position by police officers during a shift will increase the discomfort over time which may ultimately lead to MSD. This statement was linked with the current research problem of this study which sitting discomfort of a traffic police motorcycle has become a crucial issue and needs to be addressed due to the high ratings of seat discomfort and muscle discomfort as well as high prevalence of MSD among traffic police riders due to the limited space, more restriction to posture, prolonged riding, and static posture (Diyana et al. 2019, Yusof, 2016). In order to provide traffic police riders with comfort, lumbar support with a built-in massager system for motorcycle seat was developed in this study.

1.1 Objectives

This study aims to identify the product design specification (PDS) in order to develop a motorcycle seat prototype with lumbar support and a built-in massager system for traffic police riders. In order to provide riders with comfort and support of the body posture.

2. Literature Review

The motorcycle seat is characterised by shapes that provide comfort and balance for the various riding positions suitable for the riders' motorcycle model concept (Patil et al., 2014). However, most of the motorcycles in the Malaysian market are not ergonomically designed. An ergonomic design plays a vital role in improving riding comfort. This is because in a seated position during riding, most body weight is supported by the ischial tuberosities or known as buttock-sitting bone which could contribute to hazardous health conditions for the user such as MSD and muscle discomfort (Aroeira et al., 2017). Based on Marques et al. (2010), an individual would be exposed to a high risk of developing muscle discomfort when they sit for more than four hours. Muscle fatigue also could happen during the riding process due to the focus and force needed to control the motorcycle and at the same time require them to maintain body posture (Velagapudi et al., 2010). In Malaysia, a previous study found that most riders complained of muscle discomfort when riding a motorcycle especially in the low and upper back regions (Karuppiah et al., 2012; Diyana et al., 2019).

As an aim to minimise discomfort levels among riders and improve ergonomic seat design, lumbar support has been suggested by Karuppiah et al. (2012) to solve this problem where comfort among riders have been improved and muscle fatigue reduced significantly at the upper body region (Shafiei et al., 2015). Patil et al. (2014) found that when the backrest mounted to the seat is placed at the height of 100 mm on the motorcycle seat surface, discomfort would be reduced, and such a configuration was suitable for long-distance travelling. Discomfort among riders could also be reduced by increasing buttock cushions and back support (Badrulhisyam et al., 2020). Thus, in order to improve the previous studies, the present study aim to develop lumbar support with built-in massager system to further enhance the motorcycling industry with a good ergonomic aspect in design.

3. Methods

A design process of this study involved three main stages, which adapted from Pugh's total design process model, as shown in Figure 1 (Pugh, 1991). Stage 1 involves problem identification on major ergonomics problems faced by traffic police riders during the riding session and lists the criteria based on previous studies and extensive literature. Meanwhile, Stage 2 describe the design and development of lumbar support and a built-in massager system. In Stage 3, initial testing was conducted to compare the effectiveness of the designed prototype against an existing motorcycle seat.

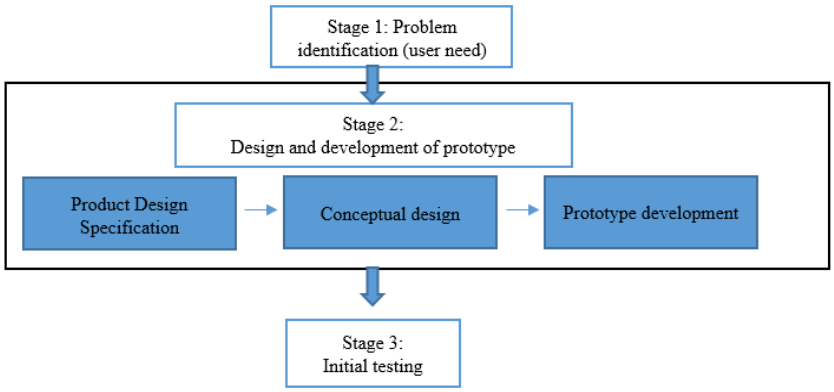


Figure 1. A design process of this study

3.1 Stage 1: Problem identification and determining criteria list

Stage 1 was performed by thoroughly reviewing extensive literature and previous studies to identify and investigate ergonomic issues among the Malaysian Traffic Police riders. In order to list out the criteria to develop a prototype, the inputs from past research works were reviewed and discussed among the research team.

3.2 Stage 2: Design and development of a prototype

I. **Product design specification (PDS)**: Basic concept and idea were generated in this stage which involved opinion from engineering expertise through discussion. The PDS was also generated from the criteria list (inputs) from stage 1.

II. **Conceptual design**: A conceptual design was determined using Pugh Chart which also involve datum design in order to make a comparison between conceptual designs. A datum design is chosen based on an existing product of lumbar support for the motorcyclist. A Pugh chart is a quantitative technique used to rank the multi-dimensional options of an option set. It is used to compare design ideas against the design criteria early in the design process. A few designs were evaluated, and the best design was chosen to be developed and tested in this study. In this case, a prototype from Karuppiah et al. (2012) was chosen as a datum since this prototype has evaluated the effectiveness in lumbar support.

III. **Prototype development**: A chosen conceptual design was fabricated based on the list of criteria and PDS. The technician was actively engaged throughout the prototype development phase with an opinion and suggestion from the research team and expertise.

3.3 Stage 3: Initial testing

An initial testing was conducted among traffic police riders, five subjects, which involved an existing seat and prototype seat by using the same type of motorcycle (Honda CBX750). The prototype seat was conducted in the same schedule and same location as an existing seat with a one-week interval.

4. Data Collection

In data collection, after obtained an approval for the safety and health aspects of the prototype, initial testing was conducted on-road among five traffic police riders. In this initial testing, a prototype was used for 20 minutes riding session, and the participant needs to answer a 100-mm visual analogue scale for motorcycle seat discomfort survey after the riding session end. The subjects also need to answer this question for the existing motorcycle seat to evaluate the effectiveness of the prototype. The observation of riding posture between motorcycle seat type was also observed and analysed among research team. All the data gathered from the questionnaire were analysed using IBM SPSS (Statistical Package for the Social Science) version 26. The data were analysed using univariate and bivariate analysis. The study was conducted using a 95% confidence interval, 80% of power, and the results of $p \leq 0.05$ were considered significant. The present study found that the data variables were not normally

distributed. Thus, a non-parametric test was used in this study. As the data from the group in this research were compared with each other, the Wilcoxon Signed-rank test was used for the independent numerical variables.

5. Results and Discussion

5.1 Stage 1: Problem identification and criteria list

Generally, the finding from this stage indicated that there is a need for a efficient and ergonomic supporting lumbar support for motorcycle riding among traffic police riders. Findings from previous studies revealed that their main work-related discomfort during riding motorcycle were primarily focused on their lower back, upper back, neck as well as shoulder (Nur Athirah et al., 2020; Diyana et al., 2019; Diyana et al., 2017). This discomfort was specifically explained due to prolonged riding hours per day (more than 5 hours), riding experience (more than 5 years), vibration, no support of the back area during riding a motorcycle.

These occupational factors such as prolonged riding hours cumulatively and static posture while riding a motorcycle may lead to muscle discomfort, fatigue, musculoskeletal disorders (MSD) and the worst case is accidents (Dutta, Basu, and Sen, 2014). Based on the previous study, Diyana et al. (2019) found that traffic police riders in Malaysia suffered high prevalence of MSD as well as muscle discomfort during riding especially in low back, neck and shoulder area due to riding for many hours while on duty with a mean of 5.64 hours per day. Prolonged maintenance of awkward posture during riding may affect postural stress, especially in the lumbar region, which is magnified with continuous exposure to ergonomic hazard. From this outcomes, Nur Athirah et al. (2020) had suggested an additional feature is needed in existing motorcycle design especially seat in order to enhance comforts and posture of traffic police riders. Thus, based on previous studies and extensive literature, a summary of the ergonomics issues among traffic police riders in Malaysia is and input details of the seat features in this study had been summarised in Figure 2. Besides that, inputs from the technician, and engineer expert were also found to help the development process where selection and fabrication process had been made.

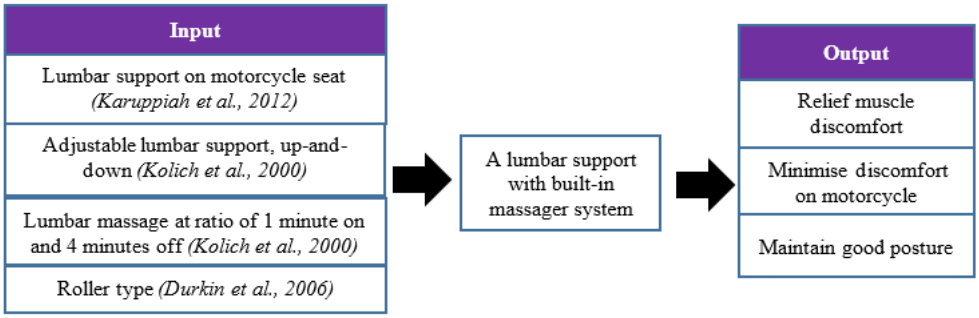


Figure 2. Criteria of the purposed prototype

5.2 Stage 2: Design and development of a prototype

The design and development stage were conducted with the intention to design, develop, and fabricate a prototype of lumbar support with a built-in massager massage system. After identification of criteria in Stage 1, research team was discussed the idea for design and development of prototype process to explore and consolidate the idea of prototype.

5.2.1 Product design specification (PDS)

A total of eighteen criteria of PDS were chosen for the development of this prototype. The criteria are performance, economy, target production cost, product life span, customer, competition, environment, size, weight, installation, maintenance, materials, ergonomics, appearance, finish, testing, safety, design time, as shown in Table 1.

Table 1. PDS for the motorcycle seat prototype

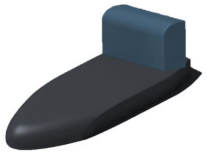
CRITERIA	PROTOTYPE
Performance	The lumbar support can be adjustable upward and downward according to the lumbar height position for the comfortability of the riders. There is also massage fitted inside the lumbar support with three dimensional rotating balls. The lumbar massage was set at a ratio of 1 minute on and 4 minutes off. However, it can also turn on/off by the user when needed. It can support up to 150 kilograms (kg) body weight.

Economy	Reasonable and practical cost (~USD 100)
Target production cost	• Low-cost • No competing product currently on the market
Product life span	It can withstand up to 10 years
Customers	• Occupation/Professional of high-powered motorcyclists
Competition	• There are no yet similar products on the market. • However, lumbar support only, backrest cushion already has on the market but not widely used. • The idea to develop the backrest of motorcycle seat with massage system came when the results showed a. High prevalence of muscle discomfort especially in the lower back b. They use a motorcycle for more than 4 hours per day c. High risk to prolonged sitting, static posture and awkward posture
Environment	• It can withstand hot and cold temperature, vibration, shock loading and dusty environment.
Size	Standard present motorcycle seat dimension
Weight	Light weight material (< 1kg)
Installation	• It was easily fixed with the existing holes and lugs in the motorcycle seat. • Can be fit to seat dimensions of an existing motorcycle. • Can be done using simple tools such as wrench and screwdriver.
Maintenance	• Keep liquids away from all electronic parts. • Make sure all components are completely dry before use, especially after cleaning. • If it has not been used in a while or abnormal symptoms have been detected such as overheating, contact a professional for assistance.
Material	• Light, small frame, robust, anti-rust, less expensive, easy to form shape, and machining.
Ergonomics	• Easy to operate, handle and maintained • Cushion with contour shape will support back posture. • Two 3D roller massager • Adjustable lumbar support
Appearance	• Easy to use, look robust and compact • Curve edges, simple, fulfil needs
Finish	Gray and black surface and cover as a finisher to make the product looks sporty, elegance and formality
Testing	• On-road initial testing had been conducted a. Observation of **riding posture.** b. The visual analogue scale had been used to rate **discomfort rating** after riding a motorcycle**.**
Safety	• No harm to the rider and other road users • Safety briefing had been mentioned clearly to the user before use
Design time	• Conceptual design-2 month • Prototype development – 12 months

5.2.2 Conceptual design

In order to identify the best seat design for this research, the Pugh Chart was used in this stage. Each design was compared with datum (an existing lumbar support motorcycle seat), based on previous research conducted by Karuppiah et al. (2012). A details evaluation between designs was illustrated in Table 2. The research team screened down the five design concepts based on criteria and constraints such as budget limit. Based on evaluation in Table 2, Design 5 was chosen as the best design for the motorcycle seat prototype.

Table 2. Conceptual design and their characteristics

	Design 1	**Design 2**	**Design 3**	**Design 4**	**Design 5**
Design Criteria					
Low cost	No	Yes	No	No	Yes
Small base frame	No (25 cm x 40 cm)	Yes (17 cm x 40 cm)			
Lightweight	No (> 1 kg)	Yes (<1 kg)	No (> 1 kg)		Yes (<1 kg)
Attractiveness	Yes (Good contour shape)	No (Flat)	Yes (Best contour shape)	Yes (Good contour shape)	
Performance	• Build-in massager in lumbar support cushion (The massager was set at a ratio of 1 minute on and 4 minutes off and can turn on/off manually).				
Durable	Yes, heavy-duty and robust				
Environment	It can withstand hot and cold temperature, vibration, shock loading and dusty environment.				
Easy to Install	No (Too big for an existing motorcycle)	Yes • Easily attached to existing motorcycle seat without any major modification • Can be done using simple tools such as wrench and screwdriver			
Ease of maintenance	Yes				
Adjustable	No	Yes (can be adjustable upward and downward)			
Safety	Yes (No harm to the rider and other road users)				
Effectiveness	Yes (Maintain good posture, relief discomfort)	No (Cannot maintain a good posture)	Yes (Maintain good posture, relief discomfort)		

5.2.3 Prototype Development Process

The prototype development process was conducted to produce this prototype (Figure 3). The process involved four stages which are massage system installation, lumbar support frame, lumbar support cushion, and assembly process.

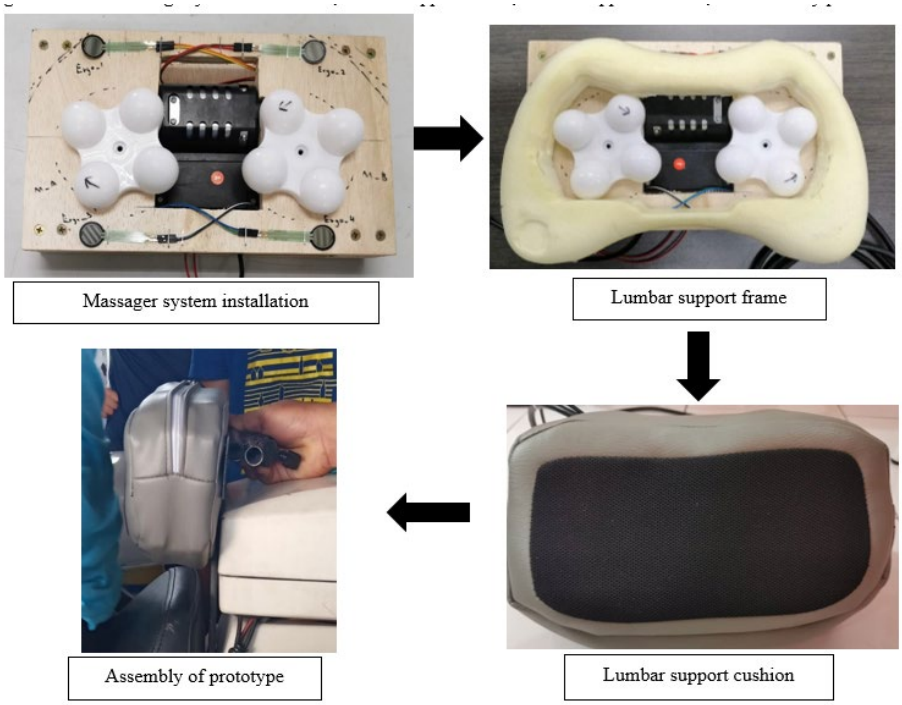


Figure 3. The prototype development process

A prototype consisted of lumbar support (37cmx18cm), which is mounted proximate to a centre portion of a motorcycle seat. An adjustable panel configured to be placed in the seat to get an ergonomic posture and comfortable to the riders, which depend on their size and height of the riders. The adjustable lumbar support height, a distance between top and bottom of the lumbar support height, was 16cm. A detail of the prototype was shown in Figure 4.

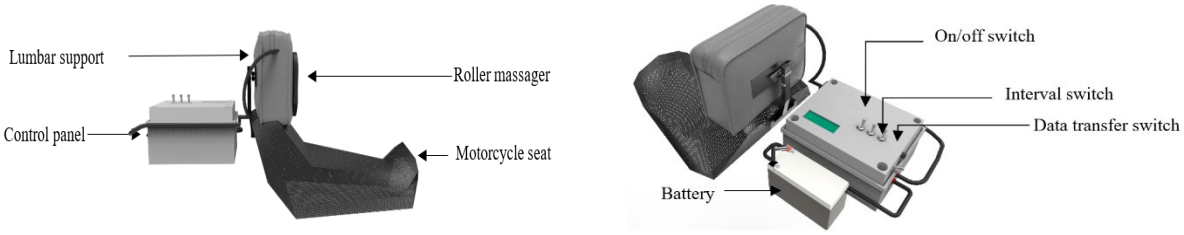


Figure 4. A motorcycle seat prototype and its components

5.3 Stage 3: Initial testing

Initial testing was conducted to analyse the efficiency of the prototype on the riding posture and the discomfort ratings. The following sub-sections describe the comparison between the existing motorcycle seat and motorcycle seat prototype.

5.3.1 Riding posture

Figure 5 shows the visual comparison of the rider's riding posture using the existing motorcycle seat and the developed motorcycle seat prototype after a 20-minutes ride. Overall, it can be seen that the prototype was able to minimise the awkward posture for a continuous riding session of 20 minutes. With the prototype, traffic police riders could lean their body while sitting on the motorcycle seat, demonstrating that the prototype is able to support body posture efficiently. The postures of the five subjects were observed and discussed among the research team members, and a mutual agreement was reached. As a result, awkward body posture from continuous riding can be minimised using the motorcycle seat prototype. Based on the previous study, this approach in designing ergonomic interventions has shown a positive outcome from the targeted end-user, resulting in positive health impact (Umar et al., 2019). This study proved that from initial testing where the results showed a positive outcome in improving the riders' posture and health.

(a) (b)

Figure 5. Posture after 20-minutes riding session, (a) existing seat and (b) prototype seat.

Table 3. Percentage of improvement of motorcycle seat prototype (N=5)

Item	Discomfort ratings (mm)		Average improvement (%)	Z statistic	p-value
	Existing seat	Prototype seat			
Seat width	38.5	35.7	2.8	-1.826	0.068
Seat length	49.2	20.5	28.7	-2.032	0.042*
Seat contour	39.1	30.6	8.5	-2.025	0.044*
Vibration	48.6	40.7	7.9	-2.023	0.043*
Physical design	43.5	29.5	14	-2.041	0.041*
Tendency to slide	50.2	20.4	29.8	-2.121	0.034*
With/without lumbar support	52.5	7.8	44.7	-2.891	0.009*
With/without massager	65.0	11.3	53.7	-2.345	0.018*
Pressure under buttocks	53.0	26.4	26.6	-2.789	0.010*
Lower back	69.1	15.9	53.2	-3.059	0.002*
Middle back	50.6	20.5	30.1	-2.032	0.042*
Upper back	57.8	18.9	38.9	-2.598	0.015*
Side of body	49.5	21	28.5	-2.179	0.033*
Buttock	47.8	23.7	24.1	-2.503	0.029*
Overall discomfort	51.0	20.0	31.0	-2.937	0.003*

5.3.2 Discomfort ratings

A valid motorcycle seat discomfort survey using a 100 mm VAS was used in this study to assess the discomfort ratings after riding a motorcycle. In this initial testing, the prototype achieved lower scores in discomfort ratings compared to

the existing seat, as shown in Table 3. Overall, the discomfort ratings were reduced by 31%. Meanwhile, the results obtained from a Wilcoxon Signed-rank test showed that majority of the items were statistically significant difference between existing seat and prototype seat namely the seat length, seat contour, vibration, physical design, tendency to slide, with/without lumbar support as well as massager, pressure under buttock, lower back, middle back, upper back, side of body, buttock, and overall discomfort ($p<0.05$). Meanwhile, there was no statistically significant different in seat width between existing seat and prototype seat ($p>0.05$). However, there was still improvement between existing seat and prototype seat. The details of the results are tabulated in Table 3.

In terms of posture, the prototype proved that it could effectively support the body posture of the riders even after 20 minutes riding session compared with the existing seat that gave slump posture after riding session end. Meanwhile, in terms of health, the prototype seat showed reduced discomfort perception of riders on muscle and motorcycle seat especially with the present of massager system. These promising initial results showed a good overview of the prototyping potential to improve the current problems of traffic police riders in order to complete a work task. This was supported by Donnelly et al. (2009) which the use of a lumbar support system has been shown to aid in the maintenance of a person's natural lordotic lumbar curvature during sitting which has been associated with reducing muscle discomfort. One of previous studies also found that there was a positive effect on the body part's comfort with the usage of lumbar support. The results also show that by using lumbar support, there was a higher comfort change in the upper back, lower back and buttock (Karuppiah et al., 2012). Besides, massage can reduce back pain, stiffness, and fatigue and could be used as a complement for the standard care of people (Chunco, 2011). The reduction in back pain is in line with Romanowski et al. (2017) findings where they found that massage can reduce musculoskeletal disorders risks in a randomised clinical pilot study. Subjective comfort measures have been positively correlated with massage (Furlan et al., 2015; Kolich, 2008) and improving sitting comfort has been targeted as a means of reducing musculoskeletal disorders (Kolich, 2008). However, this prototype concept is still in the preliminary stage and requires multiple tests and design iterations, even this prototype is completely functional and showed positive feedback as well as high potential to reduce muscle discomfort and improve posture. Thus, further testing of a lumbar support motorcycle seat with built-in massager system may require in-depth laboratory, clinical and field testing. Future study may focus on perceived discomfort and spinal angle posture to compare the results between existing seat and prototype seat in details.

6. Conclusion

A prototype (lumbar support with built-in massager system motorcycle seat) has been successfully designed and developed in this study, based on the inputs from extensive literature, research team as well as Pugh design concept. The operation and function of the prototype have been successfully simulated in riding session and have shown an initial potential to improve riding, work efficiency, safety and health conditions of the traffic police riders.

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Biography

Nur Athirah Diyana Mohammad Yusof is a PhD student in Occupational Safety and Health. Her research focuses on occupational health in motorcycle ergonomic. She actively participated in competition and conference throughout being a PhD student. She had won a Gold Award entitled 'Development of Lumbar Support for Motorcycle Seat with Built-In Massager System: Traffic Police Riders' in Research Innovation Poster Competition Series 1/2021 and 2nd Prize in Road Safety Infographic Poster Competition in 2019 organised by The Institute of Engineer Malaysia. She had listed as an Ergonomic Trained Person (Initial Ergonomic Risk Assessment) in 2021. Her scientific research interests include occupational exposure, ergonomics, musculoskeletal disorders, air pollutants, occupational safety and health.

Karmegam Karuppiah, PhD is a Head of Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia (UPM). He is also a member of the Board of Engineers Malaysia (BEM) and Human Factors and Ergonomics Society Malaysia (HFEM). His research area interests are ergonomics in product design, work-related musculoskeletal disorders (MSDs) and occupational safety and health.

Putri Anis Syahira Mohamad Jamil is a postgraduate student in PhD of Occupational Safety and Health. She is an avid researcher and has an interest in occupational health. She is a member of Malaysian Society of Occupational Safety and Health (MSOSH). She also becomes a reviewer for the Malaysian Journal of Medicine and Health Sciences. Her scientific research interests include occupational exposure, air pollutants, respiratory health, ergonomics, occupational safety and health.

Irniza Rasdi, PhD is a senior lecturer in Occupational Safety and Health. Her interest is safety culture and the automotive industry. She is a committee member in the Malaysian Society for Occupational Safety and Health (MSOSH).

Vivien How, PhD is a senior lecturer in Occupational Safety and Health. Her expertise is statistical analysis, chemical risk assessment to health, disaster risk reduction, and occupational health.

Sivasankar Sambasivam, PhD is currently working in the industry. His research areas are in vehicle and occupant safety, ergonomic product design and project management. He has over 15 years of experience in the automotive industry, where he worked in Lotus Engineering and, as a result, has worked together with major automotive manufacturers and OEMs during his time in Lotus. He hopes to be able to use his experience in the automotive industry to contribute to the continuous research for vehicle and occupant safety in Malaysia.

Kulanthayan KC Mani, PhD is a lecturer in Community Health Department, Universiti Putra Malaysia. His interest area is road safety and children safety. He is a member of the National Road Safety Council of Malaysia (MKJR) chaired by the Minister of Transport Malaysia, since 2013. Globally, he is recognised and serves as a Member of the Advisory Board of Child Injury Prevention Alliance (CIPA) based in Ohio, USA, since 2016. This approach won him recognition with three international awards awarded to his organisation in 2017: FedEx International Road Safety Award from Global Alliance of NGOs for Road Safety in Kuala Lumpur, Malaysia in April 2017, Excellence in Communication Award by Safe Kids Worldwide USA in Baltimore, Maryland USA in July 2017 and Prince Michael International Road Safety Award in London, UK in December 2017.