How to Cite:
Alias, A. N., & Karuppiah, K. (2022). Effects of armrest prototype on comfort among motorcyclists during prolonged riding process. *International Journal of Health Sciences*, *6*(S7), 5105-5122.
https://doi.org/10.53730/ijhs.v6nS7.13099

Effects of armrest prototype on comfort among motorcyclists during prolonged riding process

Ayuni Nabilah Alias
Faculty of Safety and Health, University of Cyberjaya, 63000 Cyberjaya, Selangor, Malaysia and Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

***Karmegam Karuppiah**
Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
*Corresponding Author: megam@upm.edu.my

***Abstract*---**Introduction: Motorcycles had grown to be one of the most common ways of mobility among Malaysians. However, motorcyclist struggles with discomfort of their arm during prolonged riding as arm support feature is usually absent in common motorcycles. Therefore, the main goal of this study is to investigate the effect of implementing armrest prototype in terms of discomfort level among motorcyclist during prolonged riding process. Method: A total number of 102 respondents were seated on a motorcycle in two distinct sessions; a session on a motorcycle with armrest and the other session on a motorcycle without armrest. Each respondent was required to attend two separate experimental sessions. Each session had lasted for 2 hours. During the 2-hour session, a riding simulator system was displayed, and respondents were asked to control the handlebar of motorcycle as in real road. Respondents were required to rate their level of discomfort for each body part on the Borg's CR-10 scale in every 15 minutes. Results: During the testing period, the experimental group's discomfort rating was lower than that of the control group. The results showed that, when compared to the control group, the experimental group's arm and hand discomfort ratings were considerably lower (2.0 ± 2.20, $p<0.05$). Arm and hand are the most impacted body parts prior to +82% comfort changes with the use of the prototype. Conclusion: This study has offered fresh perspectives on the impacts of armrest prototype use on motorcycle riders during a prolonged riding process in a controlled laboratory setting. The usage of armrest prototype has offered a useful ergonomics element that lessens discomfort in the body. The posture of motorcycle rider is also related to both comfort and discomfort when riding. As a result, this

Manuscript submitted: 9 May 2022, Manuscript revised: 18 July 2022, Accepted for publication: 27 August 2022

prototype (armrest) is capable of offering an ideal posture and may improve the comfortability of motorcyclists during extended rides.

***Keywords*---**Prototype, armrest, comfort, motorcyclists, riding process.

Introduction

Transportation is seen as a critical aspect in any emerging country's economic development and globalization. There are three primary modes of transportation: road, air and sea. In Malaysia, the road is considerably more popular because it is easier, more pleasant, and less expensive than the other two means (Karmegam et al., 2013). Motorcycles are well-known as an important mode of transportation locally and globally. In Malaysia, motorcycles and cars are the most popular modes of transportation for people's daily activities (Mclnally, 2003). When huge commercial vehicles and fast-moving cars are compelled to share the same roadway amenities as motorbikes that are slower and less maneuverable on busy roads, conflicts are likely to arise (Faezi et al., 2011). However, motorcycles are preferred over cars because they are more compact, consume less fuel, can easily navigate congested area, affordable and just need less maintenance (Mclnally, 2003). In Malaysia's motorcycle market, motorcycle is regarded as one of the most common ways of transportation for Malaysian. The Road Transport Department Malaysia Statistics (2015) highlighted the popularity of motorcycles in terms of the increase in the new registered motor vehicles from 2005 to 2013. Meanwhile, according to modes of road mobility, motorcyclists account for over half of all registered cars on the road (Shuaeib et al., 2002; Karmegam et al., 2009).

Motorcycle have become one of the most common ways of transportation in Malaysia and they are employed in the workplace for a variety of tasks such as fast-food delivery, delivery posts and patrols. Aside from that, motorcycles have been proved to be statistically dangerous modes of personal transportation (Shahar et al., 2010). Motorcycles are notoriously unsteady and must be controlled by the motorcyclist to travel safely. When compared to vehicle drivers and other automotive drivers, the direct exposure to the environment, noise and vibration may influence motorcycle riders (Walker, Stanton and Young, 2006). The comfortability or contentment of the human body is a requirement and a significant feature in current industrial and nonindustrial research and development (Wahab et al., 2008). The concepts of comfort and discomfort are unique in the science of ergonomics since they required human awareness (feedback) of the machine and work system environment. They are also difficult to define since they entail both objective and subjective measurement (Bridger, 1995).

Regarding motorcycles riders, their levels of comfort and discomfort may be affected by discomfort symptoms on various body regions as a result of their posture when riding (Chee et al., 2008; Kolich, 2008). Many musculoskeletal disorders begin with persons experiencing discomfort in their body parts. As a result, scientific data, and research on the impacts of this sort of riding on motorcycle comfort are required. Does the lack of arm posture support on this motorcycle cause substantial discomfort to the motorcyclist's posture and arm muscle? The major goal of this study was to reduce discomfort in both arms of motorcyclists using a prototype (armrest) (Figure 1). The riding posture of a motorcycle rider is dynamic and changes throughout the ride. Additionally, the best posture for riding will be comparable to that of sitting in a chair or car with a static posture or certain mechanical characteristics in that specific system that can support the body regarding changes or adjustments to posture. Nonetheless, these functionalities are not currently available on motorcycles (Karmegam et al., 2008). As a result, just like vehicle drivers, motorcycle riders frequently adjust their posture throughout the riding process to avoid mechanical stress and tissue ischemia (Chee et al., 2008) which can have unfavorable consequences on various body parts.

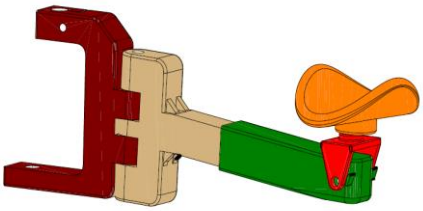

Figure 1: Armrest Prototype

Methodology

This study was experimental pre-post test study with the purpose to evaluate the effect of prototype (arm rest) on comfort among motorcyclist during prolonged riding process. This study was conducted in controlled laboratory setting. Study populations were conducted among male students and staffs in Universiti Putra Malaysia (UPM) that met the inclusion and exclusion criteria.

The sampling method for this study was purposive sampling where the respondents in this study were selected based on the criteria stated. A total of 102 motorcyclists with 51 motorcyclists for each studied group were recruited to participate in this study. The respondents were all in good condition and with no history of musculoskeletal disorders disease or arm pain at the time of experiment process. The respondents were also asked to avoid from any heavy exercise or work for three days prior to the data collection process (Karmegam et al., 2012). The inclusion criteria as listed (Karmegam et al., 2012; Chandore and Deshmukh, 2014): i) Male, ii) age between 20 – 35 years old, iii) Motorcyclist for a motorcycle of 150cc and below. The respondents would be excluding out from this study if (Reed-Jones et al., 2009; Adalarasu et al., 2012): i) Inadequate sleep prior to experiment, ii) Existence of symptoms of the simulator adaption syndrome like nausea, headache and dizziness.

Instrumentation

Questionnaire and Borg's (CR-10) Scale

There were 2 sets of questionnaires, which was given before the experiment and the second set was given during the experiment was conducted. The first set of questionnaire form (preliminary questionnaire) comprises questions regarding inclusion criteria. The purpose was to determine the respondent who had the inclusion criteria and eliminate who were not. The second questionnaire was used to determine the background information of the respondent which was related with the factors that contribute to discomfort and scale of discomfort (Borg's Scale) during riding process (Figure 2).

Meanwhile, the last section of questionnaire which was Borg's Scale must be answered during the experiment for every 15 minutes in order to determine the score level of discomfort for each body part. To assess the degree of subjective discomfort on the body part, a body chart of discomfort using the Borg's Scale (with numbers supported by textual expression) was utilised (Karmegam et al., 2012).

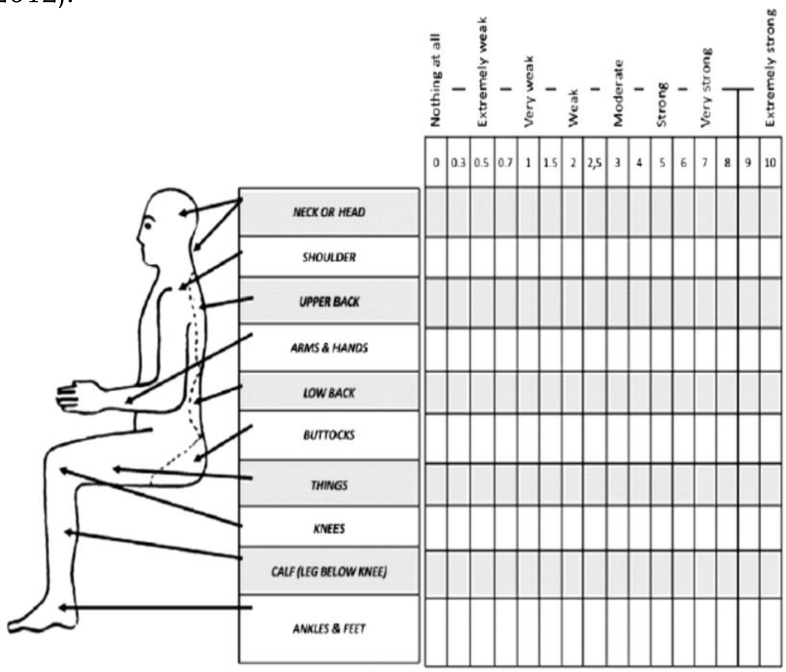

Figure 2: The body chart discomfort using Borg's (CR-10) scale
(Source: Borg, 1982; Karmegam et al., 2012)

Riding Simulator

A custom-made riding simulator system with road view had presented and projected with LCD screen located about 4 m from the motorcyclist (Figure 3). The display unit displayed road scenery with computer generated pictures simulating daytime driving condition. The speed limit legalized as in University Putra Malaysia (UPM) road area was 90 km/h.

Figure 3: Motorcyclist with road view on LCD screen

Procedure

Data collection began after receiving permission from Universiti Putra Malaysia's student affair division and Dean's Office to get the student and staff name list. They were given information sheet and consent letter and before participating in the study, a written and signed consensus was obtained. After the selections, interview and orientation was conducted to the respondents regarding to this study, procedure, and their rights. Before doing measurement, the respondents were instructed to adjust themselves comfortably with the prototype (armrest). At this point, all respondents were allowed to adjust the armrest to their comfort.

Each respondent was instructed to sit on a motorcycle for two different sessions: one on a motorcycle with an armrest (Figure 4) and the other session on a motorcycle without an armrest (Figure 5). The experiment took place in a quiet room with suitable illumination in a laboratory. Each respondent was required to attend experimental sessions on two separate days (with a minimum three-day interval between them). Each session had lasted for 2-hours. (Karmegam et al., 2012, Carvalho, 2008, Gyi and Porter, 1999). During the 2-hour session, a riding simulator system was displayed, and respondents were asked to control the handlebar of motorcycle as in real road. The video screen of the riding simulator presented a view of road scenery with computer generated video simulating daytime riding condition. At every 15-minute interval, respondents were required to evaluate their discomfort level for all body part on the Borg's Scale.

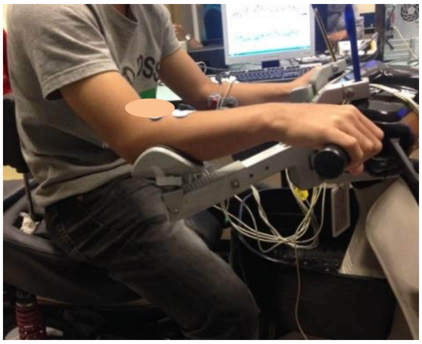

Figure 4: Respondent with armrest (Experimental group)

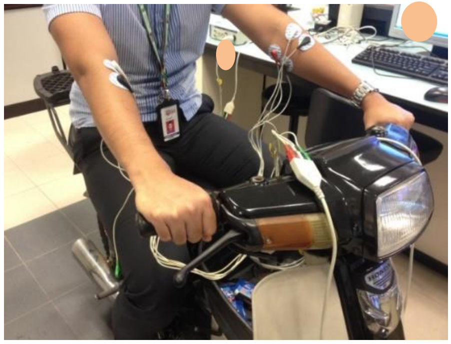

Figure 5: Respondent without armrest (Control group)

Results

Respondent background

According to Table 1, both experimental and control groups have a mean age of 23 years old. Besides, majority of the respondents were Malay (78.4% and 74.5%), followed by Chinese (15.6% and 23.5%), others (4.1% and 2%) and only Indian (1.9%) for experimental group. Both groups, mostly respondents in this study were right hand as their dominant hand (92.2% and 96.2%) compare to left-handed person (7.8% and 3.8%).

Respondent were taken from age 20 to 35 years old because at this range of age is classified as young adult. Result from statistical analysis also showed that there was no significant different of age for both groups. Around age 25, muscle strength reaches its maximum, plateaus during the years of 35 to 40, and then begins to diminish more quickly, losing 25% of its maximum force by the age of 65 (Shephard, 1998). As a result, it is critical to select an age range of 20 to 35 years old in order to prevent factors that may influence the outcome of muscle discomfort.

Table 1: Background Information

Variables	**Experimental Group (n=51)**		**Control Group (n=51)**		**z-value**	**p-value**
	Mean±SD	**Frequency (%)**	**Mean±SD**	**Frequency (%)**		
Age (years)	23±3.11		23±1.70		-0.214	**0.830**
Race						
Malay		40(78.4%)		38(74.5%)		
		8(15.6%)		12(23.5%)		
Chinese		1(1.9%)		0		
		2(4.1%)		1(2%)		

Indian		
Others		
Dominant hand	47(92.2%)	49(96.2%)
Right	4(7.8%)	2(3.8%)
Left		

N=102

From Table 2 revealed that the respondents have a normal sleeping time which is from 6 to 7 hours. Most of the respondents had 1 to 2 hours as average riding of motorcycle per day. Besides, the respondents were mostly involved in heavy works (19.6% and 26.7%) with only 1 hour of heavy work activity per week. However, majority of them actively involved in sport (76.5% and 83.3%), contributed 3 to 4 hours per week of their daily activities. Wilcoxon signed ranks test also proved that there were no significant different for average of sleeping hours, riding of motorcycle, heavy works and involved in sports for both groups.

In regard to the daily activities, only small numbers of the control (26.7%) and experimental groups (19.6%) were involved in the heavy work such as gardening and lifting things but most of them actively involved in sport with 76.5% for experimental group and 83.3% for control group. No significant different for sport activity between experimental and control groups. Therefore, these results were no confounded between the discomfort of body's part and its relation to daily activities. Table 3 depicts results from statistical analysis by using Paired T test also showed that anthropometric parameters in terms of height and weight were not significantly different between groups.

Table 2: General Information on Daily Activity

Daily Activity (hours)	**Experimental Group (n=51)**		**Control Group (n=51)**		**z-value**	**p-value**
	Mean±SD		**Mean±SD**			
Average sleep per day	6±0.997		7±1.43		-2.608	**0.69**
Average riding per day	1±1.03		2±1.97		-0.385	**0.70**
Heavy work per week	1±2.87		1±2.76		-0.826	**0.41**
Sports per week	3±3.23		4±5.97		-1.215	**0.22**
	Frequency (%)		**Frequency (%)**			
	Yes	**No**	**Yes**	**No**		
Heavy work	10(19.6%)	41(80.4%)	13(26.7%)	38(73.3%)		
Sports	39(76.5%)	12(23.5%)	42(83.3%)	9(16.7%)		

5112

N=102

Table 3: Anthropometric Background

Variables	Experimental Group (n=51)	Control Group (n=51)	t-value	p-value
	Mean±SD	**Mean±SD**		
Height (cm)	170.3±5.8	170.6±6.4	0.170	**0.866**
Weight (kg)	63.7±5.8	63.9±6.6	0.123	**0.903**
BMI (kg/m^2)	22.1±1.9	21.5±4.3	-	-

N=102

Data Distribution of Discomfort Rating Between Experimental And Control Groups

According to Figure 6-15, from 15 to 120 minutes, the experimental group exhibited lower discomfort ratings for the tested body parts than the control group. According to the findings, respondents experienced discomfort on their body parts during the testing process. The existence of the prototype (armrest) reduced the rating of discomfort in the arm and hands, as well as other parts of body.

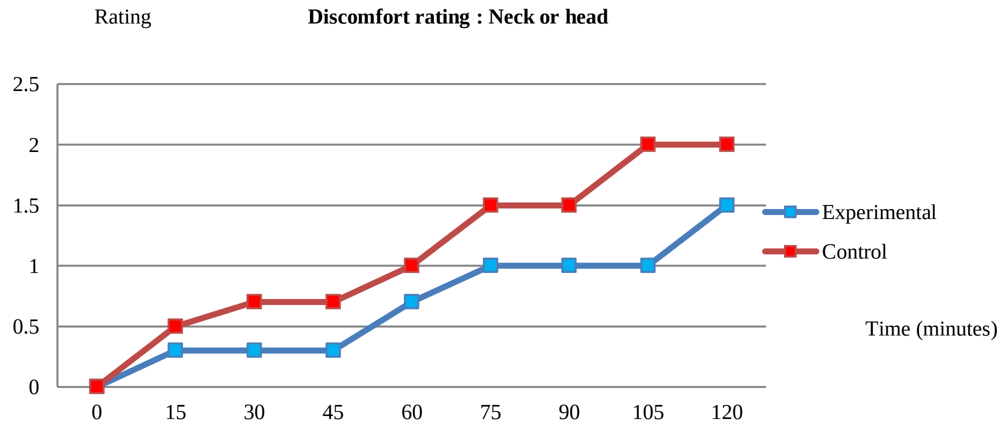

Figure 6: Changes of discomfort rating with riding duration for 2 hours for both groups

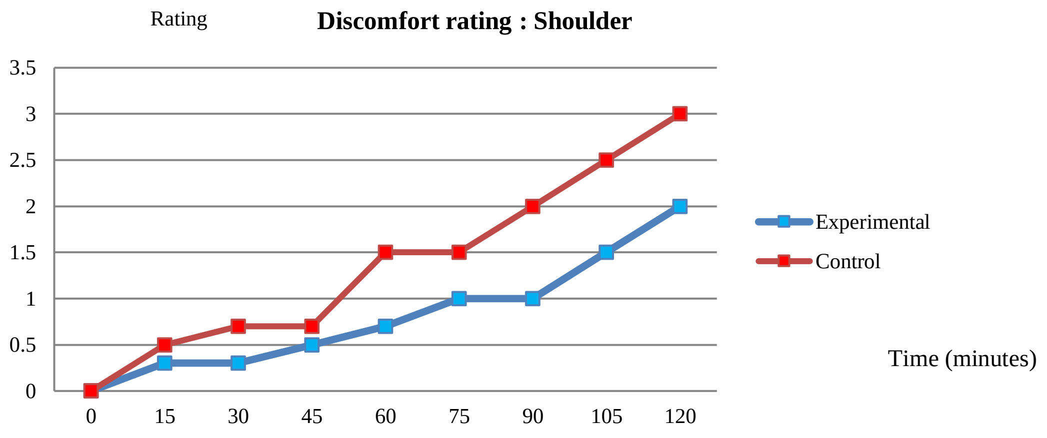

Figure 7: Changes of discomfort rating with riding duration for 2 hours for both groups

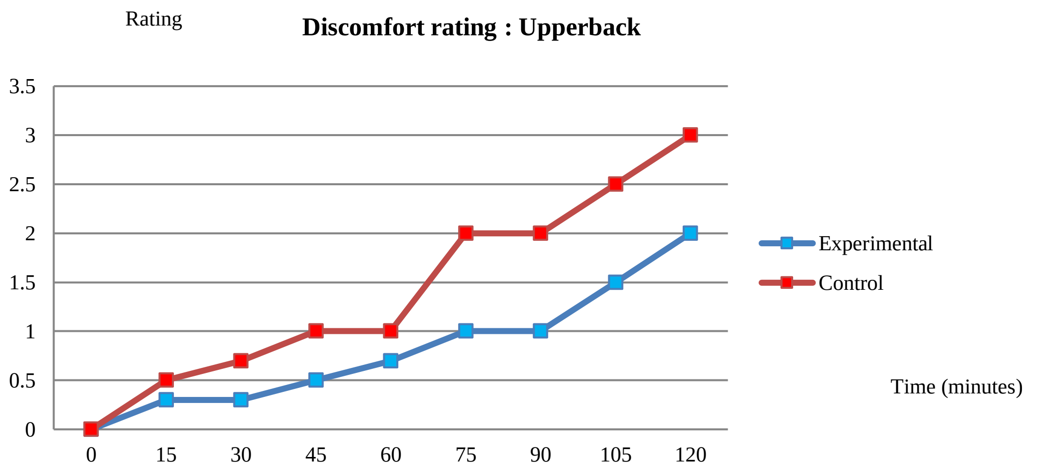

Figure 8: Changes of discomfort rating with riding duration for 2 hours for both groups

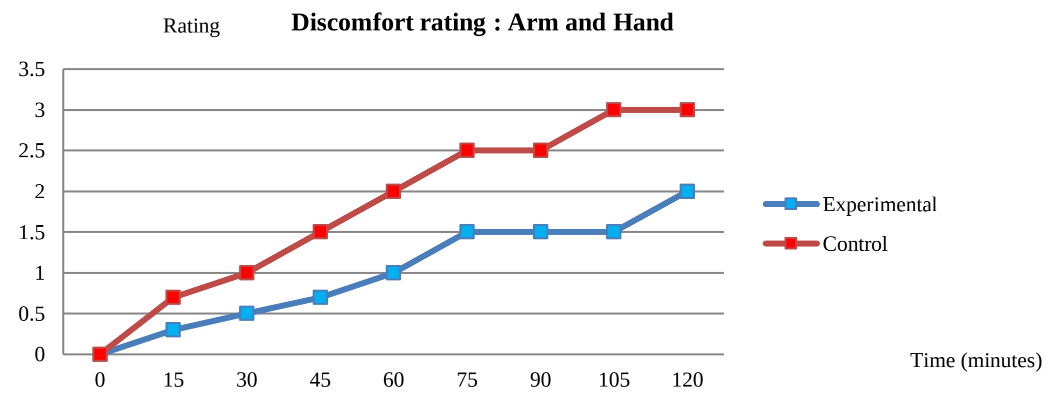

Figure 9: Changes of discomfort rating with riding duration for 2 hours for both groups

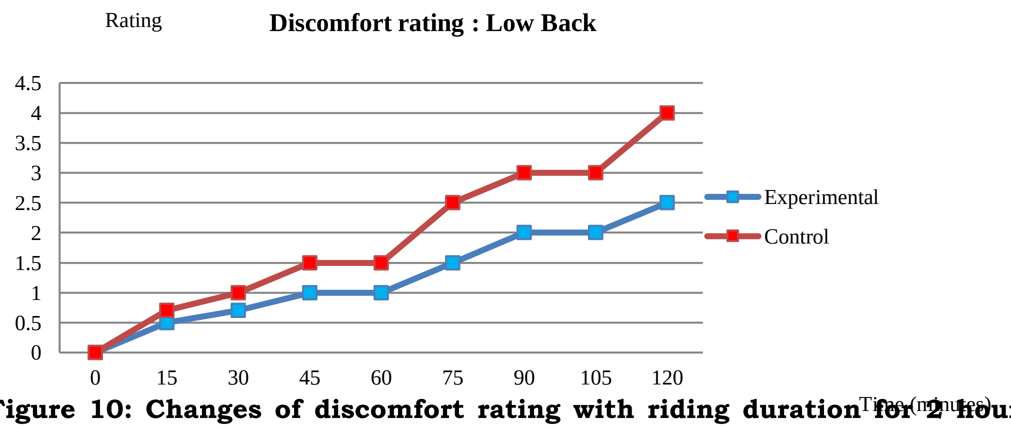

Figure 10: Changes of discomfort rating with riding duration for 2 hours for both groups

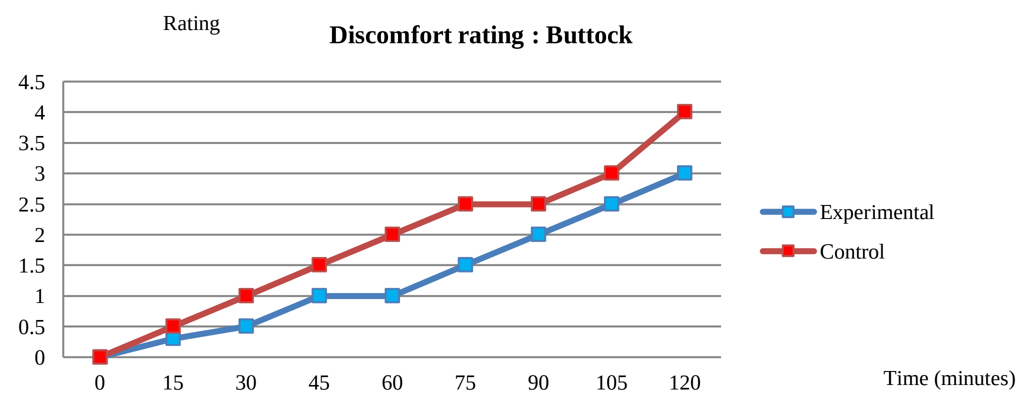

Figure 11: Changes of discomfort rating with riding duration for 2 hours for both groups

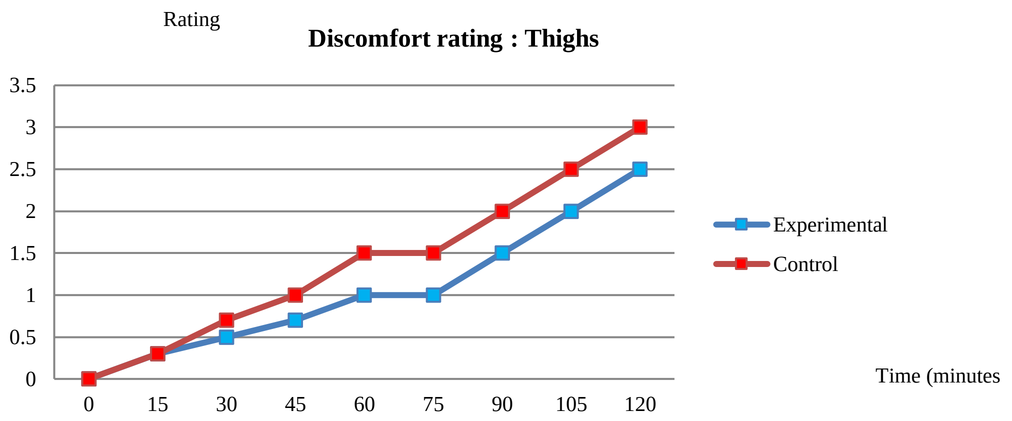

Figure 12: Changes of discomfort rating with riding duration for 2 hours for both groups

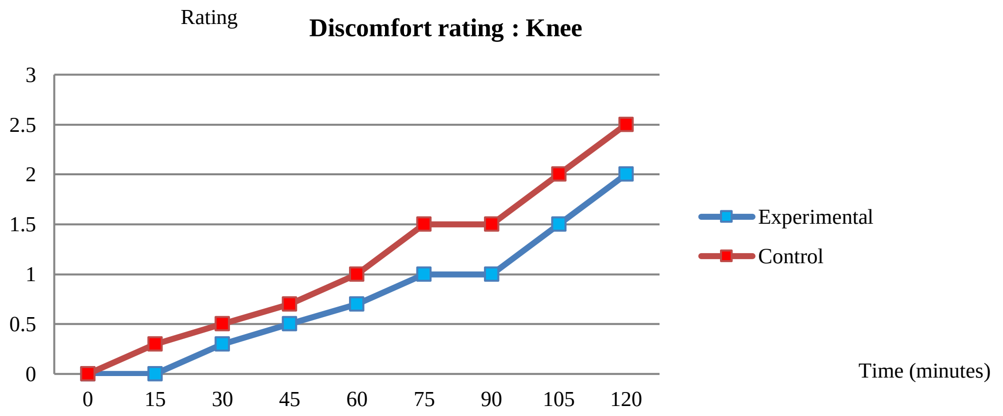

Figure 13: Changes of discomfort rating with riding duration for 2 hours for both groups

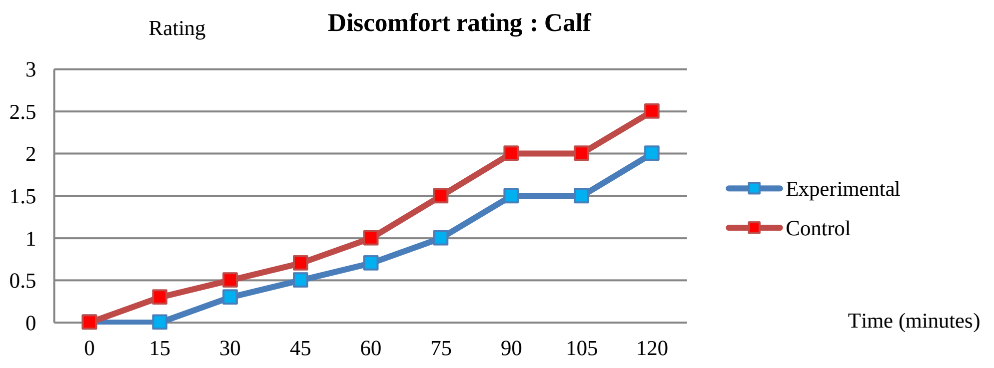

Figure 14: Changes of discomfort rating with riding duration for 2 hours for both groups

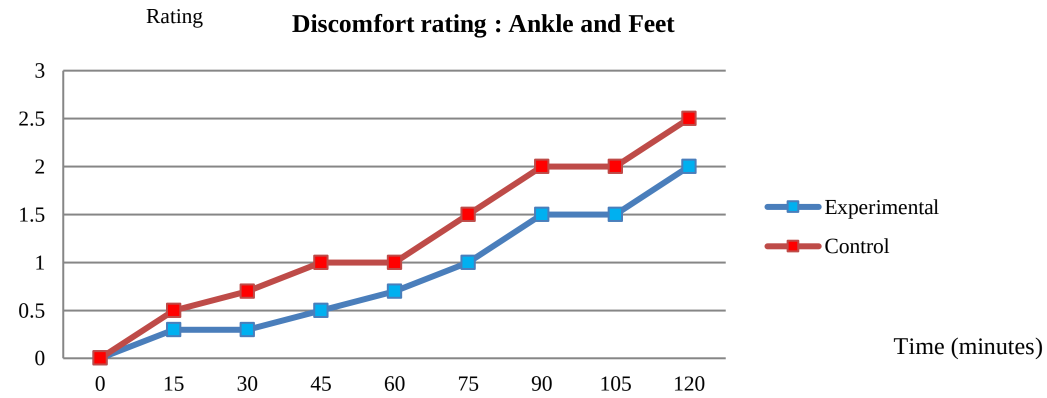

Figure 15: Changes of discomfort rating with riding duration for 2 hours for both groups

Discomfort 'break point' data distribution (Borg's Scale Rating $\geq$ 5) between experimental and control groups.

The Borg's Scale Rating ($\geq$ 5) is regarded as the 'break point', or the point at which respondents rated their discomfort as strong. As a result, this point considered where the respondents first felt discomfort in their bodily parts (Karmegam et al., 2012). Table 4 depicts the outcomes of this discomfort 'break point' between both groups. The Table 4's findings showed that there was a positive effect of comfort changes on the arm and hands with usage of prototype (armrest). The arms and hands had the greatest comfort changes in respondents, with +82% changes observed after using the prototype (armrest). Apart from that, shoulder also recorded high comfort changes after arms and hands with +75% changes, respectively. The result also showed that by using prototype (armrest), there was high comfort changes in the neck or head, upperback, lowback, buttocks, thighs, ankles and feet in the range of +20% to +67%. Meanwhile, there were least changes with only +15% comfort changes in the knees and calves among respondents as well.

Table 4: Discomfort 'break point' data distribution (Borg's Scale Rating $\geq$ 5)

Body part	**Borg's Scale Rating ($\geq$ 5) at time period (minutes)**			
	Condition	**Time (minutes)**	**Period**	**% of comfort changes**
Neck or Head	w/o	90		
	w	120		**+67**
Shoulder	w/o	90		**+75**
	w	105		
Upper Back	w/o	90		**+50**
	w	105		
Arms & Hands	w/o	75		**+82**
	w	120		

Low Back	w/o	60	
	w	120	**+60**
Buttocks	w/o	30	**+50**
	w	75	
Thighs	w/o	75	**+25**
	w	75	
Knees	w/o	75	**+15**
	w	90	
Calf	w/o	30	**+15**
	w	75	
Ankles and Feet	w/o	90	**+20**
	w	120	

N=102

w/o = testing without prototype (armrest)

w = testing with prototype (armrest)

Discomfort Rating (Arm and hands) Between Experimental And Control Groups

As previously stated, a comparison of the graph line with and without the prototype (armrest) in Figure 9 revealed considerable reductions in discomfort rating for arm and hands. Table 5 also revealed substantial variations in discomfort rating between the experimental and control groups. From 15 minutes through the completion of the 2-hour experiment, the experimental group's discomfort rating was considerably lower ($p<0.05$) than the control group's. When evaluated with the prototype, the motorcyclist's discomfort rating on the arm and hands decreased.

Table 5: Discomfort Rating (Arm and hands) between Experimental and Control Groups

Time Period (minutes)	**Median (IQR)**		**z-value**	**p-value**
	Experimental Group (n=51)	**Control Group (n=51)**		
15	0.3(0,1.0)	0.7(0,2.5)	-2.66	**0.008**
30	0.5(0.2,1.1)	1.0(0.3,3.0)	-3.14	**0.002**
45	0.7(0,2.5)	1.5(0.5,3.0)	-4.10	**<0.001**
60	1.0(0.3,3.0)	2.0(0.5,4.0)	-3.50	**<0.001**
75	1.5(0.5,3.0)	2.5(0.6,6.0)	-4.11	**<0.001**
90	1.5(0.5,3.0)	2.5(0.6,6.0)	-3.78	**<0.001**
105	1.5(0.5,3.0)	3.0(1.0,6.0)	-4.13	**<0.001**
120	2.0(0.5,4.0)	3.0(1.0,6.0)	-4.56	**<0.001**

N=102

Discussion

According to the results of many experts, comfort and discomfort are two contrasts that range from great comfort via a neutral condition to severe discomfort. Subjective measurements are one of the necessary approaches for determining the level of comfort or discomfort in the individual user (Mehta and Tewari, 2000, Goonetilleke and Feizhou, 2001, Motavalli and Ahmad, 1993, Bishu et al., 1991). As a result, in this study, a questionnaire was used to gather data, which was developed from previous studies by Lusted et al., (1994), Borg (1982), Falou et al., (2003), Koleini et al., (2008) and also Karmegam et al., (2012)

According to Figures 6 to 15, from 15 to 120 minutes, the experimental group demonstrated a significant decrease in the discomfort rating across the body areas examined when compared to the control group. The existence of the prototype (armrest) reduced the amount of discomfort in the arm and hands, as well as other sections of the body. According to the findings of this study, the experimental group had significantly lower ratings of discomfort in the arm and hands when compared to the control group. In comparison to other parts of the body, a prototype armrest for both arms was used to determine whether motorcyclists who used this armrest may raise or lessen their discomfort on the arm over the entire 2-hour riding procedure. Arm support for both hands (rather than just one arm) allowed participants to keep their wrists in a neutral position. Users who only have one arm supported may develop an asymmetric body position (Lintula, Nevala-Puranen and Louhevaara, 2001). Static stress in the neck and shoulder area was reduced when riding a motorcycle with an armrest. The weight of the arm creates a moment around the shoulder that is resisted by contractions of the anterior deltoid and other muscles, while the upper trapezius and rotator cuff muscles support and stabilize the shoulder girdle. Because the arm supports (armrests) removed some of the weight of the arm, the upper trapezius could spend less effort in its duty of assisting the shoulder to maintain its position. (Rempel et al., 2011).

Table 5 also demonstrated that the experimental group's discomfort rating was lower than the control group's during the testing period. The results showed that the experimental group's arm and hand discomfort rating was substantially lower (2.0 ± 2.20, $p<0.05$) than the control group's. A study conducted by Rempel et al., found significant reductions in discomfort rating after utilizing the prototype (armrest) (2011). His study found that when compared to the control condition, both arm support situations resulted in significantly reduced mean muscular activity of the anterior deltoid and upper trapezius muscles ($p<0.001$) and significantly higher subjective comfort ratings ($p<0.001$). These findings suggested that arm support could help reduce muscle loading and improve comfort in the shoulder and upper back throughout the pipetting procedure for workers (Rempel et al., 2011).

Lack of arm support is a risk factor for developing musculoskeletal diseases (Bergqvist et al., 1995), and the strain on the neck and shoulder contributes to pain and discomfort (Kilbom, 1996). When postures are constricted, the negative effects of awkward arm postures are accentuated (Kilbom, 1996). The stoppage of blood flow caused by static postures is proportional to the forces produced by the muscles. Blood flow is essentially obstructed when utilising with continually lifted arms (at 60% of maximum effort) (Grandjean, 1987). Intermittent arm support is a keyway to alleviate such static strains. Hunting et al. (1981) discovered that "hands and arms regularly supported" reports were strongly associated with pain relief in the neck, shoulder, and arms. According to Arndt (1983), the presence of an arm support was far more crucial than the actual location of the arms. In this study, armrests were placed on both motorcycle handles because motorcyclists used both hands to control the motorcycle riding process. According to previous research that used arm support for work using mouse and keyboards (Lintula, Nevala-Puranen, and Louhevaara, 2001), arm support for both hands (but not for one arm) allowed participants to keep their wrists in a neutral position.

As a result of this discovery, it is apparent that motorcyclists suffer discomfort throughout their bodies while riding. This discovery also demonstrates that the current interactions between humans (motorcyclists) and machines (motorcycles) do not adhere to ideal ergonomics theory (Karmegam et al., 2004). (2013). Previous research has shown that other considerations such as cost, productivity, dependability, and ergonomics do play a major part in determining the dimensions and layouts of workplaces and goods (Seitz, Balzulat and Bubb, 2000; Sengupta and Das 1997). In terms of ergonomics, the product design (motorcycle) should include the description of physical references and component arrangement, considering the appropriateness of posture and control positions based on function, the capacity to reach and view all relevant elements, and the anthropometric characteristics of possible users (motorcyclists) (Barone and Curcio, 2004). This is critical for ensuring comfort between motorcyclists (humans) and motorcycles (machine).

Overall, this research has provided new insights into the impacts of a prototype (armrest) on motorcyclists during the protracted riding process. The employment of a prototype (armrest) has produced a protective ergonomics mechanism that gives more postural stability and integrity for the musculoskeletal system of motorcyclists, particularly the arm and hands. The riding posture of motorcycle riders is also related to both comfort and pain when riding. As a result, this prototype (armrest) can offer an appropriate posture and increasing rider comfortability during extended rides. In terms of ergonomics, one of the most crucial factors to consider is the comfort of the rider. In comparison to car drivers, motorcycle riders may be more vulnerable to comfort dangers when riding. Furthermore, most motorbike handlebars lack an armrest to support both of the rider's arms during the riding process. As a result, motorcyclists tend to vary their stances in order to adapt riding comfort and also to balance the body's stress homeostasis (Karmegam et al., 2012). However, there is very little direct scientific evidence, information, and literature reviews on motorcycle discomfort and weariness (Horberry et al., 2008; Haworth and Rowden, 2006).

Conclusion

The purpose of this study was to investigate the influence of a prototype (armrest) on comfort throughout a longer riding session. According to the statistically significant findings, 1) there are reductions in discomfort rating between the experimental and control groups, 2) there is a positive effect of arm and hands on comfort with the use of the prototype (armrest) in the experimental group compared to the control group, and 3) there are significant differences in discomfort rating between the experimental and control groups. With these findings, the usage of a prototype (armrest) has offered a favourable ergonomics feature that decreases muscle and body discomfort while increasing riding performance with no negative influence on motorcycle riders. The riding posture of motorcycle riders is also related to both comfort and discomfort when riding. As a result, this prototype (armrest) is capable of offering an appropriate posture and increasing rider comfortability during prolonged rides. This demonstrates that the prototype may indirectly improve motorcyclist safety and health, as well as prevent accidents owing to motorcycle safety features.

Acknowledgement

Researchers are grateful to all respondents who agreed to participate in this experimental session involving the armrest prototype and their willingness to share their information for research progress in the ergonomic field.

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