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Effectiveness of armrest prototype on muscle activity among male motorcyclists

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***Abstract*---**Introduction: Motorcycle is one of the main transports in Malaysia that has been used for decades either for daily life activities or for working. Motorcyclist is the most important element when issues that are related to motorcycle. Therefore, this study will be able to provide evidence to reduce level electromygraphy (muscle activity) with the intervention of armrest prototype which indirectly reduce riding discomfort during prolonged riding process.Method: In 2 different sessions (with and without armrest), 102 respondents were instructed to ride a motorcycle for 2 hours in a laboratory with riding simulator system. The video screen presented by projector a view as motorcyclist in road scenery with computer generated video simulating daytime riding condition. Besides that, Electromyography (EMG) signals were used to assess recorded muscle activity for the right and left arm with the surface of electrode attached. **Results:** Muscle activity of respondents showed that there are reductions of electromyography levels for both right and left arm's muscles. There is a positive effect of exertion changes (%) on the flexor carpum radialis (right=24.54%, left=23.98%) and flexor carpum ulnaris (right=8.18%, left=10.62%) muscles of both arms with usage of prototype. The results also indicated that there were significant exertion (X^2 (63) = 757.76, p<0.001) of electromyography levels among experimental group compared to the control group within 2-hour riding process. **Conclusions:** This study was conducted to ascertain the impact of an armrest prototype on muscle activity during extended riding. The findings showed that during the testing period with the armrest prototype among motorcyclists, there were reductions in muscular activity (% of exertion) over time. The posture that rider adopt when riding a motorcycle affect both their comfort and discomfort levels.

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This demonstrates how a prototype's safety features put to a motorcycle might improve motorcyclists' safety and health while also reducing accidents.

***Keywords*---**Prototype, armrest, muscle activity, motorcyclists, riding process.

Introduction

Surface electromyography (EMG) has been widely used to detect muscle exhaustion (discomfort). Physical tests of muscle strength and continuance may be influenced directly by the patient's motivation and willingness to risk discomfort and by socioeconomic factors and secondary gain. Records of muscle performance that are in light of spectral parameters of the surface electromyography (EMG) signal may provide a more accurate measure of muscle performance than solely mechanical lists. Spectral parameters of the EMG signal are affected by metabolic fatigue (discomfort) forms that are not cognitively perceived or voluntarily regulated by the subject when performing a maintained contraction, especially when various muscle group are being monitored (Serge et al., 1995).

Motorcycle are seen to be a very intriguing subject of study to the experts and ergonomics in the field of transportation. There is indeed a requirement to satisfy the motorcyclists in a restricted workstation (motorcycle) with extremely limited changes to meet the various needs of motorcyclists (Robertson, 1986; Robertson and Porter, 1987; Robertson and Minter, 1996). Apart from that, lack of ergonomically design of motorcycle can increase the risk of getting musculoskeletal disorders and discomfort among motorcyclist. They have to adapt and fit into motorcycle's design during riding eventhough they feel discomfort and fatigue. Besides that, the presence of discomfort on the body parts of motorcyclists might be attributed to a lack of ergonomics contact between person and machine (motorcycle) in the riding environment (Robertson, 1986; Robertson and Porter 1987; Robertson and Minter, 1996; Karmegam et al., 2008).

Given their functional role during riding process, tiredness (discomfort) of the forearm muscles is highly pertinent to motorcycle riders. Intermittent and sustained fatigue (discomfort) protocols with the same subject were used to analyze forearm muscle fatigue (discomfort) depending on individual contraction intensity values (Bystrom and Kilbom, 1990). Furthermore, Clancy et al., (2008) chose the flexor digitorum superficialis and the carpi radialis, reasoning that these contractions are similar to job demands associated with the risk of repetitive stress injuries. Motorcycle riders regularly suffer from forearm discomfort, which can progress to an illness known as "compartment syndrome", necessitating surgery in some cases to alleviate pain and inflammation (Goubier and Saillant, 2003). There are complicated challenges for any motorcycle design adjustments in terms of space, comfort and safety (Karmegam et al., 2012).

Besides, human are mechanically intended to walk rather than sit (Motavalli and Ahmad, 1993) which can be related to the reaction of load and stressors in the human body. In a seated position (static), the pelvis rotates posteriorly and the lumbar lordosis straightens out, increasing pressure in the spine's posterior passive (Callaghan and McGill, 2001; Carvalho, 2008). Therefore, both sitting as a static working position and bad posture are linked to the development of musculoskeletal illnesses and discomforts in the human body (Mehta and Tewari, 2000). Therefore, this study will be able to provide evidence to reduce level of electromygraphy with the intervention of armrest prototype which directly reduce riding discomfort during prolonged riding process.

Methodology

This study was experimental pre-post test study with the purpose to evaluate the effect of prototype (armrest) on muscle activity 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.

Electromyography (EMG)

The ADI Instrument (Power Lab) has been used to conduct measurements and analyze muscle activity of the body. Electromyography (EMG) signals were obtained for the right and left flexor carpum radialis and ulnaris muscle with surface electrode was attached on arm region. The placement of the biopotential electrodes and lead wires were attached at left and right arm for both muscles. The alcohol swab wiped the skin where the muscle located. After using the alcohol, the skin was properly dried before attaching the electrode pads.

Riding Simulator

A custom-made riding simulator system with road view had presented and projected with LCD screen located about 4m from the motorcyclist (Figure 1). The display unit displayed road scenery with computer generated pictures simulating daytime driving condition.

Figure 1: Motorcyclist with road view on LCD screen

Motorcycle with Prototype (Armrest)

The armrest is an adjustable armrest to support movement of arm during riding. The armrest is attached to handle of motorcycle for both sides, right and left side and screw tightly with the handle (Figure 2). This 0.41 kg armrest consisted of 5 main components which are armrest pad, bearing support, rod cover, U-holder and arm rod. During the experiment session, armrest was activated for the experimental group for 2 hours riding process. Meanwhile, the control group was not attached with armrest during their session.

Figure 2: Prototype (armrest) attached to motorcycle’s handle

Data Collection

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. The questionnaire was distributed to all respondents to determine their backgrounds and general health status. Measurement of height and weight of the respondent was taken to determine their BMI. Prior to the measurement, all the respondents were assigned into groups randomly using systematic randomization which were experimental group (Figure 3) and control group (Figure 4).

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 armrest prototype. All respondents were permitted at this time to adjust the armrest to their comfort of their arm. Each respondent was asked to sit on a motorcycle with two different sessions; a session on a motorcycle with armrest and the other session on a motorcycle without armrest. The experiment took place in a quiet room in a laboratory with adequate lighting. Each respondent had to attend experimental sessions on two different days (with a minimum three-day interval between them). Each session had lasted for 2-hour. (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. Meanwhile, electromyography signals were used to monitor recorded muscle activity for the right and left arm of the respondents with the surface of electrodes attached.

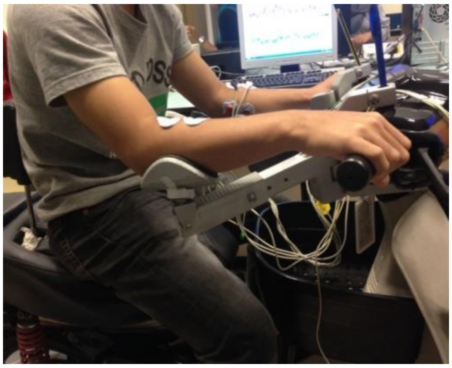

Figure 3: Respondent with armrest (Experimental group)

Figure 4: Respondent without arm rest (Control group)

There were 2 steps for Maximum Voluntary Contraction (MVC) in 10 second approximately which was used during electromyography (EMG) measurements before recording of signal in 2 hours riding process as below:

I. Extension of arm

II. Flexion of arm

All the measurements for both muscles (Flexor Carpum Radialis and Ulnaris muscle) for muscle activity using EMG were done based on these protocols. Before starting the 2 hours riding process, respondents were asked to perform two maximum bending called extension and flexion of bending. This step was used to obtain the MVC as well as to measure the strength of muslces. The MVC data is crucial for a reference value to faciliate strength comparison between individuals. The quantitative parameters that were taken for muscle activity signals were RMS value and then converted into percentage of exertion (% of exertion) as a final value for each respondent.

Results

The purpose of this study is to determine the effect of prototype (armrest) on muscle activity among motorcyclist during prolonged riding process among student and staff at Universiti Putra Malaysia (UPM). The mean age for both experimental and control group are 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. Muscle strength peaks at the age of 25, plateaus around the age of 35 or 40, and then begins to diminish, with a 25% loss of peak force by the age of 65 years (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.

Data Distribution of Electromyography Levels (% of Exertion) between Experimental and Control Groups.

The first objective of this study is to determine the data distribution of electromyography levels (% of exertion) between experimental and control groups. Basically, there were 2 types of muscles studied in this electromyography test on motorcyclists. Two types of muscle were flexor carpum radialis and ulnaris muscle for both arms. Analyzed muscles between these two studied groups were presented in Figures below. The mean power frequencies of the RMS-processed with Maximum Voluntary Contraction (MVC) signals of 10 seconds were then determined in order to estimate exertion frequency, also known as percentage of exertion (% of exertion). Thus, higher percentage of exertion indicated that there was increasing of muscle activity of arm’s part. Figure 5-8 showed that there were reductions in electromyography levels (% of exertion changes) for both right and left arm muscles in the experimental group when compared to the control group.

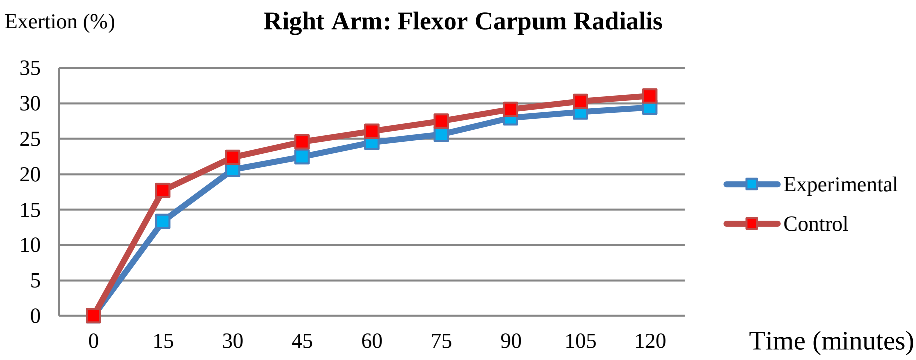

Figure 5: Changes of percentage of exertion with riding duration (2 hours)

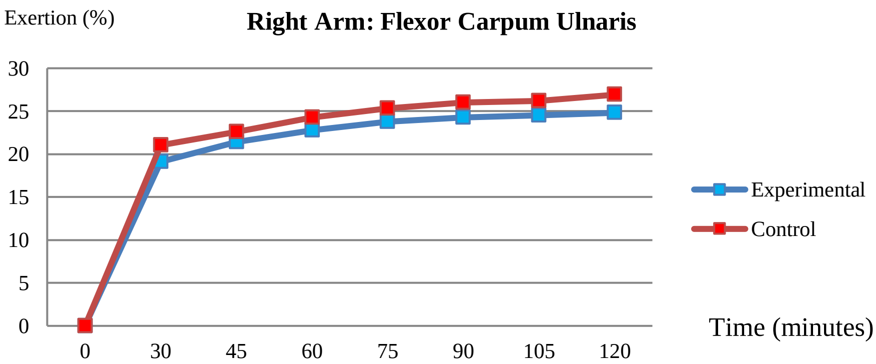

Figure 6: Changes of percentage of exertion with riding duration (2 hours)

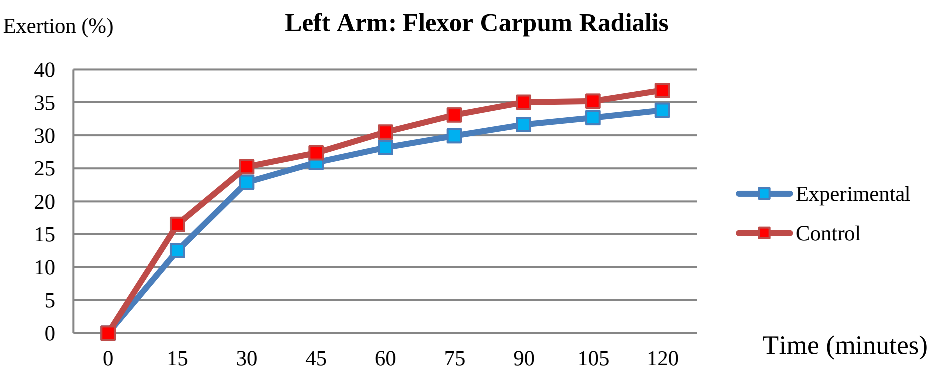

Figure 7: Changes of percentage of exertion with riding duration (2 hours)

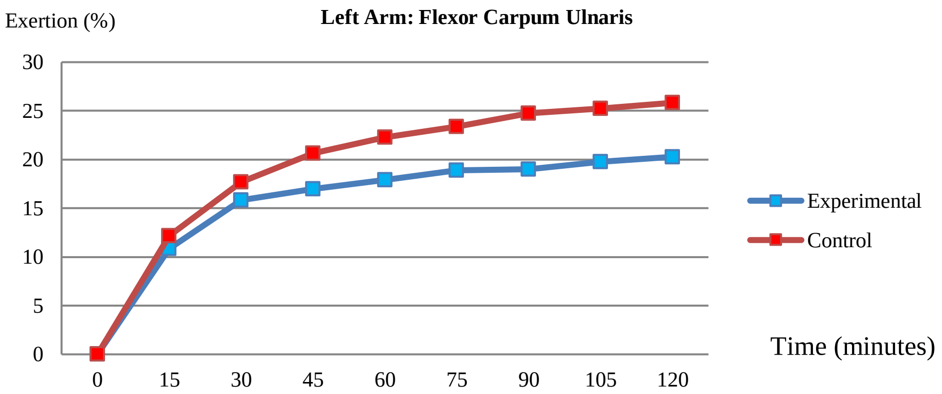

Figure 8: Changes of percentage of exertion with riding duration (2 hours)

Exertion changes (%) of Flexor Carpum Radialis and Ulnaris muscles between experimental and control groups.

The second objective of the study is to determine exertion changes (%) of flexor carpum radialis and ulnaris muscles between experimental and control groups. Exertion changes (%) are calculated based on highest difference of electromyography level (% of exertion) at period of time between studied groups.

The results in Table 1 showed that using the armrest prototype has a favourable influence on exertion changes (%) on the radialis and ulnaris muscles. It was illustrated that the percentage of exertion (%) were reduced on muscles of both arms with usage of prototype (armrest). Flexor carpum radialis of right arm showed the most reduction of exertion changes with 24.54% compare to flexor carpum ulnaris with 8.18%. In similar context, flexor carpum radialis of left arm showed the higher reduction of exertion changes with 23.98% compare to flexor carpum ulnaris with 10.62%, respectively.

Table 1: Exertion changes (%) of Flexor Carpum Radialis and Ulnaris muscles

Muscles	**Electromyography levels (minutes)**			
	Condition	**Time Period (minutes)**	**% of exertion**	**% of exertion changes**
Radialis (right)	w/o	15	17.68	**24.54**
	w	15	13.34	
Ulnaris (right)	w/o	15	17.61	**8.18**
	w	15	16.17	

Radialis (left)	w/o	15	16.47	**23.98**
	w	15	12.52	
Ulnaris (left)	w/o	15	12.15	**10.62**
	w	15	10.86	

N=102

w/o = testing without prototype (armrest)

w = testing with prototype (armrest)

Electromyography Levels (% of Exertion) of Muscles between Experimental and Control Groups.

The third objective of the study is to compare the differences of electromyography levels (% of exertion) for both muscles between experimental and control groups. Table 2 showed the percentage of exertion (% of exertion) values for both right and left flexor carpum radialis and ulnaris muscle. The results from statistical analysis by using Friedman's test which is an alternative to One-way Repeated Measure ANOVA because it does not require the dependent variable to follow a normal distribution. This test determined the difference between groups' effects as well as within subject effects. This test revealed that there were significant exertion within 2 hours riding process, X^2 (63) = 757.76, p<0.001. Post Hoc analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied, resulting that there are significant mean differences between all pairs'comparison.

Table 2: Electromyography Levels (% of Exertion) of Muscles between Experimental and Control Groups.

Time (min)	**Median(IQR)**				**Median(IQR)**		
	Experimental Group (n=51)				**Control Group (n=51)**		
	Right (Radialis)	**Right (Ulnaris)**	**Left (Radialis)**	**Left (Ulnaris)**	**Right (Radialis)**	**Right (Ulnaris)**	**Left (Radial**
15	6.17 (4.12,11.20)	9.58 (5.26,11.09)	5.30 (3.77,10.95)	7.01 (4.09,11.26)	14.72 (7.56,43.86)	19.64 (7.04,39.96)	16.15 (7.34,4
30	8.62 (5.82,12.93)	9.95 (5.87,15.21)	6.14 (5.49,12.96)	9.40 (5.67,12.27)	22.33 (8.55,53.60)	23.11 (9.13,49.56)	31.87 (12.97,5
45	9.49 (6.93,14.28)	9.85 (5.73,17.27)	7.63 (5.58,15.82)	9.54 (5.80,13.51)	23.06 (9.27,62.70)	24.51 (9.86,52.99)	43.94 (14.89,6
60	12.48 (7.10,15.54)	10.28 (7.40,17.27)	8.55 (5.54,17.40)	9.34 (7.27,13.51)	24.23 (9.48,64.72)	28.02 (9.89,55.95)	48.47 (15.39,6

75	12.32 (7.28,16.65)	10.65 (8.34,17.95)	9.20 (5.53,18.26)	9.05 (7.61,12.90)	25.62 (13.77,66.86)	31.80 (9.90,57.55)	51.13 (16.02,
90	11.75 (7.34,18.27)	10.09 (8.24,18.52)	9.81 (6.20,18.87)	9.32 (7.56,14.73)	28.27 (15.79,71.67)	34.48 (10.16,61.52)	53.26 (15.95,
105	11.84 (7.66,18.98)	10.46 (8.23,19.65)	10.32 (6.74,20.02)	9.28 (7.73,14.12)	30.82 (17.09,76.30)	39.22 (11.16,57.33)	55.74 (15.87,
120	11.61 (8.04,19.23)	10.89 (8.36,20.08)	10.57 (7.07,20.59)	9.36 (7.43,14.74)	31.79 (17.04,81.18)	37.13 (11.92,61.55)	56.16 (16.15,

[a]Pairwise comparisons with Bonferroni correction show significant differences for all pairs.

Friedman Test

*p is significant at <0.001

Discussion

Surface electromyography (EMG) is a technique that uses voltage-measuring electrodes atttached to the surface of the skin to detect and/or infer numerous events related to muscle contractions. Surface EMG has been used in most fields of ergonomics research and analysis involving muscle activity of the body because to the advancement of sophisticated modern electronic instrumentation. When used properly and understood in light of basic physiological, biomechanical and recording principles, EMG can be very valuable analytical tool. EMG can be significant tool in evaluating work performance if ergonomics research are properly designed and the limitations of the interpretation process are recognised (USDHHS, 1992).

It was easier to show the level of muscular activation as well as discomfort among motorcyclists using EMG data that corresponded with the discomfort rating during the riding process. While EMG data could not be acquired during an actual ride due to the size and nature of the equipment, riders were shown a riding simulator system that was built up as realistically as possible and emulated an actual motorbike ride. The method of data collection in the controlled environment reduced the influence of confounding variables and allowed for an accurate comparison of muscle activity after and without the use of an armrest. Furthermore, because of the controlled indoor setting in the laboratory, the impacts of weather and road conditions had no effect on muscle activity (Conrad and Marklin, 2014).

Based on Figure 5 until Figure 8, group trends were observed towards percentage of exertion (%) of both right and left flexor carpum radialis and ulnaris muscle using riding process with and without using armrest. A large interinvidual variation in the EMG values in similar 2 hours riding process is a well-demonstrated phenomenon and statistically significant changes demand these studied groups of respondents. Thus, in this study, significant reductions were obtained in the % of exertion for EMG values of the right and left flexor carpum radialis and ulnaris muscle of experimental group. Besides, during this riding process, the use of the prototype (armrest) was found increase the % of exertion for EMG values of both muscle or it remained unaffected (Garcia et al., 1998) in certain of every 15 minutes for 2 hours process.

Fatigue levels are high while motorcycle riding because motorcyclists are required to tolerate high levels of muscle strain for lengthy periods of time, particularly in their arms and forearms, when directing and using handlebar controls. Indeed, many motorcycle riders suffer with forearm compartment syndrome, which is normally treated surgically by releasing the forearm tendons from their sheaths (Goubier and Saillant, 2003). Hand flexor fatigue should result in a lower MVC with a higher EMG value and trigger poorly coordinated tasks, as well as a decrease in hand stability while completing these tasks (Leyk et al., 2006). Using a handgrip dynamometer, it was discovered that repeated usage of the hand flexors results not only in a reduction in maximal voluntary contraction (MVC), but also in an increase in the response time of the pre-motor component (Hanson and Lofthus, 1978).

Aside from that, using an armrest for both hands allowed respondents to retain their wrists in a neutral position. Arm support for only one arm may result in an unequal body position (Lintula, Nevala-Puranen and Louhevaara, 2001). According to the outcomes of their investigations, the arm support may be useful in various tasks that need continuous holding of the arms. Aside from that, arm support has an effect on shoulder muscle acitivity. The weight of the arm creates a moment around the shoulder, which is countered by contractions of the anterior deltoid and other muscles, while the upper trapezius and rotator cuff muscles support and balance the shoulder girdle. The moment about the shoulder is lowered and the anterior deltoid muscle acticity is lessened by applying a supportive force at the elbow or arm. Because the arm support eased some of the arm's weight, the upper trapezius could apply less force in its role of assisting the shoulder to maintain a static position (Rempel et al., 2011).

Meanwhile, a study conducted in New South Wales by Ma et al., (2003) on 20 motorcyclists tested over two weekend days discovered that motorcyclists reported more physical fatigue at the end of the ride day than on the control day, particularly in body regions that might be affected by the ride, such as the back, arms, and hands. Motorcyclists frequently identified insufficient breaks, long riding hours, and boring roads as possible causes of weariness in the questionnaire survey. Heat stress, cold stress, noise or vibration stress, posture or pain stress, and night-time riding have all been recognised as causes of motorcyclist weariness in the literature (Horberry, Hutchins and Tong, 2008).

Motorcyclists are subjected to extreme demands while riding, which may contribute to weariness (Motorcycle Council of North South Wales, 2006). According to the Motorcycle Council of New South Wales (2005), sitting in the same posture with restricted movement for extended periods of time can cause muscle stiffness and decreased blood flow, resulting in discomfort and possibly weariness. This highlights the importance of doing effective fatigue research in order to create countermeasures to prevent road accidents (Elliot et al., 2003). Current approaches for detecting biker fatigue rely on subjective observations and objective measures of vehicle factors such as steering torque, shock absorption level, and velocity while riding. The subjective sense of exhaustion has not been shown to be reliable in the literature (Williamson, Feyer, Friswell and Finlay-Brown, 2000)

Conclusion

The purpose of this study was to investigate the influence of the armrest prototype on muscle activity throughout a prolonged riding session. The following are the key conclusions based on statistically significant findings: 1) Electromyography levels differ between experimental and control groups. 2) The use of the armrest prototype has a good influence on the proportion of exertion changes (EMG) in the experimental group as compared to the control group. 3) Electromyography levels differ significantly between experimental and control groups. In general, this study has provided a novel way into the impacts of the armrest prototype on motorcyclists during the protracted riding process using muscle activity data. The implementation of the armrest prototype has provided a protective ergonomics mechanism that has provided more postural stability and integrity for the musculoskeletal system of motorcyclists, notably on the arm. As a result, the reduction in muscle activity for both arms revealed that this armrest prototype is capable of establishing an ideal posture and improving biker comfortability during lengthy rides.

Acknowledgement

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