MATEC Web of Conferences **135**, 00046 (2017) DOI: 10.1051/matecconf/201713500046
ICME'17

Muscular Activities Measurements of Forward Lean and Upright Sitting Motorcycling Postures via Surface Electromyography (sEMG)

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Abstract. Motorcycling postures are generically speculated to be physical and physiologically demanding – which in-turn may lead to motorcycling fatigue, and then becoming a possible factor to road accident. The objective of this study was to measure the muscular activities of various motorcycling postures. High muscular activity reading will signifies that motorcycling is indeed physically and physiologically demanding to the motorcyclist. For this particular study, the following postures were tested: i) forward lean, ii) upright sitting, and iii) neutral sitting (as control). Surface electromyography (sEMG) measurement was conducted on the following muscles: i) extensor carpi radialis, ii) upper trapezius iii) latissimus dorsi, and iv) erector spinae. The results showed that for all test subjects, the muscular activities readings for the forward lean posture was actually close to neutral sitting's. Whilst, the upright sitting had showed much higher muscular activities measurement instead. Conclusively, this study had proven that any types of discomforts associated with the forward lean posture is not originated from muscular activities. Whereas, confirming that any discomforts in regards to the upright sitting is indeed related to muscular activities. Further studies are warranted to discover the actual risk factors that causes physical and physiological discomforts for the forward lean motorcycling posture.

1 Introduction

An ergonomics study by Ma'arof et al., (2012) had discussed in great detail that motorcycling posture i.e. the sitting posture practiced by motorcyclist whilst riding; is ergonomically unfitting. The study emphasized that the working posture is constituted to be "constrained, cramped, static and poor". Even so, as unfitting it may seem, global statistics has indicated that there is an increment in the number of registered motorcycles especially in the Asian region (Shell.com, 2013, Honda Annual Report, 2012). In the wake of global

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petroleum crisis, the demands for economical mode of transportations are on the rise (Young, 2013). Most members of the society are seeking optional vehicles that have high fuel efficiency while simultaneously easy to be maintained. Indeed, the market for green vehicles does exist. Full-electric and hybrid automobiles are already mass produced in most countries. Yet, one could not deny the flexibility provided by motorcycles to tackle-down traffics on the overcrowded Asian cities and rural areas. However, with the rise of motorcycles usage, this number also shows a corresponding increase in global motorcycle roads accidents.

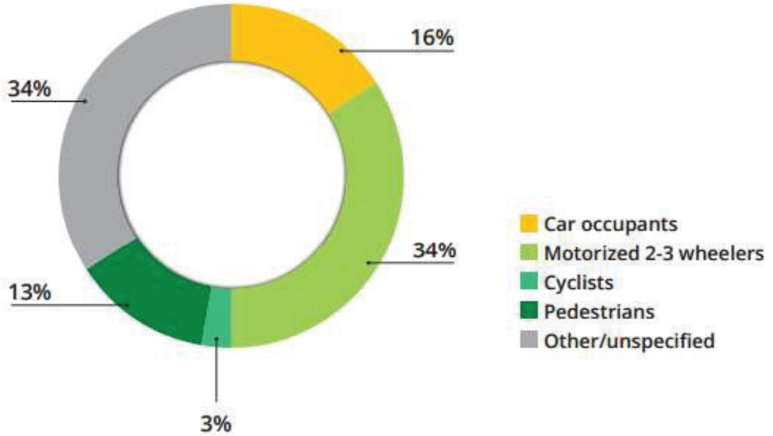

Figure 1.0(a): Deaths by road user type, South-east Asia region by "Road Safety in the South-East Asia Region" by World Health Organization (WHO) [35].

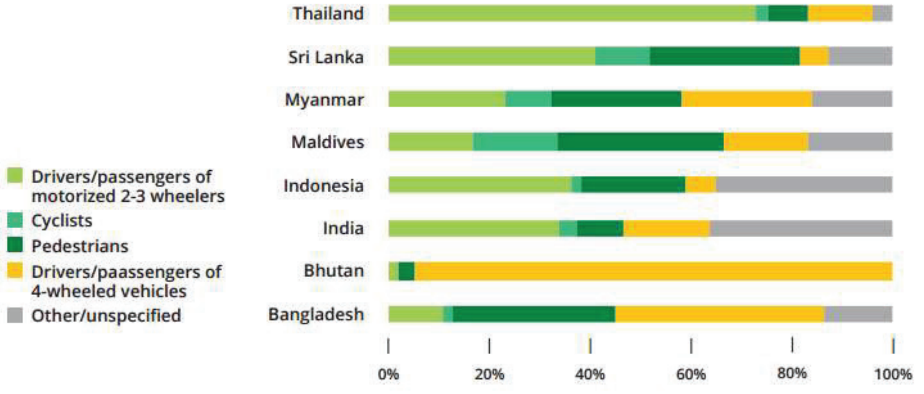

Figure 1.0(b): Distribution of road traffic deaths by type of road user by "Road Safety in the South-East Asia Region" by World Health Organization (WHO) [35].

The International Traffic Safety Data and Analysis (2013) had reported that in Malaysia; fatalities involving motorized 2-wheeled vehicles increased from 56% to 61% from the year 2003 to 2011. In the United States of America, the percentage of motorcycle road accidents has doubled from 7% to 14% in the interval of 21 years. While, United Kingdom, though, showed decrement in 2011 at 19% with respect to the year 2010 (22%), the percentage is still high in retrospect from the year 2000 (at 17%). In addition, the World

Health Organization had documented high percentage of fatal road accidents involving 2- and 3-wheeled vehicles in the Asian region. 74% was recorded in Thailand, 67% in Cambodia, 46% in Singapore, 36% in Indonesia, 35% in China and 32% in India. From the global accident reports, it could be concluded that most countries showed annual increment of road accidents involving motorized 2- and 3-wheeled vehicles.

Figures 1.0 (a) and (b) show the fatalities that occur in South-east Asia region that was recorded by World Health Organisation (WHO). Figure 1.0(a) shows that the two or three wheeled vehicles are major victims of such unfortunate incidents whereas, figure 1.0(b) shows that Thailand has the most number of accidents involving two or three wheelers, and then the number is decreasing progressively when compared with the other countries, as shown in the graph. Hence, proving that motorcyclist is indeed highly vulnerable towards road accidents.

This study upon reviewing several studies and articles on motorcycle road accidents, has reached to a conclusion that these accidents were commonly the cumulative or independent results of poor motorcycling behaviour, the non-usage of helmets, alcohol abuse, age factor, lack of motorcycling education, night-to-day riding and riding without license (Schneider et al., 2012; Keall and Newstead, 2012; Manan and Várhelyi, 2012; and Jou et al., 2012). Nonetheless, as cemented by Mr. Keith Code: globally recognized as a former motorcycle racer, writer, and founder of the California Superbike School while collective known as the ace on-track motorcycle instructor in the world; in his article Code (2010): "…horsepower wasn't the cause before, and was unlikely to be the cause now, of crashing motorcycles. Rather it is rider errors in applying core technical skills that cause them to go down." From this quote, it is clear that human error (in performing the motorcycling duties) is the main reason for motorcycle road accidents. Hence, the preceding question will be: how and in what working conditions are the motorcycling duties are performed? In following the rule of thumb of ergonomics, this study chose to start with the human operator i.e. the motorcyclist.

In examining the motorcyclist, several routes could be taken into account, for examples, the static and dynamic loadings whilst motorcycling, the psychological demands and even nutrition. Even so, this study will access the very essence of motorcycling which is the working posture. As noted earlier, Ma'arof et al., (2012) had clearly documented that the motorcycling riding posture is 'unfitting' for human operator. Yet, the same study still advocated that it is still the necessary working posture for motorcycling due to its advantages. Motorcycling postures are generically speculated to be physical and physiologically demanding – which in-turn may lead to motorcycling fatigue, and then later to be an eventual possible factor to road accident. Consequently, this study suggests for the improvement of the motorcycling riding posture – for this could improve riding safety and comfort.

The objective of this study was to measure the muscular activities (RMS values) of various motorcycling postures. High muscular activity reading will signifies that motorcycling is indeed physically and physiologically demanding to the motorcyclist. Henceforth, providing the necessary quantitative evidence that any sort of physical and physiological discomforts with respect to the particular motorcycling posture is indeed muscular related and not mere speculation.

1.1 Motorcycle Riding Postures

Motorcycles are manufactured with various designs and performance variations (Teoh and Campbell, 2010). For research purposes, motorcycles are commonly segregated and selected in various classifications systems (Ma'arof and Ahmad, 2012). Ma'arof and

Ahmad (2012) introduced the "Riding Posture Classification (RIPOC)" system – a motorcycle classification system specifically for ergonomics study. The system segregates motorcycle with respect to the human operator's trunk (upright or spinal flexion) and knee (flexed or extended) positioning. There are four riding postures introduced via the system. Table 1.1(a) provides the summary and general descriptions of each motorcycling posture.

Table 1.1(a): The General Description of the Riding Postures Designated by Ma'arof and Ahmad, 2012

RIPOC Types	**Riding Posture Name**	**Details**		
		Spinal flexion with respect to pelvis	**Arms & hands positioning**	**Knees positioning**
Type 1	Spinal Flexion Riding Posture	>20 degree	Below shoulder height	Flexed
Type 2	Upright Riding Posture	≤ 20 degree		Flexed, or ankles are perpendicular to the knees
Type 3	Upright-and-knees-extended riding posture	≤ 20 degree	Level or above shoulder height	Extended, ahead of the knees
Type 4	Spinal flexion-and-knees-extended riding posture	>20 degree		Extended, ahead of the knees

As a matter of consistency, this study will refer to the riding postures listed in Table 1.0 as motorcycling posture. In regards to the designated names, the Type 1 will be referred to as the forward lean, whilst, the Type 2 will be referred as the upright sitting. In examining the muscular activities via surface electromyography, this study had only focused on the first two motorcycling postures which were the Type 1 and Type 2. This was because these two working postures only has one common variable at the upper body region which is the spinal flexion.

Table 1.1(b): Body Parts Positioning Conditions According to the Riding Posture Establishment Conditions (RIPEC)

Human Operator Body Parts	**Motorcycle Transmission Type**		
	Manual	**Semi-Automatic**	**Automatic**
Head	Facing the direction where the human operator wanted to travel		
Right hand and fingers	Right hand-grip/throttle and front brake lever		
Left hand and fingers	Left hand-grip and clutch lever	Left hand-grip and clutch lever (or none)	Left hand-grip and rear-brake lever
Right foot	Foot-peg/board and rear-brake lever		Foot-peg/board or platform
Left foot	Foot-peg/board and gear lever		Foot-peg/board or platform
Buttocks	Seat		

In addition to the RIPOC system, Ma'arof and Ahmad (2012) also established the "riding posture establishment conditions" called the Riding Posture Establishment Conditions (RIPEC) (see Table 1.1(b)). Only by fulfilling all of the outlined conditions, the study noted that a riding posture is established. It was explained in the particular study that prior to the institution of the establishment conditions, it was observed that motorcyclists tend to be practicing various forms of sitting postures while motorcycling. Hence, for research consistency purposes, a standardized sitting posture has to be utilized. Therefore, the establishment conditions were formed. Thus, in measuring the muscular activities for this study, the "riding posture establishment conditions" were fulfilled.

From the RIPEC, Ma'arof et al., (2012) had discussed that motorcycling could be divided into two stages of human-motorcycle interfaces which are the "Human-Machine Interface (HMI) Stage" (first stage) and "Human-Machine-Environment Interface (HMEI) Stage" (second stage). The first stage is the initial stage where the motorcycle is static (no motorcycling activity) and the human operator assumes the riding posture. Only in the second stage the motorcycling activity takes place and the surrounding environment is now an integral element of the motorcycling ergonomics system. Since this study was performed in a laboratory, this study followed the outline listed for the HMI stage. The characteristics of the HMI stage as outlined by Ma'arof et al., (2012) are as follow:

I. The human operator has to successfully perform at least three (3) out of the four (4) operator's body parts positioning requirements of the RIPEC. At static, the human operator may need to independently support and balance the motorcycle.
II. Crucially, the motorcycle (workstation) must be at static.
III. The utilization of any device to keep the motorcycle at upright is negligible.

2 Research Methodology

For this study, a quantitative research approach was performed through experimental design using surface electromyography (EMG) measurement technique. The sEMG measurement was conducted to analyze the muscular activity of four selected muscle groups. The selected muscles were as follow: i) extensor carpi radialis, ii) upper trapezius iii) latissimus dorsi, and iv) erector spinae. The muscles were selected based on Velagapudi et al., (2010) and by consulting the present senior physiotherapist from the Faculty of Health Science of the Universiti Teknologi MARA (UiTM) during the sEMG pilot test (prior to this study).

2.1 sEMG Recording

2.1.1 Subjects

4 subjects (all male) had volunteery participated in this study. The subjects were informed that they could withdraw at any time and all results will be kept anonymous and confidential. Each subject was given a consent form prior to the experiment. The experimental procedure was approved by the Ethics Committee of the Research Management Institute (RMI) of the Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia. Selection criteria of the subject for the True Experiment study are as follow:

i. Subjects were male with more than 1 year motorcycling experience (motorcycle of any engine capacity)
ii. Age between 18 – 25 years old
iii. Normal Body Mass Index (BMI) between 18.5 and 24.5.
iv. Subjects were healthy prior and during the experiment

v. Subjects have no history of severe physical or physiological trauma (Snijders et al., 1995)
vi. Subjects have no previous surgery through the abdominal wall (Snijders et al., 1995)
vii. Subjects have not participated in any heavy training or physical activity 24 hours before the experiments

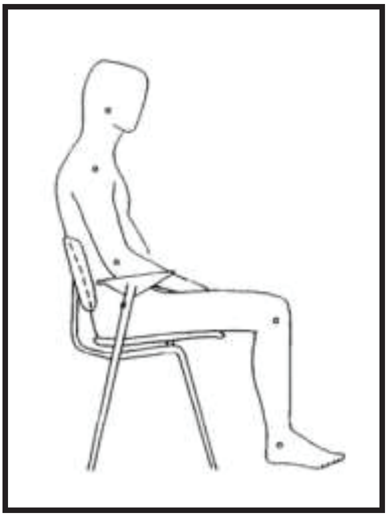

Figure 2.1.1(a): (i) Passive Sitting (Control Working Posture) Of The Subject During SEMG Recording (Source: Adapted From Snijders et al., (1995),

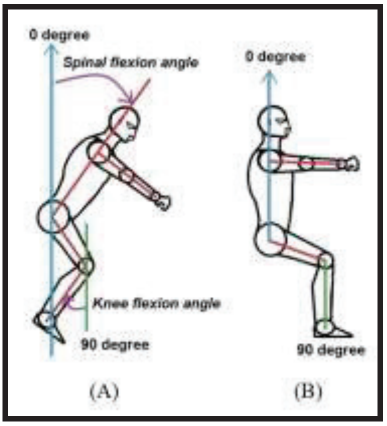

Figure 2.1.1(b): (A) Forward Lean Posture and (B) Upright Sitting Posture,

For the experiment, each subject performed three (3) working postures (passive sitting and the two motorcycling postures) as shown in Figure 2.1.1(a). The passive sitting (see Figure 2.1.1(a) (i)) was the control working posture. The control working posture provided the resting baseline for the muscle activity for the four selected muscles.

2.1.2 Experimental Procedure

The detail of the experimental procedure was as follow:

1) Each subject had performed 3 body postures throughout the experiment (1 Control posture and 3 motorcycling postures). For control, the subjects were seated on a chair (with full backrest) and positioned according to Snijders et al., (1995) (see Figure 1.(i)). The subjects were assisted with instruction to practice the passive sitting posture. Upon completing the EMG recording for the control sitting posture (passive sitting), the subjects were instructed to assume the motorcycling riding posture according to "riding posture establishment conditions" (Ma'arof and Ahmad, 2012) on 2 different motorcycles (2009 SYM 250cc Scooter and 2004 Kawasaki ZX2R). The motorcycles were positioned on a centre stand or dual paddock stand (front and rear). The experimental testing only replicates the "HMI" stage (Ma'arof et al., 2012) of the human-motorcycle interface stages.
2) All subjects were subjected to wear normal attire (shirt, pants and shoes) similar to the attire worn during the experiment conducted by Karmegan et al., (2012).
3) The lab was treated with controlled room attributes of having air-conditioning at 26°C and has sufficient lighting condition.
4) Surface electromyography (sEMG) reading of muscle activities (bilateral measurement) were taken via the Mega Biomonitor ME6000 sEMG device (with specification specifically designed for dermatological applications) for 5 minutes (with readings were taken every 0.5 seconds at 1000Hz). Therefore, each subject would generate 600 readings for the 5 minutes duration. The EMG signals were recorded with an 8-channel telemetric EMG system and a preamplifier (gain 1,000×), common mode rejection > 85 dB. The experimental time duration was very short since the objective was to measure the earliest muscular activity on the selected muscles (Kyoung and Nusbaum, 2008).
5) The four selected muscle were: i) extensor carpi radialis longus (forearm muscle), ii) upper trapezius (shoulder/neck), iii) latissimus dorsi (middle back), and iv) erector spinae (lower back).

2.1.3 Surface Electromyography (sEMG) Sensor Placement Procedure

The study procedure followed the six steps recommended by SENIAM (Hermens et al., 2000). Steps 1 and 2 were general in the sense that they were always valid, independent of the muscle on which the sensors are placed. Steps 3 to 6 were based on general starting points, which had been specified in detail for the individual muscles. The sequential procedures for sensors placement of sEMG in the study were as follow:

1) Selection of the sEMG sensors
The size of the electrodes used is 10 mm. The sensors selection for the study had adhered to the recommendations by SENIAM. An electrode material forms the contact layer with the skin and gives efficient electrode–skin contact, low electrode–skin impedance and does not cause chemical reactions at the skin interface during muscle activation by EMG. For this purpose, the pre-gelled Ag/AgCl electrodes were used.

2) Test subject's skin preparation
The skin of the subjects were prepared for good electrode–skin contact. This is important for obtaining accurate sEMG recordings in terms of amplitude

characteristics, fewer and smaller artifacts or electrical interference, less risk of imbalance between electrode and less noise. The shaving of the area of the skin surface at the sensor location was done to remove the hair. Then, the skin area was clean with alcohol and left dry by vaporization of alcohol before the sensors were positioned on the skin.

3) Positioning the subject in a starting posture
The starting postures before the placement of electrodes allow the determination for proper location of the sensors on the muscles. In the starting postures, the proper location of placement of electrodes were clearly determined by and the anatomical landmarks and palpation of the muscles. The descriptions of the starting postures were described in the experiment procedures.

4) Determination of the sensor location
The electrodes were placed with respect to the longitudinal location of the sensors on the muscles. Motor points and/or muscle tendons and the presence of other active muscles near the sEMG sensor (crosstalk) were avoided because these factors strongly influenced the stability of a sEMG recording. The centre-to centre distance between the conductive areas of two bipolar electrodes is also known as inter-electrode distance. The bipolar sEMG electrodes were applied at the sensor locations with an inter-electrode distance of 20 mm.

5) Placement and fixation of the sensors
The electrodes placements were as follow:

i. At upper trapezius slightly lateral to and halfway between the cervical spine at C-7 and the acromion (Cram et al., 1998)
ii. At latissimus dorsi three-finger width distal to and along the posterior axillary fold, parallel to the lateral border of the scapula (Lehman et al., 2006)
iii. At lumbar erector spinae at a two-finger width laterally away from the L1 spine (Guo et al. 2012)
iv. Over the belly of extensor carpi radialis (Laura et al., 1998)
v. The placement of ground electrodes were at the skin or bony prominence (Blanc and Dimanico, 2010)

The sensors placement procedures were assisted by a senior Physiotherapy lecturer from the Faculty of Health Sciences, UiTM, who had the experience regarding EMG procedures. The bipolar sEMG electrodes are placed at the sensor location of each muscle that has been identified with their orientation parallel to the muscle fibres. For each muscle, a ground/reference electrode was placed at a location in which the risk for a large common mode disturbance signal is minimal, so preferably an electrically inactive tissue was chosen.

6) Connection testing
After placement of the sensors and the reference electrodes, a test was performed by the senior Physiotherapy lecturer to determine whether the electrodes have been placed properly on the muscle and connected to the equipment so that a reliable sEMG signal can be recorded. This has been specified for each individual muscle. The clinical tests by isometric contraction of each muscle were also done to evaluate the activity of the tested muscles.

 DOI: 10.1051/matecconf/201713500046

3 Results

Table 3.1 shows the demographic details for the test subjects in the experiment. All subjects satisfied the inclusion criteria.

Table 3.1: Demographic details for the test subjects in the experiment

	Mean	Standard Deviation
Age	24	1
Height	171	7
Weight	63.25	13
Motorcycling Experience	9	2

Table 3.2: Total average RMS (uV) (for the selected four muscles) and the percentage (%) of increment of total average RMS (uv) (in comparison to control) with respect to the tested postures for Test Subject 1

Test Subject 1			
Posture	**Total RMS (uV)**	**Control (uV)**	**Percentage (%) of Increment of Total Average RMS (uV) with Respect to Control**
Forward Lean	78.6	80.1	-1.8
Upright Sitting	209.1	80.1	161.3

Table 3.3: Total average RMS (uV) (for the selected four muscles) and the percentage (%) of increment of total average RMS (uv) (in comparison to control) with respect to the tested postures for Test Subject 2

Test Subject 2			
Posture	**Total RMS (uV)**	**Control (uV)**	**Percentage (%) of Increment of Total Average RMS (uV) with Respect to Control**
Forward Lean	127.0	51.6	146.1
Upright Sitting	210.8	51.6	308.5

Table 3.4: Total average RMS (uV) (for the selected four muscles) and the percentage (%) of increment of total average RMS (uv) (in comparison to control) with respect to the tested postures for Test Subject 3

Test Subject 3			
Posture	**Total RMS (uV)**	**Control (uV)**	**Percentage (%) of Increment of Total Average RMS (uV) with Respect to Control**
Forward Lean	124.4	96.5	28.87
Upright Sitting	148.6	96.5	53.94

Table 3.5: Total average RMS (uV) (for the selected four muscles) and the percentage (%) of increment of total average RMS (uv) (in comparison to control) with respect to the tested postures for Test Subject 4

Test Subject 4			
Posture	**Total RMS (uV)**	**Control (uV)**	**Percentage (%) of Increment of Total Average RMS (uV) with Respect to Control**
Forward Lean	97.2	87.3	11.38
Upright Sitting	162.8	87.3	86.57

The results for the sEMG measured were tabulated and displayed in Table 2, Table 3, Table 4 and Table 5. Each table shows the total average RMS (uV) (the total of the average reading measured for the selected four muscles) and the percentage (%) of increment of total average RMS (uv) (in comparison to control) with respect to the tested postures for the particular test subject. In analysing the result, it was evidence that the sEMG measurement for all subjects showed 2 similar trends in the total average RMS (uV). Firstly, all test subjects generally showed the increase in the total average RMS (uV) for all motorcycling postures in comparison to the average RMS (uV) reading given by the control posture. However, it is interesting to note that only test subject 1 showed the decrement of total average RMS (uV) for the forward lean motorcycling posture. Test subject 1 recorded 1.8% decrement in the total average RMS (uV, for the selected four muscles) with respect to the control. Secondly, the lowest increment of the total average RMS (uV) for test subject 2, 3 and 4 were given by the forward lean motorcycling posture; which were 146.1%, 28.87%, and 11.35% for test subject 2, 3 and 4 are respectively. Henceforth, it was proven that this riding posture showed the least amount of muscular activity in contrast to the upright sitting motorcycling posture. The muscular activity given by practicing, maintaining and holding the forward lean motorcycling posture during the first stage of the human-motorcycle interface was almost similar to be seated on a chair with a full backrest with the arms are rested. Yet, the reading was the opposite for the upright sitting posture instead which were

161.3%, 308.5%, 53.94% and 86.57% from the control for subject 1, 2, 3 and 4 respectively. Therefore, providing the quantitative evidence that the upright sitting motorcycling posture showed the highest muscular activity in comparison to the forward lean and the control sitting postures.

4 Discussion

The objective of this study was to measure the muscular activities of various motorcycling postures. High muscular activity reading will signifies that motorcycling is indeed physically and physiologically demanding to the motorcyclist. Henceforth, providing the necessary quantitative evidence that any sort of physical and physiological discomforts with respect to the particular motorcycling posture is indeed muscular related and not mere speculation.

The results had shown that the forward lean motorcycling posture showed the lowest RMS reading for all selected muscles during the first stage of human-motorcycle interface i.e. from the very intial stage of motorcycling. Hence, with the notion that this would be further carried into the second stage of motorcycling, the forward lean motorcycling posture – in contrasting to the upright sitting posture, is the least affected by muscular activity. Therefore, has proven that any types of discomforts associated with the forward leaning posture is not originated from muscular activities. Whereas, the results confirmed that any discomforts in regards to the upright sitting is indeed related to muscular activities. In addition to the data obtained via the experiment, it was also noted that the forward lean motorcycling posture has several additional work-related advantages.

Firstly, the forward lean motorcycling posture provide the necessary physical range of motions and leverage of the entire body for motorcycling duties. By practicing the forward lean motorcycling posture, the motorcyclist could easily change his body positionings in order to change the body weight distribution (static loading) on the motorcycle while performing the motorcycling duties. For instances, by varying the elbow flexion and extension, the motorcyclist is able to change the magnitude (force) of static loading at the wrists, thus, at the handlebar. This would aids the motorcyclist to have better control and manoeuvrability over the motorcycle. By having the knees flexed and tucked in, the motorcyclist could make full use of the physical leverage provided to apply the necessary amount of force on the foot-pegs with less efforts to manoeuvre the motorcycle. The physical range of motion and the use of leverage are simultaneously performed by the motorcycle and both work hand in hand. In addition to the motorcycling duties, as noted by notable research such as Peeters et al., (2013), O'Sullivan et al., (2012), Rohlmann et al., (2011), Seidel et al., (2011), Chen et al., (2010), Eger et al., (2008) – among others, having a capacity to vary the working posture from time to time is indeed ergonomically advantageous since no posture should be hold for prolonged session – regardless of its comfort level.

Secondly, the forward lean posture also facilitate for the motorcyclist to improve the aerodynamics characteristics of the motorcycling experience by being streamlined with the motorcycle. This is commonly achieved by the motocycliste by practicing very high degree of spinal flexion. For instances, the motorcyclist's upper body will be completely in contact with the motorcycle body works (e.g. fuel tank). By improving the aerodynamics characteristics, the motorcyclist is even least affected by the windblast during motorcycling. Thus, further minimizing the muscular activity needed to hold the motorcycling posture in-place.

Although it was apparent from this study that the forward lean motorcycling posture results in the least amount of muscular activities in order to be practiced, both physical and physiological discomforts were still reported by the subjects. Based on the result, it was

 DOI: 10.1051/matecconf/201713500046

speculated that the occurrence of discomforts might as well be the result of other physical and physiological risk factors such as postural positioning hazard, static loading and pressure distributions or even blood circulation issues. Further studies are warranted to discover the actual risk factor that causes physical and physiological discomforts for the forward lean riding posture. Therefore, ergonomics intervention could be formulated in order to improve the working condition for the motocyclist. Hence, improving comfort and overall motorcycling safety.

5 Conclusion

Conclusively, from the surface electromyography (sEMG) measurement in comparison with neutral sitting (control posture), the forward lean motorcycling posture showed the lowest RMS reading for all selected muscles during the first stage of human-motorcycle interface. Whilst, the upright motorcycling posture showed much higher muscular activities measurement instead. This quantitative evidence has confirmed that any types of physical and physiological discomforts associated with the forward leaning posture is not originated from muscular activities in practicing and holding the posture. Whereas, any discomforts in regards to the upright sitting is indeed related to muscular activities. This study also emphasizes that motorcycling provides a vast field for exploration and engineering development. Therefore, it is advisable to discover the actual risk factor that causes physical and physiological discomforts for the forward lean riding posture. Hence, ergonomics intervention could be formulated to minimize the discomforts. By minimizing the level of physical and physiological discomforts, the motorcyclist could ride in the most ergonomically safe manner, thus, minimizing the possibility of road accident which originated from human error.

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