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Research paper

Advanced Motorcycle Riding Simulation: a Case Study of Sleep Deprivation Effects on Motorcyclist Muscle Fatigue

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Abstract

In enabling scientific studies on motorcycling, a full-scale ergonomic and adjustable motorcycle simulator, Postura Motergo™ was developed at the METAL laboratory, Faculty of Mechanical Engineering, Universiti Teknologi MARA, Malaysia. A case study was conducted using the simulator to simulate prolonged motorcycle riding simulation along with a wireless surface electromyography (sEMG) device to monitor the respondent's muscle activities. The aim was to investigate the effects of sleep deprivation amongst motorcyclist during prolonged motorcycle riding. It involved five (5) male respondents aged 23 years with a normal BMI and several years of motorcycling experience with one (1) respondent amongst them was sleep-deprived. They were required to ride the simulator for a maximum period of 2-hours non-stop. Seven (7) bilateral muscle groups were monitored throughout the simulations. It concluded that the muscles start to fatigue at a much earlier time significantly compared to other respondents that was mainly caused by sleep deprivation.

Keywords: *Motorcycle simulator; surface electromyography (sEMG); muscle fatigue*

1. Introduction

Motorcycle is a popular form of transport especially in big cities. In Malaysia, motorcycles are considered as reliable mode of transportation as 50.6 % of total registered vehicles in Malaysia are motorcycles [1]. Motorcycle is preferred from among choices of transportation because it is less expensive and more convenient which causes less commuter congestion within cities. Motorcycles in the other hand can effectively avoids intense traffic especially in emergency situation. As a knock on effect of fuel efficiency, motorcycles are a greener choice of transportation However, as the number of motorcycles increase, the number of accidents involving motorcycle also increases. In Asian countries, the power two wheelers (PTWs) is the most dangerous transportation because of its involvement in accidents. Furthermore, motorcyclist involve in high percentage (10-20%) of fatal accidents especially involving young male rider [1]. Bougard et.al (2012) in their study mentioned that there are three main factors that lead to motorcycle accidents which includes the riders being inconspicuous due to light deprivation or darkness, the interactions between high level exposure to environmental conditions due to poor road quality or meteorological conditions and having difficulties in handling the motorcycle especially among power two wheelers [2]. In previous research work, very little data are available concerning effects of fatigue to motorcycle crashes although road safety professional has acknowledged that fatigue is a main contributor to car and truck crashes [3]. Previous researchers reported up to 40% riders in prolonged motorcycle riding experience fatigue to the extent of half of the ride [4]. However, there is no qualitative evidence to measure fatigue among the rider as most of the researchers used subjective measures (sleepiness or feeling drowsy, tired, loss of attention, etc) to define fatigue [3-5]. In addition, it is almost impossible to measure fatigue during outdoor motorcycle riding session because it is dangerous for the rider and the pillion as they may face injuries besides results in loss of sEMG data signal. In order to overcome this constraint, this research group developed Postura Motergo™ facility, a full-scale ergonomic and adjustable motorcycle simulator to simulate near-to-real motorcycling experience in an indoor controlled laboratory. A case study was conducted to simulate the prolonged motorcycle riding simulation and a wireless surface electromyography (sEMG) device was used to monitor the respondent's muscle activity during the simulation.

2. Materials and Methods

2.1. Research Ethics

The study protocol complied with the Research Ethics Committee of the Research Management Institute (RMI), Universiti Teknologi MARA, Malaysia (600-RMI (5/1/6)).

2.2. Participants

Five (5) 23 years old, healthy males with normal BMI index participated as respondents in this case study. The respondents were required to ride the Postura Motergo™ motorcycle simulator as illustrated in Fig.1 for 2-hours non-stop.

2.3. Postura Motergo™ Simulation Setup

The Postura Motergo™ motorcycle simulator facility as shown in Fig. 1 is a full-scale ergonomic and adjustable motorcycle simulator facility developed at the METAL laboratory. It consist of semi-automated equipment and electronic devices to elevate the realness of motorcycling experience in an indoor laboratory. It includes Human-Machine-Environment Interface (HMEI) elements are embedded into the setup.
The Postura Motergo™ consists of seven subsystems: i) a custom-built motorcycle chassis installed with rider's and pillion's features; ii) a custom, counter-steering handlebar system equipped with actual throttle, clutch and brake levers, and also foot brake and gear shifter; iii) an electric motor motion system that provides left-right dynamics lean in roll axis; iv) an audio-visual system that generates the sound via surround speakers and projects visual on a custom, 180º curved projection screen; v) windblast element generated by an industrial blower; vi) vibration element generated by ButtKicker device; and vii) a controller system that uses PLC coding to simulate the simulator's vehicle dynamics.
The subsystems are practically integrated to imitate a near-to-real motorcycling experience. It provides a controllable and safer environment for both rider and pillion motorcyclist in advanced motorcycle simulation facility. The simulator is capable to cater various type of motorcycle riding postures including standard upright (Fig. 1 setup), forward-lean and slightly recline postures within a single motorcycle chassis of the simulator. Fig. 2 was during the fabrication stage where all three possible motorcycle riding postures were tested for possibility of adjustment. This is possible by adjusting the length and height positions of the handlebar, seat and foot-pegs according to existing motorcycle dimensions.

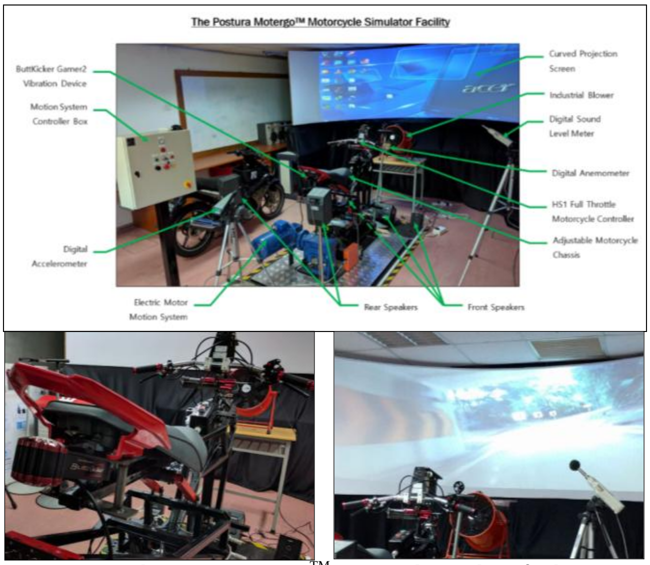


Fig. 1: The Postura Motergo™ motorcycle simulator facility

(a) (b) (c)

Fig. 2: Common motorcycle riding postures; (a) Forward-lean, (b) Standard upright, and (c) Slightly recline

Besides the motorcycling simulator itself, the environmental elements also are the main factors that can contribute to the near-to-real motorcycle riding experience. Table 1 shows the environment element settings during the experimental work.

Table 1: Environment Element Settings of the Prolonged Motorcycle Riding Simulation

Environment Element	Setting
Windblast	• Maximum windblast speed for maximum motorcycle speed limit of 110km/h is 60km/h
Vibration	• Maximum vibration for maximum motorcycle speed limit of 110km/h is between $9m/s^2$
Noise	• Maximum noise for maximum motorcycle speed limit of 110km/h is 90dB
Motion	• Maximum lean for mopeds during cornering is 15° to the left or right

2.4. Experimental Procedures

The experimental procedures in this case study consist of two main parts; the setup of prolonged motorcycle riding simulation and the measurement of muscle activity using surface electromyography (sEMG). Before the actual experimental start, the participants are provided with consent letter and briefing about the overall process of the experimental testing. The inclusion criteria of participants includes poses a motorcycle riding license with a minimum of one year motorcycle riding experience and no recent accidents in the past six months. Besides that, having normal body mass index (BMI) with healthy condition is compulsory for all participants. The participants must not have involved in previous prolonged motorcycle riding as they need to ride the simulator for 2-hours non-stop.
Before the simulation starts, the participants need to go through sEMG preparation procedures. The preparation of participant's skin before applying the electrodes referred to the Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles (SENIAM), a European standard procedure for sEMG [6]. In this case study, seven bilateral muscle groups of the upper extremity body regions were selected based on literature reviews [6-8] and results from initial questionnaire survey involving 330 participants. As shown in Fig. 3 medical grade hypoallergenic electrodes with sEMG transmitter were attached to the participant's skin at seven bilateral muscles (Latissimus Dorsi, Erector Spinae, Biceps, Extensor Carpi Radialis, Trapezius, Posterior Deltoid, and Sternocleidomastoid). The participants required to wear a complete attire including a helmet, riding jacket, jeans and covered shoes. The sEMG signals were then monitored from time to time in case for any irregularities or losses of signal during the motorcycle riding simulations as shown in Fig. 4.

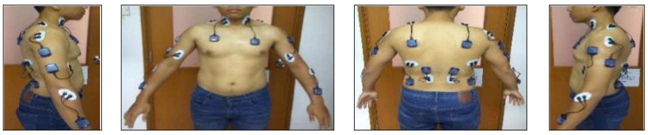


Fig. 3: Electrodes with sEMG transmitters attached at seven bilateral muscle groups

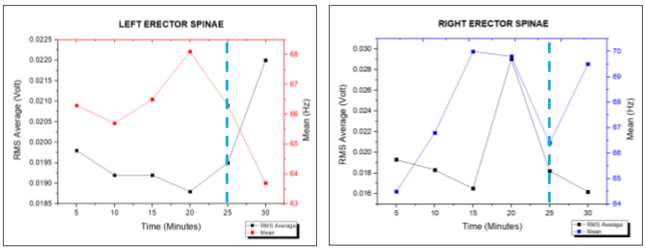
Fig. 4: Monitoring of the participants during the prolonged motorcycle riding simulations

3. Results and Discussions

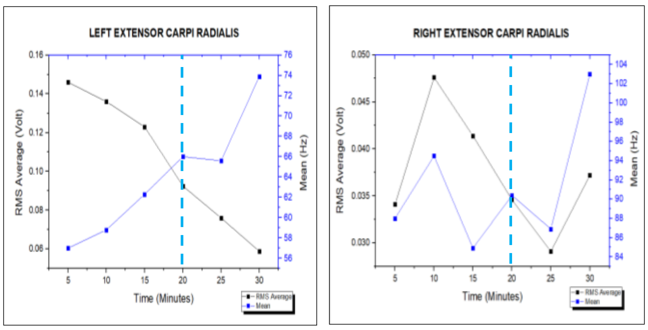
The main purpose of this case study is to advocate a motorcycling simulation setup and procedures as a reference platform for further studies especially in measuring and recording motorcyclists' muscle activities during prolonged motorcycle riding. At the end of the simulation session, a semi structured interview was conducted with the purpose of gathering information on discomfort and muscle fatigue of participants' body. From the seven bilateral muscle groups being monitored using the sEMG device, three bilateral muscle groups were claimed as experiencing the most muscle fatigue by the respondents. The three muscle groups are Erector Spinae, Trapezius and Extensor Carpi Radialis. Graph of Root Mean Square (RMS) average with Mean Power Frequency (MPF) were plotted for both left and right Erector Spinae, Trapezius and Extensor Carpi Radialis.

Based on the processed and analysed sEMG data, motorcyclist starts to experience muscle fatigue when there is a decrease in one or more of the frequency domain parameters (MPF/MF) coupled with a concomitant increase in the time domain parameters (RMS) [7]. Fig. 5 shows relevant data as muscles start to fatigue when amplitude and frequency of sEMG signals changes as the time pass [9]. However, one sleep deprived respondent did not meet the requirement of the experimental protocol after showing signs of sleepiness such as difficult to focus, frequent blinking and feeling restless and irritable at a significant earlier time approximately after 20 minutes. Only the left Erector Spinae and left Trapezius muscle groups that show a significant decrease of MPF along with an increase of RMS on the 20th and 25th minute. But the other muscle groups show a decrease for both MPF and RMS because the muscles are too fatigue to sustain the motorcycle riding workload demands. This explains why the RMS also decreases whereby it is supposed to increase (increasing more muscle effort) to maintain the riding posture and execute other motorcycle riding workload demands.

Evidence from previous study also suggests that sleep deprivation affects physical performance such as muscle strength, endurance, and physiological response involving heart rate, ventilation and oxygen consumption [10]. In detailed research of sleep deprivation, it is well established that 24 hours of sleep deprivation may not affect the peak power but it tends to decrease after 36 hours of wakefulness [11, 12]. In addition, psychological responses were affected after 30 hours of sleep deprivation but it is believed that it does not affect the physical performance [10].



(a)



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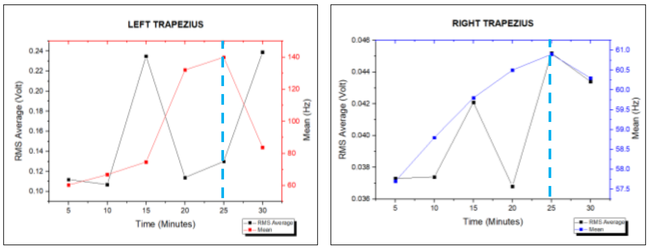

(c)

Fig. 5: (a) Graph RMS and MPF over time for left and right Erector Spinae, (b) Graph RMS and MPF over time for left and right Extensor Carpi Radialis, and (c) Graph RMS and MPF over time for left and right Trapezius

4. Conclusion

The main objective of this present research is to simulate near-to-real motorcycle riding experience using a motorcycle simulator in order to study the effects of sleep deprivation on muscle fatigue among motorcyclist for prolonged motorcycle riding. Besides that, the use of a motorcycle simulator which consist of hardware, software, motion cueing, vehicle dynamics, rendering and content for a realistic motorcycle simulator can improve the safety of motorcyclist and pillion as it can be used for various type of research on road safety. The outcomes of this study clearly show the strong relationship within level of muscle fatigue with sleep deprivation among riders. This should encourage improvement and optimization on specific support for riders especially riders involving with long duration of motorcycle riding activity. However, this case study has few limitations. First, the sleep deprived participant in this study is limited to only one male respondent and the result includes the subjective sleepiness symptoms based on questionnaire surveys. This is believed that, further studies are needed to confirm the findings.

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