ABSTRACT

Driver’s discomfort has gained a lot of attention, especially among interested parties. There are many interacting factors involving both the driver and the interior components of the car that contribute to discomfort while driving. In this study, an investigation was carried out on the contraction of the lower leg muscle among drivers when operating the accelerator pedal. The main objective of this study was to determine the pattern of muscle contraction when operating the accelerator pedal with regard to three different actions: pressing, half-pressing and releasing. Eleven participants were involved in this investigation into the muscle pattern, whereby surface electromyography (SEMG) was used to measure the activity of the lower leg muscle, known as the tibialis anterior (TA). The data collection procedure on the selected muscle was in accordance with the SEMG recommendations for the Non-Invasive Assessment of Muscles. Based on the results, the TA depicted that the highest muscle contraction occurred during the releasing action. In addition, there were significant differences between each action in the T-test analysis with p < 0.05. It can be concluded that the TA muscle works differently based on the car pedal actions.

Keywords: Driver; accelerator pedal; leg; tibialis anterior; electromyography
Many studies in the past literature focus on areas associated with assessment on driving task. Table 1 shows 14 studies with different objectives conducted in the past ten years from 2007 to 2017 on the interaction between the driver and the car. Based on Table 1, the car seat and steering wheel are two popular car components that frequently studied by the researcher. Only three studies were carried out on the car pedal. According to Table 1, these three studies related to the car pedal were focused on the road environment and vibration impact on the drivers.

| No | Reference        | Main components |
|----|------------------|-----------------|
| 1  | Adler (2007)     | x               |
| 2  | Bougard et al. (2008) | x         |
| 3  | Kyung (2008)     | x               |
| 4  | De Waard et al. (2010) | x        |
| 5  | Fouladi et al. (2011) | x        |
| 6  | Döring et al. (2011) | x          |
| 7  | Vilimek et al. (2011) | x        |
| 8  | Aubert et al. (2012) | x  x        |
| 9  | Kamp (2012)      | x               |
| 10 | Yusoff et al. (2012) | x        |
| 11 | Maël et al. (2013) | x           |
| 12 | Rudin-Brown et al. (2014) | x  x    |
| 13 | Mossey et al. (2014) | x         |
| 14 | Mansfield et al. (2017) | x        |

Car pedals can be categorized into two or three functions, based on the type of transmission. The automatic transmission has only two pedals which are the accelerator and the brake, while there is an additional pedal to the manual transmission which is known as the clutch. Even though there are two different transmissions, the car pedal is one of the main components to control the car mainly in speeding and braking task (Wang et al. 2004). Throughout the journey, drivers are required to interact with the car pedals frequently due to unexpected traffic and road conditions as well as the environment. According to Tanaka et al. (2009), there are two types of contact conditions in pedaling, between the foot-sole and pedal-pad. The effects when the foot touches the heel of the foot pedal and the floor of the car will cause discomfort to the driver while driving.

In term of biomechanics, there are two leg positions referring to ankle joint movement; plantar flexion and dorsiflexion (Keene 2010). The plantar flexion is referred to the pressing of the pedal, while dorsiflexion is referred to the releasing of the pedal. Dorsiflexion happens when the driver releases the pedal with the ankle joint angle is less than 90° and at the maximum of 70°. Meanwhile, the plantar flexion occurs when the driver presses the pedal with the ankle joint angle greater than 90° and at the maximum of 140°.

This paper aims to investigate the effect of different actions when operating the accelerator pedal. Surface electromyography (SEMG) was used to measure the Tibialis Anterior (TA) muscle activity based on different pedal actions. Basically, this paper contributes to the literature on the impact of muscle activity in two ways. First, this paper document an important relationship between pedal action and muscle activity value. Second, driver’s position influence the driver’s condition when operating the car pedal.

METHODOLOGY

PARTICIPANTS

Eleven participants (mean age of 29 years, mean height = 161 cm, mean weight = 56 kg) were assigned from the population of staff and students at Universiti Kebangsaan Malaysia (UKM) to take part in this study. Each participant was required to attend one session, either in the morning session (from 9 am to 12 pm) or in the evening session (from 2 pm to 5 pm). The inclusion criteria were all respondents held a full Malaysia driving license, had at least 3 years of driving experiences and aged between 22 to 35 years. The constriction of the age range was proposed to reduce variations in the results due to age, since even in normal ageing, people present slight perceptive variations that have a direct attitude towards driving (Antonson et al. 2014).

All participants were allowed to adapt with the car simulator setup and car seat adjustment before starting the experiment. The experiment was started after five minutes the participant had been in the driving position to allow them to adapt with the seat environment and fabrics. All participants understood and complied with the oral and written instructions provided by researcher for this experiment. Information about the experiment procedure was included. After receiving the complete information on the study, each participant signed an informed consent.

EXPERIMENT DESIGN AND PROCEDURE

The participant should sit on the car seat with the closest seated position to the car controls. The back rest of the car seat was fixed at 100° in this study, as depicted in Figure 1. During recording the SEMG data, the participant must place their hand at 10 and 2 o’clock as shown in Figure 1. In addition, the participant need to ensure the right leg at the car pedal, while the left leg at the car simulator floor, near to clutch pedal.

EXPERIMENT EQUIPMENT

SEMG measurement was used in this study to investigate the muscle activity according to the different actions while operating the car pedal. A Trigno™ Personal Monitor with Parallel-Bar Sensors from Delsys Incorporation was used to collect these analog data of muscle activity with sample rate up to 1000Hz interfaced with 5-channel signal amplifier. Figure 2 illustrates the Trigno™ Personal Monitor with Parallel-Bar Sensors.
The surface myo-electrical signal was converted to the analog data which later converted to digital data at the signal analysis personal computer interface. SEMG measurement was performed by placing electrodes on the skin’s surface and electrical activity of the right TA underneath was recorded. The data collection procedure on the selected muscle was according to the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) recommendations. This section provides details on SEMG measurement used in this study.

**SEMG DATA COLLECTION PREPARATION**

Skin inspection were performed prior to the electrodes placement which to reduce the skin impedance and avoid noises on the SEMG readings. Proper skin preparation was required to improve the electrode-skin contact. All subjects shaved at the selected muscle belly, cleaning with alcohol, rubbing with gel and abrasion with an abrasive cream such as NuPrep (Florimond 2009). The SEMG electrodes were pasted directly on the selected muscles belly after careful palpation and parallel to its muscle fibers. The procedure of electrodes placement such as body posture, location of electrodes, orientation, clinical test and task for selected muscle are depicted in Table 2. The cross symbol in the figures inside the Table 2 indicates the selected muscle. After the electrodes were placed and fixed, the electrodes could be connected to the SEMG equipment and a clinical test could be performed to test whether the electrodes have been placed properly on the muscle and connected to the equipment so that a reliable SEMG signal can be recorded.

In this study, three main actions of the accelerator pedal (half press = HP, release = R and full press = FP) were recorded as shown in Figure 3. Roughly, five seconds is taken for each pedal action. This study is conducted to investigate the reaction of the leg muscle while performing the HP, R and FP.

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**TABLE 2. Identification of selected muscle and electrode placement position**

| Muscle | Starting posture | Electrode placement | Clinical test | Orientation |
|--------|------------------|---------------------|--------------|-------------|
| TA     | Supine or sitting| The electrodes need to be placed at 1/3 on the line between the tip of the fibula and the tip of the medial malleolus | Support the leg just above the ankle joint with the ankle joint in dorsiflexion and the foot in inversion without extension of the great toe. Apply pressure against the medial side, dorsal surface of the foot in the direction of plantar flexion of the ankle joint and eversion of the foot. | |
Figure 4 shows the flow chart of SEMG data analysis. In this study, the signal processing of the SEMG data was not conducted by using Delsys software. However, Matlab and Microsoft Excel software are two main operators in processing and analysing EMG data in this study. Before starting the experiment, the signal from the selected muscle should be tested to determine whether the muscle is working properly according to the driving activity. The muscle signal is displayed in the Delsys EMG works Acquisition software. If the muscle works as predicted, then, the experiment can be started. All raw data from the Delsys software are in the form ASCII file. These file need to be transferred to the Matlab software for further analysis as shown in Figure 4. All raw data need to be filtered by using three different frequencies, high pass, notch and low pass. Then, Root Mean Square (RMS) value will be produced based on percentage of Maximal Voluntary Contraction (%MVIC). All data should be epoched before comparison based on the %MVIC can be made.

In short, there are two types of analysis were performed in this study, Temporal and Amplitude Analysis. Temporal Analysis was conducted to investigate the pattern of the muscle activity based on the pedal actions. Meanwhile, the Amplitude Analysis was carried out to determine muscle activity according to driving condition, either in contraction form or rest form. The value of muscle activity is in RMS. If the RMS of muscle activity below than 5 microvolt (μV), it means the muscle is in the rest form (Florimond 2009). Basically, the Amplitude Analysis was performed at time domain and the amplitude unit is in μV. Amplitude analysis was conducted at the stipulated epoch. The RMS equation in discrete time is defined in Equation (1), where N is the number of data and n is the SEMG data.

\[ R.M.S = \sqrt{\frac{1}{N} \sum_{n=1}^{N} EMG[n]^2} \]  

RESULTS AND DISCUSSION

TEMPORAL ANALYSIS

Figure 5 shows the example of Temporal Analysis for the TA. According to Figure 5, it is obvious that the TA is highly activated in releasing pedal position. Detailed analysis on this finding is performed using statistical analysis to determine the association between each parameter.
AMPLITUDE ANALYSIS

Figure 6 shows the Amplitude Analysis for TA based on RMS value. As stated in the previous paragraph, the TA shows different pattern when pressing and releasing the pedal. In addition, there are some significant differences between each position. Further analysis using statistical analysis method is described after this section. The mean RMS value for R action is higher than the HP and FP actions. For HP action, the mean RMS values for pre-post activity for position A are 4.58 (15%) and 5.18 µV (15%) respectively. For R action, the mean RMS values is 10.09 µV at %MVIC 30%. Meanwhile, for FP and HP action, the value is 6.37 µV at 20% and 4.58 µV at 15%, respectively.

CONCLUSION

Leg placement while operating the car pedal is expected to engage with lower leg muscle activity. The finding from this study was supported with the principle of muscle loading to joint movement while coordinating the pedal. The primary muscle for pedal are numerous, however each muscle work differently based on the tasks. It consists of biomechanical movement in operating the pedal by applying different muscles and joint angle to control the pedal. In this study, the right TA is the prime mover when releasing the pedal (works in a dorsiflexion with ankle joint movement is less than 90 degrees).

ACKNOWLEDGEMENT

The authors would like to thank Universiti Kebangsaan Malaysia for their financial support under the grant GUP-2017-094.
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Received date : 19th September 2017
Accepted date : 30th January 2018
In Press date : 1st April 2018
Published date : 30th April 2018