Muscle Activity of the Upper and Lower Body Part in Car Gearing Action: A Preliminary Study

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ABSTRACT

Understanding of the muscle activity and its activation in driving task is very important. It can provide more knowledge to study the effects on the muscle when performing different driving styles task within certain duration. The main objective of this study is to investigate the role of the main parts in shoulder and leg with regards to certain driving condition when performing gearing action. In this study, the two main muscle parts selected were deltoid anterior (DA) and gastrocnemius medialis (GM) and used a simulator with manual transmission. Two female subjects with more than three years driving experience participated in this study and they were required to drive the car simulator for 15 minutes. The Electromyography (EMG) signals were recorded during pre-driving and post-driving tasks. Research findings showed the left DA muscle has significant difference with respect to the signal pattern when changing and holding the gear from free gear to gear 1 and to gear 2. Meanwhile, the right DA and the left GM showed no significant different in its activation between each gear action. The finding of study can contribute towards improving driver's driving behavior and style.

ISSN 1823- 5514, eISSN 2550-164X

Received for review: 2016-09-08
Accepted for publication: 2017-03-03
Published: 2017-07-01

In addition, it can be used to incorporate ergonomics approach in the design of the car gearing system.

Keywords: *Electromyography, Muscle, Simulator, Gear*

Introduction

In reality, driving task requires countless patience from the driver. With unexpected occurrence from different angles and environment conditions while driving (eg: unanticipated road users' behaviour, poor weather, bad road condition). In order to arrive safely at the final destination, the car driver need to concentrate on the road and hold their irritation or driving fatigue. Furthermore, driving task require physical demands from the driver to maintain their posture in a constrained space [1]. Therefore, there is frequent occurrence of complaints regarding muscle pain after driving [2]. Throughout the driving activity, drivers have direct physical contact with the car seat, steering wheel, gear and pedals [3].

In term of gear transmission activity, changing the gear is expected to engage shoulder and left leg parts. Therefore, the changes in the muscle activity of shoulder and leg were observed. Up to this date, there were many past studies that had investigated drivers' comfort and discomfort while driving by using multiple methods [3]-[13]. Most of the studies had performed research on the interaction between the steering wheel and the car seat, while a few of them on the car pedal. However, there is lack of research had been performed on gearing activity [2, 4, 9, 13]. Table 1 shows past studies on the driver's interaction with the car internal component.

Table 1: Investigation on car-driver interaction

No	Reference	Main components				Aim
		Seat	Steering	Gear	Pedal	
1	[14]			x		Physiology
2	[15]	x				Vibration
3	[16]		x			Vibration
4	[17]		x			Behaviour
5	[2]		x	x		Muscle fatigue
6	[18]	x				Comfort
7	[19]	x				Dynamic comfort
8	[5]	x				Mixed method
9	[6]		x		x	Road environment

10	[7]		x			Behaviour
11	[20]	x				Vibration
12	[21]		x			Gestural interaction
13	[9]			x		Optimum posture
14	[10]		x		x	Road environment
15	[11]	x				Design
16	[22]				x	Vibration
17	[12]	x				Vibro-acoustic comfort
18	[13]		x	x	x	Road environment
19	[23]		x			Behaviour
20	[3]				x	Muscle activity

Therefore, based on all these research gaps, this study has explored and investigated gearing action among driver based on certain driving activity. The main objective of this study is to investigate the role of the main parts in shoulder and leg with regards to certain driving condition when performing gearing action. Two main muscles were selected in this study, which comprise of deltoid anterior (DA) and gastrocnemius medialis (GM). Knowledge of the muscle activation pattern and its development was based on certain driving activities may provide more insights for future research.

Experimental setup

This section explains the experimental setup for this study, including its procedure and analysis.

Experimental procedure

Two female subjects, aged below 30 years old were recruited from the university population. Only female subjects were selected for consistency and convenience. Each subject was required to spend 30 to 40 minutes during this experiment, including the maximum voluntary contraction (MVC) measurement, the pre and post driving measurement and driving activity (15 minutes drive in monotonous road condition by using a car simulator with manual transmission in the laboratory). All subjects were required to sit constantly on the car seat with knee angle less than 110 degrees and their hand positioned at the 10 and 2 o'clock at the steering wheel, as shown in Figure 1. A knee angle was measured using a goniometer with subjects adopting to the instructed driving position in each of the right-hand drive cars. Three sticker markers were positioned on anatomical landmarks on the right side of the body (at knee joint) to aid measurement through clothing.

Figure 1: Sitting arrangement during experiment.

During pre and post measurement, each subject was required to change and hold the gear as instructed by the researcher. As shown in Figure 2, each subject was instructed to change the gear according to these steps: 1) from N to gear 1 and hold at this position nearly to five seconds, 2) from gear 1 to N and hold at this position for about three to five seconds, 3) from gear N to 2 and hold at this position nearly to five seconds and 4) from gear 2 to N. This activity was recorded for approximately 15 seconds for each session.

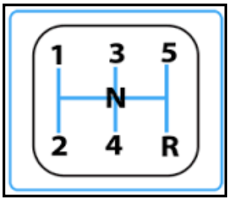

Figure 2: Gear action

Experimental analysis

A Trigno™ Wireless Systems and Smart Sensors with three channels were used in this study (left DA, right DA, and left GM). The left DA and GM were identified as active parts (involved directly in gear and pedal transmission) while the right DA was identified as non-active part (right hand static in position 2 o'clock). Electrodes were placed according to SENIAM recommendation as depicted in Table 2 [24].

Table 2: Identification of muscle location.

Muscle	**Starting posture**	**Electrode placement**
DA	Sitting with the arms hanging vertically and the palm pointing inwards.	The electrodes need to be placed at one finger width distal and anterior to the acromion.
GM	Lying on the belly with the face down, the knee extended and the foot at the end of the table.	Electrodes need to be placed on the most prominent bulge of the muscle.

Figure 3 shows the flow chart of the data analysis for this study. Based on Figure 3, all raw data from the sensor was checked and converted to 1000 Hz. Then, the Matlab software was used to filter all data by using three frequencies level, High-pass filter at 10 Hz, Notch filter at 50 Hz and Low-pass filter at 500 Hz. These three filters were recommended by SENIAM. After filtering process, all data was smoothing at RMS 500 ms. Then, it was segmented in the Microsoft Excel or known as epoch process. After performing some data processing, the RMS value was obtained based on % IMVC. Then, it was compared to find the accurate data that fit the condition.

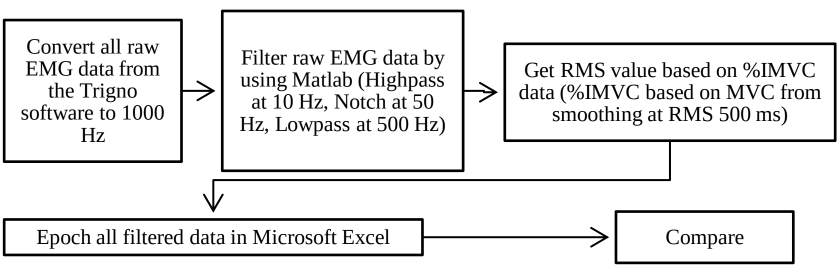

Figure 3: Flow chart of data analysis

Mathematical modelling

In this study, amplitude analysis was performed at time domain and the amplitude unit is in microvolt (µV). Amplitude analysis was conducted at the stipulated epoch. In this research, it was done at full-wave rectified sEMG signal and the Root Mean Square (RMS) value was used to evaluate the muscle contraction. The RMS equation in discrete time is defined in Equation (1).

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

where N is the number of data and n is the EMG data.

Results and discussion

Signal pattern

The left DA has significant difference in its muscle activation between each gear action. On the other hand, the right DA and the left GM muscles have no significant difference in its activation when the driver was changing the gear from N to 1 and 2. Examples of gear action for the left and right DA as well as the left GM after filtering process can be seen in Figure 4, Figure 5 and Figure 6.

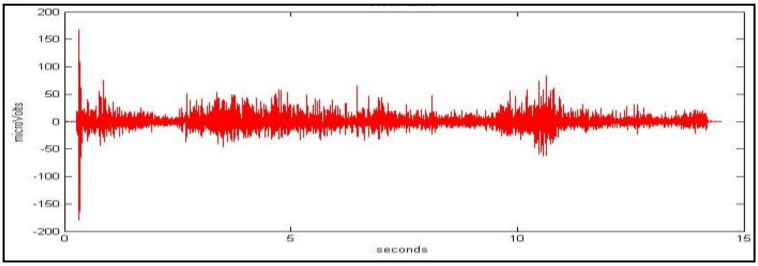

Figure 4: Signal pattern of left DA after filtering process

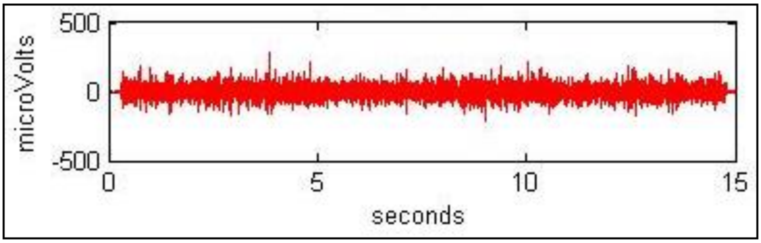

Figure 5: Signal pattern of right DA

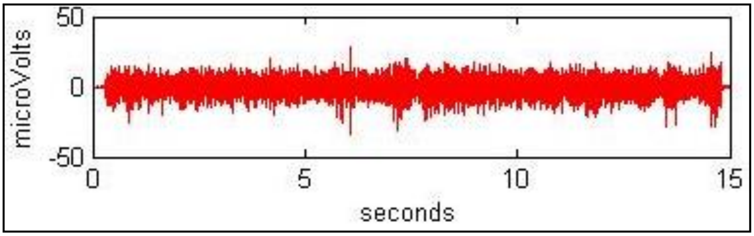

Figure 6: Signal pattern of left GM

RMS value

Table 3 demonstrates the RMS value for the gear action purely based on this experimental study. The RMS value for the whole action was taken at IMVC 10% for the right DA, while IMVC 30% for the left GM. For the left DA, IMVC 10% was recorded for the first and second action, IMVC 5% for the second action.

Table 3: RMS value for three gear actions

Action	Left DA	Right DA	Left GM
First: Gear N to gear 1 and hold	14 μV	15 μV	9 μV
Second: To gear N	8 μV	15 μV	9 μV
Third: Gear N to 2 and hold	14 μV	15 μV	9 μV

Based on the facts, the DA is known as prime mover for shoulder flexors and shoulder abduction which working concentrically. The findings of this study was correlated with the function of the muscle to move and control shoulder in driving. When the left hand changing the gear from mid (refer to gear N) to upper-left (refer to gear 1) or otherwise from mid to down-left (refer to gear 2), shoulder experienced high activation to increase range in shoulder flexion and abduction. Simultaneously, the left GM which is known to play an important role in plantar flexion will experienced high activation when pressing the car pedal. However, in this study, the findings do not show any different between releasing and pressing the car pedal for pre and post measurement because each subject pressed the car pedal only for the short duration, which is less than one second. Therefore, there is no significant different between each action for the left GM can be seen clearly in this study.

Conclusion

In this paper, results from this study of the two selected muscle contraction on driver’s posture based on knee angle less than 110 degrees showed different muscle contraction occurred for both muscles. However, only DA muscle depicts significant difference of muscle activation when performing gear transmission in this study. This was confirmed from the results of amplitude analyses. The signal pattern of selected muscle obtained from this study can provide more insight for future research particularly in ergonomics research in automotive area. The finding of study can contribute towards improving driver’s driving behavior and style. In addition, it can be used to incorporate ergonomics approach in the design of the car gearing system.

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