

MUSCLE CONTRACTION DURING MANEUVERING STEERING WHEEL USING SURFACE ELECTROMYOGRAPHY

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ABSTRACT

Driving posture is one of the factors that need to be emphasized in ensuring driver's comfort and to avoid road accidents and injuries. Meanwhile, fatigue has a strong relationship with comfortable posture and it contributes 15.7% of the total road accidents in Malaysia. Fatigue can reduce driving concentration and performances, thus increases the risk of road accidents and injuries. In order to determine the driver's comfort, this study had measured muscle contraction using the objective measurement for comfortable and optimum driving posture angles. The equipment used for conducting objective measurement on 14 respondents was sEMG. The researcher had used sEMG equipment to evaluate muscles activities at upper extremities, which comprises of Biceps Brachii (BB), Deltoid Anterior (DA) and Trapezius Upper (TU) that were involved during controlling the car steering. It involves three driving postures parameters according to the fixed elbow and shoulder angles. The results from this study showed the BB muscle increased positively when turning the steering wheel to the right within 3 to 6 times value increased. Meanwhile, DA and TU muscles experience a contraction in the opposite direction with steering wheel turning action, which shows higher right side DA and TU muscle contraction when the driver turn the steering to the left with around 80% decrease for DA and within 60% to 80% decrease value for TU. BB muscle also shows an increasing value of muscle contraction with higher elbow flexion, meanwhile DA and TU muscles contraction also show an increment in-line with greater shoulder abduction. The results showed that posture B with elbow angle at 36° and shoulder angle at 134° are the most comfortable driving postures, hence the lowest muscle contraction value of 15.67μV (BB), 19.31μV (DA) and 12.36μV (TU) compared to the other two measured postures. The results of muscle contraction from this study is capable of assisting researchers and car manufacturers to understand the relationship of steering maneuvering when developing more comfortable and suitable vehicle's driver seat compartment.

Keywords: ergonomic, driving posture, steering wheel, surface electromyography, muscle contraction.

INTRODUCTION

Ergonomics had become one of the criteria taken into consideration by driver during purchasing process. Furthermore, ergonomics also one of the factor that become main focus to be considered by car manufacturer during car seat and drivers' cabin design. Usually the inputs used in car seat design were steering wheel angle and pedal placement¹.

Car steering wheel is one of the main part in driving process and it is one of the element that is important in ensuring comfort and safety while driving^{1,2}. Car driver's spent most of their driving session handling steering wheel which muscle contraction are different according to hand movement and grasp on the steering wheel that can influence comfort and fatigue experienced while driving⁴.

Discomfort factor was often used as a factor in objective measurement that involving car driver's posture⁵. Drivers' posture play and important factor in passive safety control in order to avoid risk of accidents and injury⁶. Incorrect driving posture in long duration may contribute to fatigue problem^{7,8,9,10,11}. Correct

driving posture can ensure the driver to control the vehicle comfortably and safe¹².

Past studies had shown that it is encouraged to apply objective measurement method in identifying driver's comfort¹³. Objective measurements are included vibration, interface pressure, surface electromyography, anthropometry and many more. Additional method of objective measurement will able to support the results more strongly. Surface Electromyography (sEMG) is one of the best methods used to investigate the muscle contraction changes in driving postures. SEMG able to detect the muscle contraction during different driving posture and also able to identify fatigue level of every posture measured^{14,15}. Past research using sEMG had resulted a low correlation between the shoulder muscle activation and the movement of the steering wheel which shown that the active muscle known during is limited. Due to this, usually measurements for sEMG are done on large superficial muscle such as deltoid, trapezius, biceps and triceps¹⁶.

The purpose of this study is mainly to investigate several muscles contraction involved while

maneuvering the steering wheel during three different postures. The outcome are hoped to assist researchers to get more clear information on the relationship between the muscles and the driving action measured.

METHODS

Participants

This study involved 14 participants comprise of 6 males and 8 females. Numbers of participants involved are according to previous related research^{4,16,3}. Besides that, according to Sekaran & Bougie¹⁷, suggested numbers of participants for experimental research are within 10 to 20. All participants are required to have at least one-year driving experience. The participant’s age ranges are between 32 to 24 years old. All participants are required to signed an informed consent before the experiments and are given a token as an appreciation for their contribution at the end of the sessions.

Procedure

The experimental protocol was approved by the University’s board of research ethics due to the usage of sEMG. Each participant was briefed first in details on the objectives and procedures of the experiment. Participants then will be required to sit on the driver’s seat of a simulator with hand placement on the steering wheel at 10-2 o-clock position. Participants then need to maneuver the steering wheels for 30 second as instructed with the range of steering wheel turn between 45°-90°. The activities instructed during the 30 second are as shown in Figure 1.

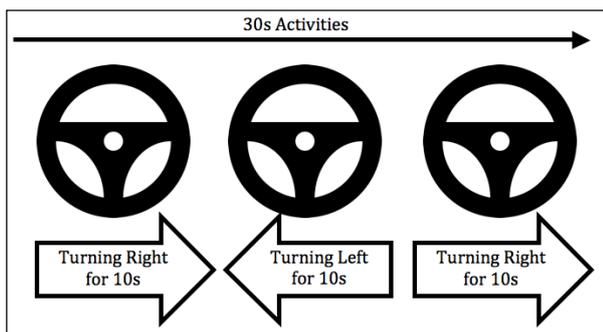


Figure 1. The Activities for SEMG Measurement

These activities then were repeated for three different postures with controlled elbow angles as shown in Figure 2. These three driving posture position are compiled from study done by Mohamad et al.¹⁸ that had published comfortable driving angles for Malaysian’s drivers.

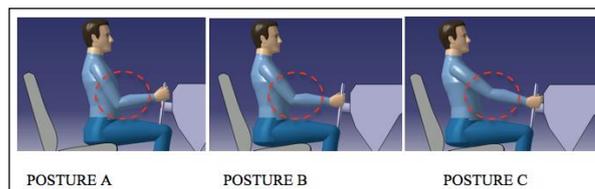


Figure 2. Postures Involved in SEMG Experiment

Surface Electromyography Experimental Design

Surface electromyography (sEMG) experiment was conducted on the participant using Trigno™ Personal Monitor with Parallel-Bar Sensors from Delsys Incorporation. Measurement was taken from the right Biceps Brachii (BB), Deltoid Anterior (DA) and Trapezius Upper (TU) muscle. The procedure in conducting sEMG experiment was accordance to the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) recommendations. Maximum voluntary isometric contraction (MVIC) was conducted to normalize electromyography signals and compare data among participants¹⁹. The MVIC reference value divided by sEMG value will give the normalized MVIC percentage value. The identification of muscles and electrode placement position on skin and the procedure to collect MVIC for every muscles is depicted in Table 1 below.

Prior to the electrode placement, detailed skin preparations were done for the participant. This process was necessary to avoid skin impedance and ensuring stable electrode contact. Standard preparation processes were done that are shaving to remove excess hair on skin and then cleaning the skin by rubbing alcohol.

SEMG Data Analysis

The collected raw electromyography data were filtered through the band pass and notch filter process using MATLAB software. The band pass filter consisted of two types that are the high pass and the low pass filter and for this experiment the value were set at 20 Hz and 500 Hz respectively. While for notch filter cut off frequency is set at 50 Hz. The cut off frequency used for both filter were according to SENIAM. After the process of data filtering, the filtered EMG signals then were epoch according to segments. Epoch is a time window in a stipulated time used for analysis. In this study, epoch is taken for 10 second in every segment. Epoch was taken based on 30% of MVIC for right turning action and 8% MVIC for left turning action for BB while 8% of MVIC for right turning action and 30% MVIC for left turning action for DA & TU.

Table 1. Identification of Muscles Involved, Electrode Placement Position And MVIC Procedure

Muscle	Starting Posture	Electrode Placement	MVIC
Biceps Brachii (BB)	Sitting on a chair with the elbow flexed at a right angle and the dorsal side of the forearm in a horizontal downwards position.	Electrodes need to be placed on the line between the medial acromion and the fossa cubit at 1/3 from the fossa cubit.	A valid biceps brachii MVC needs a very stable elbow and trunk fixation. This can best be arranged in a seated or kneeling position (in front of a bench).
Deltoid Anterior (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.	Select a seated position, if possible with fixated back. Fixate near the arms near the 90° position. The bilateral contractions guarantee a balanced force distribution for the trunk. The abduction works best for the pars acromialis of the deltoid muscle.
Trapezius Upper (TU)	Erect sitting, with the arms hanging vertically.	The electrodes need to be placed at 50% on the line from the acromion to the spine on vertebra C7.	The MVC test can be performed with one side only. A static resistance can be arranged by manually fixating the arm or arrange a large enough load to press the shoulder down (difficult).

The signals were transferred to full-wave rectified sEMG signal for amplitude analysis. Amplitude analysis calculation was then conducted using Microsoft Excel software to determine muscle activity in Root Mean Square (RMS) value. Amplitude analysis was performed at time domain and the amplitude unit is in microvolt (µV). The RMS equation in discrete time is defined in Equation 1.

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

RESULTS

Amplitude Analysis

Amplitude analysis was done to determine the muscle contraction value for each posture position. The RMS value of muscle BB, DA and TU for three different postures are calculated. The RMS value taken for each activity in steering wheel turn is taken according to MVIC percentage. For BB muscle, right turn the %MVIC taken is 30% and for left turn the %MVIC is 8% while for DA and TU muscles, right turn the %MVIC taken is 8% and for left turn the %MVIC is 30%. Figure 3, 4 and 5 shows the three muscle RMS value of two activities for Posture A (Elbow Angle<134°), Posture B (Elbow Angle=134°) and Posture C (Elbow Angle>134°).

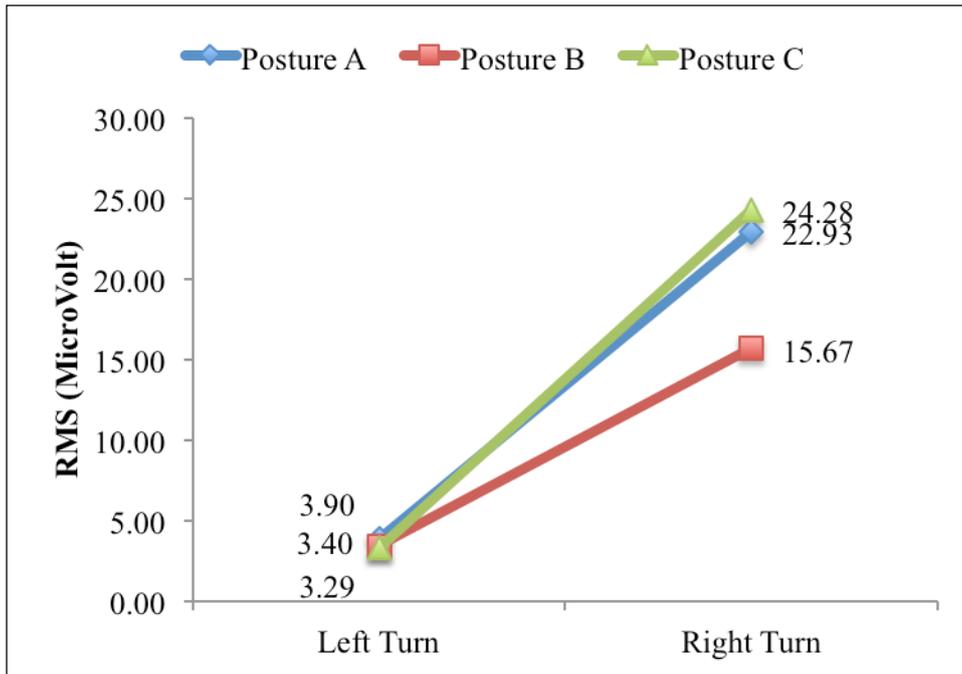


Figure 3. RMS Value for Biceps Brachii

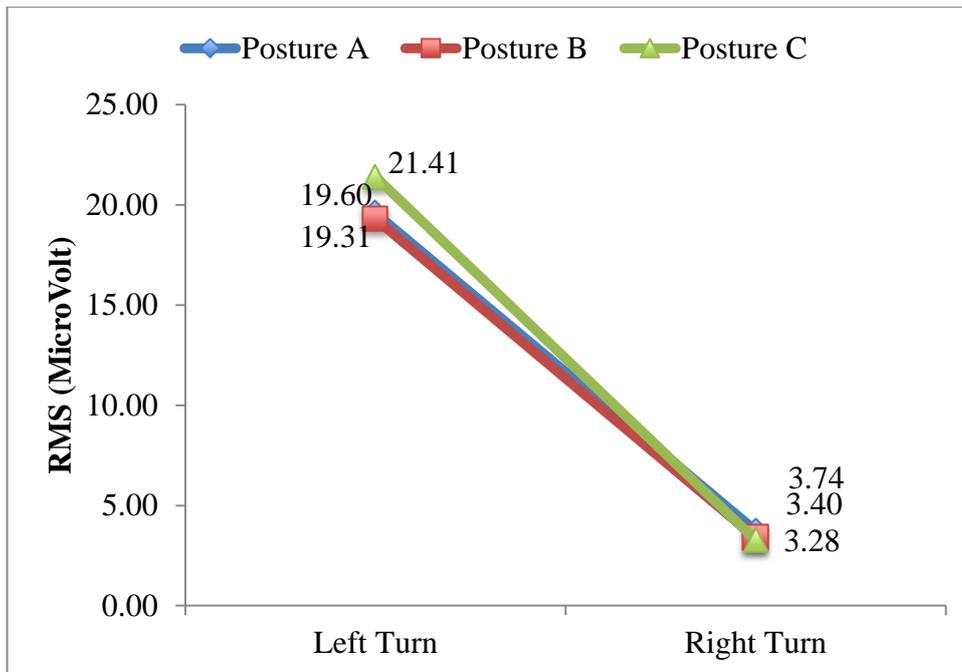


Figure 4. RMS Value for Deltoid Anterior

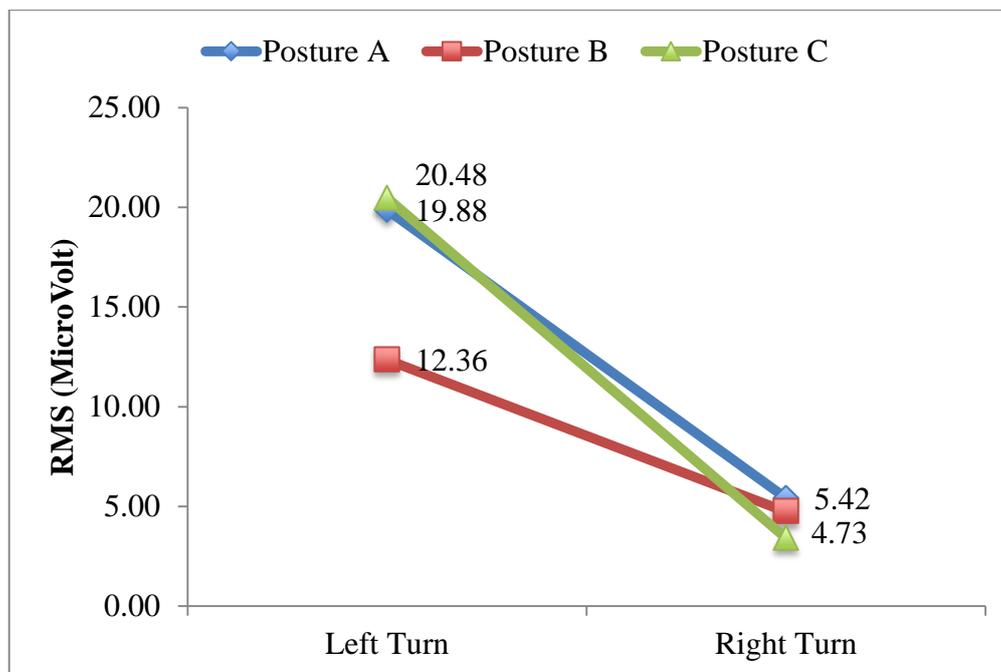


Figure 5. RMS Value for Trapezious Upper

DISCUSSION

From the line chart depicted in Figure 3, the RMS value for activity left turn is lower than activity for right turn for all three postures. This shows that the right BB muscle contraction is high when doing the right turn while driving. Past research also had shown a positive correlation of right BB muscle while maneuvering the steering wheel for right turning (Liu et al., 2012; Mo et al., 2012; Jung, Kim & Chang, 2015)^{12,21,4}. Jung, Kim & Chang⁴ had found that the biceps brachii is considered to be the main action muscle while turning the vehicle to the right.

Meanwhile in Figure 4 and 5 shows the RMS value for activity right turn is lower than activity for left turn for all three postures. This shows opposite value than the BB muscle that means muscle contraction is low when doing the right turn while driving. DA muscle had been identified as one of the main muscle involved in shoulder movement during driving process²². Past researchs also shows that DA muscle experience high contraction against the steering wheel direction^{23,24,20,1,4}. Past research from Pandis, Prinold & Bull¹⁶ had depicted a high contraction value for TU muscle while maneuvering the steering wheel to the left. This is due to the abduction of shoulder that consequently activate the TU muscle.

Figure 3, 4 and 5 also shows the differences of muscles activity value between three postures measured in this study. From the figure, the lowest muscle activity value for active turn is Posture B (Elbow Angle=134°) and the highest muscle activity value for active turn is Posture C (Elbow Angle>134°). This is inline with previous studies that found the value for EMG activity

significantly increased with higher elbow angle flexion²⁵. The low muscle activity shows that driving in Posture B is ensuring less exhaustion and more comfort for the drivers. It is supported by previous research that displays an increase trend in comfort level with low muscle contraction²⁶. Studies by Costanzo, Graziani & Orsi⁷ and Pandis, Prinold & Bull¹⁶ also shown comfortable driving posture is found with low level of EMG muscle contraction.

CONCLUSION

The objective of this study that is to investigate the BB, DA and TU muscles contraction during different driving postures is achieved. From the RMS value of sEMG, it is found that the best posture to be perceived as comfortable is Posture B with elbow angle around 134°. Besides that, this study also shows that the right BB muscle is in high contraction while maneuvering the steering wheel right and for both right DA and TU muscles is in high contraction while maneuvering the steering wheel to the left. The outcome from this study is hoped to benefit the manufacturers and designers especially in automotive field.

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