ORIGINAL ARTICLE

TABIALIS ANTERIOR MUSCLE CONTRACTION ON DRIVER'S KNEE ANGLE POSTURE LESS THAN 101º FOR FOOT PRESSING AND RELEASING AN AUTOMOTIVE PEDAL

Yusoff, A.R.[1], Deros, B.M.[1], Daruis, D.D.I.[2] and Joseph H, L.[3]

[1]*Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, Selangor, Malaysia*
[2]*Faculty of Engineering, Universiti Pertahanan Nasional Malaysia, Kuala Lumpur, Malaysia*
[3]*Faculty of Health Sciences, Universiti Kebangsaan Malayasia, Kuala Lumpur, Malaysia*

ABSTRACT

Proper driving requires a proper posture to bring comfort to drivers. A problem that commonly exists in driving is incorrect driving posture which can cause discomfort to the driver, especially when interacting with automotive pedals. Research on contraction of tibialis anterior (TA) muscle on driver's posture based on the knee angle less than 101º in a position of pressing and releasing a pedal was conducted to investigate and overcome this problem. This is a field experiment study and surface electromyography (sEMG) is used in collecting data on the TA muscle. The procedure of collecting data on the TA muscle before and after experiments follows the Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles (SENIAM) recommendations. The result of the experiment shows that there is a strong negative relationship between driver's postures in nature based on the angle of the knee with TA muscle contractions, where the Pearson correlation coefficient (r) is - .993. While the temporal analysis measurements based on Maximum Voluntary Isometric Contraction (MVIC) 60% in a position of releasing a pedal exceeding rms µV 39.38, are 39.71 and 40.25 respectively. On the other hand, MVIC 2% rms µV values: 1.19 and 1.2 are obtained in the position of pressing the pedal. The knee angle with TA muscle contractions is significant [F (1, 10) = 660, p<.05] contributing 98.5% variance (R2 = .985) in the driver's posture. A linear equations model has been developed to clearly illustrate the result. In conclusion, when the knee angle of the driver's posture is increased, the TA muscle contraction is decreased. The increase in the knee angle will directly provide comfort to the driver while interacting with the pedal; and this is due to the reduction of TA muscle contractions.

***Keywords**: Tibialis Anterior Muscle, Surface Electromyography, SENIAM Recommendations.*

INTRODUCTION

A driver will be in direct contact with the car seat, steering and pedals during driving. The driver's seat can be adjusted forward or backward; to give a certain posture to the driver. In most cases, the driver is not very concerned on his driving posture which may affect his health. Incorrect driving posture may result in body muscles not functioning properly and consequently will cause fatigue to the driver[1]. This clearly shows why driver's posture is important during driving.

According to Darliana[2], changes in the knee angle can describe the changes to driver's posture during driving. When the driver is in an uncomfortable posture, it may affect his driving; for instance when he is operating and controlling the accelerator.

In a four-wheeled vehicle driving, legs are used to control and operate pedals such as the brake pedal and accelerator or clutch pedal (for manual transmission). Normally, the right leg will control the accelerator while the left leg is at rest except for manual transmission vehicle where the left leg is used to operate the clutch. For hanging pedals design, the Ball of Foot (BOF) of the sole will be in contact with the surface of the pedal-pad[3,4].

When driving, the driver will apply a certain force to move his legs and when the leg pressed the accelerator, the car will accelerate and when the leg is released from pressing the accelerator, the car will decelerate. This movement is called a biomechanical movement. The biomechanical movement on human muscles is the calculation of force acting upon the muscles, working muscles and joint angle in completing a task such as during driving[5]. The biomechanical movement in operating and controlling the accelerator is when the there is movement of the ankle joint in pressing and releasing the accelerator. There are two leg positions resulting from the ankle joint movement, namely plantarflexion and dorsiflexion. The leg position in plantarflexion is greater than 90° from the ankle joint angle while in the dorsiflexion; it is less than 90°.

The leg position in pressing and releasing the accelerator can affect muscle contraction of the calf. The calf has twelve muscles namely, soleus, tibialis posterior, side and middle gastrocnemius, tibialis anterior, proneustertius, peroneus longus, peroneusbrevis, extensor digitorumlongus, extensor hallucislongus, flexor digitorumlongus and flexor hallucis longus[6].

It is therefore timely for a study on the TA muscle contraction in knee angle position of less than 101° during the pressing and releasing of pedals to be conducted. This study is also conducted to determine whether there is a correlation between the knee angle and TA muscle contraction. In addition, a linear equation model is also developed in this study. This study is the first of its kind as there are no previous studies conducted by any researchers prior to this.

METHODS

This study is a static field experiment where data acquired are in quantitative form. Twelve (12) respondents took part in the experiment.

EMG ACTIVITIES RESEARCH DESIGN

In the Electromyography (EMG) activities research design, the respondents' knee positions should be equal or less than 101° (Mean: 92; SD: 5.14) in the driving posture (refer to Figure 1). EMG activities signals for TA muscle were taken at two positions; when the foot is pressing the pedal and when the pedal is released. The EMG signals were taken in 60 second duration.

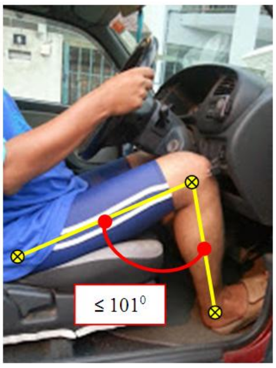

Figure 1 Knee position at equal or less than 101°

MVIC RESEARCH DESIGN

The purpose of conducting MVIC is to generate maximum muscle voluntarily during isometric muscle contraction. MVIC is conducted to compare data amongst respondents[7]. In the MVIC research design, respondents were required to perform pre-determined activities. In this study, MVIC refers to the method conducted by[8], where the respondents were required to be in the "quadruped position", the angle between the hip-bone and knee should be at 90°, while the ankle joint in the dorsiflexion position. From this experiment, the MVIC reference value was determined. The MVIC reference value is divided by sEMG value which will give the normalized MVIC percentage value.

EQUIPMENTS

In conducting this muscle contraction experiment, the researchers required a vehicle as an experiment station. A compact car with the engine turned off was used as an experiment station in the experiment. As for the raw data from TA muscle, a ME6000-T4 (4-Channel) bio-monitor was used. Data acquired were in their raw form with sampling rate of 1000 Hz. Signals produced by muscle ligaments will be extracted by the electrode and the analog signals will be amplified by a sensor before being converted to digital signals. The Common Mode Rejection Ratio (CMRR) and Analog/Digital (A/D) for this equipment was more than 95dB and the n-bit was 14 bits. In addition, A JAMAR 180° 9" (24 cm) goniometer was used to measure the knee angle.

RESEARCH PROCEDURE

The procedure used in acquiring raw signals of TA muscle was the sEMG technique. Additionally, references were also made to suggestions given by SENIAM[9]. The procedure has two parts; before and after the sEMG raw signals acquisitions. Data analysis on the sEMG raw signals was conducted off-line using Matlab version 7.11 while SPSS 20 for Windows was used for statistical analysis. The statistical analysis showed a normal distribution for the root-mean-square (rms) of the TA muscle contraction, which was based on the result of the normality test (Shapiro-Wilk: 0.959, $p > 0.05$).

PROCEDURE BEFORE EMG RAW SIGNAL ACQUISITION

In general, the procedure before signal acquisition using the sEMG technique consisted of four steps[9]. The first step was the selection of electrode (round-shaped electrode, Ag/AgCl gel). The second step was the skin preparation process (shaving the hair, abrasion with sponge and alcohol cleansing). Next, the third step was the muscle identification and electrode placement position (refer to Table 1). Lastly, the fourth step was the electrode placement (inter-electrode 20 mm).

Table 1 Identification of TA muscle and electrode placement position

Muscle	Posture to find the muscle	Location Electrode Placement	Picture
Tibialis Anterior	Supine or sitting	The electrode needs to be placed at 1/3 on the line between the tip of the fibula and the tip of the medial malleolus	

PROCEDURE AFTER EMG RAW SIGNAL ACQUISITION

At this point, the EMG signals were filtered through the band pass and notch filter[7,9] process. The band pass filter consisted of two types of filter, namely the high-pass filter and the low-pass filter. The band-pass filter was used to reduce the source of EMG signal "noise". In this experiment, the high-pass and low-pass Butterworth filters of the fourth order were used at cutoff frequencies of

20 Hz and 500 Hz respectively; while the notch filter is conducted at the frequency cutoff set at 50 Hz.

After the process of EMG signal filtering, the EMG signals were epoched in every segment. Epoch means data acquired from EMG signals in a stipulated time used for analysis. In this study, epoch is taken at one second for one segment[10]. Epoch was taken based on MVIC less than 5% in pedal pressing mode while MVIC 60% in the pedal release mode. Figure 2 shows how epoch was taken for sEMG signals.

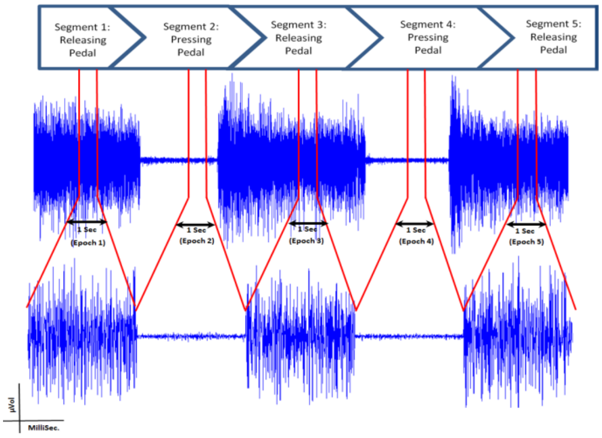

Figure 2 Epoch acquisition for EMG signals

After the sEMG signals were epoched, the signals were transferred to full-wave rectified sEMG signal for amplitude analysis. The signals were also transferred to smoothing RMS EMG with 500ms signal for temporal analysis.

DATA ANALYSIS METHOD

Data analysis for this study is divided into two types of analysis;

1) Temporal Analysis: Temporal analysis is conducted to identify the flow pattern of the muscle either at rest or during contraction. In this study, the analysis was conducted at smoothing RMS EMG with 500ms signal. The analysis was conducted visually.

2) Amplitude Analysis: 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 TA muscle contraction[11]. The RMS equation in discrete time is defined in Eq. 1.

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

Where N is the number of data and n is the EMG data in µV.

RESULTS AND DISCUSSION

The *Pearson Correlation Coefficient* between driver's posture based on knee angle and TA muscle contraction, *r* is -.993. This is due to the probability value derived from SPSS 20 for Windows (.000) is less than the prescribed alpha value (.05). There is strong evidence to conclude that $p < .05$. This shows that, there is a significant negative linear relation between the driver's posture based on knee angle and TA muscle contraction.

Results from the temporal analysis of the tibialis anterior muscle shows two situations which are muscle contraction and muscle at rest. Figure 3 shows *smoothing* 500ms RMS EMG signal of TA muscle for IMVC 60% and 2% from this study.

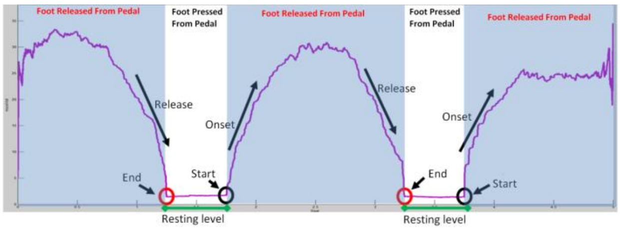

Figure 3 Result of Temporal Analysis on smoothing 500ms RMS EMG Signal for TA muscle

Figure 3 is divided into five (5) segments. The white colored segments represent the foot pressing the pedal while the blue colored segments denote the foot releasing the pedal. The EMG signals showed three segments where the foot is in releasing the pedal mode while the other two showed the foot pressing the pedal. The results show that the TA muscle contraction occurs when the foot is in releasing the pedal mode. When the pedal is pressed, the TA muscle contraction decreases until a certain position where the TA muscle is at rest. According to Florimond[12], the muscle is at rest when the amplitude reading is less than 5 µV. From the results, it can also be concluded that when the foot is releasing and pressing the pedal, the foot is in the dorsiflexion and plantarflexion positions.

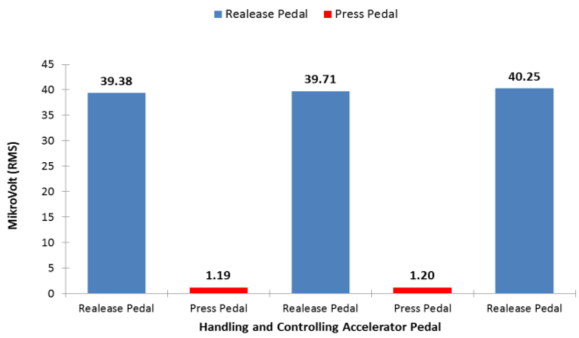

Figure 4 RMS value for TA muscle activity during foot pressing and releasing pedal modes

Figure 4 shows the rms value of IMVC 60% for pedal release segment with rms values of 39.38, 39.71 and 40.25. The rms values show the TA muscle contractions. As for IMVC 2% for pedal press segment, the rms values are 1.19 and 1.20. Since the rms value is less than 5 μV, it shows that the TA muscle is at rest.

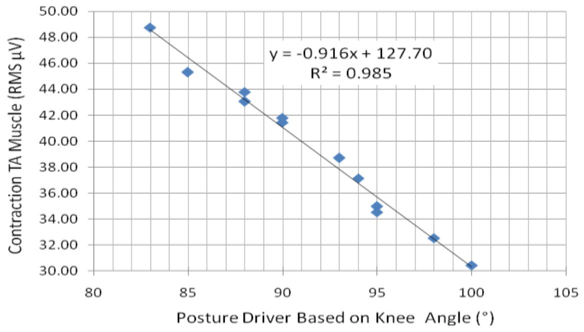

Figure 5 Result of regression test between driver's posture based on knee angle and contraction of TA muscle

Figure 5 shows the result of regression test to identify the driver's posture based on knee angle which affect the TA muscle contraction in the release pedal position. Significantly, the TA muscle contraction [F(1,10) = 660, p < .05] contributes 98.5% variance (R^2 = .985) to the driver's posture based on knee angle. Since the coefficient of correlation between driver's posture based on knee angle and TA muscle contraction is *r* = -.993, it means that when the knee angle increases, muscle contraction decreases. From this study, a linear equation model (Eq. 2) is developed.

$$y = -0.916x + 127.7 \quad (2)$$

Where y is the driver's posture based on knee angle and x is the TA muscle contraction in release pedal position.

CONCLUSION

Results from this study of TA muscle contraction on driver's posture based on knee angle less than 101° showed muscle contraction occurred in the release pedal position. This is proven from the results of both the temporal and amplitude analyses. The linear equation model clearly shows that, when the knee angle decreases, the TA muscle contraction increases. The decrease in knee angle will directly cause discomfort to the driver in his interaction with the pedal.

REFERENCES

1. Schmidt, S., Amereller, M., Franz, M., Kaiser, R., & Schwirtz, A. A literature review on optimum and preferred joint angles in automotive sitting posture. *Applied ergonomics* 2014; *45*(2): 247-260.

2. Mohamad, D. Identification of comfortable driving posture by using image recording, Master of Science Thesis (in Malay language), Universiti Kebangsaan Malaysia, Selangor, 2011.

3. SAE J4004, Positioning the H-Point Design Tool-Seating Reference Point and Seat Track Length, Society for Automotive Engineering Standard. 2008.

4. SAE J4003, H-Point Machine (HPM-II)-Procedure for H-Point Determination-Benchmarking Vehicle Seats, Society for Automotive Engineering Standard. 2008.

5. Wang, X., Le Breton-Gadegbeku, B., & Bouzon, L. Biomechanical evaluation of the comfort of automobile clutch pedal operation. *International Journal of Industrial Ergonomics 2004; 34*(3): 209-221.

6. Sasaki, K., & Neptune, R. R. Individual muscle contributions to the axial knee joint contact force during normal walking. *Journal of Biomechanics* 2010; 43(14): 2780-2784.

7. Soderberg, G. L., & Knutson, L. M. (2000). A guide for use and interpretation of kinesiologic electromyographic data. *Physical therapy 2000; 80*(5): 485-498.

8. Sousa, C. D. O., Ferreira, J. J. D. A., Medeiros, A. C. L. V., Carvalho, A. H. D., Pereira, R. C., Guedes, D. T., & Alencar, J. F. D. (2007). Electromyograhic activity in squatting at 40, 60 and 90 knee flexion positions. *Revista Brasileira de Medicina do Esporte* 2007; *13*(5): 310-316.

9. Hermens, H. J., Freriks, B., Disselhorst-Klug, C., & Rau, G. (2000). Development of recommendations for SEMG sensors and sensor placement procedures. *Journal of electromyography and Kinesiology* 2000; 10(5): 361-374.

10. Keenan, K. G., & Valero-Cuevas, F. J. Epoch length to accurately estimate the amplitude of interference EMG is likely the result of unavoidable amplitude cancellation. *Biomedical signal processing and control 2008; 3*(2): 154-162.

11. Garcia, M. C., & Vieira, T. M. M. (2011). Surface electromyography: Why, when and how to use it. *Revista Andaluza de Medicina del Deporte* 2011; *10*(6): 17-28.

12. Florimond, V. Basics of SURFACE ELECTROMYOGRAPHY Applied to Physical Rehabilitation and Biomechanics. *Montreal Canada, Thought Technology Ltd.*, February 2009 & March 2010.