Proceedings of the World Congress on Engineering 2010 Vol III
WCE 2010, June 30 - July 2, 2010, London, U.K.

# The Relationship of Head Rotation Angle and SCM EMG Value for the Development of AnS$^2$

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***Abstract*— Air travel is becoming increasingly more accessible to people with the availability of low cost air travel. However, travel by air, especially long distance, is not a natural activity for human. During air travel, people experience some degree of physiological and psychological discomforts. In this paper, four experiments were conducted to unfold the relationship of sternocleidomastoid electromyography value over head rotation angle in related with head support condition and gender. The results from the experiment served as important input for the validation of the developed adaptive neck support system for economy class aircraft seat.**

***Index Terms*— head rotation angle, EMG, AnS$^2$, economy class aircraft seat.**

## I. Introduction

Many aircraft passenger experience some degree of physiological and psychological discomfort during air travel. Excessive stress may cause passenger to become aggressive, over-reaction, and even endanger the passenger's health [1, 2]. A number of health problems can affect the passengers.

The Cambridge Advanced Learner's dictionary [3] defines comfort as a pleasant feeling of being relax and free from pain. Hertzberg [4] describes comfort as absence of discomfort. The term "seat comfort" is typically used to define the short-term effect of a seat to the human body [5]. Comfort is a generic and subjective feeling that is difficult to measure, interpret, and related to human physiological homeostasis and psychological well being [6]. Seat comfort is a very subjective issue because it is the customer who makes the final determination and customer evaluations are based on their opinions having experienced the seat [7].

Various studies [8, 9, 10, 11, 12] show that there is relationship between electromyography (EMG) activity of sternocleidomastoid (SCM) muscle and head rotation. Ylinen et al. [8] characterizes isometric rotation strength in both neutral and different pre-rotated positions of the neck. Twenty healthy men volunteered as participants. Maximal axial rotation strength of the neck muscles was measured in a neutral position and bilaterally at 30° and 60° rotation using the isometric neck strength measurement system. Isometric maximum voluntary contractions of the neck muscles in flexion and extension were tested. The highest strength values were not reached in the neutral position, but at the largest joint angles, while turning the head in the opposite direction from the pre-rotated position. Maximum strength increased with the increasing angle, and at the 60° pre-rotation angle it was 44% higher towards the right and 27% higher towards the left compared to the values obtained in the neutral position. The smallest strength values were also produced at the largest pre-rotation angles, but in the same direction. The results showed a clear relationship between the pre-rotated position of the neck and maximal voluntary strength in rotation.

Bexander et al. [9] conducted an experiment to investigate the effect of eye position on neck muscle activity during cervical rotation. In the study, the root-mean-square EMG amplitude was measured for one second during the period in which the position of the neck and head was held statically in each rotation angle (0°, 15°, 30°, 45°). The EMG amplitude of left SCM increased when the neck rotate from 0-45° during right rotation and decreased during left rotation. The result of experiment indicated that activity of SCM was specific to the direction of neck rotation.

Moon et al. [11] develop a method to estimate face direction angle using both image observation and EMG signal from neck muscles. The EMG signal of the SCM muscle concerned in the head movements is measured. The clavicle region is selected as the reference point for the EMG signal measurement because the clavicle is the near born from neck and it has no muscles. During the experiment, when the head is rotated to the right or left, the EMG signal is measured from the SCM at the opposite side. The results from the experiment showed that the changes of EMG signals slight until 30°, but linear properties appeared in the range [30°, 90°]. There was a relationship between rotated head angle and EMG signals.

Lin and Huang [12] investigate the changes of neck muscle activities when using different pillows in a time series and different kind of pillow. There was a significant decrease of SCM activity after 9$^{th}$ minutes up to 20$^{th}$ minutes when lying down from an upright position and not happened to upper trapezius muscle. The activities of SCM neck muscles decreased when changing craniocervical postures. The results confirmed the reason of participants preferred proper neck support.

In this paper, we describe an experiment to investigate the relationship between SCM EMG value and head rotation angle with related to head support condition and gender. The output from the experiment is used for the validation of the developed adaptive neck support system (AnS$^2$). Sternocleidomastoid (SCM) muscle was selected for the experiment because it is related to the head rotation activity [13]. In order to objectify the EMG value of SCM muscle at pre-defined head rotation angle, a self designed apparatus

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was built to conduct the experiment. The results would provide information for the development of adaptive neck support system during air travel.

The paper is organized as follows: Section II describes the framework of the experiment and Section III describes the methods of the experiment. Subsequently, the results presented in Section IV and discussion in Section V. The paper is concluded in Section VI.

## II. The Framework of Adaptive Neck Support System

An adaptive neck support system is developed to reduce SCM muscle stress adaptively during air travel. The developed system is designed for economy class aircraft passenger seat. Fig. 1 presents the adaptive framework for neck support system. The framework is commenced by detecting the passenger's head posture. Air pressure sensor is embedded in the seat to detect the head posture of the passenger. Subsequently, information of the head posture is sent back to the adaptive control module. The adaptive control module functions by (1) supporting passenger head based on current head posture; and (2) changing the head rotation angle of passenger to reduce the neck muscle stress adaptively. The adaptive control module would detect the low activity of passenger, once the passenger is in contact with airbag for more than 1 minute, the system will activate. The system will move the passenger head facing front and reduce the SCM muscle stress. Facing front is the most comfort head position [18].

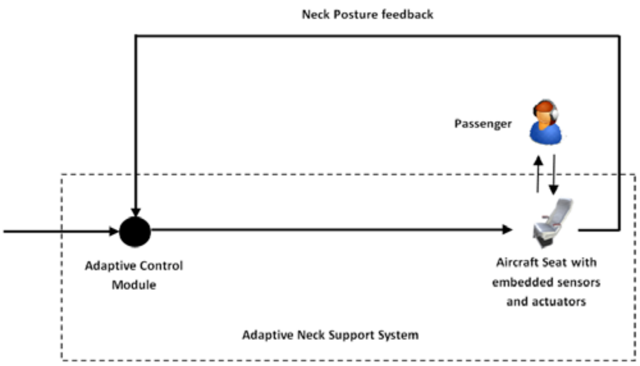


Fig. 1. An adaptive neck support system framework

## III. Methods

### A. Participant

Four participants with no neck pain from the last three months were recruited in this experiment to validate the developed adaptive neck support system (AnS$^2$). The group consisted of two female and two male aged between 27 and 30 years old (mean 28.67 years old). The subjects were students and working people. They were informed regarding the experiment which involved the sitting inside the head rotation angle measurement apparatus, video recording and recording of electromyography.

### B. Experimental Setup

We conducted the experiment by using a special head set and head rotation angle measurement apparatus. The location of experiment is in the simulation laboratory in the main building of Eindhoven University of Technology. An observation camera was used to record the activities of the subjects throughout the experiment.

### C. Apparatus and Data Recording

In order to gather EMG value of SCM muscle in different pre-defined head rotation angle, different hardware was used. The hardware used during the experiment as follows:

- MP150 Biopac System with EMG module
- Head rotation angle measurement apparatus
- Head set with laser beam
- Laptop
- Observation camera

Referring to the procedure used by Hermens et al. [14], the skin surface of the SCM was abraded and cleaned with alcohol, and subsequently the surface electrodes were applied. A pair of surface electrodes (Ag/AgCl electrodes; EL504-10; 10 mm diameter on a 25 mm square backing; Biopac Systems, Inc., USA) was placed in parallel with the muscle fibres of SCM with 20 mm inter-electrodes distance. The electrodes were placed at lower 1/3 of the line connecting sternalnotch and mastoid process [15]. Fig. 2 shows the placement of electrodes onto the SCM muscles.

Fig. 2. The SCM muscles with EMG electrodes

The sEMG signals were recorded at 1000 Hz sampling rate, band-pass filtered between 20 Hz and 350 Hz, full-wave rectified, and smoothed with a low-pass filter [16]. The high-pass cutoff frequency at 20 Hz was used to reduce motion artifacts and electrocardiography (ECG) artifacts with minimal impact on the total power of EMG [17]. Data were continuously recorded for 10 minutes with Biopac MP150 and analyzed with AcqKnowledge 3.9.1 (Biopac System Inc., USA).

### D. Experiment Procedure

We started the experiment with 30 minutes briefing to the participant and attachment of electrodes on SCM muscles. After that, we positioned the participant inside the head rotation angle measurement apparatus. Fig. 3 shows the participant who positioned inside the head rotation angle measurement apparatus with 45° head rotation to his right hand side.

ISBN: 978-988-18210-8-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Fig. 3. The participant is inside the head rotation angle measurement apparatus (45 degree)

Both right and left SCM muscles were evaluated in two head support conditions (with support and without support) and 7 rotation angles (1-L45°, 2-L30°, 3-L15°, 4-LR0°, 5-R15°, 6-R30°, 7-R45°). The participant is tested in each angle for 10 minutes. A rest period of two minutes was implemented between each angle to minimize the effect of fatigue as suggested by Cheng et al. [16]. After the measurement, the electrodes were detached from the participant and debriefing was conducted.

## IV. Results

Fig. 4 to Fig. 8 shows the normalized root mean square (RMS) of SCM EMG value for four participants. The data is the mean of the normalized EMG value, which was divided into 10 interval time. One interval time represented 60 seconds. As referring to Fig. 4, the EMG value of right SCM increased when the head turns to left hand side (from 4-LR0° to 7-L45°) and decreased when the head turn to right hand side (from 4-LR0 to 1-R45°). It is found in the same condition as in Fig. 5. For left SCM muscle, the EMG value increased when the head turn to right hand side (from 4-LR0 to 1-R45°) and decreased when the head turn to left hand side (from 4-LR0 to 7-L45°). The lowest SCM value for both right and left SCM is found during 4-LR 0 degree condition.

For the supported condition, the head of subject was supported by the developed AnS$^2$. As referring to Fig. 6, the EMG value of SCM muscle without support for four subjects is higher than the EMG value of SCM muscle with support condition.

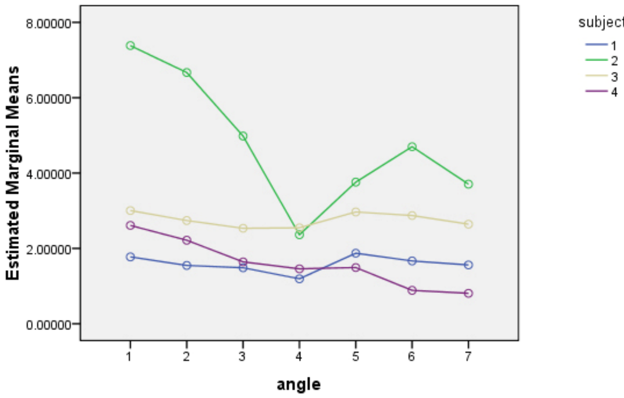


Fig. 4. Right SCM muscle

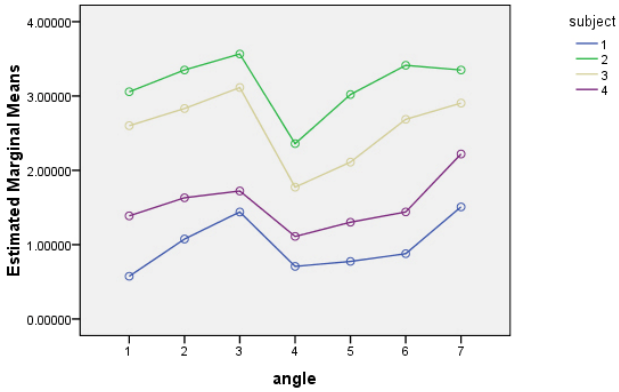


Fig. 5. Left SCM muscle

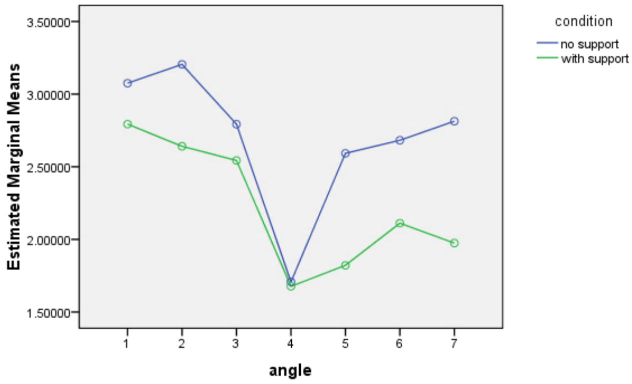


Fig. 6. Average SCM muscle EMG value in different condition

As referring to Fig. 7 and Fig. 8, female and male have different SCM EMG value in different head rotation angle.

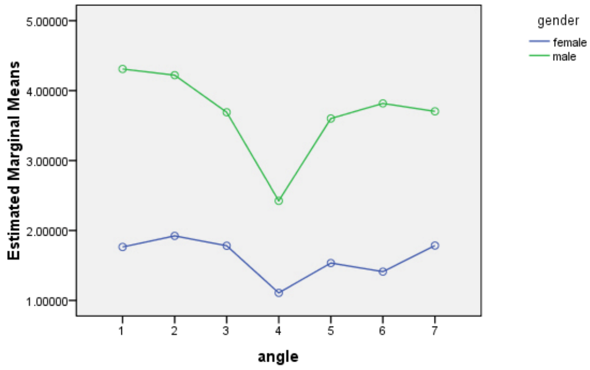


Fig. 7. Average SCM muscle EMG value of gender in no support condition

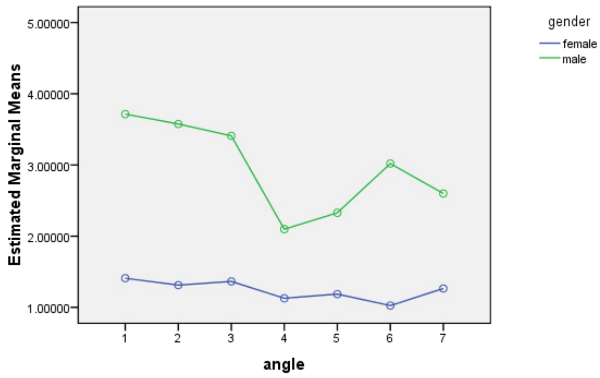


Fig. 8. Average SCM muscle EMG value of gender in support condition

Repeated measures ANOVA, with Greenhouse-Geisser correction, was conducted to assess whether there were head support condition, gender and angle differences between the average ratings of SCM EMG value. Results indicated that the condition of participant did show the SCM EMG value differently, $F$ (1, 83.44) = 51.74, $p$ < .001. Subsequently, the gender also indicated a significant main effect of SCM EMG value, $F$ (1, 1003.94) = 52.85, $p$ < .001, but not for angle, $F$ (6, 23.5) = 1.237, $p$ = .32. This indicates that different condition and gender do have different SCM EMG value.

## V. Discussion

In the current study, the SCM muscle activity was investigated in the laboratory on participants with the head rotation measurement apparatus. The first finding from the study is that the EMG value of SCM muscle increased when the head turn to opposite side. For example, the EMG value of right SCM muscle increased when the participants turn his/her head to the left hand side. The findings were similar to the results by Ylinen et al. [8], Bexander et al. [9], Gabriel et al. [10], and Moon et al. [11].

The study also found that both EMG values of right and left SCM muscles decreased when the participant's head was supported by the developed AnS$^2$. All four participants showed the same condition during the experiment. The statistical analysis shows that there is a significant difference for SCM EMG value in different condition as well as gender. The SCM EMG value at without support condition is higher than support condition. The gender also showed the different SCM EMG value, where the male SCM EMG value is higher than female SCM EMG value.

## VI. Conclusion

In this paper, we have described the experiment to investigate the relationship of SCM EMG value a head rotation angle in related to head support condition and gender. The experiment results showed that there were significant differences between head rotation angle and mean SCM EMG value as well as head support condition and gender. The experiment enables the ongoing research to quantify the SCM neck muscle, predict the support pattern and to validate the developed adaptive neck support system.

## Acknowledgement

Special thank to Ministry of Higher Education, Malaysia and Universiti Teknikal Malaysia Melaka for PhD sponsorship of the first author. The authors would like to thank the following persons for their contribution: Loe Feijs, Geert van den Boomen and Chet Bangaru.

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