Experimental Design for Sternocleidomastoid Muscle Stress Measurement

CheeFai Tan[1]
c.f.tan@tue.nl

Wei Chen
w.chen@tue.nl

Matthias Rauterberg
g.w.m.rauterberg@tue.nl

Designed Intelligence Group, Department of Industrial Design, Eindhoven University of Technology
Den Dolech 2, 5612 AZ Eindhoven, The Netherlands

ABSTRACT
In this paper we assess the sternocleidomastoid muscle stress with two experimental studies to evaluate the developed smart neck support system. The first study involving head rotation angle and sternocleidomastoid muscle (SCM) electromyography (EMG) activity. This (descriptive) study extends efforts from different authors to assess the isometric strength of SCM, in which the experiment is carried out in relation to time. This first study functions as a calibration experiment which provides the input for the second study as a validation experiment. The validation experiment was conducted inside the aircraft cabin simulator. The SCM of participant was evaluated with electromyography. The smart neck support system is to reduce the SCM muscle stress of aircraft passenger adaptively during air travel.

Author Keywords
Calibration experiment, validation experiment, smart neck support system.

ACM Classification Keywords
C.4. Computer Systems Organization: Performance of Systems: Measurement Technique.

INTRODUCTION
Aircraft passengers may experience some degree of physiological and psychological discomfort, as well as stress during air travel [1]. The aircraft passenger comfort depends on different features and the environment during air travel. Seat comfort is a subjective issue, because it is the customer who makes the final determination. Customer evaluations are based on their opinions having experienced the seat [2]. The aircraft passenger seat has an important role to play in fulfilling the passenger comfort expectations. The seat is one of the (most) important features of the vehicle and in which the passenger spends most of their time during air travel.

Several studies [3,4,5,6] conducted the experiment to measure the relationship between electromyography (EMG) activity of sternocleidomastoid (SCM) muscle in relation to head rotation. Ylinen et al. [3] evaluated the isometric rotation strength in both neutral and different pre-rotated positions of the neck. 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 neck strength measurement (system was) used to measure different rotation angles, isometric flexion and extension.

Moon et al. [4] studied EMG signal from neck muscles to estimate face direction angle. The EMG signal of the SCM muscle concerned in the head movements is measured. The clavicle region was selected as the reference point for the EMG signal measurement because the clavicle is the bone nearest to the neck and it has no muscles. During the experiment, when the head was rotated to the right or left, the EMG signal was measured from the SCM at the opposite side.

Bexander et al. [5] conducted an experiment to investigate the effect of the 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°). Recordings were made from three dorsal neck muscles on the right using electrodes and from the left SCM muscle with surface electrodes.

Lin and Huang [6] investigated the changes of neck muscle activities when using different pillows in a time series and different kinds of pillows. Each participant was investigated for neck muscle activities in sitting and supine position for 30 minutes in three conditions: with a neck support pillow, a standard pillow, or without using a pillow in a random order.

[1]Also Universiti Teknikal Malaysia Melaka, Melaka, Malaysia.

In this paper, we describe two experimental setup to investigate the relationship between head rotation angle and EMG value. The output from the experiment is used for the validation of the developed smart neck support system. Sternocleidomastoid (SCM) muscle was selected for the experiment because it is related to the head rotation activity [7]. In order to objectify the EMG value of SCM muscle at a pre-defined head rotation angle, a self designed and self built apparatus was used to perform the experiment. The results would provide information about the relationship between head rotation angle and SCM muscle EMG value. In addition, an aircraft cabin simulator was built to conduct the validation experiment on the developed smart neck support system [8,9,10].

METHODS

Calibration Experiment

Subject

Four participants with no neck pain in the last three months were recruited in this experiment. The group consisted of two females and two males.

Experimental Setup

The calibration experiment was designed to evaluate the SCM EMG value in relation to different pre-defined head rotation angles, time and gender. They were informed regarding the experiment which involved sitting inside the special designed head rotation angle apparatus, wearing a special designed head set with laser beam, video recording and recording of electromyography on SCM muscle (right and left). The location of experiment was the simulation lab in the main building of Eindhoven University of Technology. For video recording, we used a closed circuit camera (CCTV) that was installed to record the activities of the participant throughout the experiment.

Apparatus and Data

The hardware used in the experiment is as follows:

- MP150 Biopac system with EMG module
- Head rotation angle measurement apparatus
- Headset with laser beam
- Laptop
- CCTV

The EMG data of right SCM and left SCM were measured with the head rotation. The SCM muscle was related to the major neck flexors [11]. The skin surface of SCM was cleaned with alcohol before the surface electrodes were applied [12]. 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 fibers of SCM with 20 mm inter-electrodes distance. The electrodes were placed at lower 1/3 of the line connecting sternal notch and mastoid process [13]. Figure 1 shows the location of electrodes.

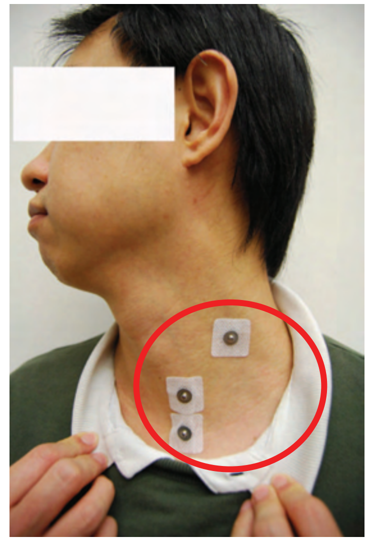

Figure 1. The location of electrodes on left SCM muscle.

The EMG 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 [14]. The high-pass cut-off frequency at 20 Hz was used to reduce motion artifacts and electrocardiography (ECG) artifacts with minimal impact on the total power of EMG [12]. Data were continuously recorded for 10 minutes with Biopac MP150 and analyzed with AcqKnowledge 3.9.1 (Biopac System Inc., USA).

Experiment Procedure

We started the experiment with 30 minutes of briefing of the participants and attachment of electrodes on SCM muscles. The participant performed maximal voluntary contraction (MVC) of the SCM by rotation of the head to the left hand side and right hand side for 10 seconds. After that, we positioned the participant in the head rotation angle measurement apparatus while wearing the headset. Figure 2 shows the participant inside the head rotation angle measurement apparatus and in LR0° head rotation.

Both right and left SCM muscles were evaluated in two conditions (with and without support) and 7 rotation angles (L45°, L30°, L15°, LR0°, R15°, R30°, and R45°). The participant was tested in each angle for 10 minutes. A rest period of two minutes was implemented between each angle to minimize the effect of fatigue [14]. After the measurement, all the electrodes were detached from the participant and the participant was debriefed.

Validation Experiment

Subject

Three participants (1 female and 2 male), which had no neck pain in the last three months, were recruited. They were informed regarding the procedure of experiment such as sitting inside the aircraft cabin simulator [16, 17,18] for

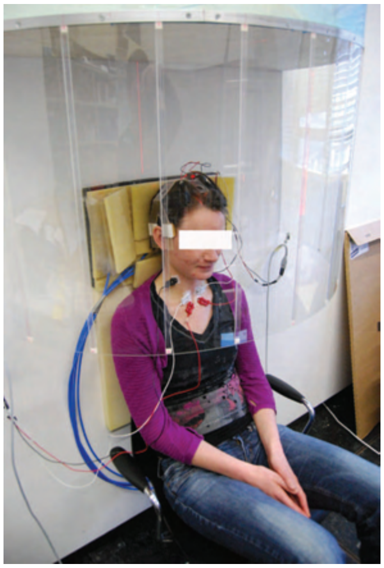

Figure 2. The participant sitting inside the head rotation angle apparatus.

one hour, video recording and attachment of EMG electrodes on their SCM muscle.

Experimental Setup

The validation experiment was conducted in the aircraft cabin simulator. The location of experiment was the simulation lab in the main building of Eindhoven University of Technology. The smart neck support system was installed at the economy class aircraft seat.

There were two CCTVs used to monitor the participant activity. One CCTV was located in front of each participant and another CCTV is located above the head of the participant. There was one additional CCTV that monitored the overall activity in the simulator.

Apparatus and Data

The hardware used in the experiment was as follows:

- MP150 Biopac system with EMG module
- Aircraft cabin simulator
- Smart neck support system
- Computer
- CCTV

Two EMG modules of MP150 Biopac system were used for each participant. The aircraft cabin simulator was designed and built to simulate the average economy class cabin. Three smart neck support systems were installed in each aircraft seat. The computer was used for data logging and video recording. The CCTVs were installed in front as well as above the participant. The acquisition of EMG signal and procedure were the same as in the calibration experiment.

Figure 3. The setup of participants in the aircraft cabin simulator.

Experiment Procedure

We started the experiment with 30 minutes of briefing to the participants and attachment of the electrodes on SCM muscles. The participant performed maximal voluntary contraction (MVC) of the SCM by rotating the head to the left hand side and the right hand side for 10 seconds. After that, we positioned the participant in the economy class aircraft seat. The aircraft seat sitting position was classified as aisle seat, center seat and window seat. Subsequently, the light in the aircraft cabin was dimmed and the participant was advised to rest during the one hour experiment. The EMG signals for participants were monitored and recorded in parallel with system logging and video recording. Figure 3 shows the view in the aircraft cabin simulator during the experiment.

CONCLUSION

In conclusion, this paper describes two experimental setups for the evaluation and validation of a smart neck support system. The calibration experiment is used to gather the SCM EMG value information in relation to different pre-defined head rotation angle, time and gender. A specially designed head rotation angle apparatus and a headset were modified for the calibration experiment. For the validation experiment, the participants sat inside the aircraft cabin simulator to validate the smart neck support system. Each participant was attached with EMG electrodes and the activities of the participant were observed with CCTV. The activity of each participant was recorded in real time. The research integrated different fields of study such as control, physiology and ergonomic for the development of the smart neck support system. Future studies are suggested to provide more insight into the experimental design process which could lead to the better objectification of the smart system.

REFERENCES

1. Kalogeropoulos, S. ***Sky rage***. Flight Safety Australia (1998), 36-37.

2. Runkle, V.A. Benchmarking seat comfort. ***SAE Technical Paper***, No. 940217 (1994).
3. Ylinen, J., Nuorala, S., Häkkinen, K., Kautiainen, H. and Häkinnen, A. Axial neck rotation strength in neutral and prerotated postures. Clinical Biomechanics, ***18*** (2003), 467-472.
4. Moon, I., Kim, K., Ryu, J. and Mun, M. Face direction-based human-computer interface using image observation and EMG signal for the disabled. ***Proceeding of the 2003 IEEE Internationa Conference on Robotics & Automation*** (2003), 1515-1520.
5. Bexander, C.S., Mellor, R. and Hodges, P.W. Effect of gaze direction on neck muscle activity during cervical rotation. ***Exp Brain Res***, ***167*** (2005), 422-432.
6. Lin, Y.-H. and Huang, W.-Y. Cervical postures and electromyographic activities of related neck muscles when using a neck support pillow. ***Journal of Biomechanics***, ***40***, 2 (2008), 414.
7. Sommerich, C.M., Joines, S.M.B., Hermans, V. and Moon, S.D. Use of surface electromyography to estimate neck muscle activity. ***Journal of Electromyography and Kinesiology***, ***10***, 6 (2000), 377-398.
8. Tan, C.F., Chen, W., Liu, H. and Rauterberg, M. Adaptive framework and user preference modelling for economy class aircraft passenger seat. ***Proceeding of 2009 Third UKSim European Symposium on Computer Modeling and Simulation***, Athens, Greece (2009), 66-69.
9. Tan, C.F., Chen, W., Kimman, F. and Rauterberg, M. Sleeping in sitting posture analysis of economy class aircraft seat. ***Electronic Engineering and Computing Technology, Series: Lecture Notes in Electrical Engineering***, Ao, Sio-long; Gelman, Len (Eds.), 1st Edition, Springer Publication, 60 (2010), 703-713.
10. Tan, C.F. Chen, W. and Rauterberg, M. Development of adaptive aircraft passenger seat system for comfort improvement. ***Proceeding of International Conference for Technical Postgraduates***, Kuala Lumpur, Malaysia, (2009), paper no. CC02-05.
11. Conley, M.S., Meyer, R.A., Bloomberg, J.J., Feeback, D.L. and Dudley, G.A. Noninvasive analysis of human neck function. ***Spine, 20***, 23 (1995), 2505-2512.
12. Hermens, H.J., Feriks, B., Disselhorst-Klug, C. and Rau, G. Development of recommendations for SEMG sensors and sensor placement procedures. ***Journal of Electromyography and Kinesiology***, ***10***, 5 (2000), 361-74.
13. Falla, D., Dall'Alba, P., Rainoldi, A., Merletti, R. and Jull, G. Location of innervation zones of sternocleidomastoid and scalene muscles – a basis for clinical and research electromyography applications. ***Clinical Neurophysiology, 113***, 1 (2002), 57-63.
14. Cheng, C.H., Wang, J.L., Lin, J.J., Wang S.F. and Lin, K.H. Position accuracy and electromyographis responses during head reposition in young adults with chronic neck pain. ***Journal of Electromyography and Kinesiology***, doi:10.1013/j.jelekin.2009.11.002, (2009).
15. Clancy, E.A., Morin, E.L. and Merletti, R. Sampling, noise reduction and amplitude estimation issues in surface electromyography. J***ournal of Electromyography and Kinesiology, 12***, 1 (2002), 1-16.
16. Tan, C.F., Chen, W. and Rauterberg, M. Interactive aircraft cabin testbed for stress-free air travel system experiment: an innovative concurrent design approach. ***Proceeding of International Conference on Advances in Mechanical Engineering***, Shah Alam, Malaysia, (2009), 137.
17. Tan, C.F., Chen, W. and Rauterberg, M. Design of aircraft cabin testbed for stress free air travel experiment. ***Proceeding of 5th International Conference on Planning and Design***, Tainan City, Taiwan, (2009), 157.
18. Tan, C.F., Chen, W. and Rauterberg, M. Total design of low cost aircraft cabin simulator. ***Proceeding of Design 2010***, Cavtat, Croatia, (2010), 1721-1728.