The Effects of Seat Surface Inclination on the Onset of Muscle Contraction during Sit-to-stand in Healthy Adults

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Purpose: Rising from a chair is important for activities of daily living. Several factors have influence on sit-to-stand movement. We studied the effect of inclination of seat surface of on the movement of rising from a chair with electromyographic (EMG).

Methods: Twelve subjects performed the sit-to-stand movement on anterior-inclined, standard, and posterior inclined chair. We measured onset time of tibialis anterior and rectus femoris with EMG on each inclination chair.

Results: The onset time at the anterior-inclined chair is significantly faster than it at the standard chair (p<0.05). And the onset time at the posterior-inclined chair is significantly slower than it at the standard chair (p<0.05).

Conclusion: Rising from anterior inclined chair appeared to be more effective than rising from the standard and posterior inclined chair. Therefore, this finding suggests that the selection of set surface inclination must be considered for activities of daily living during rehabilitation.

Keywords: Electromyography, Muscle contraction, Sit-to-stand movement

I. Introduction

Sit-to-stand (STS) is a daily ordinary movement. If this movement is disabled, one will have difficulty rising from a chair, independently functioning, and furthermore walking. Determinants of STS movement include the chair’s height, the use of an armrest, the position of the feet, knee joint posture, the use of arms, trunk posture, a chair’s inclination, standing speed, chair back height, concentration, and training. STS movement is characterized by the arrangement of body segments—which occurs for 1.6 to 1.8 seconds—and by a change in the body form. This movement can be successfully performed by muscle activation, angular movement, force, joint moment, and transfer of the center of mass. The overall STS movement pattern is shown in the order of flexion of body segments and initial extension, and is completed when one completely stands up. Wheeler et al. reported that if the posterior inclination of seat surface increases, when beginning to stand with the center of mass inclined backwards, it will increase the forward displacement of the trunk, STS movement is difficult as a result. However, nearly no research has been reported as to the effects of anterior seat inclination on STS movement.

Detecting the onset of muscle contraction from an electromyographic (EMG) signal is an important task in several types of applications. It is a marker for the start of active control of the muscle, and as such is useful when measuring performance in reaction time experiments with external stimulus. This study aims to exam the onset of muscle contraction during STS in chairs with three different inclinations, namely, anterior inclined seat (AIS), standard inclined seat (SIS), and posterior inclined seat (PIS).
II. Materials and Methods

1. Subjects

Twelve healthy adults joined this study as subjects. Patients with nervous and muscular system diseases were excluded from this study. All subjects agreed to the objectives of this study, and voluntarily participated in this study. Subjects were 23.2 ± 0.4 years old, 163.9 ± 3.6 cm tall, and weigh 52.7 ± 3.7 kg. All participants voluntarily signed a consent form prior to the experiment.

2. Experimental methods

1) Experimental instrument

For STS movement, this study used wooden chairs without armrests that have a height of 42 cm, a depth of 45 cm, and a width of 42 cm. An EMG system monitor was positioned on a 1 m-high table, which will be as high as the subject’s eye level in his/her sitting posture in the chair. To measure the onset of the rectus femoris (RF) and tibialis anterior (TA) muscle, the MP150 System (Biopac System Inc., Goleta, CA, USA) and the Bagnoli EMG System (Delsys Inc., Boston, MA, USA) were used. For EMG acquisition, Acqknowledge 3.8.2 program (Biopac System Inc.) was used, and to gather and treat EMG signals, the Acqknowledge 3.8.2 program was used. EMG analogue signals, as obtained, were sent to the MP150 system to be transformed into digital signals. The signals were processed by using the Acqknowledge 3.8.2 software in a personal computer. The sampling rate was set as 1,000 Hz. Then, a bandwidth of 20~450 Hz and the 60 Hz notch filter were used.

2) Experimental procedure

EMG was measured to define RF muscle contraction onset time during STS movement according to seat surface inclination. First, to reduce skin resistance against EMG signals, the indicated area was rubbed by using a thin sandpaper to remove the horny layer. Skin fat was removed by using disinfecting alcohol, and a small amount of electrolyte gel was applied to the electrode, which was attached to the relevant muscle. For RF, the electrode was attached to the midpoint of the line connecting the anterior superior iliac spine and the superior pole of the patella. For TA, the electrode was attached to junction of the middle and upper thirds of the leg, one-quarter of the distance from the tibial shaft to the lateral border of the leg. During maximum contraction, electrodes were attached in the position parallel with the muscle belly. The grounding electrode was attached to the center of the patella. Subjects were then given a detailed explanation of the experiment process, and were requested to concentrate on the monitor indicating the commencement of movement performance, as manipulated by the researcher.

STS movement was performed in a chair on the floor that had an inclination of 15° and 0° at the front, and a inclination of 15° at the rear. To exclude the effect of the trunk inclination degree on STS movement, subjects rose as fast as possible with their backs upright. Subjects, during STS movement, positioned their feet right below their knees in the chair sitting posture, and, to prevent the compensation action of the upper limbs, subjects rose with their arms folded. To confirm the time when the hip left the chair, and the time when STS movement was completed, sensors equipped with a force sensitive resister were attached to the chair and the subject’s shoes. To reduce errors of test results, each task was performed three times in random order. To prevent the effect of the preceding task performance on the following task performance, a three-minute break time was given between a total of nine time task performances.

3) Data reduction and statistical analysis

Data values obtained from the EMG system were statistically processed by using the Acqknowledge 3.8.2 program. Signals, which underwent full wave rectification, were processed by using the 8Hz low pass filter. The period 0.5 second before the EMG system movement commencement signal that indicated the beginning of movement was set as the baseline period, thus evaluating the EMG signal amplitude average and standard deviation. As in the Di Fabio research, the point above the calculated threshold (the baseline period average+3 standard deviation) was defined as the onset of muscle contraction: only when a value above the threshold value continued for more than 50 ms, it was set as the onset point of muscle contraction. Also, for the onset
point of muscle contraction, the percentage of each muscle contraction onset time to the time taken to rise from the chair was expressed. The average of three test values was defined as the representative value. To test the effect of seat surface inclination, onset time of muscle contraction were analyzed by one-way ANOVA, and post hoc Tukey’s multiple comparison tests with a 0.05 significance level.

III. Results

The time taken to rise from the chair was measured by measuring the time taken right before raising the hip from the chair, and the time taken to completely rise from the chair. The onset time at the anterior-inclined chair is significantly faster than it at the standard chair (p<0.05). And the onset time at the posterior-inclined chair is significantly slower than it at the standard chair (p<0.05) (Figure 1). During STS movement, the time taken right before raising the hip from the chair was in the ascending order of AIS, SIS, and PIS, and it varied significantly according to the gradient (p<0.05) (Figure 1). Also, the time taken to completely rise from the chair was in the ascending order of AIS, SIS, and PIS, and it varied significantly according to the gradient (p<0.05) (Figure 1).

The relative muscle contraction onset time varied significantly according to the chair’s gradient. Specifically, the onset time of RF muscle contraction was in the ascending order of AIS, SIS, and PIS. TA had the ascending order of AIS, SIS, and PIS (p<0.05) (Figure 2).

IV. Discussion

STS is a key ordinary movement to secure mobility in the activity of daily living. Some studies divide STS movement into four stages.\(^5\) The first stage is flexor moment, and covers the period from the commencement of movement to before raising the hip.\(^6\) The second stage is momentum transfer, and covers the period from beginning to raise the hip to the maximum dorsiflexion of ankle joints.\(^6\) The third stage is extensor moment, and covers the period from the commencement of the maximum dorsiflexion of ankle joints to hip extension.\(^6\) The fourth stage covers the period from right after hip extension to full extension, stabilizing the posture.\(^6\) To improve the impaired STS movement, diverse movement factors must be taken into account.\(^10\) Rodosky et al.\(^15\) reported that, during STS movement, if the chair height increases, the lower limbs’ joint extension range of motion (ROM) decreases, and that the maximum hip joint’s bending moment and the maximum knee joint’s bending moment decreased. Likewise, Arborelius et al.\(^7\) reported that when the subject rose from the chair using armrests, the necessary extension moment was reduced from the hip joint. Kawagoe et al.\(^8\) claimed that when the feet were positioned further in the rear, the maximum hip-joint extension moment average during STS movement was further lowered.\(^5\) Anglin and Wyss\(^13\) reported that during STS movement, when one used his arms, the entire knee force decreased. The posterior inclination seat surface increased, one increased

![Figure 1](image1.png)  
Figure 1. Total sit-to-stand (STS) time and seat-off time on each chair inclination during STS movement.

![Figure 2](image2.png)  
Figure 2. % onset time of muscle contraction on chair inclination.
his momentary trunk forward displacement upon rising with the center of mass being inclined backwards, making STS movement difficult.

In this study, during STS from chairs with three different inclinations, onset time of muscle contraction was analyzed, revealing that RF and TA had a significant difference between AIS and PIS. Based on PIS, STS movement, subjects’ muscles in AIS, STS movement were activated faster, and PIS, STS movement was activated at the slowest time. This suggests that muscle contraction commencement time in AIS, STS movement was faster than in SIS, STS movement. Specifically, it was found that if the chair gradient increased, the ROM of ankle, knee, and hip joints decreased, thus decreasing the time taken right before raising the hip, the first step of STS, and the time taken for the entire STS movement as well. Also, EMG examinations revealed that RF and TA contracted faster in AIS, suggesting that AIS enables an easier performance of the first step of the STS movement.

In patients who suffer from impaired lower limbs due to nervous or musculoskeletal diseases, STS movement is essential for their walking rehabilitation. However, in the early rehabilitation stage, due to very weak lower limb muscles, the patient has difficulty performing STS movement from an SIS chair. Thus, in the early rehabilitation stage, if AIS is used, STS movement may be performed more easily. However, patients with trunk instability may be prone to the danger of falling, so not only efficiency but also stability of STS movement should be taken into account.

In this study, various determinants of STS movement, as discussed in previous studies, were appropriately controlled and tested. However, a greater number of subjects and muscles have yet to be studied in order to generalize the test results. In order to improve the validity of the data and the generalization of the research results in future studies, the characteristics of a greater number of muscles that get involved in STS movement, using a greater number of subjects, should be examined. Thus, important information for rehabilitation training should be provided to those who have to acquire STS movement performance skills.

In this study, in healthy adults, onset time of muscle contraction, the time taken right before raising the hip, and the entire STS movement time in AIS, SIS, and PIS chairs were compared, thus, confirming that AIS is more efficient than SIS. Through this study, we suppose the possibility that AIS can be used to perform STS movement more easily during the early rehabilitation stage.

Acknowledgements

This work was supported by research grants from the Catholic University of Daegu in 2011.

References

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