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Original Article

Activation timing patterns of the abdominal and leg muscles during the sit-to-stand movement in individuals with chronic hemiparetic stroke

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Abstract. [Purpose] The purpose of this study was to determine the activation timing patterns of abdominal and leg muscles during the sit-to-stand movement in individuals with chronic hemiparetic stroke. [Subjects] Twenty adults with chronic hemiparetic stroke participated in this study. [Methods] Subjects performed five sit-to-stand movements at a self-selected velocity without using their hands. Surface electromyography was used to measure the reaction time of the bilateral transverse abdominis/internal oblique, rectus femoris, and tibialis anterior muscles during the sit-to-stand movement. [Results] There were significant differences in the reaction time between the affected and unaffected sides of the abdominal and leg muscles. Muscles on the unaffected side had faster reaction time than those on the affected side. Activation of the transverse abdominis/internal oblique muscles was delayed relative to activation of the tibialis anterior muscle during the sit-to-stand movement. [Conclusion] Our findings provide information that may aid clinicians in the examination and management of paretic muscles for transfers in individuals with chronic hemiparetic stroke.
Key words: Reaction time, Sit-to-stand, Stroke

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INTRODUCTION

The sit-to-stand (STS) movement is an important functional task, and it is a prerequisite for upright mobility during the activities of daily living[1)]. In the initial phase of normal STS movement, the activity of the tibialis anterior (TA) muscle increases to begin the weight shift. During the executive phase, the quadriceps (QUA) and TA muscles are maximally activated, after which activity usually decreases in amplitude until the standing position is fully reached. In the full standing position, the QUA and TA muscles become inactive, but the hamstrings and soleus remain active for stabilization while standing[2)]. Patients with neurological diseases, such as stroke, have difficulty performing the STS movement due to pain, spasticity, muscle weakness, sensory problems, and balance deficits in the affected limb[3, 4)]. In stroke patients, the muscle recruitment patterns in the unaffected limb compensate for the muscle deficiencies of the affected or paretic limb. This compensatory pattern is often created to achieve balance, and indicates that the unaffected TA and QUA muscles are recruited earlier than those in a normal pattern[2)]. Additionally, abdominal muscles are activated to flex the trunk in the initial phase of the STS movement. However, previous studies only focused on the activation timing patterns of the leg muscles in individuals with stroke.

To our knowledge, no previous studies have assessed the activation timing patterns (e.g., reaction time) of deep abdominal muscles, such as the internal oblique (IO) and transverse abdominis (TrA), during the STS movement in individuals with hemiparetic stroke. An investigation to clarify the reaction time of the IO and TrA muscles in individuals with hemiparetic stroke will provide important clinical information for understanding the relationship between trunk and leg muscle activation during the STS movement. Therefore, the purpose of the present study was to determine the activation timing patterns (muscular reaction time) of the abdominal and leg muscles during the STS movement in individuals with chronic hemiparetic stroke.

SUBJECTS AND METHODS

Twenty adults with chronic hemiparetic stroke (10 males and 10 females) participated in the study. All subjects were informed of the purpose of the study and agreed to participate. All protocols used in the study were approved

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by the University of Daejeon. Before the study began, its procedures, risks, and benefits were explained to all participants, who gave their informed consent. The participants' rights were protected by the guidelines of the University of Daejeon. The inclusion criteria were as follows: (1) more than 6 months after the clinical diagnosis of ischemic or hemorrhagic hemiparetic stroke, (2) sufficient cognitive function, as determined by a score of at least 24 out of 30 on the Korean version of the Mini-Mental State Examination, and (3) ability to walk without the use of a walking aid. The exclusion criteria included a history or current diagnosis of other neurological or musculoskeletal diseases, hemineglect, visual lesions, and pain. Among the 20 hemiplegic patients, 15 had an ischemic stroke and 5 had a hemorrhagic hemiparetic stroke. The average age, height, and weight of subjects were 57.3 ± 7.6 years, 165.7 ± 9.1 cm, and 66.5 ± 13.9 kg, respectively.

Surface electromyography (EMG) was used to measure muscular reaction time in the affected and unaffected abdominal and leg muscles during the STS movement. The EMG electrodes (Noraxon Inc., Scottsdale, AZ, USA) were placed on the right and left TrA/IO, rectus femoris (RF), and TA muscles. To acquire EMG data during the STS movement, the subjects were seated on an armless and backless chair, and the chair seat was adjusted to the height of their knee joints. The STS movement was performed barefoot, and the distance between each foot was 10–15 cm depending on body size. The STS movement began with a straight trunk, 10 degrees of ankle dorsiflexion, and 100–105 degrees of knee flexion measured using a goniometer. All subjects performed the initial posture to prevent impacting the timing of preparation and execution of the STS movement. Subjects moved at a self-selected velocity, as comfortable, and performed the STS movement five times without using their hands[2]. Before each movement, they received a standard instruction: "When you detect the sound, please stand up at a comfortable pace."

EMG data were collected at a sampling rate of 2,000 Hz. The acquired raw EMG data were processed a 60 Hz notch filter to reduce the noise associated with electrical interference. The root mean-square EMG amplitude for the TrA/IO, RF, and TA muscles was computed, and the EMG signal was full-wave rectified and filtered using a band-pass filter at 20–500 Hz. The EMG onset time of each muscle was identified to determine the muscular reaction time (or the time between the auditory stimulus and EMG onset time of each muscle). The onset time was determined mathematically by using MATLAB R2008A software (MathWorks Inc., Natick, MA, USA) based on an algorithm that identified the point at which the mean amplitude of 50 consecutive samples reached three standard deviations from the mean of the baseline amplitude recorded immediately before the movement stimulus[5].

One-way ANOVA with repeated measures was used to compare differences in the EMG reaction time between the affected and unaffected sides of the TrA/IO, RF, and TA muscles, as well as between these muscles. The level of significance was set at $\alpha = 0.05$. The Statistical Package for the Social Sciences for Windows, version 12.0 (SPSS, Chicago, IL, USA) was used for statistical analysis.

Table 1. Comparison of the EMG reaction time (sec) between the affected and unaffected sides of the abdominal and leg muscles

Muscle	Affected side	Unaffected side
TrA/IO	1.16 ± 0.29	0.99 ± 0.31*
RF	1.30 ± 0.14	1.11 ± 0.29*
TA	1.05 ± 0.25	0.81 ± 0.22*

The data are expressed as mean ± SD. TrA/IO: transverse abdominis/internal oblique; RF: rectus femoris; TA: tibialis anterior. *significant differences ($p < 0.05$)

RESULTS

During the STS movement, there were significant differences in the EMG reaction time between the affected and unaffected sides in individuals with chronic hemiparetic stroke (Table 1). According to the Bonferroni post hoc test, there were also significant differences in the EMG reaction time between the TrA/IO and TA muscles ($p = 0.024$) and the RF and TA muscles ($p = 0.000$), although not between the TrA/IO and RF muscles ($p = 0.067$).

DISCUSSION

The purpose of this study was to investigate the activation timing patterns (EMG reaction time) of the bilateral TrA/IO, RF, and TA muscles during the STS movement in individuals with chronic hemiparetic stroke. As anticipated, muscles on the unaffected side of the body had faster reaction time than those on the affected side or paretic muscles. The faster reaction times of unaffected muscles compensate for the weakness and delayed activation of affected or paretic limb muscles. Engardt and Olsson found that the weight-bearing limb on the unaffected side (compared with that on the affected side) achieved balance more quickly during the STS movement in individuals with hemiparesis[6]. Interestingly, the EMG reaction time of the TrA/IO muscles was delayed relative to that of the RF and TA muscles during the STS movement in the present study. Goulart et al. investigated changes in the onset latency of the neck, leg, and trunk muscles during the STS movement of healthy adults under six conditions (the reference condition, feet forward, knees first, flexion of the trunk, head supported, trunk straight)[7]. They found earlier activation of the TrA/IO muscles compared with the TA muscle in the trunk straight condition. The TrA/IO muscles are activated in the initial phase of the STS movement to flex the trunk. Early activation of the TA muscle in stroke patients, as shown in our study, may facilitate the STS movement by compensating for the delayed activation of the TrA/IO muscles. Delayed activation of the TrA/IO muscles and early activation of muscles on the unaffected side may cause patients with hemiparetic stroke to fall during the position changes in the STS movement or the reverse movement[8, 9]. Therefore, the current findings provide information that may aid clinicians in the examination and management of affected muscles for transfers in individuals with chronic hemiparetic stroke.

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