Characteristics of Initiation and Termination of Tibialis Anterior Contraction in Adults With Hemiplegia: A Preliminary Study

Yi-jung Chung, Ph.D., P.T.
Dept. of Physical Therapy, College of Health Welfare, Sahmyook University

Jung-suh Lee, M.Sc., P.T.
Dept. of Rehabilitation Therapy, The Graduate School, Yonsei University

Won-seob Shin, M.Sc., P.T.

Seung-beon An, M.Sc., P.T.

Eun-woo Lee, B.H.Sc., P.T.

Kyung-sim Jung, B.H.Sc., P.T.

Dept. of Physical Therapy, The Graduate School, Sahmyook University

Abstract

The purpose of this study was to investigate the relationship between delays in initiation and termination of tibialis anterior contraction through surface electromyographic (sEMG) analysis in adults with hemiplegia and healthy subjects and clinical assessment of lower-limb mobility. EMG activity of 6 long-term survivors of stroke and 5 healthy subjects was recorded during maximal isometric ankle dorsiflexion in 3 seconds beeper signals. It must be done as fast and forcefully as possible. Lower limb mobility was assessed with Modified Emory Functional Ambulation Profile (mEFAP). Delay in initiation and termination of muscle contraction was significantly prolonged in the affected lower limb relative to the unaffected limb. Termination of muscle contraction in the hemiplegic lower limb was significantly delayed than the initiation on the affected side. Delay in initiation and termination of muscle contraction correlated significantly with a few range of mEFAP. Abnormally delayed initiation and termination of muscle contraction may contribute to hemiparetic lower limb mobility in hemiparetic patients. Consequently, this study showed that abnormal delay of initiation and termination of muscle contraction may contribute to hemiparetic lower limb mobility in adults with hemiplegia. Further studies are needed to demonstrate a treatment effect.

Key Words: Stroke; Surface electromyography; Tibialis anterior.

Introduction

The mortality rate for strokes in 2005 was second to neoplasms at 64.3 per 100,000 people and 31,297 people were death. The prevalence of strokes tends to increase with age and increases rapidly over 50 (Ministry of Health & Welfare, 2007).

In over 50%, physical or functional disabilities remain after the stroke, of these 48% suffer mild paralysis, 22% gait disability, 12~18% language disability, 24~53% need help to execute daily chores, 32% suffer from depression (Sacco et al, 1997).

Bobath (1990) reported that ataxia was one of the neurological symptoms from strokes. Ataxia is the state of decreased coordination among agonist, antagonist, etc.
nist, synergist and fixator, and is a significant movement disorder showing loss of specific sensations, the involuntary movement. Compared to muscles controlled from normal innervations, because of upper motor neuron lesions, spasticity would appear along with weakness and muscular stiffness arising from neuro-muscular system changes, motor unit decrease, and nerve reinnervation, and decrease of firing rate (Fridén and Lieber, 2003: Hara et al, 2000). It is important to treat the functional movement disabilities from the changes of the muscle itself and the damages of movement order transmitting systems after a stroke (Chae et al, 2002). According to previous stroke mobility studies, functional disabilities ranging from muscle weakness to loss of quickness outnumbered those from spasticity after brain injury (Hammond et al, 1988: Newham and Haso, 2000: O’Dwyer et al, 1996).

With EMG studies, it was proven that there were initiation and termination delays from muscular contractions on the affected upper limb and the differences between the affected and the unaffected arose from recruitment pattern changes and a decrease of fire ratio (Chae et al, 2002: Hammond et al, 1988). However, comparisons for upper limb functional movement evaluations still lack classifying the movement injuries and quantifying the effect of treatments because the lack of studies for quickness of lower limbs.

According to the recent study of Marigold et al (2004), falling down and instability are caused from the initiation delay on the affected side having an effect on the ankle position. Chae et al (2005) study also supported that the reaction time for the tibialis anterior contraction in the lower limb hemiparesis, there appeared to be initiation and termination delays on the affected side.

Therefore, the purpose of this study was to confirm the findings of previous studies. This study was firstly intended to evaluate the initiation and termination delays of muscle contractions from the affected, the affected both for hemiplegia patients, and normal control. Secondly, to assess the correlation between the characteristics of muscle activity from damage and the evaluation of movement deficit.

Methods

Subjects
Six stable patients with a history of unilateral CVA (cerebral vascular accident) 76 to 355 days previously in the National Rehabilitation Center in Seoul, and five healthy control subjects with a similar balance of age and sex were tested. Inclusion criteria included 1) an interval of at least 2 months from stroke onset; 2) unilateral lesion; 3) manual muscle testing is poor or above in tibialis anterior muscle; 4) ability to follow three second maximal isometric contraction command. Patients who having the following conditions were excluded: those who had experienced hemiplegia on the opposite hemisphere, had other neurological problems, and had hemi-neglect, ipsilateral homonymous hemianopsia, and loss of sensation. Control groups were excluded if they reported previous injury or current orthopedic problems in their body. Characteristics of the subjects are summarized in Table 1.

Instruments
The surface electromyography (sEMG) signal was detected with an active parallel-bar electrode (bar size: 1 mm by 10 mm, located 10 mm apart differential electrode). The electrodes were placed on the tibialis anterior muscle belly (Cram et al, 1998) (Figure 1). The EMG signals were digitally band-pass filtered at 20~450 Hz and notch filtered at 60 Hz to reduce noise. A sampling frequency of 1000 Hz was used. After collection, the data were transferred to an personal computer for data reduction. The Acqknowledge 3.72 program (Biopac systems Inc., CA, U.S.A.) was employed to set up the required parameters and to store the EMG signal as computer files.

Procedures
We used EMG to measure times of initiation and
termination in isometric contraction of tibialis anterior muscle. Subjects were seated on the N-K exercise unit with seat back tilted to 75° knee flexed to 30° and ankle plantarflexed to 30°. We elected not to force the neutral ankle position, in order to minimize baseline electromyographic activity in subjects with hypertonia of the gastrocnemius muscle. Subjects were to respond to beeps to dorsiflex against the ankle apparatus and to relax the muscle as beeps were removed as fast as possible. 3-second contraction trials were measured three times and done for both stroke involved side and the opposite. The trials were enforced with the break time randomly for subjects to not expect the initiation time, and subjects and tested side were randomized during the trials. Delay in recruitment of the EMG signal was defined as the time interval between onset of the audible beep and onset of the EMG signal. The parameters evaluated low pass software filter (50 Hz) and the other parameters evaluated were the number of samples assessed in the sliding window (25 ms) and the magnitude of the deviation from the baseline required to indicated the threshold (3 SD). Processing was done using Matlab™ signal processing toolkit2).

![Figure 1. The placement of the electrodes and posture of the measurement.](image)

2) Math Works Inc., MA, U.S.A.

### Lower-Limb Motor Impairment and Mobility Assessment

The mEFAP was used to evaluate the executive capability for the specific tasks on the hemiparetic limb. The mEFAP is intended to measure the walking time in 5 common environments with or without using assistance. There are 5 specific tasks: (1) a 5 m walking on a hard floor (2) a 5 m walking on the carpet (3) standing up from a chair, a 3 m walking, and back to the seat, (4) passing by the standardized...
obstacle, and (5) walking up and down the 5 stairs. Subjects can use other assistant devices except ankle foot orthosis (AFO). All procedures were performed under supervision. The adjusted score with the assistant devices was used for the study. The reliability and validity of the mEFAP were evaluated with the proper methods (Baer and Wolf, 2001).

**Statistical Analysis**

Wilcoxon signed-rank test was used to examine the differences in delay of initiation and termination of electromyographic signal between the affected and unaffected sides. Mann–Whitney test was used to examine the differences between control and each side. To assess the relationship between electromyographic timing parameters and clinical measures, delays in initiation and termination of the affected side were normalized with respect to the unaffected side. Specifically, normalized delay in the affected side was defined as: (delay in the affected limb−delay in the unaffected limb)/delay in the unaffected limb (Chae et al., 2006). The relationship between the electromyographic timing parameters and mEFAP was assessed using the Spearman’s rank order correlation coefficient. All statistical analyses were performed using SPSS 10.0 for windows. An p-value level of <.05 was used as the level of significance.

**Results**

**Electromyographic Parameters**

The mean and SD of delays in initiation and termination of electromyographic activity between the affected, unaffected, and control limbs are shown in Table 2. Initiation and termination of muscle contraction were significantly delayed on the more affected than unaffected and control sides (Table 2). Termination of tibialis anterior muscle was significantly delayed than the initiation on the affected sides (p<.05).

**Electromyographic Parameters and Clinical Measures**

The mEFAP scores is shown in Table 3. Spearman’s rank order correlation coefficients relating delays and clinical measures are shown in Table 4. Delay in initiation of tibialis anterior muscle contraction correlated significantly with hard floor component and total score of the mEFAP. And delay in termination of tibialis anterior muscle contraction

<table>
<thead>
<tr>
<th>Measures</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 m walk: hard floor</td>
<td>13.36±9.27</td>
</tr>
<tr>
<td>5 m walk: carpet</td>
<td>16.15±11.65</td>
</tr>
<tr>
<td>Timed Up and Go</td>
<td>17.00±12.14</td>
</tr>
<tr>
<td>Obstacle course</td>
<td>32.08±30.36</td>
</tr>
<tr>
<td>5 stairs</td>
<td>18.24±14.25</td>
</tr>
<tr>
<td>Total</td>
<td>96.83±76.42</td>
</tr>
</tbody>
</table>

Table 3. mEFAP scores (Unit: sec)

<table>
<thead>
<tr>
<th>Measures</th>
<th>Initiation</th>
<th>Termination</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 m walk: hard floor</td>
<td>-.94**</td>
<td>54</td>
</tr>
<tr>
<td>5 m walk: carpet</td>
<td>-.77</td>
<td>25</td>
</tr>
<tr>
<td>Timed Up and Go</td>
<td>-.77‡</td>
<td>25‡</td>
</tr>
<tr>
<td>Obstacle course</td>
<td>-.65</td>
<td>37</td>
</tr>
<tr>
<td>5 stairs</td>
<td>-.71</td>
<td>26</td>
</tr>
<tr>
<td>mEFAP total</td>
<td>-.89*</td>
<td>66</td>
</tr>
</tbody>
</table>

*p<.05, **p<.01.
correlated significantly with carpet and Timed Up and Go (TUG) components.

**Discussion**

Normal motor process is ordered by motor strategy of the primary motor cortex and regulated by the posterior parietal cortex and premotor area (Ghez, 1991). However, muscles ordered and regulated by the nervous system often are not functional due to the lowering of higher cortex intentions, malfunction in transmitting nervous signals, muscular fiber injury which directly perform, or other peripheral dysfunction (Gandevia et al, 1995). Especially for stroke patients with EMG, the stroke involved side has a more delayed time of initiation and termination during muscle activation (Chae et al, 2002; Chae et al, 2006; Chung et al, 2003a; Hammond et al, 1988; Smith et al, 1998), muscle weakness (Chae et al, 2002), and increase of fatigue (Hu et al, 2006).

Keele (1968) had measured the responding time of activation initiated by visual signals to study the regulatory process between the neurological center and lower motor processes prior to responding passively. This method was used to measure the response time of muscle to evaluate when blue circle appears on the monitor. However, in recent studies, the signal sound was used to differentiate initiation of the muscle activation and the termination time (Chae et al, 2002; Chae et al, 2006; Chung et al, 2003b; Hammond et al, 1988). Chae et al (2006) especially showed that there were no effects on the difference of time because there were delays of both 3 seconds and 5 seconds in studying the initiation and termination of tibialis anterior muscle.

Our study compared the impaired and non-impaired side, initiation time had a 58 ms difference, termination time 616 ms. For stroke patients, problems caused by motor neurological regulatory center injuries have an effect no only on the direct activation time on the impaired side but also a delay before initiating action (Smith et al, 1998). Chae et al (2006) explained that due to the difference of initiation delay of 53 ms and termination of 337 ms, there were differences between movement order and regulation on the impaired side. Also like on the results, because of 205 ms difference between the delay of initiation time and the delay of termination time in the impaired side, termination had more delay time difference. Chae et al (2006), too, showed that there were more delay time difference in termination, which were 53 ms and 337 ms.

For mechanisms explaining the delay in termination time, there are an increase of excitation on alpha motor neurons (Delwaide, 1993), the supraspinal inhibition of interneuron pool (Ghez, 1991), increase and decrease of Renshow’s inhibition (Delwaide, 1993), decrease of corticospinal input which is only dependent on uninjured vestibulospinal, tectospinal pathway (Dewald and Beer, 2001; Dewald et al, 1999), and redistribution of cortical pathway to the spinal segmental circuit connecting to more unfocused descending inputs (Kamper and Rymer, 2001).

There were no significant differences between a normal person and the intact side of the subject. However ipsilateral pathways of uncrossed corticospinal tract initiates from the cortex, internal capsule, and the anterior side of the brain stem, the medial corticospinal tract extends only into the thoracic cord sending branches to synapse that control neck, shoulder, and trunk muscles (Lundy-Ekman, 2002). Because of the little effects of the not-impaired lower limb in this study, compared to the not-impaired side to normal, there might be no mechanism effect differences.

However, in selecting subjects, there were much smaller 96.83±76.42 ms compared to mFFAP total time 303.0±307.1 ms on Chae et al (2006) because of selecting good-conditioned subjects who were evaluated by mean of lower limb FMA was 25.2 of total 34. Due to good conditioned subjects, there were little effects on the delay between initiation and termination, there were significant results on only a few tests. For further studies, other factors influencing the movement must be considered. In previous stud-
ues, not only was there a delay between initiation and termination of movements by the problem of neurological regulation and transmission, but there were the changes of muscle fibers on the hemiplegic side as the characteristic change of the muscle itself. The diameter of muscle fibers decreased after the subacute phase, the selective type II muscle fibers atrophy, and then muscle weakness occurred (Dietz et al, 1986; Scelsi et al, 1984).

Due to muscle paralysis and weakness, stroke patients cannot produce proper power to regulate their posture or to initiate and adjust movements. Within 6 months, the number of movement-unit lessened to 50% after the event, there was no effective strength because of firing rate reductions (Bobath, 1990; Kirker et al, 2000).

In this study, there were significant impaired lower limb delays from the malfunctioning of the supraspinal control, not being controlled well of postural reflex from various downward information, and the change of the muscle itself from the stroke. Also compared to the unimpaired side, there are delays in postural control on the impaired side because of reduction of neurologic transmission speeds (Cruz-Martinez, 1983).

In the Marigold et al (2004) study, when subjects were asked to change to the forward platform translation from the erect position, the initiation delay of subjects falling tibialis anterior muscles were 23 ms difference, compared 139.2±1.6 ms to subjects not falling 116.9+196 ms. Forster and Young (1995) recorded that 73% patients fell after suffering a stroke. Disrupted timing of muscle activation also contributes to the movement problems in people with upper motor neuron syndrome. Initiation of movement is delayed, the rate of force development is slowed, muscle contraction time is prolonged, and the timing of activation of antagonists relative to agonists is disrupted in people with upper motor neuron syndrome (Sharrmann and Norton, 1977; Young and Mayer, 1982). The lower the initiation difference through therapeutic intervention, the lower causes of falling would be.

Like above, studying each muscle for delay of initiation and termination, and investigation the correlation with movement can approach to the therapeutic destination for each muscle of a person. In this study, we studied the difference and correlation of delay times. In the future, there would be much needed studies of therapeutic intervention practically reducing the delay of initiation and termination and of improving the movement and the quality of life for the stroke survivors.

**Conclusion**

This study has shown that there were differences of initiation and termination delays on tibialis anterior muscle contraction between the affected and unaffected. The clinical relation of tibialis anterior muscle delays are needed to study for therapeutic intervention which reduced the delay of tibialis anterior muscle contraction that can induce the functional recovery correlated motor control.

**References**


Newham DJ, Hsiao SF. Knee muscle isometric strength, voluntary activation and antagonist

This article was received October 9, 2007, and was accepted November 9, 2007.