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A Study of Muscular Activities and Onset Times of the Tibialis Anterior and Medial Gastrocnemius Muscles of Elderly People in Climbing Stairs

Se-Won Yoon, PhD[1)], Jeong-Woo Lee, PhD[1)], Moon-Jeong Kim[2)],
Su-Hyon Kim, PhD[4)], Woong-Sik Park, PhD[3)]

[1)] *Department of Physical Therapy, Kwangju Women's University: 165 Sanjeong-dong Gwangsan-gu, 506-713, Gwangju, Republic of Korea.*
TEL: +82 2-62-950-3659, FAX: +82 2-62-950-3882, E-mail: jwlee@kwu.ac.kr
[2)] *Department of Physical Therapy, Graduate School, Kwangju Women's University*
[3)] *Department of Occupational Therapy, Kwangju Women's University*
[4)] *Department of Physical Therapy, Hanlyo University*

Abstract. [Purpose] We examined the characteristics of lower limb muscles of the elderly in climbing stairs as a fall prevention study. [Methods] This study selected 40 elderly people aged 60 or older who could walk independently. The activity of climbing stairs was divided into four stages: standing, knee flexion, touching the stair, and ascending. Muscle activities of the lower limbs were measured by electromyography. [Results] There were significant differences in the activities of four muscles in the four stages of climbing stairs. The right leg showed significant differences in onset times of the four muscles, activities, but the left leg showed no significant differences. [Conclusion] Activity of the tibialis anterior and medial gastrocnemius muscles were different at each stage of climbing stairs. We also found that the tibialis anterior was activated first to prevent dragging of the right leg, and the left leg muscles worked simultaneously to provid stability.
Key words: Stairs, Muscle activity, Fall

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INTRODUCTION

As the average life span is increasing, the proportion of the elderly population is also increasing[1)]. The elderly experience much inconvenience in daily life owing to a decline in their physical and mental abilities and difficulties in performing personal tasks[2)]. This increase of the elderly population in our society has emerged as an important issue[1)], and has had a great influence public health. Fear of falling is one of the frequent anxieties that the elderly experience in their daily life[2)].

Factors of falls are divided into intrinsic factors and extrinsic factors[3)]. Intrinsic factors are functional disorders of eyesight, hearing or the senses and include balance disorder[4)]. Extrinsic factors are related to stairs without handrails, high steps, and thresholds, and extrinsic and intrinsic factors work in combination[5)]. When the elderly lose balance, they fall[6)].

Muscular strength is needed to keep balance. Leg strength has a great influence on the risk of falling, and muscular strength is important for keeping normal balance[7)]. In general, muscular strength increases up to the age of 30 and is maintained until the age or 50, but it does not decrease in a gradual manner thereafter[8)]. Decrease in muscular volume due to aging is found more in the lower limbs than in the upper limbs and in particular, the soleus, gastrocnemius and tibialis anterior are considered as major weakened muscles[9)].

The elderly with weakened leg muscles experience much difficulty in ascending thresholds, slopes and stairs[10)]. Stairs are frequently found in daily life[11)]. Stairs are a typical feature of traditional Korean architecture, and they are a risk factor of falls for the elderly with weakened balance ability[10)]. Han[11)] argued that going up and down stairs is a frequent activity for the elderly, following level walking, and it requires more ability than level walking. The activity of climbing stairs contains a variety of movements depending on the structure of the stairs and the subject going up the stairs, and studies of stairs should be conducted in various ways[12, 13)].

The elderly have much difficulty in walking or climbing stairs[14)]. It is necessary to analyze the functions of the legs of the elderly in climbing stairs and to measure and research the muscular activities of the tibialis anterior and gastrocnemius[15)]. Thus, this study was designed to examine the characteristics of muscular activities of the legs of the elderly in climbing stairs as a fall prevention study.

SUBJECTS AND METHODS

This study selected 40 elderly people aged 60 or older,

Table 1. General characteristics of the subjects

Sex	Male (n=20)	Female (n=20)
Age (yrs)	75.4 ± 9.0	71.6 ± 8.3
Height (cm)	167.5 ± 6.4	154.8 ± 5.0
Weight (kg)	63.5 ± 6.6	54.1 ± 5.8

(n=40) Mean ± SD

who understood the purpose and methods of this study and gave their consent to take part in this experiment. They were given a thorough explanation of experimental process and expressed their voluntary consent to take part in the experiment. The characteristics of the subjects are listed in Table 1.

Surface EMG was used to measure muscle activity depending on ankle joint angle, and surface electrodes were used.

Before attaching the electrodes, hair was removed to minimize skin resistance and the attachment site was cleaned with an alcohol swab. The recording electrodes were attached to the tibialis anterior and medial gastrocnemius. For the tibialis anterior, the electrode was fixed with tape (Scotch; 3M, St. Paul, MN) to the upper 75% area connecting the lateral knee joint and lateral malleous. For the medial gastrocnemius, the electrode was fixed with tape (Scotch; 3M, St. Paul, MN) to the upper 35% area connecting the medial knee joint and calcaneus. To reduce noise, the ground electrode was attached to the epicondyle of the femur. Surface EMG analog signals were input to a MP150 system, converted into digital signals, and stored and analyzed on a personal computer using Acknowledge 3.9 software[11].

After the tester had trained the subjects to familiarize them with the motions, the tester asked subjects to climb stairs mof 18 cm in height 10 cm away from the model by attaching electrodes to tibialis anterior and medial gastrocnemius and then measure muscular contraction strength and time. Four stages of motion standing, knee flexion, touching the stair and ascending were measured (10 seconds for each movement).

This results were analyzed using SPSS for Windows version 12.0. General characteristics of the subjects were examined with descriptive statistics. Ankle angles and RMS of EMGs were compared using the paired t-test. To test the statistical significance, a significance level of 0.05 was used.

RESULTS

Standing, knee flexion, touching the stair and ascending were compared to investigate the muscle activities of the right tibialis anterior, right medial gastrocnemius, left tibialis anterior and left medial gastrocnemius.

Comparisons of muscle activities between standing and knee flexion revealed significant differences in the right tibialis anterior, left medial gastrocnemius and left tibialis anterior, but not in the right medial gastrocnemius (Table 2).

When muscle activities between standing and touching the stair were compared, the four muscles showed significant differences which were remarkably significant for the right tibialis anterior, left tibialis anterior and left medial gastrocnemius (Table 3).

Table 2. Comparison of muscle activities between Standing and Knee Flexion RMS

	Standing	Knee flexion
RTA	2 ± 1	11 ± 6*
RMGA	2 ± 1	3 ± 2
LTA	2 ± 2	14 ± 5*
LMGA	2 ± 1	8 ± 4*

(n=40) (RMS:μV) Mean ± SD. *p<0.05. RTA : right tibialis anterior. RMGA : right medial gastrocnemius. LTA : left tibialis anterior. LMGA : left medial gastrocnemius

Table 3. Comparison of muscle activities between Standing and Touch the stair RMS

	Standing	Touch the stair
RTA	2 ± 1	8 ± 4*
RMGA	2 ± 1	4 ± 2*
LTA	2 ± 2	9 ± 4*
LMGA	2 ± 1	11 ± 4*

(n=40) (RMS: μV) Mean ± SD. *p<0.05

When muscle activities of the right tibialis anterior, right medial gastrocnemius, left tibialis anterior and left medial gastrocnemius were compared betweem standing and ascending, we found no significant difference for any of the muscles, though a change close to significance was found for the right tibialis anterior (Table 4).

The tibialis anterior of the right leg acted rapidly, 0.8±0.2 sec, and showed significant changes at the time of starting muscle activity based on the instant of ankle joint change. The tibialis anterior of the left leg acted rapidly, 1.0±0.2 sec, but without statistically significant change (Table 5).

DISCUSSION

Climbing stairs is the most common activity after walking on level ground in daily life[11]. Almost 10% of falls by the elderly occurr when going up or down stairs because the body leans in climbing stairs[16]. Therefore, this study examined the muscle activities of the tibialis anterior and gastrocnemius in climbing stairs to collect data for fall prevention.

Han[11] reported that the tibialis anterior and medial gastrocnemius showed increases in muscle activity while climbing stairs. We found a significant difference in the right tibialis anterior between standing and knee flexion(S-K), similar to the findings of Han. The increase strengthened dorsal flexion and prevented the foot from being dragged or touching the stair. However, and there was no significant difference in the activity of the right medial gastrocnemius because of antagonist action. Muscle activity was high during knee flexion of the right leg, in the left tibialis anterior and

Table 4. Comparison of muscle activites between Standing and Ascending RMS

	Standing	Climb to stair
RTA	2 ± 1	7 ± 3
RMGA	2 ± 1	4 ± 2
LTA	2 ± 2	7 ± 3
LMGA	2 ± 1	8 ± 2

(n=40) (RMS: μV) Mean ± SD. *p<0.05

Table 5. Onset time of muscle

	RTA	RMGA
Start time	0.8 ± 0.2	0.9 ± 0.3*
	LTA	LMGA
Start time	1.0 ± 0.2	1.1 ± 0.2

(measure: second) Mean ± SD. *p<0.05

left medial gastrocnemius, similar to the results of Han. We consider that the supporting generates force and prevents sway to prevent falling leg in the climbing of stairs.

Den Otter et al.[17] reported that the tibialis anterior showed muscle activity from the mid-stance to terminal swing phases and the medial gastrocnemius showed muscular contraction activity from the mid-stance to terminal swing phases. When the right tibialis anterior and right medial gastrocnemius were compared between the standing position and touching the stair (S-T), the mid-stance phase in this study, we found significant differences in the right tibialis anterior and right medial gastrocnemius muscle activities.

McFadyen and Winter[18] explained that motion supported by one leg was the point at which instability increased the most. Since the whole weight is supported by one leg, the elderly are unstable during this time because of their lack of muscular strength. The left tibialis anterior and left medial gastrocnemius in S-T were in the terminal stance phase, and we consider the left tibialis anterior and left medial gastrocnemius activated in response to the increased instability arising from standing on one leg.

Between the standing position and ascending stages (S-A), we found no significant differences in the right tibialis anterior, left tibialis anterior, right medial gastrocnemius or left medial gastrocnemius muscle activities. Although standing position and ascending are different activities, the same posture was adopted by subjects, and there was no significant difference between two positions.

Lange et al.[19] measured onset time of muscle activity by calculating the time taken for electromyographic activity to exceed 10 μV RMS and continue for over 100 ms. This study also measured onset time of muscle activity using this method.

Goulart and Valls-Sole[20] argued that the tibialis anterior supports dorsiflexion of the ankle joint and keeps center of pressure (COP) to the back of the leg, and Khemlani et al.[21] reported that rapid onset time of muscle contraction in the tibialis anterior assisted stability and forward movement of the center of gravity of the leg. This study found that the onset time of the right tibialis anterior was about 79 ms which was significantly different from that of the right medial gastrocnemius. Thus, we consider that the tibialis anterior is activated in advance by preparatory activity for lifiting the leg when the swing phase begins.

Doorenbosch et al.[22] stated that gastrocnemius had the slowest onset time of muscle contraction and contributed to the stability in standing position. Mackey and Robinovitch[23] reported that onset time of muscle contraction in the gastrocnemius was on average 73 ms in adults and 98 ms in healthy elderly. Similarly, onset time of contraction in the right medial gastrocnemius in this study was about 95 ms, similar to preceding studies. The onset time of contraction in the left tibialis anterior of supporting leg was about 0.9 ms and that in medial gastrocnemius was about 1.0 ms with no significant difference in the onset time of muscle contraction. We consider that the tibialis anterior and medial gastrocnemius acted simultaneously to stabilize the left leg.

This study has limitations in that it didn't make measurements of balance which is an important factor in the climbing of stairs by the elderly, and the relation between leg strength and balance is important for the prevention of falls by the elderly. Thus, further studies need to examine the influence of leg strength on balance in the climbing of stairs.

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