

# Comparison of Both Legs EMG Symmetry during Over-Ground Walking and Stair Walking in Stroke Patients

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**Purpose:** Gait is the most basic element when evaluating the quality of life with activities of daily living under ordinary life circumstances. Symmetrical use of the lower extremities requires complicated coordination of all limbs. Thus, this study examined asymmetry of muscle activity quadriceps femoris and tibialis anterior as a baseline for training during over-ground walking and stair walking of stroke patients.

**Methods:** Subjects were 14 stroke patients included as one experimental group. Gait speed used in this study was determined by the subject. Low extremity paretic and non-paretic EMG was compared using the surface EMG system.

**Results:** The low extremity EMG difference was statistically significant during over-ground walking and stair walking ( $p < 0.05$ ). The result of low extremity EMG substituted symmetry ratio formula was compared to EMG symmetry ratio in both legs during over-ground walking and stair walking. The average symmetry ratio of quadriceps femoris during over-ground walking was 0.65, and average symmetry ratio of quadriceps femoris during stair walking was 0.47, with significant difference ( $p < 0.05$ ).

**Conclusion:** EMG data was higher in stair walking than over-ground walking. However, in the comparison of symmetry ratio, asymmetric EMG of quadriceps femoris was significantly increased during stair walking. These findings suggested that application of stair walking for strengthening of both legs can be positive, but the key factor is maintaining asymmetrical posture of both legs. Therefore, physical therapists should make an effort to reduce asymmetry of quadriceps femoris power during stair walking by stroke patients.

**Keywords:** Stroke, Stair walking, Electromyography, Symmetry

## INTRODUCTION

Gait is the most basic element when evaluating the quality of life with activities of daily living (ADL) under ordinary life circumstances.<sup>1</sup> As a basic and efficient method of locomotion, gait is the most important aspect when considering ability to live better life. It comprises most functional activities in daily life. The recovery of gait ability is essential to functional recovery during rehabilitation of stroke patients.<sup>2</sup>

Because of muscle weakness and abnormal gait cycle, the stroke patients have a short stance phase and long swing phase of paretic. Slow gait pace and decreased balance are also observed.<sup>3</sup> The factors of decreased balance in stroke patients include decreased proprio-

ception, delayed reflexes, failed postural control due to muscle weakness and control decreased, decreased coordination in ankle as well as knee and decreased flexibility.<sup>4</sup> The hemiplegic patients affected by stroke show very high instability in the one leg stand as paretic during gait because of decreased mechanical torque of low extremity.<sup>5</sup> The physiological problems that appear in the low extremity of stroke patients are insufficient voluntary muscle contraction ability, lack of control of muscle activity intensity, and decreased motor unit during muscle contraction. These factors reduce the gait quality and gait pace. Muscle weakness of low extremity after stroke is the most common aftereffect. Functional disability is a problem despite prolonged concentrated rehabilitation of patients after a severe stroke.<sup>6</sup>

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Recently, study suggests that chronic stroke patients appearance of atrophy and weakness in the affected leg.<sup>7</sup> The resistance training for muscle strengthening improves muscle strength as well as performance of functional activity. Hence, strength training of variable way are recognized as important to stroke patients' function and gait recovery.<sup>7,8</sup> Therefore, increase in low extremity EMG of stroke patients has a positive effect on stride length, swing time, relief of asymmetric weight support and is one of the most important elements to determine patients' independent daily life and gait ability.<sup>9</sup>

Stair walking training in performing ADL is an essential element that lead to patient independence. Performing stair walking training improves the quality of life and is important to recovery of low extremity ability in stroke patients during the treatment process.<sup>10</sup> Healthy adults was reported in the stair walking at much more extensor moment, as compared to flexor moment in low extremity and more extensor moment in knee joint and hip joint, as compared to the ankle.<sup>11</sup> Walking ramps and stair walking pressure exerted on the knee joint during is about 4.25 times bigger appeared in body weight was reported in the stair walking.<sup>12</sup>

Symmetrical use of the low extremity requires complicated coordination of all limbs. Hence, the damage in coordination of stroke patients changes the gait pattern asymmetrically.<sup>13</sup> When stroke patients stand up unassisted, they show asymmetric weight support, and try hard to perform their task despite muscle weakness.<sup>14</sup> Stair walking strengthens the quadriceps femoris muscle performance and weight support training through upper movement in stroke patients. Thus, in this study examined asymmetry of muscle activity quadriceps femoris and tibialis anterior as a baseline of training during over-ground walking and stair walking of stroke patients.

## METHODS

### 1. Subjects

This study was conducted on 14 stroke patients who received rehabilitation by computed tomography (CT) or magnetic resonance imaging (MRI) from February to March 2015. Subjects who fit the following criteria were included in the study, first time stroke, more than three months after onset, no use of a stick, ability to walk over 6m, more than 24 points in MMSE-K (mini-mental state examination-Korea version), and ability to understand the researchers' requirements and perform. Subjects who had arthroplasty and bro-

ken bones or nerve disease were excluded from the trial.

## 2. Experimental methods

All participants were informed about the trial and filled out the agreement form. If they were unable to provide a signature, a representative signed for them. After investigating basic information such as patient age, cause of disease, and paresis, subjects participated in the experiment as one group. Subjects practiced walking for 5 minutes to accustom at the laboratory. Gait speed used in this study was to determine by themselves. The stairs were used as the test design for the rehabilitation of stroke patients. The dimensions of the stairs were 100 cm in width, 30 cm tread length, and 12 cm in height. electromyography (EMG) data during stair walking was used to average value of three times measurements by manufactured stairs. Guide rail is not used in consideration of the stabilization reaction force by the hand. Results of the test were not shared between subjects and the order of measurement was also random (Figure 1).

### 1) Measurement

#### (1) Surface EMG system

FREE EMG (BTS Co. Italy) was used for measuring low extremity



Figure 1. Stair walking on manufactured stairs.



**Figure 2.** Attached surface electrodes & FREE EMG (BTS Co. Italy).

EMG. The converted digital signal was processed using MYOLAB (software, BTS Co, Italy) on a personal computer. Signal sampling rate was set as 1,024 Hz, and BPF (band pass filter) of 20-500 Hz was used to minimize the noise. The collected signal was processed to root mean square (RMS). Surface electrodes on muscles were fixed for measuring EMG. At this time, all hair near the part to be measured was removed and then wiped with medical alcohol to reduce error. Electrodes were attached to the quadriceps femoris and tibialis anterior. The electrodes were attached to the muscle belly for measurement of EMG during over-ground walking and stair walking. The maximum of RMS in quadriceps femoris and tibialis anterior during stance phase was measured and recorded. To reduce the measurement error, subjects rested every 5 minutes and the average value of 3 measurements was used (Figure 2).

**(2) Symmetry ratio**

The EMG results of quadriceps femoris and tibialis anterior were substituted with symmetry ratio's formula for easy determination of the symmetry ratio of paretic and non-paretic. The symmetry ratio formula was as follows.<sup>15</sup> Symmetry ratio = paretic side (parameter value)/non-paretic side (parameter value).

Thus, when symmetry ratio was 1, paretic and non-paretic was completely symmetrical and if the result were different from 1, symmetry ratio would be large. If symmetry ratio was > 1, paretic value was higher than non-paretic's, and if it was < 1, non-paretic value was higher than paretic's.

**2) Statistical analysis**

SPSS version19.0 was used for all statistical analyses. Paired t-test was conducted to compare quadriceps femoris with tibialis anterior

**Table 1.** General characteristics of subjects (N = 14)

	Characteristic	N	Percent (%)
Gender	Male	9	64.3
	Female	5	35.7
Factor	Hemorrhage	7	50.0
	Infarction	7	50.0
Affected side	Right	7	50.0
	Left	7	50.0

EMG, by subject. Paired t-test was conducted on quadriceps femoris with tibialis anterior symmetry ratio, by subject. Statistical significant level of the study was < 0.05.

**RESULTS**

**1. General characteristics of subjects**

The 14 subjects who were diagnosed with stroke were 64.3% male and 35.7% female. The cause of disease was 50% of brain hemorrhage, 50% of cerebral infarction, and paralysis was 50% of right for hemiplegia and 50% of left for hemiplegia (Table 1). Average age of subject was 50.4 years. Average disease period of subjects was 8.7 months.

**2. The comparison of EMG for each trial on over-ground walking and stair walking**

The extent of low extremity EMG of paretic and non-paretic was compared using the surface EMG system during over-ground walking and stair walking. The EMG average of paretic's quadriceps femoris during over-ground walking was 83.09 μV, and the EMG average of paretic's quadriceps femoris during stair walking was 114.33 μV, with significant difference (p < 0.05). The EMG average of non-paretic's quadriceps femoris during over-ground walking was 138.55 μV, and the EMG average of non-paretic's quadriceps femoris during stair walking was 279.15 μV, with significant difference (p < 0.05). The EMG average of paretic's tibialis anterior during over-ground walking was 88.8 μV, and the EMG average of paretic's tibialis anterior during stair walking was 114.41 μV, with significant difference (p < 0.05). The EMG average of non-paretic's tibialis anterior during over-ground walking was 163.92 μV, and the EMG average of paretic's tibialis anterior during stair walking was 231.45 μV, with significant difference (p < 0.05) (Table 2).

**Table 2.** The comparison of EMG for each trial at Over-ground walking and stair walking (N= 14)

Trial	Over-ground walking ( $\mu$ V)	Stair walking ( $\mu$ V)	p
AQF	83.09±44.17	114.33±41.84	0.003 <sup>†</sup>
NQF	138.55±80.36	279.15±128.30	0.000 <sup>†</sup>
ATA	88.80±41.53	114.41±55.53	0.019 <sup>*</sup>
NTA	163.92±36.08	231.45±70.58	0.001 <sup>†</sup>

\*p<0.05, <sup>†</sup>p<0.01.

AQF, Affected side of Quadriceps Femoris; NQF, Non-affected side of Quadriceps Femoris; ATA, Affected side of Tibialis Anterior; NTA, Non-affected side of Tibialis Anterior.

### 3. The comparison of symmetry ratio for each trial on over-ground walking and stair walking

The result of low extremity EMG substituted symmetry ratio formula was compared to EMG symmetry ratio in both legs during over-ground walking and stair walking. The symmetry ratio average of quadriceps femoris during over-ground walking was 0.65, and symmetry ratio average of quadriceps femoris during stair walking was 0.47, with significant difference (p<0.05). The symmetry ratio average of tibialis anterior during over-ground walking was 0.54, and symmetry ratio average of tibialis anterior during stair walking was 0.51, without significant difference (Table 3).

## DISCUSSION

The gait ability of hemiplegic stroke patients is most highly regarded by the patients' family and the patients themselves. Recovery of gait ability is thus the most important target in rehabilitation of stroke patients.<sup>16</sup> But stroke patients assume an asymmetric position by supporting below 25-43% of weight in the low extremity of the affected side in standing position.<sup>17</sup> Lack of exercise intensity has a bad influence on patient balance and gait ability; and walking pattern asymmetry such as severe difference of left and right's stride is increased during gait.<sup>18</sup> So temporal gait variable that is symmetry ratio of the time in one leg stand, step on the ground and, spatial gait variable that is symmetry ratio of step length in the gait of stroke patients is affected by functional balance and gait.<sup>19</sup>

The effect of muscle strengthening exercise of stroke has been studied. Furthermore, studies on quadriceps femoris in over-ground walking, standing, and balance of patients, are ongoing.<sup>20</sup> Stair walking is one way of muscle strengthening that shows lots of movement in non-paretic and paretic in stroke patients; and gait

**Table 3.** The comparison of symmetry ratio for each trial at Over-ground walking and stair walking (N= 14)

Trial	Over-ground walking	Stair walking	p
QF	0.65±0.21	0.47±0.21	0.004 <sup>†</sup>
TA	0.54±0.22	0.51±0.28	0.662

\*p<0.05, <sup>†</sup>p<0.01.

QF, Quadriceps Femoris; TA, Tibialis Anterior.

training was required to increase paretic's muscle strength and movement in stairs and ramps as part of the exercise program.<sup>21</sup> Stair walking was very stable at gait ability test in research on stair walking performance tests and was suitable for estimating diverse aspects of stroke patients' gait performance.<sup>22</sup>

In this study, a comparison was made between paretic's low extremity muscle activity and non-paretic's low extremity muscle activity using surface EMG system during over-ground walking and stair walking. As a result, statistically EMG of over-ground walking and stair walking in quadriceps femoris and tibialis anterior paretic and non-paretic was significantly different (p<0.05); and it was higher than over-ground walking for stair walking. Because extent of muscle activity was higher in stair walking than over-ground walking, we can expect more muscle activity during stair walking training. The result of low extremity EMG substituted symmetry ratio formula was compared to EMG symmetry ratio in both legs during over-ground walking and stair walking. As a result, the symmetry ratio average of quadriceps femoris during over-ground walking was 0.653, and symmetry ratio average of quadriceps femoris during stair walking was 0.465, with significant difference (p<0.05). The result showed that muscle activity asymmetry during stair walking was increased. Thus, when symmetry ratio was 1, paretic and non-paretic was completely symmetrical and if the result was far from 1, symmetry ratio would be large.

Stair walking is very often used by means of movement with over-ground walking and requires more power of low extremity and muscle strengthening than over-ground walking because of horizontal migration and perpendicular ascent during maintaining body balance.<sup>23</sup> Over-ground walking appears as repeating intersectional feet movement and placing both feet together on the ground. However, each step starts from toe and sole, rather than the heel, and all power is required by antigravity of weight. Stair walking is required a lot body balance and legs power. So kinematic effort is more required in stair walking than over-ground walking.<sup>24,25</sup>

Use of low extremity is asymmetrically increased in stroke patient, and they try hard to perform their task despite muscle weakness. Another research indicates that the stroke patients who have walking difficulty make more rapid recovery on over-ground walking than stair walking and it is uncertain whether it is better to climbing stairs.<sup>26</sup> As the similar study, there was research of locomotor limitation in stroke patients about muscle weakness and decrease aerobic ability.<sup>27</sup> The recent studying of clinical assessment for stair walking qualitative research is performed.<sup>28</sup>

Stroke patients have asymmetric gait cycle by decline in optional muscle control and joint exercise patterns. To correct the gait pattern, increase of muscle activity and recovery of gait symmetry ratio have to be set, and effective exercise method is to be considered. To stimulate functional recovery, activity of daily living, using paretic limbs spontaneously and balance and physical intelligence are all improved through weight movement and load exercise. Walking speed and treatment that puts emphasis on paretic and non-paretic's symmetry ratio can improve functional independence.<sup>29,30</sup>

In this study, using surface EMG system for over-ground walking and stair walking in stroke patients, the extent of paretic and non-paretic's low extremity EMG is compared and the EMG's result is substituted for symmetry ratio's formula; hence, EMG's symmetry ratio is compared in both legs. As a result, EMG data was higher in stair walking than over-ground walking. EMG data in stair walking is increased significantly, and application makes low extremity EMG higher. But asymmetric EMG data of quadriceps femoris is increased significantly during stair walking in the comparison of symmetry ratio. In conclusion, stair walking application for strengthening of both legs can be positive, but the key factor is maintaining symmetrical posture in both legs and gait training is used when the stroke patients need according to asymmetric increased EMG of quadriceps femoris. Therefore, physical therapists need to effort to reduce asymmetry of quadriceps femoris power during stair walking to stroke patients. Future research is also necessary comparing additional kinematic values of over-ground walking and stair walking, clinical trials will be needed on efficient and effective ways of stair walking in stroke patients.

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