# The Effects of Three Weight Shifting Training on Lower Extremities Muscle Activities and Foot Pressure of Normal Adults in Standing Position

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***Purpose*** The purpose of this study was to determine the effective weight-shifting training. The subjects were 33 normal adults who hadn't experienced lower extremity injury. ***Methods*** Weight-shifting training was classified into 3 performances for toe off, heel off, toe off with hip external rotation. In standing position, subjects were performed the 3 performances in dominant side. Non-dominant side supported their body weight during weight-shifting trainings. Muscle activities and Foot pressure of non-dominant leg were recorded during 3 Weight-shifting trainings. The muscle activities of the gluteus maximus, gluteus medius, vastus medialis, vastus lateralis, Biceps femoris, semitendinosus muscles were recorded by EMG according 3 weight-shifting training. In foot pressure, we evaluated value of total Pressure ratio, front and back moving, lateral and medial moving, average of pressure, Fore and Rear pressure using by Gaitview Pro. ***Results*** The results of this study were that semitendinosus significantly increased among three weight-shifting training($p<0.05$). Biceps femoris showed significantly difference only toe off with hip external rotation($p<0.05$). In three weight-shifting training, total Pressure-ratio, front moving, lateral and medial moving, average of pressure, Fore and Rear pressure were significantly increased in toe off with hip external rotation. Back-moving significantly increased in toe off($p<0.05$). ***Conclusion*** The result of this study suggests that weight-shifting during toe off with hip external rotation is effective method on weight shifting to affected side for stroke patient.

***Key words*** Weight Shifting, Foot Pressure, Muscle Activity. Lower Extremity

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## I. Introduction

Gait is a basic requirement for daily activity, and is able to evaluate an essential element of quality of life including activity of daily living and functional activity. It is a complex motor skill and can be consumed less energy, interacting between normal antigravity muscle tones.[1)]

Bohannon(1987) reported that balance ability, strength of lower extremity and weight-bearing allow to walk.[2)] Also, most important things that make mature gait are the period of one leg standing, gait velocity, step length, the number of steps per minute and the ratio to pelvic width during gait.

Symmetrical weight-bearing is able to be an assessment tool for standing balance, and weight shifting with normal weight bearing ability is an essential for balance. It has an effect on ankle and hip joints related to static postural control.[3)]

Shifting to the other lower limb is a base of mobility and daily activities, required to posture control. Not only is it important to reach for something, it is also crucial that people can walk.[4)]

Asymmetric posture makes people to move with abnormal heel strike and heel off. With this, physical disability is caused by independent activities of daily living difficulties.[5)]

Dettmann at el reported that deficit of weight shifting to affected side lead to gait abnormalities in hemiplegic,[6)] both reducing the bilateral asymmetry of the body and maintaining and controlling standing balance make patients with hemiplegic increase in gait pattern.[7)]

WHO presented that stroke is second rank of leading causes of death, rising ageing of population. In Korea, individuals with stroke have a partial paralysis of a limb on the affected side. When patients with stroke are standing, they have an asymmetric posture, supported affected side about 25 to 43 percentages.[8)]

Gait disturbance can be caused by neurological (stroke, parkinson's disease, cerebellar degeneration and brain tumor) or muscular skeletal diseases with dystonia, hemiplegia or weight shifting difficulty. Generally, symmetrical body-weight distribution trainings in hemiparetic individuals have been a crucial part of the rehabilitation.[9)]

Under previous studies, using several treatments for patients with stroke, weight - transfer training upon the gait patterns of hemiplegic patients through visual and auditory feedback,[10)] manual therapy for stroke,[11)] lateral weight-shifting,[12)] and lower extremity weight bearing under various standing conditions,[13)] method using a ball are used to give them proper exercise in clinics.[14)]

Since hip muscles are essential for stepping, their weaknesses have a bad effect on weight shifting position. Gluteus medius is responsible for the stabilization of the hip joint in the initial phase of the gait cycle.[15)] It is also important for activating hip adduction, flexion and internal rotation from heel off to mid stance. Also, the most of muscle power related with hip joint is gluteus medius in single limb support.[16)] Delp at el have founded that hip external rotation makes glueus maxius increase in moment value.[17)] Dalsra and Huiskes have reported that gluteus medius of posterior fiber makes hip extension and external rotation.[16)]

The aim of this study was to evaluate the sequence of activity of gluteus maximus, gluteus medius, biceps femoris, semitendinous, vastus medialis, vastus lateralis and the plantar foot pressure during weight shift over the supporting limb. It was performed for effects of weight shift which influenced on the lower limbs muscular activity needed in gait.

## II. Materials and Methods

### 1. Subjects

Thirty-tree healthy college students volunteered to participate in this study. Subjects were excluded if they had any history of foot and low back pain, lower-limb pathology or neurological disorder within six month. The rights of the subjects were protected at all times, and all subjects gave informed consent to participate. The list of those who participated in the test is as follows.

### 2. Instrumentation

#### 1) Electromyography (EMG)

Electromyographic (EMG) data were collected using KEYPOINT® (Medtronic). The signal was differentially amplified and sent to a base unit via a fiber optic cable where it was sampled at 1000Hz and set up bandwidth (20 to 450Hz) with 50Hz notch filter. From surface EMG recordings, root mean square (RMS) values of three times were calculated during 5 second measuring and 3 second resting. Surface electrodes were placed over muscle belly without hair, marking for reducing error.

#### 2) Plantar foot pressure measurement

Plantar pressures were recorded during level barefoot walking using a system (Gaitview pro) comprising a 0.15mm thick floor mat(0.73㎡)and incorporating 2,304 sensors(48 x48).

It was measured foot pressure related to value of foot pressure like total volume of pressure, forward, backward, right and left distance of weight shifts and pressure ratio.

#### 3) Design

Subjects could lift dominant lower limbs for bearing non-dominant in standing. During lifting the feet, there are three weight shift training programs, including toe off, heel off, and toe off in hip external rotation. Under these programs, foot pressure and muscle activity values (gluteus maximus, gluteus medius, quadriceps femoris, vastus lateralis, vastus medialis) were measured.

After weighing and entering data, subjects were an

**Table 1. General characteristics of the subjects**

| | Experimental (N=20) | Control (N=20) | t |
|---|---|---|---|
| Age (yrs) | 75.00±3.37 | 74.80±5.64 | 0.136 |
| Height (cm) | 152.32±5.67 | 156.32±5.69 | 1.456 |

anatomical position for thirty seconds on foot plate.

4) Data Analysis

To analyze resulting values, we used SPSS statistical software (version: 22.0). One way ANOVA was performed for comparing all the data examined: muscle activity values of non-dominant extremity under three ways of weight shifting, each muscle activity values and foot pressure.

## III. Results

### 1. Comparisons of muscles activity in non-dominant lower extremity according to the methods of weight shifting

In weight shifting with toe-off dominant side, there was the highest muscle activation in biceps femoris, whereas the lowest activation was in semitendinous. Weight shifting using heel- off, the results showed that gluteus maximus was the lowest activation, while the highest was in semitendinous. ($p<.05$). As for weight shifting with hip external rotation, in muscle activation figures, gluteus maximus values was the lowest, whereas the highest in semitendinous($p<.05$)<table. 2>< Figure 1>.

### 2. Comparisons of each muscles activity in non-dominant lower extremity according to the methods of weight shifting

After comparing in each muscles activity of non-dominant lower extremity on shifting methods in weight, there were not significantly differences of muscles activity values in gluteus maximus, gluteus medius, vastus medialis, and vastus lateralis while in case of weight-shift combined with hip joint lateral rotation, the values of rectus femoris and semitendinous were higher than others($p<.05$)<table. 3>.

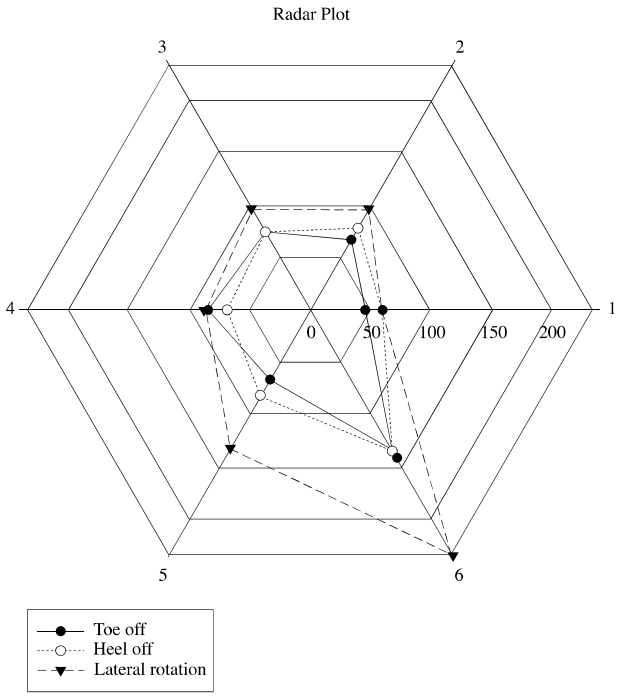


**Figure 1. Graph of muscles activity according to the methods of weight shifting**
(1=GMx, 2=GMd, 3=VM, 4=VL, 5=BF, 6=ST)

### 3. Comparisons of foot-pressure in non-dominant lower extremity according to the methods of weight shifting

Statistically, there were significant differences in resulting values of pressure-ratio, forward, backward, right and left pressure shifting distance but in mean foot pressure, total forward pressure and total backward pressure were not($p<.05$)<table. 4)

## IV. Discussion

As mentioned above, this study was designed for normal person to measure values of muscle activity and foot-pressure changes in non-dominant extremity when they were using three different weight shifting methods in standing position but, a majority of previous studies on the effect of weight-shift training were aimed at hemiparetic patients and mostly experimented on weight bearing of their paretic low limb.[18)]

**Table 2. Comparisons of muscles activity in non-dominant lower extremity according to the methods of weight shifting**

| Method of weight shifting | Muscle | Mean | SD | F | P | Post arc |
|---|---|---|---|---|---|---|
| Toe off | GMx | 45.46 | 29.15 | 4.37 | 0.00* | a |
| | GMd | 67.30 | 29.13 | | | a |
| | VM | 75.85 | 65.59 | | | a |
| | VL | 85.73 | 84.50 | | | a |
| | BF | 67.18 | 101.90 | | | a |
| | ST | 140.12 | 59.94 | | | b |
| Heel off | GMx | 59.58 | 53.50 | 3.78 | 0.00* | a |
| | GMd | 78.18 | 90.40 | | | a |
| | VM | 75.91 | 87.86 | | | a |
| | VL | 69.58 | 53.82 | | | a |
| | BF | 82.18 | 63.69 | | | a |
| | ST | 134.82 | 104.16 | | | b |
| Lateral rotation | GMx | 59.45 | 37.38 | 7.42 | 0.00* | a |
| | GMd | 96.39 | 98.14 | | | ab |
| | VM | 97.79 | 133.34 | | | ab |
| | VL | 88.12 | 78.27 | | | ab |
| | BF | 132.27 | 131.38 | | | b |
| | ST | 234.79 | 222.22 | | | c |

GMx Gluteus Maximus, GMd Glueteus Medius, VM Vastus Medialis, VL Vastus lateralis, BF Biceps femoris, ST Semitendinosus.

**Table 3. Comparisons of each muscles activity in non-dominant lower extremity according to the methods of weight shifting.**

| muscle | Method of weight shifting | Mean | SD | F | P | Post arc |
|---|---|---|---|---|---|---|
| Gluteus maximus | 1 | 45.37 | 29.16 | 1.285 | 0.28 | a |
| | 2 | 59.58 | 53.54 | | | a |
| | 3 | 59.40 | 37.48 | | | a |
| Glueteus medius | 1 | 67.30 | 65.60 | 0.965 | 0.38 | a |
| | 2 | 78.25 | 90.41 | | | a |
| | 3 | 96.38 | 98.16 | | | a |
| Vastus medialis | 1 | 74.85 | 84.45 | 0.507 | 0.60 | a |
| | 2 | 75.92 | 87.87 | | | a |
| | 3 | 97.75 | 133.28 | | | a |
| Vastus lateralis | 1 | 70.77 | 67.12 | 0.791 | 0.45 | a |
| | 2 | 69.61 | 53.79 | | | a |
| | 3 | 88.15 | 78.14 | | | a |
| Biceps femoris | 1 | 67.14 | 59.98 | 4.609 | 0.01* | a |
| | 2 | 82.22 | 63.77 | | | a |
| | 3 | 132.23 | 131.43 | | | b |
| Semitendinosus | 1 | 140.10 | 143.74 | 3.878 | 0.02* | a |
| | 2 | 134.74 | 104.19 | | | a |
| | 3 | 234.81 | 222.22 | | | b |

Findings in this study showed that after calculating data about changing of muscle activity of non-dominant lower extremity under certain training conditions: weigh-shift training with active ankle dorsiflexion, with active plantarflexion and with active hip lateral rotation, there were considerable changes in thigh muscles' values on the backside such as biceps femoris, semitendinous and etc.

In Yang and Roh study, after analyzing the resulting values of muscle activity from his study, targeted at two hemiplegic patients to enhance their ability of weight distribution, on muscle activity of both lower limbs in a semi-squat position on unstable platform, it was reported that at the stage of flexion and extension, there were differences significantly in muscle activity values of vastus medialis, tibialis anterior, lateral hamstring, and lateral gastrocnemius depending on supporting surface condition, however, these results was thought to be different from the outcome of this article.[19)]

Seo said that during six weeks, stroke patients were trained to practice weight shifting exercise with two groups: unstable surface training group and stable surface training group, after then, their muscle activity values were measured.[20)] Later, its findings showed that improved values were in tibialis anterior, vastus medialis, rectus femoris, hamstring and etc. but it was appeared to be different from what we found.

Koh article on comparing changes of muscle activity before and after sit-to-stand and stand-to-sit training implementing with different foot positions showed that when those of who were in training group with asymmetrical postures put their paretic side foot in backside, their muscle activity in paretic side of low extremity, especially in rectus femoris and tibialis anterior had increased its values and also, there was notable increase in gastrocnemius.[21)]

In this study, however, there were three types of ways of weight shifting, based on gait cycle, which was applied to subjects, such as ankle dorsiflexion like heel-strike, ankle plantarflexion like heel-off and hip lateral rotation which was seen in beginning of swing phase after toe-off of the cycle.

After applying with these simple and easy-to-understand ways, the result had notable differences in muscle activity of gluteus medialis, vastus medialis, vastus lateralis, rectus femoris and semitendinous in non-dominant lower extremity. And also, statistically, considerable increases were in muscles activity of rectus femoris and semitendinous particularly.

We also examined variables related changes of foot-pressure, such as weight-bearing ratio, forward weight shifting, internal and external weight shifting and backward weight shifting depending upon aforementioned methods.

Kim mentioned that after two hemiplegic patients participated six-week-task-oriented training, they had significant differences in some of factors(variables), for example, forward and backward weight shifting distance, inside and outside weight shifting distance, contact-pressure and contact-time and the exercise make them improved in ability of balance.[22)]

Aruin et al illustrated about eight hemiplegic patient who participated experimental program which planned for wearing ,every single day during ten weeks, different height of shoes (7,10,13 mm) on less affected side of their foot, and thus the rate of their foot pressure was noticeably increased.[23)]

From Kim's study to examine the central pressure of right and left foot in children with cerebral palsy in standing position, after weight shifting exercise, participants' foot pressure in less affected side transferred into affected side's one and the gap between both side of its pressure figures more substantially decreased than before.[24)]

In this article, among the hip lateral rotation group, we could see statistical increases of some variables of foot pressure of non-dominant low extremity such as weight bearing-ratio, forward weight shifting, internal and external weight shifting, on the other hand in group of toe-off, backward weight shifting figures increased quite a bit.

Some studies provided its related information. Kim et al was said that after weight shifting exercise with visual and auditory feed-back, eighteen hemiplegic patients had improvements of their symmetrical standing posture[10)] and gait pattern. Research conducted by Lee and Shim, showed that hemiplegic patients had in-

**Table 4. Comparisons of foot-pressure in non-dominant lower extremity according to the methods of weight shifting**

| | Method of weight shifting | Mean | SD | F | p | Post arc |
|---|---|---|---|---|---|---|
| Pressure ratio *2 (%) | 1 | 50.69 | 15.45 | 13.50 | 0.00* | a |
| | 2 | 48.27 | 24.08 | | | a |
| | 3 | 60.12 | 18.16 | | | b |
| front moving (mm) | 1 | 33.30 | 18.70 | 10.70 | 0.00* | b |
| | 2 | 19.14 | 8.34 | | | a |
| | 3 | 36.26 | 18.85 | | | b |
| back moving (mm) | 1 | 42.79 | 28.40 | 4.01 | 0.02* | b |
| | 2 | 40.89 | 15.82 | | | b |
| | 3 | 29.91 | 11.67 | | | a |
| left moving (mm) | 1 | 6.16 | 2.70 | 3.11 | 0.05* | ab |
| | 2 | 5.73 | 2.56 | | | a |
| | 3 | 7.74 | 4.70 | | | b |
| right moving (mm) | 1 | 8.55 | 4.70 | 6.73 | 0.00* | a |
| | 2 | 6.77 | 2.39 | | | a |
| | 3 | 11.07 | 6.39 | | | b |
| ave pressure (Kpa) | 1 | 21.68 | 11.27 | 0.05 | 0.95 | a |
| | 2 | 21.33 | 7.84 | | | a |
| | 3 | 22.05 | 8.21 | | | a |
| F/F presure (Kpa) | 1 | 20.89 | 12.93 | 0.81 | 0.45 | a |
| | 2 | 20.79 | 9.33 | | | a |
| | 3 | 31.77 | 67.89 | | | a |
| R/F pressure (Kpa) | 1 | 23.32 | 15.03 | 0.87 | 0.42 | a |
| | 2 | 23.03 | 12.54 | | | a |
| | 3 | 26.99 | 13.23 | | | a |

creased their supporting ratio of affected side after four weeks of training using electric weighing scales.[25] .According to Goo et al study, stroke patients' ability in balance and gait had improvement when they were trained with functional weight bearing exercise.[26] Consequently, many of research gave explanation about effectiveness of their practice for subjects. We suggest that weight bearing exercise in paretic low extremity and weight shifting practice on both limbs, there was progress in ability of balance control. In addition, for making standing balance, gait pattern, function of exercise and daily activity better, bio-feedback exercise is good method for them.

After analyzing muscle activity and foot pressure in each condition respectively, this experiment, aimed at thirty tree normal people in their twenties, described that given the results, in the area of muscle activity values, hip lateral rotation group substantially higher than other groups, especially in semitendinous and rectusfemoris, and foot pressure as well. Thus, hip lateral rotation was thought to be the most efficient way of others for effective weight shifting.

The small number of subjects studied could be a source of bias and also it would be limited to generalize for hemiplegic patients with stroke because we designed for normal person. For further study, we need to be aware of the limitations. With complementing these deficiencies, it will be able to utilize informative clinical data for treatment of stroke patients.

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