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Original Article

The influence of an ankle foot orthosis on the percentage of weight loading during standing tasks in stroke patients

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Abstract. [Purpose] The aim of this study was to investigate the effects of an ankle foot orthosis on weight-bearing abilities of stroke patients by comparing weight loading during performance of tasks in various standing positions on the affected side. [Subjects and Methods] This study was performed with 16 stroke patients. To measure the weight loading value and percentage of weight loading in affected lower extremities, 5 standing tasks were performed with and without an ankle foot orthosis in random order. [Results] In the rising from a chair, maintaining a standing position, and forward weight shifting tasks, the affected lower extremities showed a significantly higher percentage of weight loading with an ankle foot orthosis. In the tasks requiring weight shifting to one leg, weight shifting to the lateral side showed the best weight-bearing ability with or without an ankle foot orthosis, followed by the forward and backward weight shifting, respectively. There were statistically significant correlations in all 5 tasks with or without an ankle foot orthosis. [Conclusion] An ankle foot orthosis improves the weight-bearing ability, especially when shifting weight forward, resulting in increased weight-bearing ability in activities of daily living tasks such as quiet standing and rising from a chair. The 5 tasks in this study would be a fine assessment tool under clinical conditions to investigate the postural stability of the affected side with or without application of an ankle foot orthosis.

Key words: Ankle foot orthosis, Stroke, Weight-bearing ability

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INTRODUCTION

Impaired balance caused by spasticity, abnormal movement synergies, and muscle weakness after stroke results in several problems such as changes in gait patterns, increased fall risk, and reduced independence of activities of daily living[1, 2)]. Thus, improving the balance ability in stroke patients is one of the most important goal to normalize the gait patterns and reduce the risk of falls[3)].

It is essential for balance and independent gait to be able to shift the weight toward both lower extremities in a standing position[4)]. In a previous study, it was reported that stroke patients have difficulties in shifting weight bearing in a specific direction without foot movement, especially in the case of affected lower extremities[5)]. Stroke patients find it difficult in ADL to shift their weight onto the affected limb when changing from a bipedal stance to a one-leg stance or when climbing stairs of varying heights[6)]. Thus, Eng and Chu (2002) reported that measurement of the weight-bearing ability of the affected side during performance of diverse tasks in various standing positions can be used as a reliable index for neurological rehabilitation[7)].

The ankle joint is one of the most important components in control of the balance when standing and during gait[8)]. This is because the ankle joint is a key joint for weight shifting and postural stability[3)]. Hemiparetic patients commonly show instability of the affected ankle joint because of the spasticity of gastrocnemius-soleus muscle group and deficient motor control[9)]. As a result, the risk of falls increases, and balance is impaired[3)]. An ankle foot orthosis (AFO) is a orthotic device generally used to recover the function of the ankle joint and improve balance and gait function[3)]. An aFO can help patients who have problems with postural control in dynamic tasks requiring voluntary weight shifting on both limbs by improving the stability of the injured ankle-foot mechanism. In addition, a previous study reported that the AFO has a positive effect not only on the ankle but also the knee, hip and pelvis, resulting in the recovery of balance ability and gait function[10, 11)].

Thus, the aim of this study was to investigate the effects

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of AFO on weight-bearing abilities of stroke patients by comparing weight loading during performance of tasks in various standing positions on the affected side.

SUBJECTS AND METHODS

Subjects

This study was performed with 16 stroke patients who were inpatients of a general hospital in Deagu, Republic of Korea. Information about the purpose of this study was provided to them before the start of the study. The inclusion criteria were as follows: 1) diagnosed with hemiplegia caused by ischemic brain injury or intracerebral hemorrhage, 2) over 6 months since stroke onset, 3) MAS (modified ashworth scale) score of 0–1 with an AFO on the affected ankle joint, 4) able to independently walk over 10m, and 5) over 24 points on the Korean version of the Mini-mental State Examination (MMSE-K). Patients who had any musculoskeletal and neurological problems were excluded (Table 1). This study was approved by the IRB of Daegu Fatima Hospital and written consent was obtained from the patients or caregivers before conduct of this study.

Table 1. General characteristics of subjects (mean±SD)

Variables	General characteristics
Gender (male/female)	5/11
Age (years)	65.2±9.3
Affected side (left/right)	7/9
Type (hemorrhage/infarction)	8/8
Modified ashworth scale (G0/G1)	10/6
Time since stroke (month)	9.94±1.98
Height (cm)	162.3±4.7
Weight (kg)	68.5±9.2

Methods

To measure the weight loading value and percentage of weight loading in affected lower extremities, 5 standing tasks were performed with and without an AFO in random order. The first task was rising from a chair, the second task was a standing in a quiet standing position, the third task was weight shifting laterally toward the affected side, the fourth task was weight shifting forward on the affected side, and the fifth task was weight shifting backward on the affected side.

In the first and second tasks, the subjects were instructed to bear the weight evenly on both limbs. In the third to fifth tasks, the subjects were instructed to bear the weight on one leg as much as possible. Verbal instructions were given by one therapist in each task. The instructions given were “stand up from the chair without using your hands” for the first task, “keep standing” for the second task, “move your weight to the lateral side as much as you can” for the third task, “move your weight forward as much as you can” for the fourth task, and “move your weight backward as much as you can” for the fifth task. However, the subjects were instructed not to take their feet off of a set of force plates and had to maintain the position for at least 2 seconds.

Each task was performed 5 times, and the mean value of the middle 3 times was used for statistical analysis. To avoid learning effects, the tasks were performed in random order. A 1-minute break was provided between trials to prevent possible fatigue. The subjects performed tasks in bare feet and stood comfortably with their feet 15–20 cm. In addition, they were instructed to maintain the width between their feet in tasks four and five.

Two force plates fixed to the floor were used to measure the loading on the lower extremities, and a force plate was placed under the chair to confirm the moment that the hips were no longer in contact with the chair. The force plate was 32×47 cm, and it had 1,504 pressure sensors to measure the static and dynamic pressure. Sampling for data collection was performed at 600 Hz. Weight loading values were normalized by the percentage of weight loading according to subjects’ body weight. In the first and second tasks, since 50% of the body weight was loaded on the affected side, the weight loading value for half of the body weight was presented by percentage. In the single-leg stance tasks (shifting the weight laterally, forward, and backward), since affected lower extremities had to bear the whole body weight, the weight loading value for the whole body weight was presented by percentage.

PASW 18.0 was used to analyze the collected data. Descriptive statistics were presented as means and standard deviations. Two-way ANOVA was performed to compare the weight-bearing ability and percentage of weight loading for the affected lower limbs according to AFO application. The Mann-Whitney test, a nonparametric test, was also used to compare differences between tasks. To compare tasks concerning weight shifting on one leg, Kruskal-Wallis analysis was conducted. Pearson correlation analysis was performed to analyze the correlations between each task according to AFO application. The significance level was 0.05.

RESULTS

Two-way ANOVA was performed to compare the percentage of weight bearing according to AFO application. There was a significant difference according to AFO application and between tasks ($p<0.05$). In the correlation analysis between tasks and AFO application, there were significant differences in the percentage of weight loading ($p<0.05$).

The results of comparison of the percentage of weight loading on the affected side according to AFO application in each task were as follows: In all tasks, the affected lower extremities showed a higher percentage of weight loading with an AFO. In the rising from a chair, maintaining a standing position, and forward weight shifting tasks, in particular, the affected lower extremities showed significantly higher percentage of weight.

In the rising from a chair and maintaining a standing position tasks, the affected side supported 90% and 92% of the body weight (50% of the whole body weight), respectively, with an AFO, showing 21% and 17% higher weight loading than without an AFO ($p<0.05$). In forward weight shifting, the affected side supported 70% of the body weight (100% of the whole body weight) with an AFO, showing 11% higher weight loading than without an AFO ($p<0.05$).

Table 2. Weight bearing and corresponding normalized values for the standing task in paretic limb (mean±SD)

Task	non-AFO (N)	non-AFO normalize (%)	AFO (N)	AFO normalize (%)	Difference
Rising from a chair	262.76±47.91	78.67±12.43	330.75±54.09	99.32±15.15	21*
Quiet standing	252.35±43.46	75.86±13.01	307.48±53.18	92.35±15.74	17*
Weight-shift laterally	484.49±123.08[a]	71.70±13.46[b]	531.04±73.36[c]	79.52±8.11[d]	8
Weight-shift forward	396.28±89.17[a]	59.05±10.26	467.95±92.94[c]	70.11±12.16[e]	11*
Weight-shift backward	311.15±88.78	46.49±12.46	319.73±95.47	47.99±14.21	1

* p<0.05: significant difference between with non-AFO and with AFO
[a] p<0.05: significant difference to weight-shift backward
[b] p<0.05: significant difference to weight-shift forward and weight-shift backward
[c] p<0.05: significant difference to weight-shift backward
[d] p<0.05: significant difference to weight-shift forward and weight-shift backward
[e] p<0.05: significant difference to weight-shift backward

Table 3. Correlational analysis for standing task for test session (mean±SD)

non-AFO	Quiet standing	Weight-shift laterally	Weight-shift forward	Weight-shift backward
Rising from a chair	0.751*	0.621*	0.633*	0.638*
Quiet standing		0.512*	0.783*	0.665*
Weight-shift laterally			0.712*	0.842*
Weight-shift forward				0.745*
AFO				
Rising from a chair	0.779*	0.538*	0.591*	0.678*
Quiet standing		0.560*	0.750*	0.751*
Weight-shift laterally			0.823*	0.651*
Weight-shift forward				0.591*

*p<0.05

In the weight shifting tasks on one leg, weight shift to the lateral side showed the best weight-bearing ability, followed by forward and backward weight shifting, respectively, with or without an AFO. Post hoc testing revealed that there was a significantly higher percentage of weight loading in lateral weight shifting without an AFO (p<0.05) and a significantly higher percentage of weight loading in lateral weight shifting with an AFO compared with forward and backward weight shifting, and weight loading was significantly higher for forward weight shifting than backward weight shifting (p<0.05).

There were statistically significant correlations in all 5 tasks with or without an AFO (p<0.05) (Tables 2 and 3).

DISCUSSION

In neurological physiotherapy, the weight-bearing ability on the affected side during various tasks is a very important component for gait, balance, and ADL. In this study, our aim was to investigate the effects of an AFO on weight-bearing ability of the affected side in stroke patients by comparing lower extremities after applying an AFO to support the function of the ankle joint, which is very important for postural control.

The subjects of this study performed 5 tasks, rising from a chair, maintaining a standing position, weight shifting laterally toward the affected side, weight shifting forward on the affected side, and weight shifting backward on the affected side.

The first and second tasks were bilateral weight-bearing tasks in which the subjects could use both their legs. There is a tendency for non-affected lower extremities to compensate for affected lower extremities in quiet standing and rising from a chair, both legs can be used in those tasks[7]. In the quiet standing and rising from a chair tasks in this study, the percentage of weight loading was high on the affected side with an AFO and was higher than the percentage of weight loading without an AFO. This result is due to the very weak contractile elements of the affected knee in stroke patients and the AFO providing stability to the knee joint[12]. It is believed that this effect of the AFO helped the affected lower extremities to bear a higher percentage of weight during quiet standing and rising from a chair. If the weight-bearing ability is weaker than patients expect during rising from a chair, falling is possible, and falling causes greater increases in asymmetric weight distribution[13]. Thus, it is believed that the increased weight-bearing ability of the affected side resulting from use of an AFO can decrease the asymmetry caused by falling and prevent falling in ADL.

The third to fifth tasks were single-limb weight-bearing tasks in which the goal was to move the weight to one leg voluntarily as much as possible. It is known that the ability to shift the weight toward the affected side is especially decreased in the forward direction ability to shift the weight in the forward direction is especially decreased on the affected side[7]. Stroke patients generally flex the front knee when trying to move the weight forward. This posture essentially needs eccentric control of the knee joint and the stability of the ankle and pelvic joint[7]. In previous studies, it was reported that an AFO decreases ankle spasticity, activates the quadriceps muscle, corrects equinus and recurvatum, reduces anterior pelvic tilt, and increases hip extension, resulting in the recovery of gait and balance function[10, 11]. In this study, the percentage of weight loading in the fourth task was significantly increased with and AFO than without an AFO. This result is believed to be due to the positive effects on the ankle enabling the knee and pelvis to increase the weight-bearing ability of the affected limbs in the flexed condition, in line with previous studies.

Although it is known that stroke patients have difficulty supporting weight in the forward direction, another study reported that lateral weight shifting in the frontal plane also diminishes[14]. Voluntary weight shifting to the lateral side is necessary for balance control and independent gait. The decreased ability to shift weight to the lateral side is caused by a control deficit between the gluteus medius and medial gastrocnemius muscle of the affected and non-affected sides[4]. However, in this study, the percentage of weight loading was higher in lateral weight shifting than forward and backward shifting. In addition, although the AFO is known to increase lateral stability in stroke patients, there was not much difference in lateral weight-bearing ability between with and without an AFO. In our opinion, lateral weight bearing is not performed through normal mechanisms of the gluteus medius and medial gastrocnemius but is instead performed through mechanisms related to the inherent stiffness of passive hip/knee structures and sacroiliac structures, resulting in a significant higher percentage of weight loading toward the lateral side than forward and backward sides and it is believed that subjects could support the weight on the lateral side even without an AFO.

There were significant correlations in all 5 tasks with or without an AFO. In a previous study, it was reported that these 5 tasks have a strong correlation in stroke patients and that injuries affecting postural stability and muscle strength limit performance of the 5 tasks[7]. In this study, there were significant correlations in all tasks with or without an AFO, showing that weight-bearing ability in the 5 tasks is a fine assessment tool to investigate balance ability and the effect of rehabilitation even when an AFO is applied.

In conclusion, an AFO improves weight-bearing ability, especially forward weight shifting, resulting in increased weight-bearing ability in ADL tasks such as quiet standing position and rising from a chair. In addition, the 5 tasks would be a fine assessment tool under clinical conditions to investigate the postural stability of the affected side and therapeutic effects with or without application of an AFO.

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