

# Structural Assessment of Spastic Hemiplegic Foot using the Foot Posture Index



The Journal of Korean Society of Physical Therapy

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**Purpose:** The aims of this study were to assess the degrees of foot abnormalities by comparing foot abnormalities after stroke using the FPI, and to investigate the relationship between the FPI and spasticity.

**Methods:** 33 hemiplegic patients (patient group) and 39 healthy subjects (control group) were evaluated foot posture by the FPI. Spasticity in patient group was measured by the MAS. And the relationship between Foot posture and spasticity in patients group were investigated.

**Results:** Hemiplegic feet in patients were supinated feet compare with non-hemiplegic feet in hemiplegic patients and the foot in control group. The degree of spasticity affected foot posture.

**Conclusion:** Foot posture is related to stroke impairments, stroke patients with more severe spasticity have more severe foot abnormalities as supinated foot.

**Keywords:** Foot Posture Index, Hemiplegic foot, Spasticity

Received: November 10, 2011

Revised: November 25, 2011

Accepted: November 26, 2011

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## I. Introduction

The walking function in people with strokes has a very large effect on their quality of life, so it is an important feature for their survival and rehabilitation.<sup>1-3</sup> Gait types in people with strokes appear as characteristic gait patterns, such as foot drop, genu recurvatum, and equinovarus on the affected lower limb. Plantar flexion deformity with talipes varus, in particular, is the most common deformity among hemiplegic patients. Hemiplegic gait appears as an anterior-lateralized phenomenon, with weight-bearing on the paretic feet occurring mostly in the forefoot or lateral side due to inappropriate muscular recruitment on the paretic lower limb and imbalance of the muscles on the ankle joint.<sup>4-6</sup> Abnormal gait types appearing to compensate for them are shown characteristically as hemiplegic gait patterns.<sup>5</sup> Although there are many studies of gait among hemiplegic patients, most have been done from the neurological and gait analysis perspective, and few have detected musculoskeletal problems on the foot itself.<sup>7</sup>

A number of different methods have been described in the literature to quantify or classify standing foot posture.<sup>8</sup> Foot posture index (FPI) is a novel, foot-specific outcome measure that was developed in order to quantify variations in the position of the foot easily and quickly in a clinical setting. It is particularly suited for large sample studies where complex assessments (e.g., gait laboratory assessment) is impractical or unnecessary.<sup>9</sup> The FPI has demonstrated moderate to good intra-rater and inter-rater reliability, as well as criterion validity.<sup>10,11</sup> Furthermore, classification of foot posture based upon the FPI has shown an association with the development of various overuse injuries of the lower extremity and osteoarthritis of the knee.<sup>12-14</sup> Likewise, the FPI has been used in studies of risk factors for injury in athletes and naval recruits, treatment of plantar heel pain, and response to orthotic therapy in different foot types.<sup>12,15-18</sup> However, previous studies have rarely investigated foot postures using FPI among people living with a stroke. Forghany et al.<sup>2</sup> were the first to explore foot abnormalities after stroke by investigating static foot posture to measure

FPI among people with strokes, and their relationship to weakness, spasticity, and walking limitations. Their study demonstrated that abnormal foot posture was associated with walking limitations, but the relationship between foot posture, weakness, and spasticity is weak; this finding challenges the beliefs that stroke survivors with more severe impairments, such as weakness or spasticity, have more frequent and severe foot abnormalities.

Our goal is to collect preliminary data to study structural change on foot in stroke patients. As such, the aims of this study were to assess the degrees of foot abnormalities by comparing foot abnormalities after stroke using the FPI in people with stroke, and to investigate the relationship between the FPI and spasticity.

## II. Methods

### 1. Subjects

There were 72 participants recruited in this study. Thirty-three patients with hemiplegia caused by stroke were recruited in the experimental group, all of whom were able to walk independently. Thirty-nine healthy adults (dominant feet) were recruited in the control group, none of whom had any systemic diseases such as rheumatoid arthritis or gout, previous foot surgery, recent trauma of the foot, or had taken taking non-steroidal anti-inflammatory drugs within 3 months, and steroid injections. The mean time since onset in the experimental group was 20.8±14.7 months. There were no statistically significant differences between the patients group and the control group (Table 1). Subjects voluntarily agreed to participate in the experiments after listening to the purpose and method of the study.

**Table 1.** Demographic data of subjects (mean±standard deviation)

|                   | patient group | control group | p    |
|-------------------|---------------|---------------|------|
| number of cases   | 33            | 39            |      |
| sex (male/female) | 23/3          | 21/18         |      |
| age (years)       | 62.8±7.6      | 62.3±7.8      | 0.77 |
| height            | 166.6±7.4     | 166.3±8.9     | 0.86 |
| Weight            | 64.4±9.2      | 65.1±8.5      | 0.72 |
| BMI               | 23.1±2.3      | 23.5±1.6      | 0.42 |

## 2. Experimental methods and analysis

### 1) The Foot Posture Index

The FPI measures foot abnormality.<sup>19-21</sup> We followed the same procedure for FPI as described in the literature to measure foot posture.<sup>19</sup> Briefly, this procedure involved asking the subject to take several steps in-place, prior to settling into a comfortable stance position. While each subject stood in their relaxed stance position with their arms by their side and looked straight ahead, each of the 6 clinical criteria of the FPI were assessed and scored on a 5-point scale from -2 to +2 by the same assessor. The six criteria were: position of the head of the talus, observation of the curves above and below the lateral malleoli, the extent of calcaneal inversion/eversion, the extent of the bulge in the region of the talonavicular joint, the congruence of the medial longitudinal arch, and the extent of abduction/adduction of the forefoot on the rearfoot.<sup>19</sup> A negative score indicated “supination” and a positive score indicated “pronation.” The 6 scores were then summed to give each subject a composite score ranging from -12 to +12. The patients stood in their relaxed stance position with double limb support. They were instructed to stand still, with their arms by their sides and look straight ahead. During the assessment, they were asked not to swivel to try to see what is happening, as this will significantly affect the foot posture. They were asked to stand still for approximately two minutes in total in order for the assessment to be conducted.

### 2) Modified Ashworth Scale

In order to assess the degree of spasticity of muscles in the ankle joint for the patient group, the Modified Ashworth Scale (MAS)<sup>22</sup> was used. Patients were asked to prevent voluntary muscle contraction by relaxation. The examiner evaluated this relaxation on a grade of 0~4 based on the resistance of self-feeling on passive joint movements.

### 3) Data analysis

Statistical analyses were performed using PAWS statistics 18 (SPSS, USA). Paired t-test was used for comparing FPI between hemiplegic feet and non-hemiplegic feet in the patient group, and a one-way ANOVA was used for comparing FPI among hemiplegic feet, non-hemiplegic feet in patient group, and feet in the control group. Duncan was used as post hoc test. Spearman analysis and simple linear regression were used to determine the relationship between the MAS and FPI in the

patient group. The p-values less than 0.05 were used to identify significant differences.

### III. Results

#### 1. FPI in both patient group and control group

There was a statistically significant difference between the FPI for both affected and non-affected feet in the patient group ( $p < 0.01$ ). There was also a statistically significant difference between the FPI for the affected feet in the patient group and for the feet in the control group ( $p < 0.05$ ). However, there was no significant difference between the FPI for the non-affected feet in the patient group and for the feet in the control group ( $p > 0.05$ ) (Table 2).

**Table 2.** Comparison of the Foot Posture Index (mean  $\pm$  standard deviation).

|             | patient group                 |                     | control group  |
|-------------|-------------------------------|---------------------|----------------|
|             | hemiplegic feet               | non-hemiplegic feet | dominant feet  |
| FPI (score) | -0.64 $\pm$ 4.8 <sup>*†</sup> | 1.79 $\pm$ 2.3      | 1.54 $\pm$ 2.7 |

FPI: Foot Posture Index

<sup>\*</sup> $p < 0.01$ , comparison between hemiplegic and non-hemiplegic feet

<sup>†</sup> $p < 0.05$ , comparison between hemiplegic feet and the feet in control group.

#### 2. Relationship between the MAS and the FPI in the patient group

There was a strong negative correlation between the MAS and

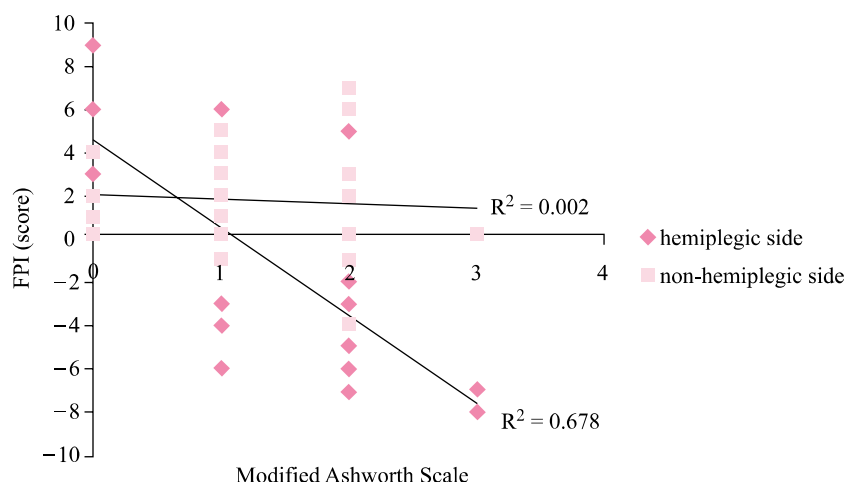
the FPI in hemiplegic feet in the patient group ( $p < 0.01$ ) (Figure 1). This suggests that the feet with increasing spasticity in the affected side were supinated. On the other hand, there was no correlation between the MAS and the FPI in non-hemiplegic feet in the patient group ( $p > 0.05$ ).

### IV. Discussion

This study found that hemiplegic patients have supinated feet when assessing foot posture in hemiplegic patients. When analyzing the relationship between spasticity using the MAS and the FPI, hemiplegic patients have more supinated foot posture, based on increased spasticity.

The human foot posture is generally characterized by the alignment of the foot skeleton, and this varies considerably between individuals. Variations in normal foot posture has long been thought to influence the function of the foot and the lower limb during gait, thereby predisposing it to injury.<sup>23</sup> Thus, demonstrating the relationship between various impairments and foot posture is meaningful to clinicians as part of prevention and treatment impairments.

The FPI is a foot-specific outcome measure that was designed to provide an objective measure of foot posture quickly and easily in a clinical setting. This measure was developed in response to a commonly expressed need for better foot measures due to the absence of a widely accepted or adequately validated method for quantifying variations in foot postures in the clinical



**Figure 1.** Comparison of the Foot Posture Index according to the Modified Ashworth Scale.

FPI: Foot Posture Index

setting.<sup>9</sup> Recently, studies have demonstrated associations with specific diseases such as various overuse injuries of the lower extremity, osteoarthritis of the knee, plantar heel pain, and foot postures using the FPI.<sup>12-14,18</sup> However, studies measured foot postures using the FPI in patients with neurological disease are rare, particularly assessments of foot postures in patients with stroke that have characterized structural changes.

Following a stroke, patients may develop hemiparesis, which can have a profound effect upon walking ability. A common gait deviation, often occurring unilaterally following a stroke, is an equines deformity of the foot, caused by total or partial central paralysis of the muscles innervated by the common peroneal nerve and/or spasticity of the plantarflexors.<sup>24</sup> It is the cause of anterior lateralized phenomena that forefoot or lateral surface is contacted initially when the foot comes in contact with the ground, and causes difficulties in sustaining the weight load.<sup>5</sup> The temporal distance and joint kinematic and kinetic gait patterns of patients with equines deformity of the foot are reported to be adversely affected by this condition. The incidence of equines deformity of the foot in adult stroke patients has been reported to vary between 10% and 20%.<sup>24</sup>

The literature states that equinovarus (excessive supination) is a predominant foot problem, but Forghany et al. found that abnormal pronation (16%) is just as frequent as abnormal supination (13%).<sup>2</sup> This study demonstrates that hemiplegic feet have both abnormal supination (51%) and abnormal pronation (15%). We believe that in Forghany et al., the investigation focused on hemiplegic feet only, but our study directly compared both hemiplegic feet with non-hemiplegic feet, thus, hemiplegic feet are more supinated than non-hemiplegic feet. In addition, spasticity was not variable in Forghany et al., and they were not investigating relevance with spasticity. This study found that hemiplegic feet in grade 0 and 1 in MAS with lower spasticity had 21% supinated and 26% pronated feet. Our result is similar to Forghany et al., in that abnormal pronation is just as frequent as abnormal supination. On the other hand, hemiplegic feet in grade 2 and 3 in MAS with higher spasticity had mostly supinated feet. These results are consistent with the existing information in the literature, therefore the FPI may be a good measurement tool to assess feet in hemiplegic patients with foot abnormalities.

As for the degree of spasticity in hemiplegic patients, the differences in the degree of ankle dorsiflexion, changes of gait

cycle, structural, and functional changes are expected.<sup>7</sup> It also affects balance and gait for promoting ADL and independent activities, thus affecting the quality of life in stroke patients. Therefore, in order to demonstrate the relationship between spasticity and foot posture in hemiplegic patients, this study investigated whether spasticity in hemiplegic patients using the MAS affects abnormal foot posture using the FPI. The literature state that the primary influence on foot abnormalities is abnormal muscle control. This study found that the relationship between the MAS and the FPI is strong; thus, foot posture is abnormally more supinated with increasing spasticity.

The FPI have recently been used to demonstrate the relationship between foot posture and various diseases. Although characteristic changes of foot posture in stroke patients are expected, there were few studies on foot posture in stroke patients, or there was discord with current clinical beliefs. Hemiplegic feet in hemiplegic patients after a stroke were supinated feet compared with non-hemiplegic feet in hemiplegic patients, and the feet in the control group using the FPI. In analyzing the relationship with the MAS and the FPI, the degree of spasticity affects foot posture. Thus, foot posture is related to stroke impairments: stroke patients with more severe impairments have more frequent and severe foot abnormalities. Future studies will need to investigate foot posture in patients with other various diseases as well as hemiplegic patients.

### Author Contributions

Research design: Park S, Park JW

Acquisition of data: Park S

Analysis and interpretation of data: Park S, Park JW

Drafting of the manuscript: Park S

Administrative, technical, and material support: Park JW

Research supervision: Park JW

### Acknowledgements

1. This work was supported by research grants from the Catholic University of Daegu in 2010.

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