

Effect of changes in postural alignment on foot pressure and walking ability of stroke patients

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Abstract. [Purpose] The aims of this study were to determine (1) the significance of walking and foot pressure in stroke patients, and (2) the association between changes in postural alignment of stroke patients. [Subjects and Methods] Foot pressure and walking ability based on postural alignment were measured in 50 stroke patients. Trunk imbalance, trunk rotation, pelvic tilt, kyphosis, lordosis were measured using DIERS formetric4D (DIERS International GmbH, Schlangenbad, Germany), which analyzes 3-dimensional spinal structure in order to measure postural alignment. To determine foot pressure, the support rate of weight and, average foot pressure were measured using DIERS pedoscan (DIERS International GmbH, Schlangenbad, Germany) apparatus as a pressure platform. [Results] DIERS formetric 4D, DIERS pedoscan, and a 10 m walking test were utilized to measure foot pressure and walking ability relative to changes in postural alignment in participating stroke patients. [Conclusion] This study confirmed the significance of foot pressure and walking ability as related postural alignment, indicating that postural alignment education and a recovery therapy program for functional improvement of stroke patients should be provided together.

Key words: Postural alignment, Foot pressure, Walking ability

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INTRODUCTION

Stroke refers to neurological disorders in the central nervous system that are caused by cerebrovascular diseases and continue for more than 24 hours¹⁾. Stroke patients have unbalanced posture because paralysis leads to muscle atrophy, which then causes an unbalanced alignment in the structure of spinal joints²⁾. Evaluation and therapy of postural alignment are important as early predictable factors in the overall daily function of stroke patients³⁾. Improper postural alignment of stroke patients causes degradation in balance and walking because of an increased imbalance between the right and left sides of the body⁴⁾. Foot pressure is used as an index to check the quality of balance and walking. Moreover, foot pressure is of clinical interest in terms of total foot pressure and pressure applied to specific parts during daily activities⁵⁾. When foot pressure exceeds the normal range, it may cause musculoskeletal damage as well as physiological disorders. Furthermore, an imbalanced weight load in the lower limbs leads to postural malalignment⁶⁾. An

imbalanced weight load occurs in 79–87% of stroke patients because less than 25–43% of weight is loaded on paralyzed legs⁷⁾. Imbalanced posture is evident in movements such as walking, standing and sitting. More weight is loaded on non-paralyzed lower limbs than on paralyzed lower limbs⁸⁾. Instability of posture control and balance between the right and left sides of the body causes many problems, such as degradation in balancing ability and posture alignment⁹⁾.

Gait function is an important factor that determines the ability of post-stroke patients to function independently during activities of daily living¹⁰⁾. Stroke patients typically have a slow walking cycle. Changes in stride length of the affected side results in a short stance on that side and a relatively long phase, with a walking speed of approximately 1/3 of that of normal people of the same age¹¹⁾.

Our research aimed, to analyze the factors in posture alignment that affect foot pressure and walking. This was accomplished by targeting stroke patients to provide effective evaluation according to the changes in postural alignment and actual data for planning an appropriate therapy program.

SUBJECTS AND METHODS

Study subjects 50 patients hospitalized after the diagnosis of stroke. Inclusion criteria for the objects were (1) right hemiparalysis, (2) more than 3 points each on items no. 5, 6 and 7 of the Berg Balance Scale (BBS) on balance evaluation of standing posture, (3) absence of any orthopedic diseases

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that can affect the experiment, (4) absence of hemi-neglect symptoms, (5) ability to walk more than 10 m without assistance, (6) ability to understand and follow instructions, (7) consent to participate, (8) ability to understand the research objectives, and (9) ability to communicate with more than 24 points on the Korean Mini-mental State Examination (MMSE-K). All subjects signed the consent form approved by the Sehan University Institutional Review Board.

Trunk imbalance, trunk rotation, pelvic tilt, kyphosis, lordosis were measured using DIERSformetric4D (DIERS International GmbH, Schlangenbad, Germany), which is a system that analyzes 3-dimensional spinal structure in order to measure postural alignment. Subjects were imaged, with their upper body clothing removed and underwear lowered, exposing the coccyx to facilitate visualization of points on the sacrum. Subjects were instructed to relax the whole body by stretching both legs and to maintain a comfortable standing posture. The procedure was performed over a short period of time, approximately 0.04–6 s, and pictures of participants were cropped to include only portions necessary for the study¹²⁾.

To determine foot pressure, the support rate of weight and average foot pressure were measured using DIERS pedoscan (DIERS International GmbH, Schlangenbad, Germany) apparatus as a pressure platform. Measurements were taken while each subject maintained a comfortable posture, relaxing the whole body and stretching both legs on the pressure platform.

The 10-m walking test, which measures time elapsed while a subjects walks 10 m on level ground, was performed to assess walking ability. The test evaluates balance and walking speed and can be used as a mobility recovery criterion for patients with hemiparalysis.

Data analysis was performed using Windows SPSS 18.0 (SPSS Inc., Chicago, IL, USA). An independent t-test was used for regularity verification of research targets and multiple regression analysis was performed to determine the relationship between foot pressure, balance and postural alignment according to the measurement. Statistical significance level was set $\alpha = 0.05$.

RESULTS

In multiple regression analysis using average foot pressure on the non-paralyzed side and postural alignment, the value of F was 0.67, with $p = 0.00$ explaining a significant effect on performance. As a result of testing the contribution level and statistical significance of individual independent variables on the dependent variables, the independent variables that affected performance significantly were trunk imbalance ($p=0.04$), pelvic tilt ($p=0.02$), and trunk rotation ($p=0.03$). According to the standardized coefficient which represents the relative contribution level of independent variables, the factors affecting performance were, in order, trunk imbalance, pelvic tilt, and trunk rotation (Table 1).

In multiple regression analysis to determine the effect of postural alignment on the average foot pressure on paralyzed side, the values of F and p were not significant at 1.25 and 0.31, respectively. As a result of testing the statistical significance and contribution level of individual independent

Table 1. Factor affecting average pressure

TEST	Non-affected side	Affected side
TI	0.91±0.01*	0.72±0.02
PT	0.54±0.03*	0.62±0.04
TR	0.7±0.03*	0.83±0.03
KY	0.61±0.01	0.51±0.01
LOR	0.7±0.01	0.71±0.01
adjusted R ² =0.792		adjusted R ² =0.391
F=0.67, p=0.00 (p'<0.05)		F=1.25, p=0.31 (p'<0.05)

M±SD (mean ± standard deviation)

'multiple regression analysis

*p<0.05

TI: trunk imbalance; PT: pelvic tilt; TR: trunk rotation; KY: kyphosis; LOR: lordosis; unit: N/cm²

Table 2. Factor affecting weight bearing

TEST	Non-affected side	Affected side
TI	0.83±0.01*	0.59±0.04
PT	0.76±0.02*	0.8±0.14
TR	0.6±0.08*	0.75±0.06
KY	0.78±0.01	0.99±0.07
LOR	0.67±0.02	0.76±0.08
adjusted R ² =0.746		adjusted R ² =0.13
F=2.19, p=0.00 (p'<0.05)		F=0.66, p=0.50 (p'<0.05)

M±SD (mean ± standard deviation)

'multiple regression analysis

*p<0.05

TI: trunk imbalance; PT: pelvic tilt; TR: trunk rotation; KY: kyphosis; LOR: lordosis; unit: %

variables on the dependent variables, no significance was shown.

In multiple regression analysis using the weight support rate of non-paralyzed parts and posture alignment, statistical value of F was 2.19 with $p = 0.00$, explaining a significant effect on of performance. As a result of testing the statistical significance and contribution level on dependent variables, independent variables that significantly affected performance were trunk imbalance ($p=0.05$), pelvic tilt ($p=0.03$), and trunk rotation ($p=0.05$). According to the standardize coefficient, which represents the relative contribution level of independent variables, performance was affected in order, by pelvic tilt, trunk rotation, and trunk imbalance (Table 2).

In multiple regression analysis to determine the effect of postural alignment on the weight support rate on paralyzed side, the value of F was 0.66, with $p = 0.50$, indicating no significant effect on performance. As a result of testing the statistical significance and contribution level on dependent variables of individual independent variables on the variables, no significant relationship was shown.

In multiple regression analysis using walking speed and postural alignment, the value of F was 0.40, with $p = 0.00$, explaining a significant effect on performance. As a result of testing the contribution rate and statistical significance of independent variables, the independent variables that significantly affected performance were pelvic tilt ($p=0.02$) and,

lordosis ($p=0.04$). According to the standardized coefficient, which represents the relative contribution rate of independent variables, performance was affected in order, by pelvic tilt and lordosis (Table 3).

DISCUSSION

In this study, research was conducted to analyze the factors of postural alignment that affect balance, weight support and postural pressure in stroke patients. Stroke causes substantial changes in posture when weight is being moved because of imbalanced postural alignment. Furthermore, after stroke, stable posture is difficult to maintain on a weight-bearing surface. An imbalanced postural alignment decreases balancing ability, which ultimately causes problems in functional activities¹³. Alignment of posture should be included in the performance of functional activities and daily routines for stroke patients¹⁴. Lim et al.¹⁵ which researched correlation of foot pressure distribution and spinal alignment in the standing position of normal adults in the research, reported there was a higher correlation between spinal alignment and foot pressure distribution. In the same study, the relationship between foot pressure distribution and trunk imbalance, trunk rotation, and pelvic tilt was found to be highly significant. Uhm et al.¹⁶ reported significant differences between soccer players who used only one side of the body and those who used both sides in terms of postural alignment and weight distribution ratios of left-to-right and front-to-back. Their research also demonstrated, significance in weight distribution ratio and postural alignment in stroke patients, which means that body weight and load are not distributed uniformly over the feet through the knees and the ankles because of imbalance in postural alignment. Verheyden et al.¹⁷ confirmed that the pelvis moves faster than the head, resulting in different trends in moving patterns of normal adults when using both sides of the body and the pelvis asymmetrically upon walking. According to a study by Hirose et al.¹⁸, the number of strides and walking ability between a normal postural alignment group and a non-alignment group showed a significant difference, confirming that walking ability decreases more with the occurrence of lumbar kyphosis. In the research of De Bujanda et al.¹⁹ and others, irregular movements of the pelvis increased when treadmill walking speed increased. On checking pelvis and shoulder movements during the treadmill exercise, pelvic movement in 2 positions and shoulder movement in 1 position were different from that in normal people while walking. The present study confirms the significant relationship between postural alignment and walking speed of stroke patients. Thus, postural alignment is considered to be related to walking speed.

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Table 3. Factor affecting gait velocity

TEST	Gait velocity
TI	0.78±0.14
PT	4.57±0.41*
TR	1.22±0.01
KY	0.17±0.07
LOR	0.29±0.09*

adjusted $R^2=0.77$, $F=0.40$, $p=0.00$ ($p<0.05$)

M±SD (mean ± standard deviation)

*multiple regression analysis

* $p<0.05$

TI: trunk imbalance; PT: pelvic tilt;

TR: trunk rotation; KY: kyphosis;

LOR: lordosis; unit: %

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