

# Correlation between balance and gait according to pelvic displacement in stroke patients

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**Abstract.** [Purpose] The purpose of this study was to investigate the correlations of balance and gait according to pelvic displacement in stroke patients. [Subjects] The subjects of this study were 58 stroke patients who had been admitted to a hospital. [Methods] A Global Postural System was used to measure pelvic displacement. To measure the balance ability, a Tetrax balance system was used to measure the weight distribution index and stability index. Gait ability was measured during the 10-Meter Walking Test and Figure-of-8 Walk Test. [Results] The results of this study showed that was significant positive correlation between the anterior superior iliac spine height difference in pelvic displacement and the weight distribution index and significant positive correlation between the posterior superior iliac spine height difference and the stability index in the normal position with the eyes closed. Statistically significant positive correlation also was found between the anterior superior iliac spine height difference and the straight and curved gait ability. [Conclusion] The increased pelvic displacement in stroke patients results in a decrease in balance ability and gait speed. This suggests that control of pelvic displacement is necessary before functional training for patients with stroke.

**Key words:** Balance, Pelvic displacement, Stroke

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## INTRODUCTION

Stroke patients have increased postural sway due to a decrease in ability to balance and distorted standing posture; and tend to load much of their weight on the non-paretic leg<sup>1)</sup>. Stroke patients who support 30–40% of their weight on the paretic side have diverse problems, such as a qualitative decline in balance ability and standing posture, which results from the instability in left-right side balance and postural adjustment<sup>2, 3)</sup>. Moreover, using only the lower limb on the non-paretic side for a long time gradually weakens the upper and lower extremities. Imbalance and weakened muscle strength results in a considerably slow gait speed and short gait time, which causes these patients difficulty in leading an ordinary life<sup>4)</sup>. Compared to decreased amount of activity, the energy consumption rate for the same movements is higher than that of healthy people, and the possibility of triggering secondary diseases is high. Therefore, recovery of balance and gait ability should be prioritized and the primary goal should be the patients' participation in exercise programs<sup>5)</sup>.

Such imbalance does not trigger a major problem in healthy people, but stroke patients find it difficult to walk normally because their ability to maintain the spine upright, rotate the trunk, move the pelvis forward and backward during movement of weight, or maintain balance response<sup>6)</sup>. The pelvis is an important element in overall posture<sup>7)</sup>. It connects the spine and the lower limbs, and it plays a role in supporting the body maintaining weight when sitting and in transfer of weight from the spine to the lower limbs<sup>8)</sup>. Asymmetric pelvic alignment between the pelvis and the lower limbs affects the stability of the lower limbs and the trunk, making normal gait impossible<sup>9)</sup>. The shapes of the lower limbs are much affected by the living environment. Sustaining an incorrect posture for a long time triggers inappropriate tension in the adjacent muscles and joints. Consequently, flexibility decreases, and the patient experiences pain and restricted movement<sup>10)</sup>. In a normal gait, pelvic rotation, pelvic tilt, stance phase flexion of the knee joints, movements of the ankle and knee joints, and pelvic translation are important elements<sup>11)</sup>.

Training to adjust pelvic tilting improves balance ability and therefore enhances ability to maintain sufficient weight support when standing. Pelvic tilting exercises affect the asymmetric pelvis of stroke patients, enhancing balance and gait ability<sup>12)</sup>. It has been reported that differences in the slopes of the left and right pelvis trigger diverse clinical symptoms. Therefore, research on the correlation between differences in such slopes and balance and gait is necessary.

This preliminary study examined the functional disability

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**Table 1.** The correlations of balance and gait associated with pelvic displacement

	EO-WDI	EC-WDI	EO-SI	EC-SI	10MWT	F8WT (time)	F8WT (steps)
Difference in ASIS height	0.38**	0.30*	0.22	0.10	0.41**	0.34**	0.29*
Difference in PSIS height	0.18	0.17	0.21	0.32*	0.22	0.19	0.18
Difference between ASIS and PSIS left height	-0.06	0.05	0.17	0.15	0.08	0.00	0.26*
Difference between ASIS and PSIS right height	0.06	0.13	0.15	0.08	0.20	0.13	0.33*

ASIS: anterior superior iliac spine; PSIS: posterior superior iliac spine; EO: normal position with eyes open; EC: normal position with eyes closed; WDI: weight distribution index; SI: stability index

10MWT: 10-Meter Walk Test; F8WT: Figure-of-8 Walk Test

\* $p < 0.05$ , \*\* $p < 0.01$

and movement restriction that may appear because of pelvic displacement. It investigated the correlation between balance and gait in stroke patients, according to pelvic displacement. In addition, its aim was to provide basic data on a therapeutic intervention program aimed at improving the functions of stroke patients by verifying the correlation between balance and gait according to pelvic displacement.

## SUBJECTS AND METHODS

This study involved 58 patients who had been diagnosed with stroke and hospitalized for treatment in a rehabilitation hospital. It was approved by the hospital, and all the participants provided written informed consent. The inclusion criteria were as follows: hemiplegic patients who were diagnosed with a stroke; those who had no disability in visual, auditory, and vestibular organs; those who were able to walk independently at least 10 meters without assistance; those who had no history of orthopedic diseases, such as contracture, fracture, or arthritis in the lower limbs; those who did not take medication affecting posture and balance; and those who had the cognitive ability and willingness to follow the directions given in this study.

Fifty-eight (38 males, 20 females) subjects participated in this study. There were 25 subjects with left sided hemiplegia and 33 subjects with right-side hemiplegia. Thirty-nine subjects had cerebral infarction and 19 had cerebral hemorrhage. The average duration of stroke was 25.7 months. The average age, height, and weight were 59.4 years, 165.4 cm, and 64.8 kg, respectively.

Pelvic displacement was measured using a Global Postural System (GPS). A digital camera was used to photograph the subjects. The photographs were then used to analyze body alignment. In order to improve reliability, measurements were taken three times, and the average values were used for the analysis.

A Tetrax balance system was used to measure static balance ability. The Tetrax balance system consists of four separate force plates. The four force plates measure changes in vertical pressure in the forefoot and hindfoot of the bilateral feet. The subjects' weight distribution index (WDI) and stability index (SI) were measured with their eyes open and closed.

The 10-meter walk test (10MWT) was used to measure straight gait ability. The subjects walked 14 meters in a straight line at an ordinary speed. For precise measurement,

an acceleration phase and a deceleration phase of 2 meter each were included. The time taken to walk the middle 10 meters, that is, excluding the acceleration and deceleration phases, was measured using a stopwatch<sup>13)</sup>.

The Figure-of-8 Walk test (F8WT) was used to measure curved gait ability. Two obstacles with total length of 1.52 m and width of 1.21 m were placed within a circle. The test started with the subject standing at the midpoint between the two obstacles. The time taken for the subject to turn around one obstacle in the counterclockwise direction, walk around the next obstacle in the clockwise direction, and then reach the original location was measured<sup>14)</sup>.

All data collected from the subjects were analyzed using SPSS for Windows Version 17.0. Descriptive statistics for the general characteristics of the subjects were calculated. The Pearson correlation coefficient was used to analyze the correlations between pelvic displacement and straight gait ability, curved gait ability, body distribution index, and stability index. To verify the significance of all results in the statistical analysis, the significance level was set at  $\alpha = 0.05$ .

## RESULTS

Regarding pelvic displacement, the differences in height of the anterior superior iliac spines (ASIS) and the posterior superior iliac spines (PSIS) were  $12.9 \pm 9.8$  mm and  $4.8 \pm 2.5$  mm, respectively. The height difference between the left side ASIS and PSIS was  $43.1 \pm 22.0$  mm, and the height difference between the right side ASIS and PSIS was  $39.4 \pm 21.7$  mm.

Regarding balance ability, the weight distribution index was  $8.7 \pm 4.4\%$  with the eyes open (EO) and  $8.4 \pm 4.7\%$  with the eyes closed (EC). The stability index was  $32.9 \pm 15.4$  with the eyes open and  $44.2 \pm 26.1$  with the eyes closed. The straight gait ability was  $23.8 \pm 19.6$  sec. The curved gait ability was scored as  $22.2 \pm 18.6$  sec and  $23.3 \pm 9.9$  steps.

The obtained correlations between pelvic displacement and balance ability are shown in Table 1. In relation to differences in ASIS height, there was a significant correlation with the weight distribution index in the normal position with the eyes open (EO-WDI) and that in the normal position with the eyes closed (EC-WDI) ( $p < 0.05$ ), but there was no correlation with the stability index in the normal position with the eyes open (EO-SI) or that in the normal position with the eyes closed (EC-SI) ( $p > 0.05$ ). In relation to differences in PSIS height, there was a significant positive correlation with

EC-SI ( $p < 0.05$ ) but there was no correlation with EO-WDI, EC-WDI, and EO-SI ( $p < 0.05$ ). Regarding differences in height difference between the left ASIS and PSIS and right ASIS and PSIS, there was no correlation with EO-WDI, EC-WDI, EO-SI, and EC-SI ( $p > 0.05$ ).

The correlations between pelvic displacement and gait ability are shown in Table 1. In relation to differences in ASIS height, there was a significant correlation with time and the number of steps in the 10MWT and the F8WT ( $p < 0.05$ ). There was no correlation for any items with the height of the PSIS ( $p > 0.05$ ). Regarding differences in the heights of the left and right ASIS and PSIS, there was a significant positive correlation with the number of steps in the F8WT ( $p > 0.05$ ). However, there was no correlation for time between the 10MWT and F8WT.

## DISCUSSION

The results verified correlations between differences in the pelvic displacement of stroke patients and their weight distribution and stability indices. The greater the differences in pelvic displacement of the subjects, the greater the increase in both the weight distribution index and the stability index, and the greater decrease in balance ability. In addition, there was correlation between differences in pelvic displacement and gait time and number of steps. The greater the difference in pelvic displacement, the greater the increase in gait time and number of steps.

Posture and balance adjustment ability provide the basis for all motions. During ordinary life, many tasks require the adjustment of posture and balance, which are maintained by the center of gravity within the base of support (BOS). When the BOS changes, the balance adapts to the new situation through the postural adjustment system<sup>15</sup>. When the neuromusculoskeletal system is damaged, stability maintenance, weight load adjustment, and gait ability decline in the standing posture, which has a negative effect on functional recovery, resulting in functional failure<sup>16</sup>. The effects of a stroke trigger body imbalance, asymmetric posture, declining muscle strength, and restricted range of motion and flexibility, causing difficulty in carrying out normal movement strategies<sup>17</sup>.

In stroke patients, the forward and backward pelvic tilt are frequently affected. Therefore, it is important to improve the patient's ability to maintain or adjust the neutral posture of the pelvis. Pelvic displacement triggers difficulty in maintaining balance and normal gait, and it restricts social participation<sup>18</sup>. Pelvic exercises improve the balance of stroke patients, and trunk and pelvic stabilization exercises enhance their ability to function<sup>19</sup>.

The results of the study also showed a significant positive correlation between ASIS height differences and EO-WDI, EC-WDI, and EO-SI. In addition, there was significant positive correlation between differences in PSIS height and EC-SI and between the right side ASIS and PSIS heights and EC-SI. The present study supports previous research that showed a correlation between pelvic displacement and balance. Therefore, the inclusion of an intervention to modify pelvic displacement is considered helpful in improving the balance ability of stroke patients.

Prior studies on gait affected by pelvic displacement observed that in normal gait, the joints and muscles of the pelvis and legs operate in coordination. When disharmony in this operation occurs, abnormal gait appears. Objective and quantitative evaluation are then required to analyze the cause and implement treatment<sup>20</sup>. Because of asymmetric posture, the weight supported by the lower limb on the paretic side decreases<sup>21</sup>. During the swing phase, the backward tilting of the pelvis shifts the body center to behind median line, making it difficult for the lower limb on the paretic side to move forward.

Strengthening the pelvic movement in stroke patients improves gait pattern, promotes perception of the lower limbs on the paretic side, increases the symmetry of pelvic alignment, stimulates normal movement, and decreases excessive muscle tone. A previous study reported enhancement of gait speed in stroke patients after performance of pelvic tilt exercises<sup>22</sup>. In a study of the angle of pelvic tilt, improvement in gait function after stroke patients performed trunk adjustment exercises was related to changes in the angles of paretic and non-paretic pelvic tilt<sup>23</sup>.

The present study also found a significant correlation between the number of steps in the 10MWT and F8WT and differences in ASIS height, as well as a significant correlation between time and number of steps in the F8WT and in height differences of the ASIS and PSIS between the left and right sides.

Therefore, asymmetric posture resulting from pelvic displacement may affect the gait ability of stroke patients. The results of the present study showed a correlation between pelvic displacement and gait ability and were similar to those in research that verified a correlation between stroke patients' pelvic tilting angle and gait ability. They also support the results of previous research<sup>24</sup> that examined the effects of angle of pelvic tilt on plantar foot pressure during the gait of patients with chronic low back pain. The findings verified that pelvic displacement is correlated with gait.

Previous studies showed that interventions in the pelvis had significant effects on balance and gait. The present study verified correlations among balance, gait, and low back pain. The authors intend to conduct a study using a larger number of subjects in order to examine the differences in changes according to duration of the disease in stroke patients. The authors recommend further studies on the correlations between balance, gait, and other functional activities affected by pelvic displacement, including the qualitative elements of gait.

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