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Research Article

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Correlation between Weight Bearing Ratio and Functional Level for Development of Pressure Sensor Biofeedback in Stroke Patient

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| Abstract |

PURPOSE: This study aimed to determine the correlation of weight bearing ability at the affected side with balance and gait abilities for the development of pressure biofeedback based equipment to stroke patients.

METHODS: This study included 35 patients with stroke patient. The tests were conducted to determine the weight bearing ratio while pushing a step forward the affected side, static balance ability using the total length of COP(Center of pressure), sway velocity of COP, COP velocity at the X and Y axis. Functional reaching test (FRT), berg balance scale (BBS) were used to assess the dynamic balance ability and timed up and go test (TUG), 10m walk test (10mWT) were used assess the gait ability respectively. In order to determine the correlation between measured variables, bivariate correlation analysis was conducted.

RESULTS: A significant correlation of the weight bearing ratio were shown with COP total length and velocity(r=-.34), Y-axis velocity(r=-.39), FRT(r=.42), BBS(r=.54), TUG (r=-.39), and 10m walking test (r=-.42).

CONCLUSION: This study result showed that as patients with stroke had more weight bearing ratio at the affected side, not only their static and dynamic balance abilities increased more but also functional gait ability improved more. These results mean that, to improve stroke patients' static, dynamic balance ability and gait ability, weight bearing training with the affected side foot placed one step forward necessary for gaits are important.

Key Words: Balance, Gait ability, Stroke, Weight bearing

Ⅰ. Introduction

After onset, stroke which is a representative cerebrovascular impairment causes not only sensory disorder, perception disorder, language disorder, and emotional disturbance but also upper and lower extremity dysfunction, gait disturbance, and disabilities in activities of daily living (ADL) due to hemiplegia and increases related individual and social costs(Chon et al., 1998).

When standing, many stroke patients show an imbalance of weight bearing that loads less than 50% of their total weight on their affected side lower extremity(Kim, 1995) and such stroke patients reach 79～87% of all stroke

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patients(Sackley, 1990). This asymmetry of weight bearing affects the recovery of the patients' gait ability(Kim, 1995) because functional weight shifting between the lower extremities on the both sides is essential for the ability to maintain and control balanced standing postures necessary to reduce the asymmetry between the left and right sides of the body and recover gait ability(Wall and Turnbull, 1986; Bobath, 1990). Stroke patients perform functional movements also loading more weight on the less-affected side lower extremity. Dettmann et al. (1987) stated that the cause of abnormal gaits of hemiplegia patients due to stroke was that they could not shift their center of mass(CoM) to the affected side lower extremity. In previous studies, diverse intervention methods have been implemented to improve stroke patients' affected side lower extremity's weight bearing ability and many studies reported improvement in weight bearing ability as well as in balance, gait abilities(Kim, 2011; Kim, 2009; McCain et al., 2008).

The decline in performance capability after stroke onset hinders postural and selective motor control(Sackley et al., 1992), and disrupts weight bearing control and gait ability (Kim and Eng 2003; Keenan et al., 1984). Therefore, balance training is important to reduce stroke patients' risk of falling risk and increase their physical activity ability(Catherine et al., 2009). Yavuzer et al.(2006) reported that balance training affected stroke patients' gait toward the improvement of their affected side weight shifting and postural control ability.

The re-gain of gait ability after stroke is an important element directly related to the patients' independence (Taylor-Piliae et al., 2012) and their gait functions should be recovered at least to the extent that functional activities are possible. For ideal gaits, the effectiveness that can minimize fatigue and the stability that can prevent falling are require(Neumann, 2004). However, stroke patients' gaits show states in which they are hard, slow, and not well coordinated and also show low gait velocity, reduced stance phase time, reduced weight bearing, and increased swing phase time(Geiger et al., 2001; Ikai et al., 2003). Kim and Eng(2003) reported that stroke patients' reduced weight bearing on their affected side lower extremity affected their gaits.

Although many studies reported the enhancement of weight bearing ability and the improvement of balance and gait abilities, most of the studies focused on the improvement of abilities through interventions and studies on correlations are insufficient. In addition, most of studies on correlations are on the correlations between stroke patients' gait and their balance (Keenan et al., 1984; Bohannon, 1989) and studies on direct correlations between affected side weight bearing ratios and their balance/gaits are insufficient. Furthermore, most studies measured affected side weight bearing ratios in general bipedal standing position with patients' two feet placed parallel to each other and measurements of affected side weight bearing ratios in affected side stance phases which are the periods of weight bearing by the affected side during gait cycles that are emphasized for actual improvement of gait ability are quite insufficient.

Therefore, the purpose of the present study was to measure stroke patients' affected side weight bearing ratios, static balance ability, dynamic balance ability, and functional gait ability to examine the correlations between them.

Ⅱ. Methods

1. Participants

The present study was conducted with 182 stroke patients in D rehabilitation hospital in Daejeon. The inclusion criteria for the subjects were as follows; patients with hemiplegia due to stroke that could walk at least 10m independently without using any gait assisted-aid, had no other neurologic problem than stroke, had no orthopedic

problem in their lower extremities and spine, and showed at least 24 points in the mini-mental state examination-Korean version (MMSE-K). Among 76 patients that satisfied the inclusion criteria, 35 patients that agreed to participate in the study finally participated in the study. The subjects of the present study voluntarily wanted to participate in the experiment and signed on an agreement to the experiment. The present study was deliberated by the Daejeon University Institutional Life Ethics committee before being conducted (No. 1040647-201403-HR-024-03).

2. Materials and methods

1) Assessment of the weight bearing ability of the affected side

A gait evaluation system named Gaitview (Alfoots, Seoul, Korea) was used to assess affected side weight bearing ability in positions similar to mid-stance phases during gait cycles. The measurement was conducted when the participant took a forward step with the affected side foot with a step width similar to the step width during gaits similarly to mid-stance phases during gait cycles. The participant's affected side weight bearing ability was measured in two positions; a comfortable standing position with the affected side foot placed forward by one step and a standing position with weight shifted as much as possible to the affected side foot placed forward by one step. In this case, the affected side weight bearing ability was measured using the difference between the weight bearing ratio(%) in the comfortable standing position with the affected side foot placed forward by one step and that in the standing position with weight shifted as much as possible to the affected side foot placed forward by one step. In all cases of the measurement, the participant was instructed to maintain the position as soon as the start was notified and the weight bearing ability was measured for 5 sec (Fig 1). The measurement was conducted three times and the average value was used as a measured value.

$$weight\ bearing\ ability(\%) = \frac{comfortable\ standing\ affected\ foot}{body weight} - \frac{forward\ step\ affected\ foot}{body\ weight} \times 100$$

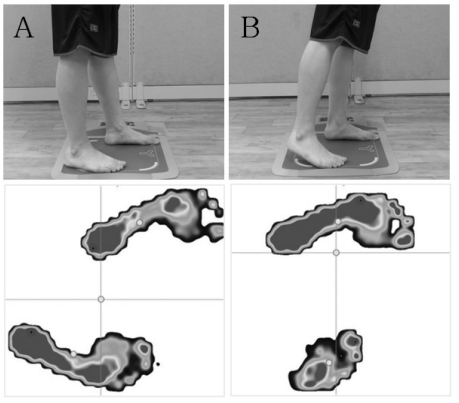

Fig 1. Evaluation of weight bearing ratio on affected side. (A) Standing position on affected side forward step. (B) Weight bearing on affected side.

2) Static balance ability assessment

A Gaitview was used to assess the subjects' static balance ability. The subject stood upright on the foothold of the equipment looking straight ahead. The subject was instructed to maintain the standing position for 30 seconds with the eyes open and the subject's COP total length, COP sway velocity, COP X axis velocity, and COP Y axis velocity were measured. The measurement was conducted three times and the average value was used as a measured value.

3) Dynamic balance ability assessment

Functional reach test (FRT) and Berg balance scale (BBS) were used to assess the participants' dynamic balance ability.

(1) Functional reach test (FRT)

FRT were conducted to assess the participants' dynamic balance ability. In a standing position with his/her feet apart at the shoulder width, the subject bent the shoulder joint by 90°, extended the elbows, and clenched his/her fists. After measuring the distance from the center of the shoulder joint to the hand in the start position, the subject was instructed to stretch out the arm forward while maximally bending within the extent not to fall forward and the distance in this case was measured. The value obtained by deducting the specific value obtained in the initial start position from the later measured value was used. FRTs have high reliability and validity as their validity is r=.71, intra-rater reliability is r=.89, and inter-rater reliability is r=.98(Duncan et al., 1990). The measurement was conducted three times and the average value was used as a measured value.

(2) Berg balance scale (BBS)

The BBS was used to assess the participants' dynamic balance ability. The BBS is a method of measuring stroke patients' or elders' balance ability that assesses the ability to perform 14 tasks comprising tasks ranging from low level ones such as balance in sitting positions to high level ones such as one leg standing and placing alternate foot on stool (Wee et al., 2003) with a full score of 56 points. Higher scores mean better balance ability. This scale has high reliability and validity in assessing balance ability as its intra-rater reliability and inter-rater reliability are r=.99 and r=.98 (Berg et al., 1992). The measurement was conducted three times and the average value was used as a measured value.

4) Functional gait ability assessment

(1) Timed up and go test (TUG)

TUG were conducted to assess the participants' functional gait ability. The time taken for the subject to stand up from an upright sitting position on an armchair according to a verbal command 'Start', walk to a point 3m away on the front, come back, and sit on the chair again was measured in seconds. this test has high reliability as its intra-rater reliability is r=.99 and inter-rater reliability is r=.98(Podsiadlo and Richardson, 1991). The measurement was conducted three times and the average value was used as a measured value.

(2) 10m walking test (10mWT)

The 10mWT was conducted to assess the participants' functional gait ability. The participant walked a total of 14m at comfortable walking speed and the walking time for the 10m section excluding the first 2m and the last 2m was measured in seconds considering acceleration and deceleration. This test has high reliability as its intra-rater reliability is r=.95, and inter-rater reliability is r=.95(Hunt et al. 1981). The measurement was conducted three times and the average value was used as a measured value.

3. Statistical analyses

The collected data were statistically processed using the SPSS window ver. 18.0 program. The means and SDs of the participants' characteristics were calculated using descriptive statistics. Pearson's correlation coefficients were used to analyze the correlations between affected side weight bearing ratios and static, dynamic balance ability, functional gait ability. The level of significance was fixed at .05.

Ⅲ. Results

1. Participants characteristics

The present study was conducted with a total of 35 stroke patients. With regard to the subjects' general characteristics, the subjects consisted of 24 males and 14 females, their age was 60.14±9.54 year, their weight was

66.03±13.92kg, and their height was 162.97±10.84cm. Time after onset of stroke of the subjects was 47.89±36.78 months. With regard to their affected side, the subjects consisted of 15 right hemiplegia patients and 20 left hemiplegia patients(Table 1).

Table 1. General and Medical Characteristics of Subjects.

Variables	Subjects
Age (years)	60.14±9.54a
Height (cm)	162.97±10.84
Weight (kg)	66.03±13.92
Onset (months)	47.89±36.78
Sex (mele/female)	21(60.00)/14(40.00)b
Affected side (Rt./Lt.)	15(42.86)/20(57.14)

[a]mean±S.D.
[b]The number of persons (%)

2. Correlation between affected side weight bearing ratios and static balance ability

Affected side weight bearing ratios and the COP total length/sway velocity as static balance ability showed significant negative correlations($r=-.34$, $p<.05$). Affected side weight bearing ratios and Y axis velocity showed statistically significant negative correlations($r=-.39$, $p<.05$) but affected side weight bearing ratios and X axis velocity did not show any statistically significant correlation(Table 2).

3. Correlation between affected side weight bearing ratios and dynamic balance ability

According to the results of measurement between affected side weight bearing ratios and dynamic balance ability, both FRT($r=.42$, $p<.05$) and BBS($r=.54$, $p<.05$) showed significant positive correlations(Table 2).

4. Correlation between affected side weight bearing ratios and functional gait ability

Both TUG($r=-.39$, $p<.05$) and 10mWT($r=-.42$, $p<.05$) that are two variables for assessment of the correlations between affected side weight bearing ratios and functional gait ability showed statistically significant negative correlations(Table 2).

Table 2. Correlations between weight bearing on affected side ratio, static balance, dynamic balance and functional gait ability

	Weight bearing on affected side ratio	p
COP total length	-.34	.49*
COP sway velocity	-.34	.49*
COP X axis velocity	-.25	.15
COP Y axis velocity	-.39	.02*
FRT	.42	.01*
BBS	.54	.00*
TUG	-.39	.02*
10mWT	-.42	.01*

*$p<0.05$
COP : Center of pressure
FRT : Functional reach test
BBS : Berg balance scale
TUG : Timed up and go test
10mWT : 10m walk test

Ⅳ. Discussion

Stroke patients show asymmetric weight bearing between the affected side and less-affected side and have the dysfunction of declined balance and gait abilities. Therefore, the improvement of affected side weight bearing ability should essentially precede the improvement of balance ability and gait ability. In previous studies, the improvement of balance ability and gait ability was shown through the improvement of affected side weight bearing ability(Eng and Chu, 2002; Hwang, 2014; Pollock et al., 2011; Robinson et al., 2011). However, in many previous studies(Geiger et al., 2001; Kim, 2012; Son et al., 2012), the assessment of affected side weight bearing ability has been conducted in parallel and symmetrical upright standing positions and cases of the assessment of weight bearing ability during gaits in which patients' base of

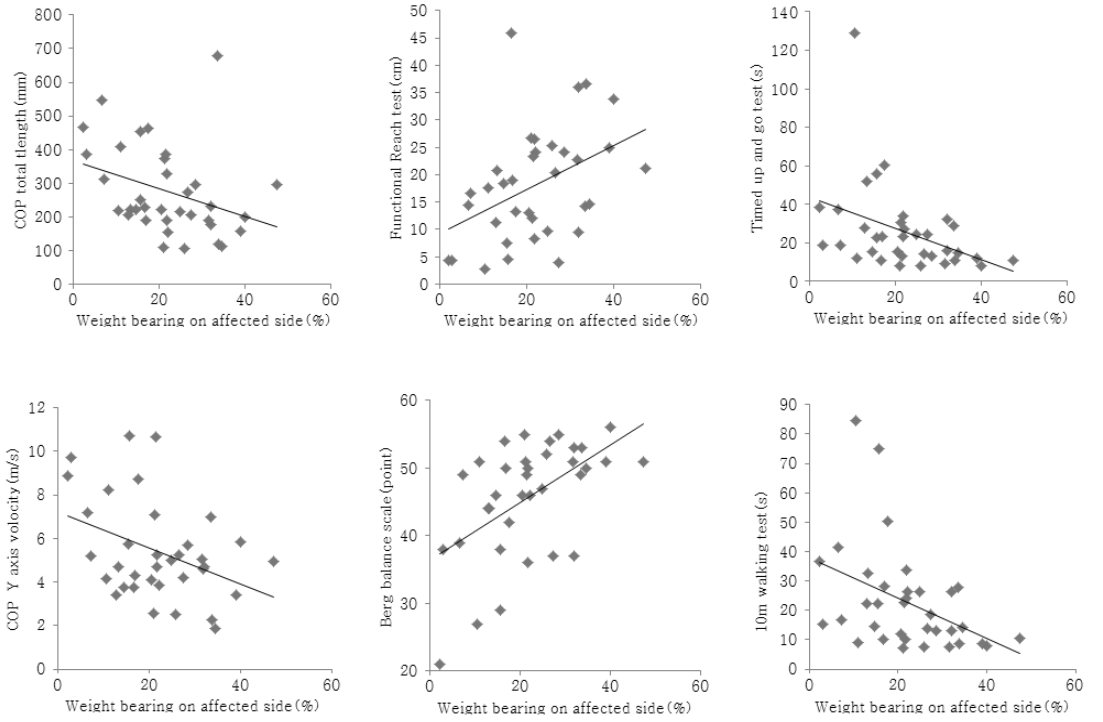

Fig 2. Correlation graph between weight bearing on affected side ratio and static(COP total length, COP Y axis velocity), dynamic(FRT, BBS) balance and functional gait ability(TUG, 10mWT)

support and weight distribution vary are quite insufficient. Therefore, in the present study, stroke patients' affected side weight bearing ratios were measured in positions similar to gaits to examine the correlations between affected side weight bearing ratios and balance ability/gait ability. In the present study, the affected side weight bearing ability was assessed using the difference between the weight bearing ratio (%) in the comfortable standing position with the affected side foot placed forward by one step and that in the standing position with weight shifted as much as possible to the affected side foot placed forward by one step.

Affected side weight bearing ratios and COP total length, COP sway velocity showed significant negative correlations with r=-.34. This means that weight bearing ability in positions with the affected side foot placed forward by one step similar to gaits is related to balance ability in symmetrical upright standing positions. In addition, affected side weight bearing ratios showed significant negative correlations with Y axis velocity that indicates anterior-posterior postural sway(r=-.39). This means that subjects with higher affected side weight bearing ratios have better ability to control anterior-posterior postural sway in standing positions. Harburn et al.(1995) advised that hemiplegia patients experienced reduction in endurance necessary for weight bearing due to the affected side lower extremity's abnormal muscle recruitment and had difficulties in maintaining static standing positions due to increased static postural sway. In a study conducted by Lee et al.(2010), it was reported that, through motor imagery and gait training, stroke patients showed improvement of static balance ability and further improvement of anterior-posterior postural sway velocity compared to medial-lateral postural sway velocity. Another

study indicated that balance in static standing positions was the ability to shift weight to the affected side, a prerequisite for functional movement, and important for activities of daily living such as sit to stand, gait, and stair up and down(Eng and Chu, 2002). Although many previous studies reported that medial-lateral balance ability was related to stroke patients' functional balance and gait ability, the present study showed that anterior-posterior balance ability was also significantly correlated with functional balance and gait ability.

In the present study, when the correlations between affected side weight bearing ratios and dynamic balance ability were assessed, significant positive correlations were shown as FRT was r=.419 and BBS was r=.538. Some previous studies assessed stroke patients' balance ability and reported that it was significantly correlated with ADL and gait ability (Desrosiers et al., 2002; Robinson et al., 2011; Pollock et al., 2011). However, Tyson et al.(2006) argued that the measurement of balance impairment that measures the degree of medial-lateral weight bearing was not much related to the measurement of balance disability that measures static, dynamic balance abilities. In a study conducted by Walker et al.(2000), the researchers stated that although visual feedback balance training was effective in helping stroke patients to have symmetrical standing postures, it was doubtful whether the training improved functional balance ability. However, Eng and Chu(2002) advised that, in the case of stroke patients, weight bearing ability was correlated with functional performance capability and that stroke patients' ability for anterior- posterior, medial-lateral movements of weight in static standing postures was their ability for anterior-posterior, medial-lateral movements of affected side weight bearing, and that it could be directly connected to gaits. Since the FRT tests conducted in the present study were used as a way to measure active anterior-posterior weight shifting ability in static standing postures, the results of the present study are consistent with the results of previous studies(Eng and Chu, 2002). In addition, a previous study conducted by Kim(2012) indicated that BBS and affected side weight bearing ratios were significantly correlated with each other with r=.34 consistently with the results of the present study.

In addition, TUG and 10mWT that assessed affected side weight bearing ratios and functional gait ability showed significant negative correlation with r=-.39 and r=-.42 respectively. Hwang (2014) reported that patients with higher affected side weight bearing ratios had better TUG functions and Geiger et al.(2001) reported that when affected side weight bearing training was implemented using balance ability measuring equipment, TUG scores were improved. Although a previous study (Kim, 2012) reported that affected side weight bearing ratios were not statistically significantly correlated with 10m gait velocity, the present study showed statistically significant correlations between affected side weight bearing ratio and 10mWT. A study conducted by Son et al.(2012) reported that when 10m gait velocity was measured after weight shifting training with the joint mobilization technique applied to the affected side ankle, the 10m gait velocity showed significant increases. This means that the improvement of gait velocity that is clinically used as a scale for measuring the levels of independent gait ability necessary for ADL is associated with the enhancement of affected side weight bearing ratios (Keenan et al., 1984). These results of previous studies are thought to be grounds that support the results of the present study indicating the correlations between affected side weight bearing ratios and static, dynamic balance ability, functional gait ability.

Since the stroke patients' affected side weight bearing ratios used in the present study was obtained by analyzing the data measured while the subjects were consciously implementing weight bearing by the affected side, the present study has a limitation that unconscious affected side weight bearing ratios appearing in actual gaits could not be reflected. In addition, since the present study was conducted with subjects that could walk without any gait

assisted-aid or help, future studies should be conducted with more diverse subjects along with the assessment of weight bearing ratios appearing during actual gaits to derive study results regarding the correlations between stroke patients' affected side weight bearing and functional balance ability/gait ability.

Ⅴ. Conclusion

The present study was intended to examine the correlations between variables obtained by measuring weight bearing ratios, static/dynamic balance ability, and functional gait ability in states where the affected side foot had taken one forward step similarly to affected side stance phases in stroke patients' gait cycles. Affected side weight bearing ratios showed statistically significant correlation not only with static balance ability but also with other variables such as FRT, BBS, TUG, and 10mWT. These results mean that the improvement of affected side weight bearing ratios can indicate the improvement of functional performance capabilities related to patients' balance and gait.

Therefore, these results mean that, to improve stroke patients' static, dynamic balance ability and gait ability, not only alternative weight bearing training between the affected side and the non-affected side but also weight bearing training with the affected side foot placed one step forward necessary for gaits are important. Stroke patients' functions are expected to be improved further through the development of pressure bio feedback based equipment for the improvement of stroke patients' weight bearing ratios and functional levels so that these training methods can be effectively applied.

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