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Original Article

Relationship between the ability to perform the sit-to-stand movement and the maximum pelvic anteversion and retroversion angles in patients with stroke

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Abstract. [Purpose] The purpose of this study was to investigate the relationship between the ability to perform the sit-to-stand movement and the maximum pelvic anteversion and retroversion angles of patients. [Subjects] Thirty-two stroke patients (66.7±7.6 years) (>3 months post-stroke) who were able to sit unsupported and 50 age-matched healthy subjects participated in this study. The stroke patients were classified into two groups according to the sit-to-stand movement test: the group that was able to stand up (the stand-able group) (18 persons) and the group that was unable to stand up (the stand-unable group) (14 persons). [Methods] Pelvic anteversion and retroversion maximum angles were measured by a manual goniometer attached to an inclinometer. [Results] The maximum pelvic anteversion angles were −1.6 ± 5.0°, 1.2 ± 2.8°, and −12.4 ± 6.1° in the control group, the stand-able stroke group, and the stand-unable stroke group, respectively. A significant main effect of group was found. An angle discriminating between the two stroke groups was found: the maximum anteversion angles in the stand-able group were distributed above −5°. [Conclusion] The maximum pelvic anteversion angle was significantly smaller in the stand-unable group than in the stand-able and control groups.
Key words: Stroke, Pelvis, Sit-to-stand

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INTRODUCTION

There appears to be evidence that aspects of trunk control in the sitting position can be used as predictors of comprehensive activities of daily living function in patients with stroke[1)]. The following characteristics of the sitting position in post-stroke hemiparetic patients have been reported: the stability of the sitting position is lower in patients with stroke than in age-matched healthy subjects[2–4)]; a delay of activation of the trunk muscles to control the sitting position is observed in patients with stroke[5, 6)]; and synchronization between activation of pertinent trunk muscle pairs is reduced in patients with stroke[7)]. The sacral sitting posture with a great degree of spinal flexion and neck extension is frequently observed in patients with stroke. This sitting posture is adopted to prevent falling over backwards due to poor abdominal muscle activation and excessive hip extension[8)].

Numerous studies investigating trunk movement have considered the supine position as one segment ignoring the complexity of intervertebral movement[9)]. This tendency is similar in studies about sitting posture in patients with stroke. Few studies have investigated the movements of the spine and pelvis separately. Verheyden et al. reported on pelvic movement during lateral reach movement in the sitting position[10)], and Messier et al. described the movements of the upper trunk and pelvis when subjects touched a target placed in front of them with the forehead[11)]. Riley et al. suggested that the sit-to-stand activity is the most mechanically demanding task undertaken during daily activities[12)]. To smoothly execute the sit-to-stand activity, the pelvis has to be leaned forward to flex the hip joint, and the trunk has to be flexed to use the hip extension moment, reduce the knee extension moment, and project the center of gravity into the base of support[13–18)].

Therefore, the sacral sitting posture that is characteristic of patients with stroke is not the ideal posture for smoothly executing the sit-to-stand activity. Maintaining the sitting position with the pelvis retroverted may be necessary to increase the sitting stability of patients with stroke. However, the ability to antevert the pelvis is required to execute

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the sit-to-stand activity. The purpose of this study was to investigate the relationships between the pelvic anteversion and retroversion angles and the ability to perform the sit-to-stand movement. We hypothesized that patients with stroke who are able to stand from sitting in a chair have a larger maximum pelvic anteversion angle than patients who are unable to stand from sitting in a chair.

SUBJECTS AND METHODS

Thirty-two hemiparetic subjects (15 females, 17 males; mean age ± standard deviation (SD), 66.7 ± 7.6 years) and 50 age-matched healthy control subjects (40 females, 10 males; 64.2 ± 8.2 years) gave their informed consent to participate in the present study. Inclusion criteria were predetermined as more than 3 months post-stroke, and an ablity to maintain the sitting position without using aids. The hemiparetic subjects were classified into two groups according to the sit-to-stand movement test described later: the group that was able to stand up (the stand-able group) (18 persons) and the group that was unable to stand up (the stand-unable group) (14 persons). Patients with a history of low back pain or surgery, hemispatial neglect, bilateral stroke, visual deficit, comprehension impairment, cognitive and/or communication deficits that precluded cooperation, as well as neurological or musculoskeletal disorders unrelated to the current stroke, were excluded. The exclusion criteria for the healthy subjects were known vestibular dysfunction, previous history of neurological disease, or orthopedic conditions that could have interfered with the experiment. This study was approved by the institutional ethics committee of Kanazawa University and conformed to the ethical principles of the Declaration of Helsinki.

All measurements were taken with the participants sitting on a wooden chair. The chair's seating face was square, 50 cm on each side, and 3 cm thick. The participants sat down on the chair 66% of their thigh length from the greater trochanter on the seat. Keeping both arms crossed on the chest, the subjects sat with their feet parallel, with no support for the trunk or upper extremities. The chair seat height was adjusted to 100% of the subject's lower leg length, determined as the distance from the lateral femoral condyle to the ground, and the knee flexion angle was 90°.

In this study, pelvic angles were evaluated using a simple method for measuring the sacral inclination angle[19]. A manual goniometer attached to an inclinometer with a resolution of one degree was used to measure pelvic angles (Fig. 1)[19]. The basic axis and the moving axis of this goniometer were defined as the vertical line and the longitudinal axis through the midline of the dorsal surface of the sacrum, respectively. Therefore, pelvic anteversion was reported as a positive angle and pelvic retroversion was reported as a negative angle. An experimenter operated the goniometer that was attached gently to the midline of the dorsal surface of the sacrum, and another experimenter measured the angle with 1-degree resolution.

After maintaining a quiet sitting position for 20 seconds, the participants performed maximum pelvic anteversion and retroversion five times alternately. The subjects were instructed to keep the initial acromion anteroposterior position

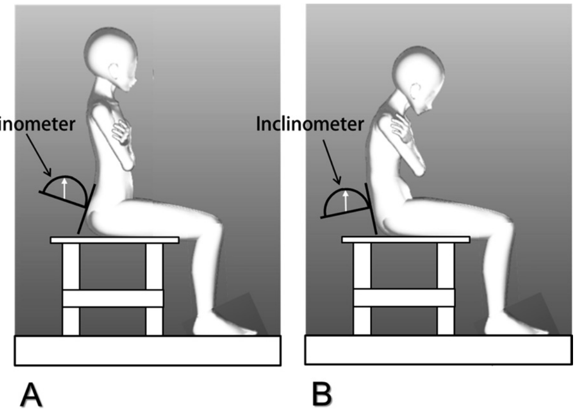

Fig. 1. Schema for measurement of the maximum pelvic anteversion and retroversion angles
(A) Anteversion angle, (B) Retroversion angle

during the movements to avoid trunk anteroposterior movement. The maximum value and the minimum value of the five measurements were discarded and the mean value of the three remaining measurements were recorded as each participant's representative value. The range of pelvic motion was defined as the angle difference between the maximum pelvic anteversion and retroversion angles.

Next, the stroke patients were asked to stand up barefoot at a self-selected speed keeping their arms folded across the chest. Three trials were performed with no restrictions on the position of the feet. Before each trial, a brief rest interval was allowed. Patients with stroke who could independently perform all three trials were classified as the stand-able group. The remaining patients were classified as the stand-unable group.

The normality of the maximum pelvic anteversion angle, the maximum pelvic retroversion angle, and the range of pelvic motion in each group was evaluated by the Shapiro-Wilk test. Normality was not observed for the maximum pelvic anteversion angle of the stand-unable group. Therefore, the Kruskal-Wallis test was used to assess the effect of group on the maximum pelvic anteversion angle. When a significant main effect of group was found, multiple-comparison analysis was performed using the Mann-Whitney U test with the Bonferroni correction. One-way ANOVA was performed for the maximum pelvic retroversion angle and the range of pelvic motion. The differences indicated by one-way ANOVA were examined by *post hoc* multiple-comparison analyses with the Newman-Keuls test. The alpha level was chosen as $p<0.05$. All statistical analyses were performed using SPSS 14.0 J (SPSS Japan, Tokyo, Japan).

RESULTS

The maximum pelvic anteversion angle was distributed between 5° and −4° in the stand-able group, between −5° and −22° in the stand-unable group, and between 10° and −13° in the control group (Table 1). An angle discriminating between the two groups of hemiparetic subjects was found. The maximum pelvic anteversion angles in the stand-able

Table 1. Mean, standard deviation and range of the pelvic angles in each group

		The stand-able group (n = 18)	The stand-unable group (n = 14)	Control group (n = 50)
The maximum pelvic anteversion angle (°)	mean ± SD	1.2 ± 2.8	−12.4 ± 6.1[a,b]	−1.6 ± 5.0
	range (Max–Min)	5 to −4	−5 to −22	10 to −13
The maximum pelvic retroversion angle (°)	mean ± SD	−18.5 ± 5.6[b]	−19.6 ± 4.6[b]	−27.6 ± 8.1
	range (Max–Min)	−30 to −10	−27 to −10	−46 to −10
The range of pelvic motion (°)	mean ± SD	19.7 ± 5.1[b]	7.2 ± 5.1[b]	25.9 ± 7.6
	range (Max–Min)	28 to 10	15 to 0	49 to 9

[a]Significant difference from the stand-able group. [b]Significant difference from control group.

group were distributed above −5°, in contrast to the stand-unable group angles that were distributed below −5° (Table 1).

The means and standard deviations of the maximum pelvic anteversion angles were 1.2 ± 2.8°, −12.4 ± 6.1°, and −1.6 ± 5.0° in the stand-able group, the stand-unable group, and the control group, respectively. A significant main effect of group was found (p<0.001). The value of the maximum pelvic anteversion angle was significantly smaller in the stand-unable group than in the control group and the stand-able group. Therefore, the pelvic anteversion movement was significantly more limited in the stand-unable group than in the control group and the stand-able group.

The maximum pelvic retroversion angles were distributed between −10° and −30° in the stand-able group, between −10° and −27° in the stand-unable group, and between −10° and −46° in the control group (Table 1).

The means and standard deviations of the maximum pelvic retroversion angles were −18.5 ± 5.6°, −19.6 ± 4.6°, and −27.6 ± 8.1° in the stand-able group, the stand-unable group, and the control group, respectively. A significant main effect of group was found ($F_{(2, 87)}$ = 11.9, p<0.001). Significant differences were found between the control group and the stand-able group (p<0.001), and between the control group and the stand-unable group (p<0.001).

The range of pelvic motion was distributed between 10° and 28° in the stand-able group, between 0° and 15° in the stand-unable group, and between 9° and 49° in the control group (Table 1).

The means and standard deviations of the ranges of pelvic motion in each group were 19.7 ± 5.1°, 7.2 ± 5.1°, and 25.9 ± 7.6° in the stand-able group, the stand-unable group, and the control group, respectively. A significant main effect of group was found ($F_{(2, 87)}$ = 43.7, p<0.001). Significant differences were found among the groups (the control group and the stand-able group: p<0.001; the control group and the stand-unable group: p<0.001; the stand-able group and the stand-unable group: p<0.001).

DISCUSSION

The maximum pelvic anteversion angle was significantly smaller in the stand-unable group than in the stand-able group and the control group. The maximum pelvic retroversion angle was significantly larger in the control group than in both the stroke patient groups. No significant difference was observed in the maximum pelvic retroversion angle between the stroke patient groups. The range of pelvic motion was significantly smaller in the stand-unable group than in the stand-able group and the control group. Therefore, the hypotheses that the maximum pelvic anteversion angle in the stand-able group and the range of pelvic motion are significantly larger than those in the stand-unable group were confirmed. It is noteworthy that there was a value of the maximum pelvic anteversion angle that discriminated between patients with stroke into the stand-able group and the stand-unable group. The data suggest that the maximum pelvic anteversion angle required to perform the sit-to-stand movement in patients with stroke needs to be greater than −5° .

To smoothly execute the sit-to-stand movement, the pelvis is anteverted to flex the hip joint and the trunk to use the hip extension moment, reduce the knee extension moment, and project the center of gravity into the base of support[13–18]. Sitting position stability was worse in patients with stroke than in the age-matched healthy subjects[2–4]. The patients with stroke could not sufficiently flex the hip joint when the trunk extensor muscles were required to be activated during sitting[8]. Patients with stroke usually sit with kyphosis and pelvic retroversion to avoid falling backward, due to insufficient abdominal muscle activity. Hence, the sit-to-stand movement in patients with stroke may require larger trunk forward leaning, because of kyphosis and pelvic retroversion, to shift the center of gravity into the base of support of the feet. Lecours et al. observed that trunk forward leaning angles are larger in patients with stroke than in healthy subjects when performing the sit-to-stand movement[20]. Hesse et al. reported that the average center of gravity projection in the base of support of patients with stroke was 3 cm posterior to that of healthy subjects during the seat-off phase in the sit-to-stand movement[21]. In addition, when the trunk is flexed, the hip extension moment is reduced due to a lack of pelvic anteversion, and patients with stroke may depend primarily on knee extension moment to stand up.

Some studies have reported a high correlation between pelvic inclination in the sitting position and the degree of lumbar lordosis[9], and a strong relationship between the sacral angle of inclination and the lumbar lordosis[22, 23]. Hence, pelvic inclination (anteversion and retroversion) reflects lumbar movement (lordosis and kyphosis). The range of pelvic motion in the stand-unable group was extremely limited, being only 28% of the control group and 36% of the stand-able group values. Accordingly, lumbar movement in the sagittal plane (lordosis and kyphosis) in the stand-unable group was probably limited compared to the control group and the stand-able group.

The pelvic angle measurements were conducted in the sitting position while maintaining 90° of knee flexion with the feet in contact with the ground. The hip joints work as pivotal axes in pelvic anteversion and retroversion in the sitting position. One factor that should influence the hip range of motion is the extensibility of the hamstrings, which drive the hip and knee as bi-articular muscles. Hamstring stretching improves the pelvic anteversion angle[24] and mobility of the hips of elderly people[25]. The sitting position in this study fixed the knee flexion angle at 90°, which should have increased hamstring tension during the measurement. For this reason, pelvic anteversion should have been restrained by the increased tension of the hamstrings. On the other hand, since there was no significant difference in the maximum pelvic retroversion angle between the two stroke groups, it indicates that the pelvic retroversion angle did not affect the stroke patients' ability to perform the sit-to-stand movement. However, the range of pelvic motion was markedly restricted in the stroke groups compared to the control group. In patients with stroke, pelvic anteversion appears to be an important factor for patients to regain the ability to perform the sit-to-stand movement. Our results are in agreement with a previous study (Otao et al.), which concluded that the ability to anteriorly tilt the pelvis during active exercise may be related to basic movements, such as the sit-to-stand movement, in patients with stroke[26].

This study had a number of limitations. First, the sample sizes of the stroke groups were smaller than that of the control group. Sample sizes of patients with stroke should be increased in future studies. Second, although the results indicate the importance of the maximum pelvic anteversion angle for the ability of patients with stroke to perform the sit-to-stand movement, other factors, such as muscle strength, equilibrium, coordination, and hip and ankle range of motions should be investigated in future studies. Third, the present pelvic angles were not measured during the sit-to-stand movement. The range of pelvic motion is one of the factors involved in the sit-to-stand movement, and its contribution should be clarified in future studies. Finally, this study investigated Japanese patients whose culture and life style are different from those of other countries, which means that the findings of this study may not be universally applicable.

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