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Assistive Cushions for Symmetric Wheelchair Sitting by Stroke Patients

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Abstract. [Purpose] This study determined the best adjustable cushion for the maintenance of normal sitting balance by stroke patients in wheelchairs from among air cushions, gel cushions, and spongy cushions. [Subjects and Methods] Thirty stroke participants and 20 age-matched control participants were recruited. The enrolled participants were evaluated using the Functional Ambulatory Category (FAC) and The Force Sensitive Application System was used to assess weight shift and symmetry in wheelchair sitting and with the various cushion types: air cushion, gel cushion, and spongy cushion. [Results] No significant differences in symmetry index (SI) were detected according to cushion type between the lesion sides. The SI of FAC 3-point patients was higher than those of FAC 4-point patients in post hoc tests. FAC 3-point patients had a significantly higher SI than 4-point patients in the wheelchair seat tests. FAC-3 point patients had a significantly higher SI than 4-and 5-point patients on the spongy seat on the wheelchair. The stroke group had a higher SI than the normal control group in simple wheelchair sitting. [Conclusion] The findings of the present study demonstrate that stroke patients can maintain a more symmetrical sitting posture on various cushions than is possible when simply sitting in a wheelchair seat.

Key words: Cushions, Functional ambulatory category, Stroke

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INTRODUCTION

Stroke is the leading cause of adult disability. Fifty percent of stroke survivors experience physical and functional disability, and 79% of stroke patients either require treatment or die within 10 years[1)]. Physical inactivity after stroke may contribute to the sedentary everyday lives of stroke survivors. Optimal functional recovery is the ultimate objective of physical therapy following stroke. Physical therapists generally focus initial therapy on relearning functional movements for functional recovery[2,3)]. Balance dysfunctions in standing and sitting are a devastating sequel of stroke. A prospective study demonstrated that 48% and 27% of stroke patients were unable to sit independently at the onset and the end of the rehabilitation, respectively[4)]. Functional ability to maintain normal sitting posture is based on functional activities in a seated posture. The ability to balance and maintain a stable posture is integral to the execution of motor skills, and cannot be separated from the action being conducted or the environment in which it is being carried out[5)]. Therefore, it is important that physical therapists help stroke patients regain their normal sitting posture.

Balance involves the regulation of the movement of linked body segments over a base of support[6)]. When standing, the lower limbs perform an important role in stabilizing the trunk and pelvis[7)]. However, when sitting without trunk support, postural control occurs principally at the pelvis[8)]. Studies that have employed instrumental methods to study sitting balance have focused on the analysis of spontaneous weight-bearing asymmetry[9)]. These methods have been previously employed in the assessment of postural control, but in addition, force platforms have also been utilized to evaluate postural symmetry[10)]. For this reason, a great deal of effort has been dedicated to the maintenance of normal sitting posture in stroke patients, which has led to the appearance of a broad variety of wheelchair cushion models on the market[11)]. Wheelchair cushions can be classified according to their composition into spongy, gel, air, etc. These cushion materials can also be combined to provide different attributes.

Laboratory and clinical tools are employed to measure balance. The Force Sensitive Application (FSA; Vista Medical Inc., Canada) system is a force platform system that is commercially available for the evaluation of balance. A previous study assessed stroke patients on the adjustable seat of an unsupported wheelchair, a mat, and a saddle-shaped chair using the FSA system[12)]. The FSA system can be used to evaluate different types of adjustable cushions.

A few comparative studies have been published regarding the mechanical performance of different types of cushions in a sample of patients with spinal cord injury (SCI)[13,14)]. However, it is difficult to find literature regarding the use of adjustable cushions with stroke patients. The principal objective of the present study was to determine which adjustable seat, among air-cushions, gel-cushions, and spongy cushions, is the best adjustable seat for placement on wheelchairs for maintaining the normal sitting balance of stroke patients.

SUBJECTS AND METHODS

Thirty-two stroke participants were recruited in Daegu, Korea. Subjects who met the following selection criteria were recruited: hemiparesis caused by first stroke within the last 6 months; MMSE-K scores above 24; and ability to maintain independent sitting posture without support. Two patients who were unable to flex both the hip and knee at least 90 degrees were excluded from this study, because they tended to slide out of their seats. Twenty age-matched controls were also recruited. All of the enrolled participants provided their written informed consent prior to this experiment, in accordance with the ethical standards established in the Declaration of Helsinki.

Walking abilities may affect the sitting posture. The Functional Ambulatory Category (FAC) has six categories measuring walking ability and was designed to provide information regarding the level of physical support required by patients to ambulate safely. We evaluated the FAC of participants before the other measurements.

FSA System 4.0 software was used to assess the symmetry of participants. After participants were evaluated on the same wheelchair, they were randomly assessed on each cushion. The FSA system is a computerized force platform system with four adjustable force transducers, which measures vertical force only. Center of force data is expressed as the percentage change in body weight distribution. The measuring system consists of a matrix of piezoresistive pressure sensors which react to the perpendicular force exerted on them. The matrix used in the presented study measured 48 × 48 cm and consisted of 16 rows and 16 columns of sensors, a total of 256 sensors. The acquisition frequency was set at 5 Hz. The stated working range is 0–200 mmHg, with a resolution of 1 mmHg. The system was also calibrated to assign absolute pressure values to the digital output from the A/D converter connected to the sensing pad. This was done by applying pressure distribution as similar as possible to the actual conditions, within a 200 mmHg load value. For research purposes, this study used a basic wheelchair with a 50-cm floor-to-seat height, 40-cm seat depth, and 46-cm seat width.

We first measured the subjects in the wheelchair seat with their eyes-open. Then subjects were measured on the gel cushion filled with silicone (Hanyoung Med, Korea), the 30 mmHg air cushion (Silver Med, Korea), and the spongy cushion (Hanyoung Med, Korea) on the seat of the wheelchair (Fig. 1). Tanimoto et al. (2000) reported that when the quantity of air is small, it was used for all subject’s weight is distributed evenly[15]. Therefore; the pressure of the air cushion used in the present study was 30 mmHg and it was used for all subjects. The subjects sat comfortably with their arms folded and feet on the footrests, which were adjusted to keep the joints flexed at 90 degrees. The pelvis was placed as far back on the seat as possible, with the thighs in a level position. The seat surface was horizontal and the backrest was tilted backwards without support. The bilateral 3 × 3 pressure transducer data of the area of the ischial tuberosity were processed. This study used 60 seconds of data sampled from 70 seconds of measurement (the first and last 5 seconds were discarded).

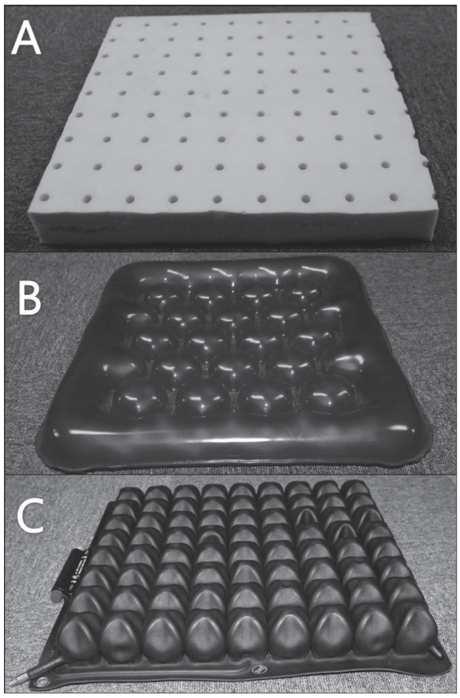

Fig. 1. Cushions employed in the present study
A: Spongy cushion; B: Gel cushion; C: Air cushion

The symmetry index (SI) was developed to calculate the differences in weight distribution between the nonparetic and paretic limbs during the stance phase of the gait cycle. In the present study, SI was used to assess the differences in pressure distribution on the seats. A SI of 0% represents equal pressures on both sides. The SI formula is shown below[16,17].

$$\text{Symmetry Index (\%)} = \frac{\text{Variables (Nonparetic)} - \text{Variables (Paretic)}}{\text{Variables (Nonparetic)} + \text{Variables (Paretic)}} \times 2 \times 100$$

All data were analyzed using SPSS version 17.0. Descriptive statistics were analyzed (mean and standard deviation and range). The independent t-test was used to analyze the differences of both lesion sides and the differences between the normal control group and stroke patients. One-way ANOVA and repeated multivariate analysis were used to calculate the symmetric index in seat types according to FAC scores and the difference of seat types on the FAC score of the same group.

RESULTS

Table 1 shows the general characteristics of the participants. The 30 stroke patients were aged between 60~75 years, and their mean age was 65.8 ± 3.7 years. The control group subjects were aged between 65~72 years,

Table 1. General characteristics of participants (n=50)

	Control group (n=20)	Stroke group (n=30)
Age (years)	68.9 ± 1.9	65.8 ± 3.7
Body Mass Index	25.5 ± 3.7	23.7 ± 2.5
Mean duration after stroke (days)		101.9 ± 30.1
Lesion side right /left		14/16
Functional Ambulatory Category 3/4/5		5/12/13

Table 2. Symmetry index according to lesion side

Lesion side	Right	Left
Wheelchair sitting	26.7 ± 18.6	30.5 ± 27.5
Spongy cushion	10.9 ± 11.4	23.4 ± 28.2
Air cushion	15.3 ± 20.2	21.2 ± 24.0
Gel cushion	15.2 ± 13.7	23.4 ± 21.7

p>0.05.

Table 3. Symmetry index according to functional ambulatory category

Functional Ambulatory Category	3	4	5
Wheelchair seat	57.0 ± 33.4^{a}	18.9 ± 16.9^{b}	31.0 ± 22.2
Spongy cushion	53.1 ± 52.1^{a}	13.4 ± 10.4^{b}	13.8 ± 16.7^{b}
Air cushion	33.0 ± 39.9	11.6 ± 13.5	21.0 ± 23.5
Gel cushion	34.6 ± 47.1	17.2 ± 9.5	18.5 ± 16.5

a>b.

Table 4. Comparison of the symmetry index between the control group and the stroke group

	Control group	Stroke group
Wheelchair sitting	11.3 ± 15.1	28.7 ± 23.4*
Spongy cushion	15.7 ± 13.4	17.5 ± 22.6
Air cushion	26.7 ± 23.6	18.4 ± 22.1
Gel cushion	22.2 ± 14.9	19.6 ± 18.6

*p<0.01.

with a mean age of 68.9 ± 1.9 years. The Body Mass Index was 23.7 ± 2.5 kg/m^2 for stroke patients, and 25.5 ± 3.7 kg/m^2 for the control group. Fourteen stroke patients had right side lesions, and 16 had left side lesions; 13 of the patients were FAC 5-point patients.

Table 2 shows the SI of cushion types according to lesion side. We noted no significant differences in SI according to cushion type between lesion sides.

Pllai's trace and Wilks' lambda of repeated multivariate analysis showed no differences among cushion types according to FAC scores (p>0.05). Table 3 shows the SI of cushion types according to FAC scores. The SI of FAC 3-point patients was higher than those of FAC 4-point patients in post hoc tests (p<0.05). FAC-3 point patients were significantly higher SI than 4-point patients in wheelchair sitting. FAC 3-point patients had significantly higher SI than the 4- or 5-point patients on the spongy cushion on the wheelchair seat.

Table 4 shows the comparison of symmetry according to cushion type between the normal control and stroke patient groups. The stroke patient group had a higher SI than the normal control group in simple wheelchair sitting (p<0.01).

DISCUSSION

The sitting of stroke patients is a predictor of functional outcome. Wheelchair cushions for stroke patients are used to facilitate normal posture and redistribute pressure in the support area. The purpose of the present study was to evaluate adjustable cushion which best helped stroke patients to maintain a normal sitting posture in a wheelchair. In particular, this study assessed the effect on stroke patient's sitting of an air cushion, a gel cushion, and a spongy cushion on the seat of a wheelchair. The FSA pressure-recording system used in the present study was very useful for assessing the mechanical characteristics of the different types of cushions.

Survivors of right-hemisphere strokes may have problems with spatial and perceptual cognition, and left-hemisphere stroke patients tend to have fewer motor problems than right-hemisphere stroke patients. The present study assumed there would be differences in symmetry among different cushion types according to the affected hemisphere; however, no differences in symmetry were observed according to lesion side. The reason for this may be that the subacute stroke patients in the present study compensated for poor sitting balance, and also because the subjects had not been affected for a prolonged period by the cerebral vascular accident.

We assumed that the greater the walking ability of stroke patients was, the less asymmetric their sitting posture would be. The FAC 3-point group showed the most asymmetric posture among all the FAC score groups. Although no statistical differences were found, all the stroke patients enrolled in this study showed reduced asymmetry when sitting on the air cushions or the gel cushion. The best cushion for FAC 3-point stroke patients was the air cushion. Because sitting sway of FAC 3-point stroke patients was less than that of FAC 4- and 5-point stroke patients, the air cushion maybe beneficially support the wide area of pressure of such patients, according to Pascal's law. Spongy and gel cushions were better cushions for FAC 4- and 5-point stroke patients than for FAC 3-point stroke patients. It is possible that the more solid elastic cushions better support the narrower base area of FAC 4- and 5-point stroke patients. The air cushion delivered better results than the gel and firm foam cushions for paraplegics in a previous study[18,19]. Although the results for the air cushion were not significantly different from the gel and spongy cushions, the air cushion helped the normal sitting of stroke participants in the present study. We guess the reason that air cushion was the best cushion for FAC-3 patients was that the sitting of these patients was more asymmetrical than those of the normal control group. When the cushions were used, the differences in sitting posture symmetry between the normal control group and stroke group were less than those reported in a previous study. This may be attributable to the cushioned seats causing an increase in asymmetry in the normal group and increase in symmetry in the stroke patients group.

The findings of the present study demonstrate that, as compared to simply sitting in a wheelchair, the use of a variety of cushions can help to improve the sitting symmetry of stroke patients.

We think that the results presented here are sufficiently valid because all the cushions were compared using the same measurement system. The present study had some limitations. This study did not reach conclusions regarding the full range of FAC scores and cannot be generalized to all stroke survivors, because the sample was limited to 30 inpatients. Future studies should assess the relationship between symmetry and other functional outcome measurement tools such as FIM and BBS. Additional studies in which a variety of cushion types are used will be necessary to improve the symmetry of stroke patients.

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