Abstract. [Purpose] The purpose of this study was to investigate adapting wheelchair cushions to hemiplegic individuals based on trunk function and a single-leg driving motion. [Subjects and Methods] Subjects were 18 hemiplegic adults who were able to use and sit up in a wheelchair. Subjects were grouped into Able and Unable groups according to the Functional Assessment for Control of the Trunk (FACT). The posterior pelvic tilt angle and the driving speed and muscle activity at the long head of the biceps femoris at the start of wheelchair use were measured for three wheelchair cushion conditions, and FACT factors and cushion factors were then analyzed. [Results] The cushion with anchoring functionality and no thigh pad on the driving side resulted in significantly lower posterior pelvic tilt and muscle activity of the long head of the biceps femoris. No significant difference was found among the FACT factors. The Unable group did not exhibit a difference in driving speed between no cushion and a single-layer urethane foam cushion. [Conclusion] The results suggest that the cushion with anchoring functionality and thigh pad removed on the driving side was well adapted to hemiplegic wheelchair users and particularly effective for those with low trunk control ability.

Key words: Hemiplegia, Trunk function, Adaptation of wheelchair cushion

INTRODUCTION

Wheelchairs must adequately distribute body-supporting pressure and support the body in a stable manner. However, few wheelchairs have these functions. In response, Yoneda et al. are promoting the use of wheelchair cushions1). Wheelchair cushions are not merely preventive implements against pressure ulcers, but also should be recognized as an integral part of the wheelchair for supporting body weight and stabilizing the body. Mitsuno et al. produced a classification of seated position ability2) and reported on modified wheelchairs and wheelchair cushions, but their study did not consider hemiplegic wheelchair users. There are no similar reports on adapting wheelchair cushions to the trunk function of hemiplegic individuals and wheelchair propulsion movements by one-sided leg propulsion.

We have previously confirmed that wheelchair cushions with anchoring functionality and a removable thigh pad on the driving side are able to suppress posterior pelvic tilt when sitting still, that the period from sitting still until the start of driving is important3), and that this effect continues until immediately after the start of driving4). From the above, we considered that it was necessary to investigate adapting wheelchair cushions based on trunk functionality from a single-legged driving motion.

The importance of trunk functionality for hemiplegic individuals has been noted5, 6), and a relationship with ambulation has been reported7). The trunk items on the Stroke Impairment Assessment Set8), the Trunk Control Test9), and a test for the motor function of the neck, trunk, and pelvic girdle10) and the like have been used. However, few tests are linked to the selection of a specific physical therapy intervention. In recent years, Okuda et al. developed the Functional Assessment for...
FACT is a therapy-oriented evaluation index, and it has been reported to have interoperator reliability and correlation with activities of daily living. In addition, we used FACT for this study because it has the advantage of easily making a determination without burdening the subject when selecting a wheelchair cushion for a hemiplegic individual in the clinical setting, and because the items under inspection include observing the fixedness of the trunk when moving the legs.

Against this background, this study aims to shed light on adapting wheelchair cushions to hemiplegic wheelchair users taking into consideration trunk function, based on a trunk function evaluation and a single-leg driving motion.

**SUBJECTS AND METHODS**

Subjects were 18 hemiplegic adults (Table 1) selected from those at N Rehabilitation Center who were able to drive their own wheelchairs and who could sit up in them. Exclusion criteria were serious spinal deformity, marked sensory impairment, and severe higher brain dysfunction/inability to understand an explanation of the study.

This study was performed with the approval of the International University of Health and Welfare ethics committee (approval number 09-122) after obtaining the consent of each subject and their presiding physician.

FACT measurements were made by two people, the researcher and the therapist in charge, to confirm interoperator reliability and correlation with activities of daily living. In addition, we used FACT for this study because it has the advantage of easily making a determination without burdening the subject when selecting a wheelchair cushion for a hemiplegic individual in the clinical setting, and because the items under inspection include observing the fixedness of the trunk when moving the legs.

Against this background, this study aims to shed light on adapting wheelchair cushions to hemiplegic wheelchair users taking into consideration trunk function, based on a trunk function evaluation and a single-leg driving motion.

**Table 1. Subject characteristics**

| Item                  | Value          |
|-----------------------|----------------|
| Age (yrs)             | 61.6 ± 8.3     |
| Height (cm)           | 164.4 ± 4.9    |
| Weight (kg)           | 57.5 ± 10.5    |
| Gender (Female/Male)  | 1/17           |
| Paralyzed side (Right/Left) | 9/9         |
| Period from onset (days) | 112.5 ± 41.0 |
| BRS score (people)    | II; 3, III; 8, IV; 7 |
| FIMcore               | 98.8 ± 18.9    |

**Table 2. FACT elements**

| Item No. | Element                                                                 |
|----------|-------------------------------------------------------------------------|
| 1        | Static Use of upper limb support                                         |
| 2        | Static Upper limb support disuse                                         |
| 3        | Dynamic Moving the center of gravity downwards/reaching, small rotations of the trunk, and concomitant trunk activity due to gravity and against gravity |
| 4        | Dynamic Moving the center of gravity forward, concomitant righting of the legs and trunk, and further moving the center of gravity to the right and left while making selective small movements of the pelvis and trunk |
| 5        | Dynamic Moving the center of gravity laterally over a wide area, and concomitant righting |
| 6        | Dynamic Moving the center of gravity slightly backwards and to the side, concomitant righting, and the ability to hold the trunk on both sides while raising both legs |
| 7        | Dynamic Moving the center of gravity backwards over a wide area, concomitant righting, and the ability to hold the trunk on both sides while raising both legs |
| 8        | Dynamic Moving the center of gravity laterally over a wide area, and further selective rotation of the pelvis/trunk |
| 9        | Dynamic Rotation while trunk is extended                                 |
| 10       | Dynamic Maximum spine extension                                          |

Quoted from the Development and reliability of Functional Assessment for Control of the Trunk (FACT)
To measure kinematic data, we used a three-dimensional (3D) motion analysis system (Vicon MX), consisting of 8 infrared cameras and an electromyograph (DKH). The camera sampling frequency was 120 Hz. The propulsion pathway was 3.6 m, and the measurements were made starting at the 1.8 m mark and continued thereafter. Infrared reflective markers were pasted at the following 15 locations: bilateral acromion, spinous process of the second thoracic vertebra, bilateral anterior superior iliac spine (ASIS), bilateral posterior superior iliac spine (PSIS), hip joint, knee joint, external malleolus, and head of the fifth metatarsal. To calculate the pelvic angle, the bilateral ASIS and PSIS markers were used to define a pelvic coordinate system.

Electromyography was used to analyze muscle activity during the propulsion movements and was synchronized to the 3D motion analysis system. Data were sampled at 1,080 Hz and input into a PC after A/D conversion. The waveform of the electromyogram was processed with a 20–450 Hz band-pass filter and subjected to full-wave rectification to determine the integrated electromyogram. The muscle measured was the biceps femoris long head. Electrodes were attached at the positions recommended by Aldo et al.

All patients used the same adjustable wheelchair (Nissin Medical Industries Co., Ltd.). The adjustable wheelchair had 24-inch propulsion wheels and 5-inch casters, and the height difference of the seat from front to back was set at 0 cm. The bottom of the back support was raised so that the markers attached to the pelvis were visible from behind. The five adjustable parameters of the wheelchair were seat height, depth, and width, as well as arm height and back support height. Adjustment of the wheelchair to match patient dimensions was conducted with reference to the Wheelchair SIG workshop text (2003).

The method for analyzing wheelchair single-leg driving was the same as that in a previous study of single-leg driving and data used were the posterior pelvic tilt angle when seated still, the posterior pelvic tilt angle when beginning driving, the %IEMG of the long head of the biceps femoris, and the drive speed. The three measurement conditions were without a cushion, with cushion 1 (standard cushion used in the clinical setting), and with cushion 2 (with anchoring functionality and the thigh pad on the driving side removed). Cushion 1 had a thickness of 4 cm (elevation difference: 0 cm), and was made of a single layer of urethane foam. Cushion 2 had a thickness of 8 cm (elevation difference: 2.5 cm), and comprised a cushion bottom made from polyethylene foam and a cushion pad made from a low-rebound, high-density urethane. The cushion cover was made of polyester and was the same for each cushion. The order in which the conditions were measured was randomized. For the condition without a cushion, the subject rode the wheelchair while sitting on the seat surface (made of nylon) of a molded wheelchair.

Because the start of driving from sitting still is important for suppressing posterior pelvic tilt, the FACT factors were factor 1 and the cushion factors were factor 2. Two-way repeated measures analysis of variance (ANOVA) was performed for the posterior pelvic tilt angle when seated still, the posterior pelvic tilt angle when beginning driving, the %IEMG of the long head of the biceps femoris, and the drive speed using the FACT factors and cushion factors. The Bonferroni method was used for subtests. The significance level was set to p<0.05 and the statistical analysis used SPSS ver. 150 J for Windows.

### RESULTS

The results of the two-way repeated measures ANOVA are shown in Table 4. No interaction between the FACT factors and the cushion factors was found for the posterior pelvic tilt angle when seated still, the posterior pelvic tilt angle when beginning driving, or the %IEMG of the long head of the biceps femoris, and the patterns of change were identical. No significant difference was found between FACT factors. Among the cushion factors, a significant difference was found between no cushion and cushion 2 (p<0.01), and between cushion 1 and cushion 2 (p<0.05). No significant difference was found between no cushion and cushion 1.
Interaction between the FACT factors and cushion factors was found in the drive speed, and the pattern of change was different. A simple primary effect determination could not be made. Among the cushion factors, a significant difference was found between no cushion and cushion 2, and between cushion 1 and cushion 2. No significant difference was found between no cushion and cushion 1. Furthermore, the unable group did not exhibit a change in drive speed between no cushion and cushion 1. No significant difference was found in any of the FACT factors.

**DISCUSSION**

When the posterior pelvic tilt angle when seated still, the posterior pelvic tilt angle when beginning driving and the %IEMG of the long head of the biceps femoris were investigated in terms of the FACT factors in FACT items 6 and 7 and the cushion factors, no interaction was found between the FACT factors and cushion factors, and the change patterns were identical. Among the cushion factors, using cushion 2 (anchoring functionality and no pad at the driving-side thigh) resulted in a significant decrease in posterior pelvic tilt and %IEMG at the long head of the biceps femoris. In addition, no significant difference was found between the FACT factors. From these results, it is conceivable that suppressing posterior pelvic tilt when sitting still is important for all hemiplegic patients, and that to achieve this, it is effective to use a cushion with anchoring functionality and with the thigh pad at the driving side removed. In addition, because there was no change in driving speed between having no cushion and cushion 1 (single-layer urethane foam cushion) in the unilateral Able group for FACT item 6 and the Unable group for item 7, it is conceivable that a cushion with anchoring functionality and the thigh pad on the driving side removed would be suitable for these groups.

FACT item 6 required the ability to raise a single leg while holding the ipsilateral side of the trunk in place, while item 7 required the ability to hold both sides of the trunk in place while raising both legs, and so these require the coordinated movement of the abdominal internal oblique muscle, the abdominal external oblique, the rectus abdominis muscle, and the erector spinae muscle group. Engstrom notes that when hemiplegic individuals drive wheelchairs, it is important that the pelvis and trunk be immobile during movements of the legs. It is conceivable that sitting in a cushion with anchoring functionality reduces posterior pelvic tilt, bringing the alignment of the lumbar spine closer to the physiological lordosis and facilitating the coordinated activity of the abdominal internal oblique muscle, the abdominal external oblique, the rectus abdominis muscle, and the erector spinae muscle group, which contribute to stabilizing the spine.

This study examined only subjects capable of self-propulsion of a wheelchair. By performing additional investigations in the future with hemiplegic individuals with lower levels of autonomy, we believe it will be possible to perform a study that is compatible with a broad section of the population. Efforts are needed toward the development and practical application of wheelchair cushions that are effective for hemiplegics. To achieve this, the accumulation of objective information on the wheelchair driving motion of hemiplegic individuals is a task for future research, and so we wish to continue our practical efforts.

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