Abstract. [Purpose] This study sought to ascertain whether, in hemiplegic patients, the effect of a wheelchair cushion to suppress pelvic posterior tilt when initiating wheelchair propulsion would continue in subsequent propulsions. [Subjects] Eighteen hemiplegic patients who were able to propel a wheelchair in a seated position participated in this study. [Methods] An adjustable wheelchair was fitted with a cushion that had an anchoring function, and a thigh pad on the propulsion side was removed. Propulsion movements from the seated position without moving through three propulsion cycles were measured using a three-dimensional motion analysis system, and electromyography was used to determine the angle of pelvic posterior tilt, muscle activity of the biceps femoris long head, and propulsion speed. [Results] Pelvic posterior tilt could be suppressed through the three propulsion cycles, which served to increase propulsion speed. Muscle activity of the biceps femoris long head was highest when initiating propulsion and decreased thereafter. [Conclusion] The effect of the wheelchair cushion on suppressing pelvic posterior tilt continued through three propulsion cycles.

Key words: Hemiplegia, Wheelchair cushion, Continuity of effect

INTRODUCTION

Hemiplegic patients can acquire wheelchair propulsion movements relatively quickly, and therefore those who have ambulatory difficulties or who are receiving training before being able to walk again use wheelchairs. However, hemiplegics are prone to posterior tilting of the pelvis due to factors such as wheelchair depth, hamstring contraction, and sitting for long periods, and these factors are difficult for many people to change. To date, few studies have investigated the effect of long-term pelvic posterior tilt on wheelchairs, and compared with research on therapy that aims to reestablish ambulation, research on wheelchair posture tends to receive less attention. Kinose et al. noted wheelchair problems as a reason for this; that is, most wheelchairs in hospitals and therapeutic facilities are likely to be standard models with dimensions and a seat that cannot be adjusted for individuals. Less than an optimal posture while propelling a wheelchair can easily aggravate abnormal muscle tension and associated responses, which can then become major clinical problems in themselves.

The dimensions of wheelchairs and their seats have been noted as possible causes of pelvic posterior tilt, and the use of a wheelchair cushion is therefore recommended. The effect of using a wheelchair cushion with anchor support and notches for the thigh section on the propulsion side have been reported for hemiplegic subjects. The importance of heel-ground contact, footrest height, and seat height in wheelchair propulsion by hemiplegic subjects has been previously reported. However, these reports often use propulsion speed as an evaluation indicator, and there are no reports that have quantitatively evaluated the angle of pelvic posterior tilt. We previously found that pelvic posterior tilt could be suppressed by using a wheelchair cushion in hemiplegics under the conditions of being seated without moving up to initiation of propulsion. However, this effect of the cushion needs to be examined in more detailed by investigating how the angle of pelvic posterior tilt changes under the conditions of being seated through initiation and continuation of propulsions. Thus, in this study, we investigated the continuity of the effect of using a cushion to suppress pelvic posterior tilt through three propulsion cycles.
In addition, because hemiplegics use the lower limb on the propulsion side to control both propulsion and steering when propelling a wheelchair\(^7\)), the wheelchair propulsion movement examined in this study was one-sided leg propulsion.

**SUBJECTS AND METHODS**

The subjects were 18 hemiplegics (17 men and 1 woman; age range, 44–73) who could propel a wheelchair while in a seated position. Subjects were excluded if they had severe spinal deformation, marked sensory impairment, or severe higher brain dysfunction and could not understand an explanation of the study. The physical functions and disease characteristics of the subjects are shown in Table 1. Nine subjects had right hemiplegia, and 9 had left hemiplegia (112.5±39.8 days from disease onset to day of measurement). Physical function was assessed using the leg Brunnstrom Recovery Stage and the Functional Independence Measure. We assumed that age and sex differences would have a negligible effect on the results. Although such effects are a possibility, previous studies that were mixed sex and that considered a broad range of ages have not reported age or sex differences\(^11, 12\)).

Measurements were obtained under two conditions: 1) subjects seated without moving in an adjustable wheelchair and 2) from the seated position through three propulsion cycles of travel in a straight line under one-sided leg propulsion. Maximum isometric contraction of the long head of the biceps femoris was measured for 5 s in the prone position. The initial ground contact of the propelling foot through to the next ground contact of the same foot was defined as the initiation of propulsion.

We used the same wheelchair cushion in this study as in our previous study\(^12\)). The cushion had an anchoring function, and the thigh pad on the propulsion side was removed. The thickness of the cushion was 8 cm (difference in elevation of 2.5 cm). The cushion comprised a polyethylene foam pad underneath a low-rebound, high-density urethane pad and a polyethylene cushion cover.

To measure kinematic data, we used a three-dimensional (3D) motion analysis system (Vicon MX), consisting of 8 infrared cameras, and an electromyograph (DKH). All patients used the same adjustable wheelchair (Nissin Medical Industries Co., Ltd.). 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 (IEMG). The muscle measured was the biceps femoris long head, and the electrodes were attached at the positions recommended by Aldo et al\(^13\)).

The adjustable wheelchair had 24-inch propulsion wheels and 5-inch casters, and the height difference of the seat from

| Subject | Sex | Age | Diagnosis | Paralyzed side | Period from onset (days) | Height (cm) | Weight (kg) | BRS score | FIM score |
|---------|-----|-----|-----------|----------------|--------------------------|-------------|-------------|-----------|-----------|
| a       | Male| 51  | Cerebral infarction | Left           | 111                   | 168.2       | 74.0        | IV        | 125       |
| b       | Female| 72 | Multiple cerebral infarction | Left | 166            | 156.0       | 44.8        | IV        | 105       |
| c       | Male| 53  | Cerebral hemorrhage | Right         | 89                     | 173.4       | 63.0        | IV        | 99        |
| d       | Male| 60  | Cerebral hemorrhage | Left           | 141                   | 166.7       | 64.0        | IV        | 113       |
| e       | Male| 61  | Cerebral hemorrhage | Right         | 106                   | 160.3       | 63.4        | III       | 95        |
| f       | Male| 62  | Cerebral hemorrhage | Left           | 83                     | 168.1       | 50.3        | III       | 66        |
| g       | Male| 55  | Thalamic hemorrhage | Left           | 63                     | 161.3       | 51.0        | III       | 109       |
| h       | Male| 63  | Cerebral hemorrhage | Right          | 116                   | 168.4       | 78.0        | IV        | 100       |
| i       | Male| 44  | Cerebral hemorrhage | Right          | 141                   | 162.5       | 51.0        | III       | 114       |
| j       | Male| 62  | Thalamic hemorrhage | Right          | 106                   | 165.2       | 65.5        | IV        | 122       |
| k       | Male| 63  | Cerebral hemorrhage | Left           | 147                   | 165.3       | 66.9        | III       | 79        |
| l       | Male| 49  | Cerebral hemorrhage | Right          | 62                     | 167.1       | 54.3        | II        | 76        |
| m       | Male| 73  | Thalamic hemorrhage | Left           | 95                     | 158.0       | 44.7        | III       | 100       |
| n       | Male| 67  | Thalamic hemorrhage | Right          | 140                   | 160.4       | 48.4        | II        | 76        |
| o       | Male| 65  | Putamen hemorrhage | Right          | 211                   | 163.5       | 50.0        | IV        | 66        |
| p       | Male| 67  | Thalamic hemorrhage | Right          | 116                   | 160.7       | 52.3        | III       | 113       |
| q       | Male| 72  | Cerebral infarction | Left           | 91                     | 160.3       | 45.1        | III       | 121       |
| r       | Male| 69  | Cerebral hemorrhage | Left           | 41                     | 173.4       | 68.5        | II        | 99        |

BRS: Brunnstrom Recovery Stage; FIM: Functional Independence Measure
The pelvic posterior tilt angle from the seated position without moving through three propulsion cycles, the propulsion speed for each propulsion cycle, and the biceps femoris long head %IEMG are shown in Table 2. A significant difference was found in the pelvic posterior tilt angle between being seated without moving and the initiation of propulsion (p<0.05), between being seated without moving and the second propulsion cycle (p<0.05), and between being seated without moving and the third propulsion cycle (p<0.05). Significant differences were found in the propulsion speed and biceps femoris long head %IEMG between the initiation of propulsion and the second propulsion cycle (p<0.01) and between the initiation of propulsion and the third propulsion cycle (p<0.01).

### DISCUSSION

This study revealed significant differences in the pelvic posterior tilt angle and propulsion speed between being seated without moving and initiating propulsion and between being seated without moving and the second and third propulsion cycles. In addition, the propulsion speed had increased by the third cycle. The pelvic posterior tilt angle changed over time, and was 11° when sitting still; it had increased by the third propulsion cycle. Significant differences were found in the propulsion speed and biceps femoris long head %IEMG between the initiation of propulsion and the second propulsion cycle (p<0.01) and between the initiation of propulsion and the third propulsion cycle (p<0.01).
patient when initiating propulsion, and with the acceleration obtained, the wheelchair could subsequently be moved by exerting a lower amount of force\textsuperscript{16}). So, the patient could move forward using a lower force from the second propulsion cycle onward. As the propulsion speed increased, it is likely that the effect of the wheelchair cushion on suppressing pelvic posterior tilt continued through the third propulsion cycle.

To conclude, analysis of one-sided leg propulsion revealed continuity of the effect of a wheelchair cushion on suppressing pelvic posterior tilt from the seated position without moving through three propulsion cycles. Future research should compare cushions of differing materials and shapes, verify their long-term effects, and investigate potential application to wheelchair cushion design.

REFERENCES

1) Letts RM: General principles of seating, principles of seating disabled. CRC Press, 1991, pp 6–7.
2) Andersson BJ, Ortengren R, Nachemson A, et al.: Lumbar disc pressure and myoelectric back muscle activity during sitting. I. Studies on an experimental chair. Scand J Rehabil Med, 1974, 6: 104–114. [Medline] [CrossRef]
3) Chaffin B, Andersson BJ, Martin J: Occupational Biomechanics, 3rd ed. New York: John Wiley & Sons, 1999, pp 355–391.
4) Kroemer KH, Grandjean E: Fitting the Task to the Human, 5th ed. London: Taylor & Francis, 2003, pp 53–99.
5) Kinose T: Modular wheelchair and seating system. Jpn J Occup Ther, 1999, 33: 335–340 (in Japanese).
6) Takeda F, Okuda Y, Furuya M: Efficacy of a modular wheelchair for wheelchair propulsion by adult hemiplegics. Saitama Phys Ther, 2003, 10: 33–37.
7) Eguchi H, Ikushima H, Uematsu M, et al.: Charactristics of oneleged driving with wheelchair: analysis from driving-force and electromyogram. Bull Jpn Soc Prosthet Orthot, 1995, 11: 158–167 (in Japanese).
8) Hirose H, Kinose T: Seating of Elderly. Tokyo: Miwashoten, 2006, pp 78–79 (in Japanese).
9) Cron L, Sprigle S: Clinical evaluation of the hemi wheelchair cushion. Am J Occup Ther, 1993, 47: 141–144. [Medline] [CrossRef]
10) Iwamoto A, Higashi Y, Tsumagari Y, et al.: The effect of footrest height on wheelchair propulsion. J Jpn Occup Ther Assoc, 2004, 23: 198 (in Japanese).
11) Uematsu M, Yamada M, Eguchi H: Prescription factors which influence wheelchair operability in patients with hemiplegia: evaluation of seat height and depth. J Phys Ther, 1994, 21: 256–263 (in Japanese).
12) Kawada K, Matsuda T, Takanashi A, et al.: Motion analysis of wheelchair propulsion movements of hemiplegic patients: effect of a wheelchair cushion on the initiation of propulsion. Rigakuryohokagaku, 2013, 28: 787–790 (in Japanese). [CrossRef]
13) Aldo O: (Ryozi K trans.): Anatomical Guide for the Electromyographer: The Limbs and Trunk. Tokyo: Nishimurashoten, 2007, pp 166–167 (in Japanese).
14) Kawada K, Yamamoto S: Motion analysis of driving wheelchairs with lower legs of hemiplegic patients. Rigakuryohokagaku, 2008, 23: 789–793 (in Japanese). [CrossRef]
15) Engstrom B: (Ritsuya K, Kaoru Y trans.): Ergonomic Seating. Osaka: LAC Healthcare Ltd., 2003, pp 216–225 (in Japanese).
16) Yokota T: Physics for nurses and medical caregivers. Tokyo: Kyoritsu Shuppan, 1993, pp 21–22 (in Japanese).