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Original Article

Influence of sitting posture on anterior buttock sliding during wheelchair propulsion of hemiplegic stroke patients

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ABSTRACT
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Objectives: This study investigated the influence of different sitting postures on wheelchair propulsion ability.
Methods: The subjects were stroke patients who scored at least 2 points on the Stroke Impairment Assessment Set for abdominal muscle strength and trunk verticality and 3 points for non-paralytic side lower-limb muscle strength. Moreover, the patients were divided by their everyday wheelchair propulsion posture: Lean on Back Support (LBS); n = 8), those who leaned their back against the back support; and non-LBS (n = 11), those who moved their back away from the back support. For the wheelchair propulsion method, straight one-hand, one-leg propulsion was used on the non-paralyzed side for 10 m, followed by turning around a target 3 m ahead on each of the paralyzed and non-paralyzed sides. We then compared the propulsion times, number of propulsions, and difference in length from the front end of the patella on the non-paralyzed side to the front end of the seat surface (buttock sliding distance) between the groups.
Results: The buttock sliding distance was significantly shorter in the non-LBS group than in the LBS group in the paralyzed and non-paralyzed side turning tasks ($p < 0.05$). Propulsion times, number of propulsions, and grip strength did not differ significantly between the groups.
Conclusion: Even in patients with good trunk function, propulsion while leaning against the back support can easily result in anterior buttock sliding, leading to a secondary risk of injury. These results suggest that it is necessary to provide guidance on the propulsion posture and seating to hold the trunk vertically to minimize anterior sliding during propulsion.
Key words: stroke, wheelchair, driving ability, anterior sliding

Introduction

Most wheelchair propulsion studies have focused on patients with spinal cord injuries, while few have examined patients with stroke [1]. This could be because walking is the primary mobility goal for stroke patients, while mobility in a wheelchair is temporary. In addition, many patients who use wheelchairs are severely ill and experience difficulty propelling themselves. According to Jørgensen et al., 18% of stroke patients who underwent rehabilitation did not regain the ability to walk [2]. Tanino et al. also reported that patients with a Functional Independence Measure (FIM) gait item score of 1 or 2 points on admission had difficulty walking independently at discharge. Furthermore, they reported that a patient with an FIM gait item score of 3 points continued to be monitored from admission to 8 weeks [3]. Thus, patients who are unable to acquire walking movements or for months after stroke onset often use wheelchairs daily.

Furthermore, many stroke patients have trunk dysfunction, which is characterized by an asymmetric, posteriorly tilted pelvic sitting position [4]. As a result, a stroke patient sitting in a wheelchair frequently leans against an armrest or backrest, a posture maintained during wheelchair propulsion. These patients may use their backs to push on the back support, immobilize the trunk, and gain compensatory propulsion. In such cases, the buttocks may slide anteriorly, which should not be ignored because it may cause bedsores. In

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clinical practice, however, some patients are seen sitting in wheelchairs with their backs off of the back support and the trunk in a vertical or forward leaning posture. Differences in cushion type and the impact of motor function on propulsion speed have been documented in studies of wheelchair propulsion in patients with stroke [5, 6]. However, we found no studies that reported differences in performance despite comparable motor function levels.

Thus, this study examined the effects of different seating postures during wheelchair propulsion on the ability of patients with good trunk function and leg muscle strength on the non-paralyzed side to propel a wheelchair as a preliminary way to investigate effective seating to prevent anterior sliding.

Subjects

The participants were 19 first-time stroke hemiplegic patients with unilateral tent lesions who were admitted to Fujita Health University Nanakuri Memorial Hospital, used a wheelchair as their primary mode of daily mobility, and scored 5 or 6 points on the FIM motor item score [7] for wheelchair mobility, at least 2 for abdominal strength and trunk verticality, and 3 for non-paralyzed side lower-limb muscle strength on the Stroke Impairment Assessment Set (SIAS) [8]. Patients with hemispatial neglect and those who had trouble understanding the measurement methods were excluded. Each patient agreed to participate.

Methods

The subjects were divided based on their everyday wheelchair propulsion posture into the Lean on Back Support (LBS, n = 8; those who leaned their backs against the back support), and the non-LBS (n = 11; those who moved their backs away from the back support) group (Table 1).

Each patient was seated in a standard wheelchair (Kawamura Cycle, KA820-40B-M: 15.9 kg/KA820-40B-LO: 15.6 kg) and completed three tasks in the following order: 1) 10 m straight ahead; 2) paralyzed side turning back to a target 3 m from the starting position (paralyzed side turning); and 3) non-paralyzed side turning back to a target in the same setup (non-paralyzed side turning). At a comfortable propulsion speed, the three tasks were completed once in order. The subject was seated in a wheelchair with the front edge of the foot support aligned with the starting line, and an evaluator steered the wheelchair. The estimated end time was when the wheelchair passed the finish or starting line. The propulsion times, number of lower-limb propulsions (number of propulsions), and difference in length between the anterior edge of the patella on the non-paralyzed side and the anterior edge of the seat surface before and after the propulsion (buttock sliding distance) were evaluated. In addition, grip strength (measured values) of the SIAS was assessed before the measurements to assess physical function. To reduce the differences in propulsion ability due to body size, patients less than 160 cm tall used the KA820-40B-LO wheelchair, while those 160 cm or taller used the KA820-40B-M wheelchair.

Table 1. characteristics of the subjects.

	LBS group	Non LBS group	*p*-value
Number of patients	8	11	
Age (year)	56.0 ± 9.5	66.5 ± 12.3	ns
Sex (male / female)	7 / 1	6 / 5	ns
Paretic side (right / left)	3 / 5	5 / 6	ns
Height (cm)	165.8 ± 6.1	161.2 ± 9.2	ns
Thigh length (cm)	42.6 ± 3.6	41.0 ± 4.8	ns
Lower leg length (cm)	46.0 ± 2.2	45.2 ± 2.6	ns
Days to measurement (day)*	36.5 ± 23.3	39.2 ± 17.7	ns
SIAS			
Abdominal strength (0/1/2/3)	0/0/2/6	0/0/3/8	ns
Trunk verticality (0/1/2/3)	0/0/3/5	0/0/1/10	ns
Nonparalytic side lower limb muscle strength (0/1/2/3)	0/0/0/8	0/0/0/11	ns
Grip strength (kg)	25.9 ± 10.1	28.3 ± 8.8	ns

(Mean±SD)
LBS group, Lean on Back Support Group; Non LBS group, Non Lean on Back Support Group; SIAS, Stroke Impairment Assessment Set.
*Number of days from when FIM wheelchair item score reached 5 points to the measurement date.
Mann-Whitney *U* test: age, height, thigh length, lower leg length, day to measurement, grip strength.
Chi-square test: gender, paralyzed side.
ns: not significant.

Furthermore, the front seat height was set at 90−110% of the lower thigh length. The participant propelled the wheelchair using the hand and leg on the non-paralyzed side.

The LBS and non-LBS groups were compared using the Mann-Whitney *U* test for age, number of days from when the FIM wheelchair item score reached 5 points to the measurement date, height, thigh length, lower leg length, propulsion times, number of propulsions, buttock sliding distance, and grip strength, while the chi-squared test was used to examine gender and paralyzed side. The number of days from the time the FIM wheelchair item score reached 5 points to the date of the measurement was calculated using the date of evaluation from our database, which was updated every 2 weeks from admission, and the date of admission was 0 days. The significance level was set at $p < 0.05$. JMP version 14.0 for Macintosh was used to perform the statistical analyses.

Results

Table 2 and Figures 1−3 show the findings of each evaluation in the LBS and non-LBS groups. The mean buttock sliding distance (cm) was 1.5±0.6 in the LBS group and 0.2±0.6 in the non-LBS group for the paralyzed side turning task versus 1.5±1.4 in the LBS group and 0.1±0.6 in the non-LBS group for the non-paralyzed side turning task ($p < 0.01$ and $p < 0.05$, respectively). In terms of propulsion times and number of propulsions for the 10-m straight-ahead task, the non-LBS group outperformed the LBS group. Furthermore, the non-LBS group tended to have fewer propulsions for all tasks.

Discussion

In this study we investigated the influence of different wheelchair propulsion postures on the propulsion ability of patients with stroke. The LBS and non-LBS groups had similar propulsion times and

Table 2. Comparison of LBS group and Non-LBS group.

		LBS group	Non LBS group	*p*-value
Driving time (sec)	10 m straight ahead	21.8 ± 5.8	17.6 ± 6.6	ns
	paralyzed side turning	21.7 ± 4.9	21.6 ± 10.7	ns
	non-paralyzed side turning	21.2 ± 5.0	20.9 ± 10.7	ns
Number of driving times (times)	10 m straight ahead	20.0 ± 4.4	17.3 ± 4.7	ns
	paralyzed side turning	22.5 ± 4.4	22.7 ± 10.5	ns
	non-paralyzed side turning	20.2 ± 4.7	20.1 ± 7.5	ns
Buttock sliding distance (cm)	10 m straight ahead	0.9 ± 1.2	0.4 ± 0.5	ns
	paralyzed side turning	1.7 ± 1.0	0.2 ± 0.6	<0.01
	non-paralyzed side turning	1.4 ± 1.5	0.1 ± 0.6	<0.05

(Mean±SD)
LBS group, Lean on Back Support Group; Non-LBS group, Non Lean on Back Support Group.
The Mann-Whitney *U* test was used for comparison two groups.
ns: not significant.

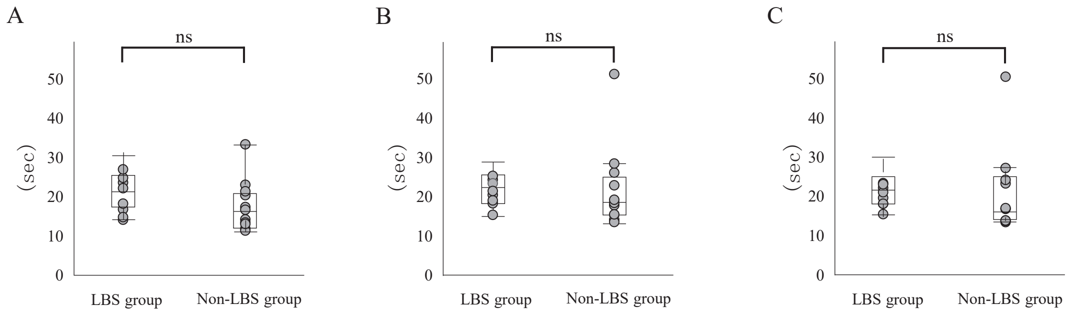

Figure 1. Comparison of driving time.
Show the results of the driving time of the LBS and Non-LBS groups.
A. 10 m straight ahead
B. Paralyzed side turning
C. Non-paralyzed side turning
There were no significant differences between the two groups in all tasks.
(Mann-Whitney *U* test, ns: not significant)

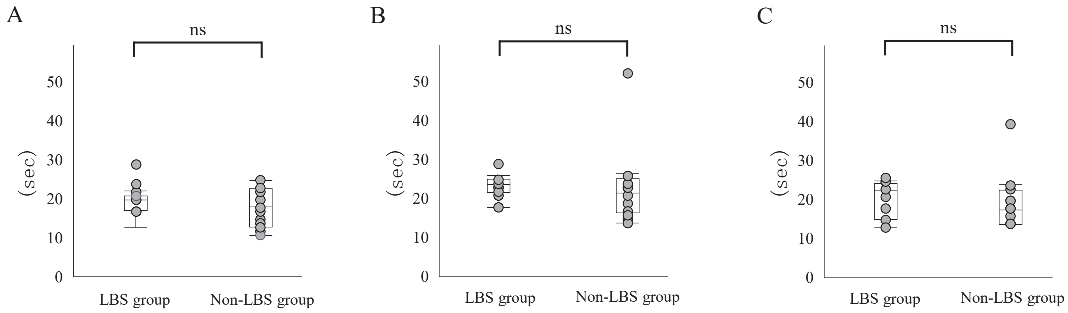

Figure 2. Comparison of number of driving times.
Show the results of the number of driving times of the LBS and Non-LBS groups.
A. 10 m straight ahead
B. Paralyzed side turning
C. Non-paralyzed side turning
There were no significant differences between the two groups in all tasks.
(Mann-Whitney *U* test, ns: not significant)

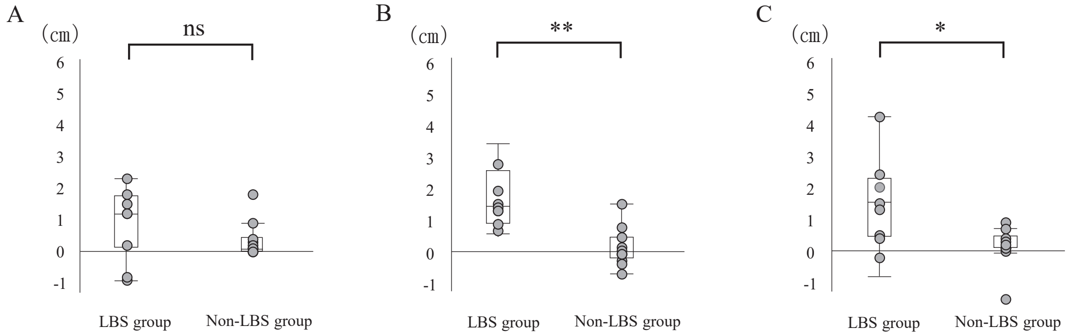

Figure 3. Comparison of buttock sliding distance.
Show the results of buttock sliding distance of the LBS and Non-LBS groups.
A. 10 m straight ahead
B. Paralyzed side turning
C. Non-paralyzed side turning
A significant difference was showed between paralyzed side and non-paralyzed side turning.
(Mann-Whitney *U* test, **: $p < 0.01$, *: $p < 0.05$, ns: not significant)

numbers; however, regarding the buttock sliding distance, only the task of turning the wheelchair was shorter in the non-LBS group in terms of buttock sliding distance, implying that the difference in propulsion posture may impact the body.

We found no significant intergroup difference in propulsion times for any tasks. Otao et al. investigated the factors affecting wheelchair propulsion speed in stroke patients and reported that abdominal muscle strength and standing balance are important [6]. Since this study targeted patients with similar trunk function levels and non-paralyzed leg muscle strengths, there was no significant difference in propulsion speed between the two groups. In addition, although no significant difference was observed in the number of propulsions, the non-LBS group tended to have shorter propulsion times than the LBS group. The subjects' trunk function, lower-limb muscle strength, and grip strength did not differ significantly between the groups, implying that other factors were involved in the number of propulsions.

Julien et al. reported that anterior trunk and neck flexion during wheelchair propulsion in quadriplegic patients improved propulsion by transferring upper-limb forces to the push rim [9]. The non-LBS group did not lean on the back support while propelling the wheelchair, which may have resulted in a more forward trunk position and more effective transfer of propulsion by the non-paralyzed upper limb to the push rim with shorter propulsion times than the LBS group. Furthermore, although there was no significant difference in the propulsion time and number of propulsions for the 10-m straight-ahead task, the non-LBS group showed better results than the LBS group, indicating that the propulsion method without leaning on the back support has a higher propulsive efficiency.

Some studies that investigated the buttock sliding distance in a sitting position on a wheelchair used a reclining or tilt wheelchair mechanism [10, 11]. However, few studies have examined the sliding distance of the buttocks during wheelchair propulsion in patients with stroke. For the paralyzed side turning and non-paralyzed side turning tasks, the non-LBS group had substantially shorter buttock sliding distances than the LBS group. The difference in buttock sliding distance was evident in the wheelchair turning tasks, whereas no difference was noted in the 10-m straight-ahead task. Tasks involving straight-ahead propulsion and those involving turning while moving reportedly have similar success rates [12], implying that this is unlikely to impact task complexity. The subjects in this study had good trunk function; however, it is possible that propulsion while leaning on a back support may have activated the back muscles more than the abdominal muscles. As a result, the trunk was in an extended position, and it was possible that the pelvis tilted more posteriorly and the buttocks slid anteriorly during turning.

The subjects in this study had comparable motor function levels; however, their daily wheelchair propulsion postures differed. The reason why the non-LBS group chose propulsion without back support may be due to propulsive efficiency and secondary body disability. Concerning the first point, Kirby et al. stated that when a hemiplegic patient propels a manual wheelchair using one hand and one leg, the upper limb works as a propulsive force and the lower limbs work to correct the direction [13]. This may have been chosen as the propulsion pattern because tilting the trunk forward during propulsion enhances the degree of freedom of the propulsion upper limb's shoulder girdle and improves the efficacy of transmission of the propulsive force to the hand rim. This could be because there were more women in the non-LBS group (despite no intergroup difference in ratio) and women tend to have less muscle strength than men. As a result, it was assumed that the trunk was bent forward to compensate for the propulsive force of the upper limbs, thereby improving the efficiency. Concerning the second point, secondary disabling effects on the body and leaning on the back support may promote a slumped posture due to posterior pelvic tilting, increase buttock shear forces, and cause stress on the intervertebral discs due to lumbar kyphosis, resulting in buttock and lower back pain [14]. Based on these findings, we speculated that the non-LBS group favored a propulsion style that did not lean on the back support to avoid pain.

This study clarified that anterior buttock sliding was less likely to occur during wheelchair propulsion without leaning on the back support. Clinically, however, even in cases of good physical function, the patient may propel the wheelchair while leaning on the back support, which can easily result in anterior buttock sliding. Anterior buttock sliding increases sacral shear forces [15]; thus, to minimize sliding during propulsion, it is necessary to devise a wheelchair body using the seating technique. In particular, adjusting the axle forward, moving the large wheel and hand rim forward, and positioning the back support at a height that does not conflict with upper-limb propulsion may increase upper-limb propulsive range and efficiency [16, 17]. As for the cushion, shaving the thigh on the propulsion side or using a cushion with a front-back height difference (anchor function) may facilitate lower-limb propulsion while preventing posterior pelvic tilting [18, 19]. Making such adjustments in seating and repeating the propulsion method using this method may decrease the likelihood of anterior buttock sliding.

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