



Original Article

Immediate effects of quick trunk movement exercise on sit-to-stand movement in children with spastic cerebral palsy: a pilot study

ABBAS ABDOLRAHMANI, PT, MSc^{1)*}, HIROYUKI SAKITA, PT, BS²⁾, RYO YONETSU, PT, PhD¹⁾, AKIRA IWATA, PT, PhD¹⁾

¹⁾ Graduate School of Comprehensive Rehabilitation, Osaka Prefecture University: 3-7-30 Habikino, Habikino City, Osaka 583-8555, Japan

²⁾ Osaka Medical Center and Research Institute for Maternal and Child Health, Japan

Abstract. [Purpose] This pilot study examined the immediate effects of quick-seated trunk exercise on sit-to-stand movement in children with cerebral palsy. [Subjects and Methods] Five children with spastic cerebral palsy (hemiplegia, 3; diplegia, 2; age 6–17 years) performed five sessions of natural-seated trunk exercise at a self-selected speed (control). Following a 50-min rest period, five sessions of the quick-seated trunk exercise were conducted (experimental intervention) for each child. Each seated trunk exercise included 10 repetitions in the anterior-posterior and lateral directions. Sit-to-stand was assessed before and after each intervention using a motion analysis system. The total sit-to-stand task duration and sagittal, angular movements of the trunk, hip, knee, and ankle were calculated. [Results] There was a significant difference in the total duration of the sit-to-stand movement before and after natural-seated trunk exercise (2.40 ± 0.67 s vs. 2.24 ± 0.44 s) as well as quick seated trunk exercise (2.41 ± 0.54 s vs. 2.06 ± 0.45 s). However, the sit-to-stand duration increased after natural-seated trunk exercise in one participant while that after quick-seated trunk exercise decreased in all participants. [Conclusion] Performing a trunk exercise in a seated position resulted in immediate improvement of the temporal sit-to-stand parameters in children with spastic cerebral palsy.

Key words: Fast trunk exercise, Sit-to-stand, Cerebral palsy

(This article was submitted Jan. 24, 2017, and was accepted Feb. 16, 2017)

INTRODUCTION

The sit-to-stand (STS) movement is a common skill of daily living and an important measure of physical function that requires adequate postural control to transfer the center of mass over the feet and maintain alignment of the upper and lower body segments^{1, 2)}. However, children with cerebral palsy (CP) have difficulty in performing STS movement effectively^{3, 4)}, as they often show deficits in movement and postural control. Impairments in muscle function including weakness, spasticity, lack of coordination, and reduced selective motor control result in various abnormal movement patterns during STS in children with CP compared with normally developing children⁵⁾. Therefore, improvement of STS performance is important to allow children with CP to interact with the environment in which they live.

In recent years, a few studies have investigated the effectiveness of STS interventions in children with CP^{6–8)}. After these children used ankle and foot orthoses and underwent a botulinum toxin injection in the ankle plantar flexor muscle, increased ankle dorsiflexion was observed during STS movement^{6, 7)}. Moreover, children with spastic diplegia underwent a neurodevelopmental treatment session in which they performed STS movement. Not only was the ankle dorsiflexion increased, but the forward tilt of the trunk was also decreased⁸⁾. However, despite having beneficial effects, these interventions mainly

*Corresponding author. Abbas Abdolrahmani (E-mail: abas_rahmani@ymail.com)

©2017 The Society of Physical Therapy Science. Published by IPEC Inc.

This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License. (CC-BY-NC-ND 4.0: <http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Table 1. General characteristics of the participants

Participant	Age (months)	Gender	Height (cm)	Weight (kg)	GMFCS	Type
A	76	Male	124	30	I	SH
B	98	Female	120	21	I	SH
C	105	Male	129	25	II	SD
D	103	Male	132	30	I	SH
E	205	Male	169	49	II	SD

GMFCS: Gross Motor Function Classification System, SD: spastic diplegia, SH: spastic hemiplegia

focused on lower limb impairment with less consideration of the key role of trunk control during STS movement^{1, 9, 10}) and its deficit in children with CP¹¹). Moreover, unlike the assumption of previous studies, altered trunk movements by children with CP during gait reflect a true underlying trunk deficit, but the compensatory role of trunk movements with respect to lower limb impairments might be quite limited¹²). From this view, further intervention that targets trunk control deficits in children with CP might facilitate STS movement more efficiently.

To improve trunk control in children with CP, it is difficult to focus on trunk control exercises during conventional therapy. There is some evidence that hippotherapy and its simulator have a positive effect on trunk stability in children with CP^{13, 14}). However, the inevitable risk of falling, high cost of equipment, and need for the active involvement of a therapist limit the wide feasibility of these interventions. Therefore, employing a new, simple, and safe exercise is necessary. Exercise that emphasizes speed has been shown to be an important predictor of balance and functional mobility^{15, 16}). Moreover, several studies indicated that velocity is an essential component of muscle power during functional movements¹⁵⁻¹⁷). Gray et al. reported that performing an exercise that comprised fast functional movements improved muscle activation and postural responses in people with stroke^{18, 19}). However, this exercise was not always safe enough as the participants performed it in a standing position. To reduce this risk, Iwata et al. suggested that fast exercise should be used with the patient in a more stable position^{20, 21}). They used fast trunk movements to assess the mobility of frail, elderly people while they sat on a chair. These studies found that quickness of trunk movement is related to functional performance such as gait and STS movement. From these points of view, we are interested in understanding whether quick trunk movements could be performed safely and could lead to an improved trunk control in children with CP. If their trunk control ability could be improved, STS exercises could also be performed efficiently.

Thus, the purpose of this pilot study was to examine the immediate effects of a quick-seated trunk movement exercise (STE) on STS movement in children with spastic CP to determine whether this exercise improves trunk control and alleviates abnormal trunk movement.

SUBJECTS AND METHODS

Five children with spastic CP who received regular physical therapy were recruited to participate in this study (Table 1). The inclusion criteria were: children with spastic diplegic or hemiplegic CP, age ranging between 6 and 18 years, Gross Motor Function Classification System (GMFCS)²² level of I or II (able to perform STS exercises independently), modified Ashworth scale grade 1-2²³), those without deformities in the lower limbs and did not undergo any orthopedic procedure within the past 6 months, and those with the ability to understand simple commands.

This study complied with the ethical standards of the Declaration of Helsinki. The purpose of this study was explained to the participants' parents, and written consent was obtained. This research study was conducted with the approval of the ethics committee of Osaka Prefecture University (2015-118).

All participants received five sessions of natural STE (NSTE) at a self-selected speed as a control intervention. Following a 50-min rest period⁷), five sessions of the quick STE (QSTE) were conducted as an experimental intervention for each child. Each STE session included 10 repetitions in the anterior-posterior and lateral directions. The duration of each intervention was 5-10 min. Participants were assessed before and after each intervention.

The children with CP were required to sit on a stool that was placed in front of a wall, with a gap of approximately 5 cm between the children's backs and the wall. The trunk was upright and the feet were kept shoulder-width apart. The children raised both of their arms to shoulder height in front and laterally, with the elbows extended as far as they could extend them. For children with spastic hemiplegia, a wooden cylinder block or small-sized ball was used to allow them to achieve symmetric, bimanual reach. Targets (physio rolls) were placed at a distance of approximately 10 cm from the tips of their fingers. The children were asked to tap the targets by moving their trunk, and they repeated this movement while looking forward and without changing the position of their feet. The therapist fixed the child's feet on the floor if he or she tried to widen the area supported by the feet during the exercise. Then, the STE was performed at a self-selected speed and as quickly as possible²¹). The STE session was performed 10 times in the anterior-posterior and lateral directions each. Twenty seconds of rest time

Table 2. Differences in the start position in the pre-test data

Joint angle (°)	Natural STE (n=5)	Quick STE (n=5)
Trunk forward tilt	5.5 ± 2.1	5.6 ± 2.3
Hip flexion	95.4 ± 8.4	94.1 ± 10.4
Knee flexion	87.2 ± 8.2	85.2 ± 10.4
Ankle dorsiflexion	-1.1 ± 4.5	1.4 ± 4.2

STE: seated trunk exercise; max: maximum
Data are presented as mean ± standard deviation

Table 3. Differences in the temporal and kinematic parameters in the pre-test data

	Natural STE (n=5)	Quick STE (n=5)
Temporal parameters		
Total duration (s)	2.40 ± 0.67	2.41 ± 0.54
Before LO (s)	0.85 ± 0.13	0.88 ± 0.17
After LO (s)	1.61 ± 0.55	1.54 ± 0.49
LO (%)	35.9 ± 6.5	37.6 ± 6.5
Kinematic parameters (°)		
Trunk forward tilt max	47.5 ± 8.9	49.9 ± 6.5
Ankle dorsiflexion max	9.3 ± 6.7	8.8 ± 5.7

STE: seated trunk exercise, LO: lift off, max: maximum
Data are presented as a mean ± standard deviation

was set between each session. The total time for each intervention was 5–10 min.

To assess STS movements, we used a motion analysis system (Kinema Tracer, Kissei Comtec, Matsumoto, Japan) with four cameras (30 Hz) that were synchronized with a pressure-sensitive trigger device (100 Hz). Two cameras were placed on each side of the participant: one perpendicular and one oblique to the sagittal plane of their body. Ten markers were placed bilaterally at the acromion process, greater trochanter, lateral tibial condyle, lateral malleolus, and lateral aspect of the fifth metatarsal.

The participants sat on a hard-surface stool that was set at the height of their knee joint in the sitting position. Each participant performed the STS task at a self-selected speed while barefoot, with the soles of their feet on the floor and their hands placed on their chest. Both feet were kept shoulder-width apart. The task began with the participant's trunk positioned as upright as possible and their knees bent at approximately 90°. Participants were asked to look forward and start the task without changing the position of their feet. Five trials were recorded for each child. Among the five trials for each participant, three smooth trials were selected for data analysis.

The sagittal and angular movements of the trunk, hip, knee, and ankle were calculated for a total of 7 lower limbs including the affected side in 3 children with spastic hemiplegia and 2 with spastic diplegia. All these data were normalized from the beginning of the STS task (0%) to the end of the STS task (100%). The beginning of the STS task was the time when the magnitude of the horizontal velocity at the midpoint between the acromion markers was >5% of its peak value²⁴. The time when the magnitude of the horizontal velocity of the midpoint between the hip markers was equal to or less than 0.10 m/s was considered the endpoint of STS task²⁴.

The time at which the electrical waveform that was derived from the trigger device reached its initial lowest electrical voltage was defined as lift off (LO). STS movement was divided into before and after the LO phases. In this way, the total duration of the STS movement and the durations of the two phases were assessed.

Angular movements were defined similarly to those reported in a previous study⁸. Then, we calculated the total STS task duration and the maximum trunk forward tilt and ankle dorsiflexion angle.

The data were analyzed using SPSS version 23 (SPSS Inc.). Data are expressed as the mean ± standard deviation. Non-parametric tests were used for all outcomes. The differences of variables within and between the groups were assessed with the Wilcoxon signed-rank test and the Mann-Whitney U-test, respectively. Significance was accepted for p-values < 0.05.

RESULTS

There was no significant difference between the pre-test data for angular movement in the start position before the NSTE and QSTE (Table 2). Moreover, the temporal and kinematic parameters for all pre-test data had no significant difference

Table 4. Differences in the start position in the pre-test and post-test data for each intervention

Joint angle (°)	Natural STE (n=5)		Quick STE (n=5)	
	Pre	Post	Pre	Post
Trunk forward tilt	5.5 ± 2.1	5.6 ± 1.8	5.6 ± 2.3	5.1 ± 2.4
Hip flexion	95.4 ± 8.4	94.3 ± 4.6	94.1 ± 10.4	92.5 ± 6.4
Knee flexion	87.2 ± 8.2	85.5 ± 9.5	85.2 ± 10.4	86.3 ± 9.9
Ankle dorsiflexion	-1.1 ± 4.5	-2.2 ± 5.1	1.4 ± 4.2	1.6 ± 5.0

STE: seated trunk exercise, Data are presented as mean ± standard deviation

Table 5. Differences in the temporal and kinematic parameters in the pre-test and post-test data for each intervention

	Natural STE (n=5)		Quick STE (n=5)	
	Pre	Post	Pre	Post
Temporal parameters				
Total duration (s)	2.40 ± 0.67	2.24 ± 0.44*	2.41 ± 0.54	2.06 ± 0.45*
Before LO (s)	0.85 ± 0.13	0.83 ± 0.13	0.88 ± 0.17	0.80 ± 0.13
After LO (s)	1.61 ± 0.55	1.41 ± 0.36	1.54 ± 0.49	1.27 ± 0.44
LO (%)	35.9 ± 6.5	37.7 ± 4.5	37.6 ± 6.5	39.8 ± 7.9
Kinematic parameters (°)				
Trunk forward tilt max	47.5 ± 8.9	49.0 ± 5.3	49.9 ± 6.5	49.1 ± 7.5
Ankle dorsiflexion max	9.3 ± 6.7	4.1 ± 6.4	8.8 ± 5.7	9.9 ± 6.2

STE: seated trunk exercise, LO: lift off, Data are presented as mean ± standard deviation, *p<0.05

(Table 3). The start position between the pre-test and post-test data was not significantly different for each intervention (Table 4). There was a significant difference in the total duration of the STS movement before and after NSTE as well as for QSTE. However, no significant change was found in angular movements with either of the interventions (Table 5). In addition, the total duration of STS task increased after NSTE in one subject while that after QSTE decreased in all subjects.

DISCUSSION

This study was conducted to examine the immediate effect of QSTE on STS movement in children with spastic CP. The temporal parameters of the STS movement improved immediately after implementing the QSTE. The aim of this study was to alleviate the abnormal kinematic pattern of the upper body during the STS movement, which was not the focus of previous studies^{6, 8)}. For this purpose, trunk-targeted exercises that emphasized on speed^{18, 19)} were chosen so that participants with CP could perform them safely in a seated position^{20, 21)} to improve trunk control. Therefore, QSTE could facilitate the STS movement by improving trunk control. The exercises may decrease the total duration of STS movement, reduce maximum trunk forward tilt, and allow greater ankle dorsiflexion.

Several studies demonstrated that changing the initial position of the trunk and ankle affects the temporal and kinematic parameters of the STS movement²⁴⁻²⁶⁾. With regard to the present study design, before and after each intervention, the STS movement might be performed in the same initial position. The finding of the present study showed that there was a similar angular movement in the start position before the NSTE and QSTE. Thus, the same STS performance was expected. Although the design of this study was only applicable to a small population size, the possibility of carry-over effects should be considered carefully. For this reason, 50 min of rest time was set between the NSTE and QSTE⁶⁾. As a result, the STS movement had similar temporal and kinematic parameters before NSTE and QSTE, without a carry-over effect. These findings demonstrated that the present study design could clarify the immediate effect of QSTE on the STS movement in children with CP. The total duration of the STS movement significantly decreased after both interventions, which was similar to the results of previous studies^{6, 8)}.

STE may improve trunk control, which in turn would help children with CP to get up faster. Although the total duration of the STS task decreased after both interventions, in one participant, the total duration of the STS movement increased after NSTE while that after QSTE decreased in all participants. Therefore, greater improvement of the STS duration was found in QSTE. As demonstrated previously, fast movement improved muscle activation and postural responses^{18, 19)}. Thus, QSTE helps children with CP to get up faster. According to the hypothesis of this study, both temporal and kinematic parameters might improve after QSTE. However, unlike the results of previous interventions to facilitate STS movements in children with CP, in this study, QSTE did not effectively alleviate abnormal movement patterns. It is known that children with CP

exhibit various impairments in muscle activity and movement coordination⁴). Therefore, these children have difficulty performing effective STS movement, which requires inter-segmental interaction between the upper body and lower limbs^{27, 28}. Lack of inter-segmental interaction during the QSTE may have led to insufficient change in the abnormal kinematic patterns of STS. Further studies are needed to examine the beneficial effects of fast movements that are conducted in multi-segmental structures to improve both the temporal and kinematic parameters of the STS movement in children with CP.

This study has some limitations. First, the sample size was small and it is difficult to generalize the results. Second, the QSTE in this study mainly focused on trunk movement that was insufficient to change the abnormal kinematic patterns of multi-segment tasks in the STS movement.

In conclusion, this study demonstrated that quick trunk exercises that were performed in a seated position immediately improved the temporal parameters of the STS movement in children with CP; however, this exercise could not change the abnormal kinematic pattern of the STS movement.

REFERENCES

- 1) Massion J: Postural control systems in developmental perspective. *Neurosci Biobehav Rev*, 1998, 22: 465–472. [[Medline](#)] [[CrossRef](#)]
- 2) Seven YB, Akalan NE, Yucesoy CA: Effects of back loading on the biomechanics of sit-to-stand motion in healthy children. *Hum Mov Sci*, 2008, 27: 65–79. [[Medline](#)] [[CrossRef](#)]
- 3) Shepherd RB, Gentile AM: Sit-to-stand: functional relationship between upper body and lower limb segments. *Hum Mov Sci*, 1994, 13: 817–840. [[CrossRef](#)]
- 4) Levitt S: Treatment of cerebral palsy and motor delay. New Jersey: Wiley-Blackwell, 2010, pp 125–259.
- 5) Park ES, Park CI, Lee HJ, et al.: The characteristics of sit-to-stand transfer in young children with spastic cerebral palsy based on kinematic and kinetic data. *Gait Posture*, 2003, 17: 43–49. [[Medline](#)] [[CrossRef](#)]
- 6) Park ES, Park CI, Chang HJ, et al.: The effect of hinged ankle-foot orthoses on sit-to-stand transfer in children with spastic cerebral palsy. *Arch Phys Med Rehabil*, 2004, 85: 2053–2057. [[Medline](#)] [[CrossRef](#)]
- 7) Park ES, Park CI, Chang HC, et al.: The effect of botulinum toxin type A injection into the gastrocnemius muscle on sit-to-stand transfer in children with spastic diplegic cerebral palsy. *Clin Rehabil*, 2006, 20: 668–674. [[Medline](#)] [[CrossRef](#)]
- 8) Yonetsu R, Iwata A, Surya J, et al.: Sit-to-stand movement changes in preschool-aged children with spastic diplegia following one neurodevelopmental treatment session—a pilot study. *Disabil Rehabil*, 2015, 37: 1643–1650. [[Medline](#)] [[CrossRef](#)]
- 9) Pai YC, Rogers MW: Speed variation and resultant joint torques during sit-to-stand. *Arch Phys Med Rehabil*, 1991, 72: 881–885. [[Medline](#)] [[CrossRef](#)]
- 10) Yu B, Holly-Crichlow N, Brichta P, et al.: The effects of the lower extremity joint motions on the total body motion in sit-to-stand movement. *Clin Biomech (Bristol, Avon)*, 2000, 15: 449–455. [[Medline](#)] [[CrossRef](#)]
- 11) Heyrman L, Desloovere K, Molenaers G, et al.: Clinical characteristics of impaired trunk control in children with spastic cerebral palsy. *Res Dev Disabil*, 2013, 34: 327–334. [[Medline](#)] [[CrossRef](#)]
- 12) Heyrman L, Feys H, Molenaers G, et al.: Altered trunk movements during gait in children with spastic diplegia: compensatory or underlying trunk control deficit? *Res Dev Disabil*, 2014, 35: 2044–2052. [[Medline](#)] [[CrossRef](#)]
- 13) Hamill D, Washington KA, White OR: The effect of hippotherapy on postural control in sitting for children with cerebral palsy. *Phys Occup Ther Pediatr*, 2007, 27: 23–42. [[Medline](#)] [[CrossRef](#)]
- 14) Shurtleff TL, Engsborg JR: Changes in trunk and head stability in children with cerebral palsy after hippotherapy: a pilot study. *Phys Occup Ther Pediatr*, 2010, 30: 150–163. [[Medline](#)] [[CrossRef](#)]
- 15) Fielding RA, LeBrasseur NK, Cuoco A, et al.: High-velocity resistance training increases skeletal muscle peak power in older women. *J Am Geriatr Soc*, 2002, 50: 655–662. [[Medline](#)] [[CrossRef](#)]
- 16) Bean JF, Herman S, Kiely DK, et al.: Increased Velocity Exercise Specific to Task (InVEST) training: a pilot study exploring effects on leg power, balance, and mobility in community-dwelling older women. *J Am Geriatr Soc*, 2004, 52: 799–804. [[Medline](#)] [[CrossRef](#)]
- 17) Marigold DS, Eng JJ, Dawson AS, et al.: Exercise leads to faster postural reflexes, improved balance and mobility, and fewer falls in older persons with chronic stroke. *J Am Geriatr Soc*, 2005, 53: 416–423. [[Medline](#)] [[CrossRef](#)]
- 18) Gray VL, Juren LM, Ivanova TD, et al.: Retraining postural responses with exercises emphasizing speed poststroke. *Phys Ther*, 2012, 92: 924–934. [[Medline](#)] [[CrossRef](#)]
- 19) Gray VL, Ivanova TD, Garland SJ: Effects of fast functional exercise on muscle activity after stroke. *Neurorehabil Neural Repair*, 2012, 26: 968–975. [[Medline](#)] [[CrossRef](#)]
- 20) Iwata A, Higuchi Y, Kimura D, et al.: Quick lateral movements of the trunk in a seated position reflect mobility and activities of daily living (ADL) function in frail elderly individuals. *Arch Gerontol Geriatr*, 2013, 56: 482–486. [[Medline](#)] [[CrossRef](#)]
- 21) Iwata A, Higuchi Y, Sano Y, et al.: Quickness of trunk movements in a seated position, regardless of the direction, is more important to determine the mobility in the elderly than the range of the trunk movement. *Arch Gerontol Geriatr*, 2014, 59: 107–112. [[Medline](#)] [[CrossRef](#)]
- 22) Palisano RJ, Rosenbaum P, Bartlett D, et al.: Content validity of the expanded and revised Gross Motor Function Classification System. *Dev Med Child Neurol*, 2008, 50: 744–750. [[Medline](#)] [[CrossRef](#)]
- 23) Bohannon RW, Smith MB: Interrater reliability of a modified Ashworth scale of muscle spasticity. *Phys Ther*, 1987, 67: 206–207. [[Medline](#)]
- 24) Khemlani MM, Carr JH, Crosbie WJ: Muscle synergies and joint linkages in sit-to-stand under two initial foot positions. *Clin Biomech (Bristol, Avon)*, 1999, 14: 236–246. [[Medline](#)] [[CrossRef](#)]
- 25) Shepherd RB, Koh HP: Some biomechanical consequences of varying foot placement in sit-to-stand in young women. *Scand J Rehabil Med*, 1996, 28: 79–88. [[Medline](#)]
- 26) Kawagoe S, Tajima N, Chosa E: Biomechanical analysis of effects of foot placement with varying chair height on the motion of standing up. *J Orthop Sci*, 2000, 5: 124–133. [[Medline](#)] [[CrossRef](#)]
- 27) Riley PO, Schenkman ML, Mann RW, et al.: Mechanics of a constrained chair-rise. *J Biomech*, 1991, 24: 77–85. [[Medline](#)] [[CrossRef](#)]
- 28) Schenkman M, Berger RA, Riley PO, et al.: Whole-body movements during rising to standing from sitting. *Phys Ther*, 1990, 70: 638–648, discussion 648–651. [[Medline](#)]