Effect of Exercise on Static and Dynamic Balance in Children with Cerebral Palsy Using a Swiss Ball:A Case Report

Dong-Eun Kim, Eun-Jeong Lee, Jung-Sun Kim, Woo-Nam Chang, Sun-Kyu Lim*

Department of Physical Therapy, Severance Rehabilitation Hospital, Yonsei University Health System

Purpose This study aimed to examine the effect of exercise on static and dynamic balance in children with cerebral palsy (CP) using a Swiss ball. ***Methods*** The subjects(n=7) underwent the Independent Standing Time and Modified Timed Up and Go tests before and after one treatment session with a Swiss ball. We compared these data to specifically determine the effect of the intervention without it being influenced by other variables. ***Results*** We found a significant increase (p<0.05) in the Independent Standing Time with eyes opened and closed after the intervention. We also found a significant difference between the Modified Timed Up and Go test before and after intervention. ***Conclusion*** Thus, exercise with a Swiss ball can improve static and dynamic balance in subjects with CP diplegia.

Key words Cerebral palsy, diplegia, ball exercise, bouncing, swing

Corresponding author Sun-Kyu Lim (bobathlim@yuhs.ac)

Received date 23 December 2016
Revised date 25 January 2017
Accepted date 24 February 2017

Ⅰ. Introduction

Cerebral palsy (CP) comprises a group of disorders characterized by non-progressive impairment in the immature brain, leading to disability in movement and postural control. These symptoms are accompanied by problems related to cognition, sensation, communication, and perception.[1] Most children with CP experience difficulty in walking and complain of poor balance control.[2] In particular, children with spastic diplegia usually have neuromuscular dysfunction in the lower extremities, and they experience difficulty performing normal movements. These children have limitations in standing and gait ability required to independently perform daily activities.[3]

Balance control is defined using two factors. First, static balance is the ability to keep one's center of gravity (COG) stationary, such as during standing or sitting. Second, dynamic balance is the ability to keep one's equilibrium when one's COG changes, such as during walking and running.[4] Balance control is dependent on the central integration of information from the visual, vestibular, and somatosensory systems.[5] It is important thatchildren with CP are provided with postural balance training because of the period during which the central nervous system demonstrates high plasticity in response to sensory stimulation.[6-7] Many studies have investigated the effects of various approaches, including gross motor exercise such as ball exercise and functional electrical stimulation, hippotherapy, and Nintendo Wi-based movement therapy, on balance improvement in children with CP.[8-11]

Ball exercise with unstable surfaces is one of the treatments recommended for children with CP. A Swiss ball is a useful tool to correct posture and it can improve muscle strength(especially of the trunk muscle), endurance, coordination, and flexibility. This leads to an enhanced physical functional capacity resulting from improvements in balance sense and ability by stimulating proprioception.[12-14]

According to Archie et al., Swiss ball exercise with swing in a prone posture can significantly improve movement in children with CP.[15] Hosseini and Ghoochani have reported that Swiss ball exercise involving three motions, up and down(bouncing), to

doi : http:dx.doi.org/10.17817/2017.03.25.5624

and fro, and spinning, is effective in improving gross motor function in patients with CP diplegia.

These studies commonly use Swiss ball exercise using various postures and ways, and propose a correlation between ball exercise and improvements in the functional ability of patients with CP. However, studies using both swing and bouncing motions using a Swiss ball as an intervention are limited. Moreover, investigation of static and dynamic balance in this context is relatively unexplored.

Thus, the aim of this study was to examine the effects of exercise on static and dynamic balance in childrenwith CP using a Swiss ball. We hypothesize that Swiss ball exercise can improve both static and dynamic balance in subjects with CP diplegia.

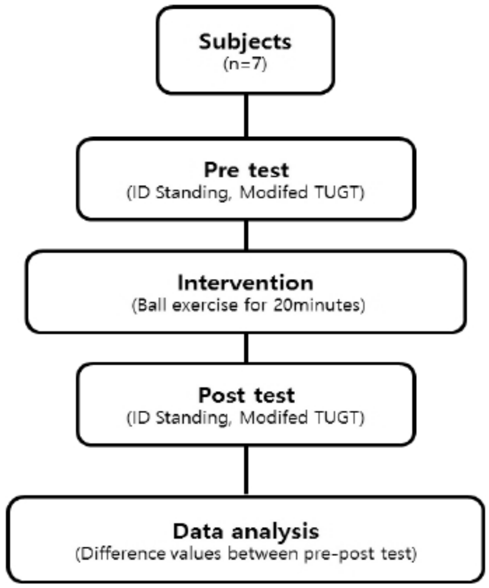


Figure 1. Flow diagram of the experimental protocol.

II. Materials and Methods

1. Participants

A total of 7 children diagnosed with cerebral palsy diplegia at S university hospital in Seodaemun-gu, Seoul, Korea, participated in the study, after having understood its purpose and the procedure of the experiments (Table 1). The subjects were between 3 and 14 years old, and were classified as Level II or higher using the Gross Motor Functional Classification System (GMFCS). None of the subjects were excluded from this study.

2. Procedure

This study investigated the effect of one treatment session (intervention) on two balance measures, without being influenced by other variables. Each subject participated in a ball exercise session for 20 minutes. To evaluate the effect of the intervention session on static and dynamic balance, we performed the Independent Standing Time(ID Standing Time) test and Modified Timed Up and Go test (Modified TUGT) before and after the intervention. The ID standing time test was performed with two conditions: eyes opened and eyes closed. The experimental protocol is presented in Figure 1.

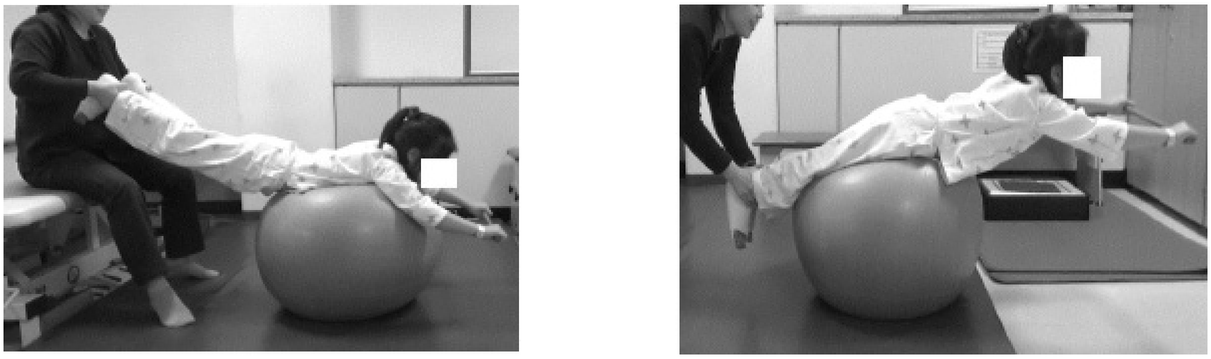
3. Intervention

Each participant performed exercise using a Swiss ball for 20 minutes in two postures, prone and sitting. First, the prone posture was used one way of “To and Fro” with sway accompanied volitional upper extremity extension like superman for 5 minutes(Figure

Table 1. General characteristics of participants (n=7)

	CharacteristicValue (mean ± SD)
Sex (male/female)	4/3
Age (years)	8.71 ± 5.29
Height (cm)	115.43 ± 40.4
Weight (kg)	25.57 ± 19.3
GMFCS (level)	2 ± 1.00

Abbreviations: GMFCS, Gross Motor Functional Classification System; SD, standard deviation.



A B

Figure 2. Prone posture was applied one way of "To and Fro" with sway accompanied volitional upper extremity extension like superman for 5 minutes
A and B : To and Fro

A B C

Figure 3. The sitting posture was used to perform the "Up and Down", "To and Fro", and "Spinning" movements
A : Up and Down B : To and Fro C : Spinning

2). Second, the sitting posture was used to perform the "Up and Down," "To and Fro," and "Spinning" movements (Figure 3). Each session lasted 5minutes, and the participants were instructed to perform rhythmical movements.

4. Examination tools

(1) ID Standing Time

We measured the time for which the subject could stand without external physical assistance. The ID standing time was measured in two ways: standing with eyes opened and standing with eyes closed. The ID standing time with eyes closed was measured while the subject was wearing an eye patch. The distance between the participants' feet was the same for the tests performed before and after the intervention.

(2) Modified TUGT

Modified TUGT measures the time taken for a subject to move forward by three meters without external assistance. The test begins with the child seated such that his/her thigh parallel to the floor and his/hersole is touching the ground. During the course of the test, the child gets up, moves forward by three meters, and comes back to the original position. The subjects are allowed to wear shoes or orthoses which they usually wear, and use a cane or walker, depending on their functional level.

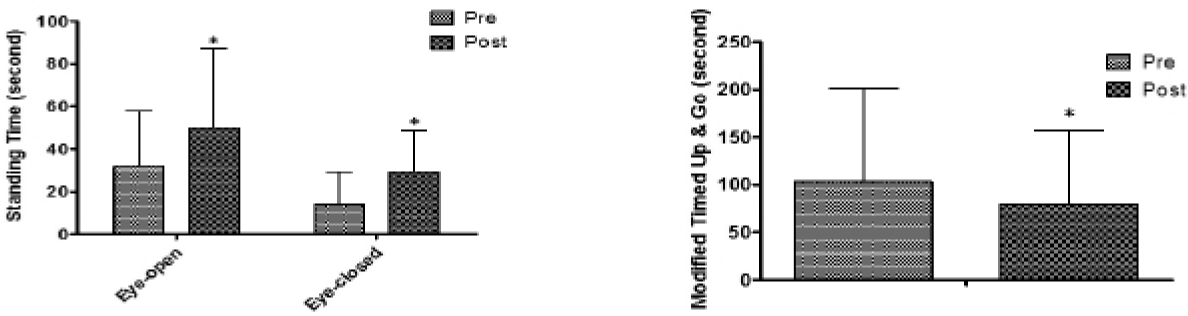
However, they are not allowed to seek external assistance. The difference between this version and the original TUGT is that the modified TUGT can improvethe children's motivation levels by setting up a

A B C

Figure 4. Modified TUGT

A : The test begins with the child seated such that his/her thigh parallel to the floor and his/her sole is touching the ground.

B and C: The difference between this version and the original TUGT is that the modified TUGT can improve the children's motivation levels by setting up a target such as a toy.



A B

Figure 5. Outcome measures pre- and post-intervention

A : ID Standing Time B : Modified TUGT

target such as a toy. Prior to the evaluation, subjects were given the opportunity to practice(16). The test was performed thrice, and the average time recorded across the three trials was used as the final measurement (Figure 4).

III. Results

1. ID standing Time

We found a significant increase (from 32 s to 50 s, $p<0.05$) in the ID standing time with eyes opened after intervention. Similarly, the ID standing time with eyes closed also significantly increased from 14.14 s to 29.43 s ($p<0.05$) (Figure 5).

2. Modified TUGT

In the modified TUGT, there was a statistically significant difference (from 103.57 s to 79.29 s, $p<0.05$) betweenthe time recorded before and after the intervention (Figure 5).

IV. Discussion

All the subjects showed improvements in the ID standing and modified TUGT results following intervention that involved exercise using a Swiss ball. These significant differences between the measurements made before and after the intervention can be explained using the following reasons:

1. Core stabilization

Mostafa et al. argued that exercise performed in the Superman posture promotes core stabilization through core muscle activation. This can be an effective method for trunk tone build-up in patients with diplegia with a poor trunk due to tightness and shortness of iliopsoas, which limits the activity of deep abdominals and gluteus maximus muscles. In Mostafa's experiment, it was confirmed that the stability of antero-posterior and medial-lateral improved by the biodex stability system while standing. Stability of the static posture also promoted dynamic balance through anticipatory postural activity of the feed-forward system for reciprocal movement.[17]

2. Vestibular stimulation

The exercise program using a Swiss ball was performed with a rhythmical sway, which can stimulate the vestibular system of children with CP and diplegia. Vestibular stimulation can affect static and dynamic balance in patients based on the following reasons:

Guyton et al. suggested that vestibular stimulation activates antigravity muscles to control postural tone control and increase equilibrium. Vestibular stimulation facilitates activation of postural muscles of the trunk and limbs; soleus and gastrocnemius, tibialis anterior, gluteus medius, tensor fascia late, iliopsoas, thoracic erector spinae, and abdominals through the lateral vestibulospinal tract.[18] At the same time, stimulation through the medial vestibulospinal tract and vestibulocolic pathway delivers to cervical spinal cord, trapezius, sternocleidomastoid muscle to maintain adjust head position for righting as vestibular stimulation. Facilitation of these muscles allows individuals to maintain appropriate postural tone and posture for static and dynamic balance.[19]

According to Krutsberget al., vestibular stimulation accelerates synaptic maturation of the inhibitory tract. Thismay inhibit inappropriate reflexes like the ATNR to allow posture maintenance and functional movement. It may also reduce pathologically abnormal muscle activation, so that patients can maintain normal body alignment and postural tone.[20]

Vestibular stimulation inputs increase the arousal level in children with CP, thereby promoting interactive interpretation with other sensory inputs. Increased somatosensory inputs by facilitated vestibular system can improve proprioception and raise the body's awareness and control of itself. In addition, improvement of the vestibulo-ocular reflex(VOR) followed by increasing the visual sensory input promotes gaze stabilization in children withCP to maintain a stable visual field. This increased sensory integration may help patients with altered vestibular systems to perform functional movements.[15]

Our study had some limitations. It is difficult to generalize the effects of exercise using a Swiss ball on balance inchildren with CP and diplegia, because the number of subjects and treatment frequency are both low. Second, there is a risk of confounding effects of variables dependent on the body condition, pain, and concentration. of subjects in the process of evaluating results of the comparison of the onetime treatment. The last limitation of our study was absence of balance analysis system like electromyography and the Biodex stability system for accurate interpreting the results. Clinical studies that address these limitations are needed in the future. To improve the clinical applicability of this approach, future studies need to investigate the effects of swinging and bouncing using a Swiss ball as an intervention to improve balance in children with CP.

V. Conclusion

Core stabilization and vestibular stimulation were improved by exercise using a Swiss ball, resulting in increased static balance. As the static balance increased, the dynamic balance also increased by facilitation of reciprocal movement. This improvement led to improvements in the ID standing test and the modified TUGT. Thus, Swiss ball exercise can improve static balance and dynamic balance in children with spastic diplegic cerebral palsy.

References

1. Bax M, Goldstein M, Rosenbaum P, et al. Proposed definition and classification of cerebral palsy. Dev Med Child Neurol. 2005;47(8):571-6.
2. Shahanawaz SD, Tushar J, Palekar, et al. Effect of swiss ball on balance in children with spastic diplegia: a case study. Int J Res Ped. 2015;1(1):8-11.
3. Cerebral Palsy Treatment Ideas. Hong JS. 2nd. Koonja. 2014.
4. Gallahue DL, Ozmun JC. Understanding motor development: Infants, children, adolescents, adults, 6th ed. Boston: McGraw-Hill, 2006.
5. Steindl R, Kunz K, Schrott-Fischer A, et al. A Effect of age and sex on maturation of sensory and balance control. Dev Med Child Neurol. 2006;48:477-82.
6. Alsaif AA, Alsenany S. Effects of interactive games on motor performance in children with spastic cerebral palsy. J Phys Ther Sci. 2015;27:2001-3.
7. Geldhof E, Cardon G. Static and dynamic standing balance: Test-retest reliability and reference values in 9 to 10 year old children., De Bourdeaudhuij I. Eur J Pediatr. 2006;165(11):779-86.
8. Katz-Leurer M, Rotem H, Keren O. The effects of a ‘home-based’ task-oriented exercise programme on motor and balance performance in children with spastic cerebral palsy and severe traumatic brain injury. ClinRehabil. 2009;23(8):714-24.
9. Karabay I, Dogan A. Effects of functional electrical stimulation on trunk control in children with diplegic cerebral palsy, Arslan MD. Disabil Rehabil. 2012;34(11):965-70.
10. Zadnikar M, Kastrin A. Effects of hippotherapy and therapeutic horseback riding on postural control or balance in children with cerebral palsy: A meta-analysis. Dev Med Child Neurol. 2011;53(8):684-91.
11. Gatica-Rojas V, Méndez-Rebolledo G, Guzman-Muñoz E, et al. Balance Board improve standing balance? A randomized controlled trial in children with cerebral palsy. Eur J Phys Rehabil Med. 2016;24.
12. Kim SG, Yong MS, Na SS. The effect of trunk stabilization exercises with a swiss ball on core muscle activation in the elderly. J Phys Ther Sci. 2014;26:1473-4.
13. Kim MK. The effects of trunk stabilization exercise using a Swiss ball in the absence of visual stimulus on balance in the elderly. J Phys Ther Sci. 2016;28(7):2144-7.
14. Marcelo C, Fábio J, Hisa M, et al. Swiss ball exercises improve muscle strength and walking performance in ankylosing spondylitis: a randomized controlled trial. Rev Bras Reumatol(English Edition. 2017;57(1):45-55.
15. Archie H. Children with cerebral palsy: A manual for therapists, parents and community workers. SAGE Publications. 2007.
16. Sanjivani ND, Prema AK, SuvarnaSG. Reliability of “Modified timed up and go” test in children with cerebral palsy. J Pediatr Neuro sci. 2012;7(2):96-100.
17. MostafaS MA, FatenH AE, Ghada MA. Effect of core stabilization program on balance in spastic diplegic cerebral palsy children. 2016
18. Guyton, Hall. Guyton and Hall text book of medicalphysiology. 2006. Elsevier 571-81.
19. Laurie Lundy-Ekman. Neuroscience. Elsevier. 2013.
20. Kreutzberg J. Effects of Vestibular Stimulation on the Reflex and Motor Development in Normal Infants. 1976