Effect of using visual cognitive task on gait in children with spastic diplegia

Zeinb A. Hussein

Department of Pediatric, Faculty of Physical Therapy, Cairo University, Cairo, Egypt

Correspondence to Zeinb A. Hussein, PhD, Pediatric Department, Faculty of Physical Therapy, Cairo University, 7 Ahmed Elzayad, Dokki, Giza 12613, Egypt
Tel: +20 102 041 9642; fax: 202-37617629; e-mail: z3256929@yahoo.com

Received 21 September 2015
Accepted 22 September 2015

Bulletin of Faculty of Physical Therapy
2015, 20:176–180

Background

Cognitive processing plays an important role in motor performance; thus, the aim of this study was to evaluate the effect of concurrent use of visual cognitive task and gait training task on gait in children with spastic diplegic cerebral palsy.

Participants and methods

Fifteen spastic diplgic cerebral palsied children selected from out patient clinic Faculty of Physical Therapy Cairo University (nine boys and six girls) participated in this study. Children with a mean age of 8.15 ± 1.21 years, with a degree of spasticity 2 according to the modified Ashworth scale, with level II according to the Gross Motor Function Classification System, and having a trunk lurching pattern during gait were selected. They received the physical therapy program for an hour and visual cognitive task during gait training for another hour per day. The treatment program was conducted three times per week for 3 successive months. The lateral trunk lurching and gait parameters (spatial and temporal) were assessed, before and after treatments with the proreflex system.

Results

The results revealed a significant decrease in lateral trunk lurching angle before and after treatment ($P < 0.001$), a significant decrease in gait speed and cadence, and a significant increase in stride length and time of double limb support before and after treatment ($P < 0.001$).

Conclusion

The concurrent use of visual cognitive task during gait training in conjunction with physical program improves the stability of trunk and measured gait parameters for children with diplegic cerebral palsy

Keywords:
cerebral palsy, diplegic children, gait, trunk lurching, visual cognition

Bulletin of Faculty of Physical Therapy 20:176–180

1110-6611

Introduction

Cerebral palsy (CP) is a static lesion occurring in the immature brain, which may occur as a developmental defect such as lissencephaly, as an infraction such as a middle cerebral artery occlusion in a neonate, or as trauma during or after delivery. The lesion leaves children with a permanent motor impairment [1]. The lesion is attributed to nonprogressive disturbances that occurred in the developing fetal or infant brain; prenatal events are thought to be responsible for about 75% of all CP cases [2], and 10 to 18% of CP is thought to be caused postnatal [3].

The predominant types of motor impairment of CP are spastic, dyskinetic, and ataxic [4,5]. Approximately, 70 to 80% of children with CP are spastic, which is anatomically distributed into three types: hemiplegia, diplegia, and quadriplegia [6,7]. Spastic diplegia is the most prevalent type of CP, which accounts for about 44% and may account for 50% of the total incidence of CP [8,9].

Walking patterns of diplegic CP children are established at ~5 to 7 years of age and they change with age. The common problems in the stance phase of gait pattern are equinovarus, jump knee, crouch knee, and internal rotation of the legs, whereas shortened step length and impaired foot clearance are the common problems in the swing phase [9]. These problems occur at the sagittal plane, which may coexist with frontal and transverse pathologies [10]. A child with CP may walk with excessive frontal plane sway (trunk lunching gait), which is an increase in the side-to-side movement of the trunk during walking [9]. It is caused by deficiency of balance and it may represent compensation for reduction in the distal degree of freedom [11].

Visual cognition is an ability to manipulate and integrate visual inputs with other sensory information to gain knowledge, solve problems, formulate plans, and make decisions [12]. The visual cognition considered as highest order in a hierarchical model of visual perceptual process, which consists of visual cognition, visual memory, pattern recognition, visual scanning, and visual attention (visual acuity, visual field, and oculomotor control). Therefore, the visual cognitive processing cannot occur without visual attention – that is, the ability of the central nervous system to receive clear, concise visual input from the environment through the visual functions of oculomotor control, visual fields, and visual acuity [13].

Simultaneous using of cognitive task and motor task is defined as a dual-task condition which requires high attention, therefore attention divided into two tasks [14,15]. The attentional requirements of balancing of a CP child when performing a task, while simultaneously performing a second cognitive task cause reduced attention to balance control and an increased risk for falls [16]. Thus, the aim of this study was to evaluate the concurrent use of visual cognitive task and gait training task on gait in children with spastic diplegic CP.

Participants and methods

This study was conducted on 15 spastic diplegic CP children (nine boys and six girls). They were selected from the outpatient clinic, Faculty of Physical Therapy, Cairo University. Children with a mean age of 8.15 ± 1.21 years [17–19], a degree of spasticity of 2 according to the modified Ashworth scale [20], and level II of the Gross Motor Function Classification System [21] were included in the study. They had trunk lurching gait pattern, intelligence quotient not less than 85 on Stanford Binet as referred by a psychologist, and the ability to see, hear and communicate, whereas children with fixed deformities in the ankle or knee joints were excluded from the study. Parents of children with selected criteria were asked to sign an informed consent form approved by the Committee on the Protection of the Rights of Human Subjects at the Faculty of Physical Therapy.

The children received selected physical therapy program for 1 h, in addition to gait training with concurrent visual cognitive task for another 1 h. The treatment was conducted three times per week for 3 successive months. Trunk lurching angle from the frontal plane during walking and kinematic gait parameters (spatial and temporal) were measured using the proreflex system before and after treatment procedures.

Assessment procedures

The trunk lurching and gait parameters were measured with the proreflex system, which consists of six cameras acting as three-dimensional cameras; it was calibrated using a wand-kit, moving it in three planes, the X, Z, and Y planes, to assure accuracy of the values obtained by viewing the dots on three cameras on each side. The reflected dots were put bilateral on both sides on the anterior superior iliac spines, lateral malleolus, the base of fifth metatarsal bones, and sternal notch, for every child.

Each child was asked to walk from the end of a wooden walkway to its other end far enough from the measurement area to enable the child to take a natural walking pattern without any interference to his or her gait pattern, but care was taken to keep him or her from falling. The gait cycles were captured within the measuring area (complete cycle starts from initial contact of one leg to terminal swing of the same leg), selectively entered into the Q_tools software and then imported into the TSV file to be saved and analyzed. The data displayed from the proreflex system are as follows:

(1) The peak angle of trunk deviation (peak-to-peak angle in degrees), which is the summation of the angle of maximum deviation of the trunk to the right side with the angle of maximum deviation to the left side. This angle is considered as amount of trunk lurching [22].
(2) Kinematic gait parameters (spatial and temporal): Spatial parameters are velocity and stride length, and temporal parameters are percentage of swing time, percentage of stance time, and cadence [14].

Treatment procedures

(1) The physical therapy program included gait training, start with side way walking, then forward walking, and end by backward walking, also increase difficulty of each exercise by using stepper, obstacles of different sizes and up and down stairs of different heights, and balance exercise applied by using wooden and soft ramps, balance board, and balance beam.
(2) Visual cognition task.

Selection of pictures

About 204 pictures were selected, which were familiar to normally developed children to be identified and named at this age. These pictures were grouped into six groups as follows: group 1 included 38 pictures of foodstuffs such as fruits, vegetables, and sandwich; group 2 included 44 pictures of animals and plants; group 3 included 26 pictures of means of transportation; group 4 included 36 pictures of clothes; group 5 included 20 pictures of furniture; and group 6 included 40 pictures of tools used in home, or in the school [14]. Each child was first seated on a comfortable chair in front of the laptop to identify and name all pictures.

Time of picture rotation

Pictures were changed at a rate of one picture every 3 s, which was calculated using a stop watch [23]. Moreover, we conducted a pilot study to ensure the time taken to name each picture.

Picture presentation

The pictures were presented on Microsoft Power Point slide 2010 United States on full screen by choosing slide show tool on the laptop, with the height of the tripod at the level of the child's eyes using the height scale.

The task during gait training

The child was asked to stand at the end of the walkway 6 m away from the laptop. Children were instructed to walk directly forward without stopping and without deviation and concentrate on the pictures in front of them and say its name clearly. Verbal guidance was used to prevent the child from falling and also to reward for the accurate answer as very good, excellent, or that is well. The training was carried out for 1 h per time, three times per week, for 3 successive months. The pictures were selected from groups and changed after two or three times of training to keep the interest of the child well.

The pretreatment and post treatment mean values of gait parameters (spatial and temporal), and the trunk lurching angle were measured and compared by using unpaired t test. Statistical Package for Social Sciences (SPSS) computer program (version 19 windows) was used for data analysis. P value ≤ 0.05 was considered significant.

Results

The post treatment mean values of trunk lurching angle (the peak angle of trunk deviation) decreased to 21.8 ± 7.23° degrees with mean difference about 18.53° which was statistically significant (P < 0.001) (Table 1).

Gait parameters

On comparing the post-treatment mean values of velocity (1.07 ± 0.17 m/min), percentage of stance time (69.21 ± 7.04% of time of total gait cycle), and cadence (75.36 ± 16.61 steps/min) to the pretreatment mean values (1.14 ± 0.21 m/min, 84 ± 5.07% of time of total gait cycle, and 79.07 ± 14.85 steps/min, respectively), there was a decrease with significant differences (P < 0.05*), whereas there was an increase in the post-treatment mean values of stride length (61.00 ± 12.29 cm) and percentage of swing time (31.05 ± 6.8%), with significant differences (P < 0.05*) when compared with the pretreatment mean values, which were 46.86 ± 120.61 cm and 15.57 ± 5.23%, respectively (Table 2).

Discussion

Children in this study used visual cognitive task concurrently during gait training as a rehabilitation program adjunct with physical therapy program. The results showed decrease in the angle of lateral trunk lurching (deviation of trunk laterally) and change in gait parameters after training for 3 months. In visual cognitive task, interesting and motivating pictures

Table 1 Comparison between pretreatment and post-treatment mean values of peak-to-peak angle of lateral trunk deviation

Time of test	Sample size	Mean ± SD (deg.)	Mean difference	*t*-Value	*P*-value (<0.05)	Percentage of improvement
Pretreatment	15	40.33 ± 12.34°	18.53°	6.8	*	45.94%
Post-treatment	15	21.8 ± 7.23°				

*Significant.

Table 2 Comparison between pretreatment and post-treatment mean values of kinematic gait parameters

Gait parameters	Time of test	Sample size	Mean ± SD	Mean difference	*t*-Value	*P*-value (<0.05)
Spatial						
Velocity (m/min)	Pretreatment	15	1.14 ± 0.21	0.07	2.95	*
	Post-treatment	15	1.07 ± 0.17			
Stride length (cm)	Pretreatment	15	46.86 ± 120.61	14.14	12.03	*
	Post-treatment	15	61.00 ± 12.29			
Temporal						
Stance time %	Pretreatment	15	84 ± 5.07	−14.79	19.72	*
	Post-treatment	15	69.21 ± 7.04			
Swing time %	Pretreatment	15	15.57 ± 5.23	15.93	11.78	*
	Post-treatment	15	31.05 ± 6.8			
Cadence (steps/min)	Pretreatment	15	79.07 ± 14.85	3.71	2.45	*
	Post-treatment	15	75.36 ± 16.61			

*Significant.

were used for the children to identify and name during the gait training program, which increased the level of complexity of cognitive tasks by increasing sensory information at the tasks (visual and proprioception) and by dividing attention between two tasks (visual task and postural control during walking). After training, it was found that lateral trunk lurching angle decreased which might increase postural control, because the child used attention in its two levels: a voluntary level (directed by the cortex), which focuses on decreasing body sway, and an automatic or reflexive level (controlled by brain stem), which focuses on pictures appearing in the peripheral visual field. These results were supported by Sethi and Raja [24], Marshall *et al.* [25], and Bensoussan *et al.* [26], who mentioned that when the task places a greater difficulty on a child, it is effective in improving balance and functional recovery and that interactions between cognitive function and motor behaviors improve attention with training, which could affect balance.

The trunk lurching angle (body sway) decreased by 18.53° in post training program with using visual cognitive task during walking (Table 1). It was found that the visual feedback information is primarily used to control balance in the laterolateral direction, as the visual system provides information not only about the target distance and presence of obstacles but also about maintaining balance during walking and adjusting trajectories when an obstacle appears or if the target is shifted [27–29]. This agreed with the opinion of Levitt [30], who stated that the most treatment programs use more afferent stimuli of visual, auditory, and proprioceptive stimuli with various methods intended for reduction of abnormal postural alignments and stimulate normal movement pattern.

Moreover, improvement of good alignment of the trunk after gait training using visual task may be due to use visual gaze on the fixed picture in front of the child's sight, that also concluded by Cromwell *et al.* [31], that gaze stabilization was expected to gradually facilitate head and trunk vertical alignment as stationary visual information has a stabilizing effect on posture. There is a reciprocal relationship between head–trunk stability and gaze stability. This vertical alignment of the trunk facilitates the vestibular system, which sends motor control signals through the nervous system to the muscles of the eyes with the vestibule-ocular reflex. The vestibule-ocular reflex is responsible for maintaining stability of the image on the center (fovea) of the retina during rapid head movement. This enables the eyes to remain fixed in pace (gaze stability) during functional task and so gaze stabilization exercise, which utilizes the focal vision, is commonly used to rehabilitate patients with postural imbalance and vice versa [32–34].

The parameters of gait changed after training using visual cognition, as interference of attention divided between the two tasks, leading to decrease in the post-treatment mean value of velocity compared with pretreatment mean values when walking at 0.07 m/min. This may have an impact on trunk stability, as the body can be displaced with a proper speed, keeping it more constant as possible for the conservation of momentum and minimizing upper body oscillations and hence the risk of fall [35,36]. Slow gait velocity that occurred in post treatment gait pattern, it might provide greater stability by decreasing trunk sway and increasing percentage of stance time (i.e: time at which the both feet are on the ground simultaneously) [37]. The improvement in the percentage of stance time and swing time might be due to the improvement of trunk stability, which is essential to the control of walking [38].

Training improves the ability of the child to direct attention selectively, which is one of the most important things that is emphasized by established motor learning theories and strategies. Introduction of early distraction to visual task other than the motor task may improve children's ability to deal with irrelevant information, and gives the children a chance to develop strategies for selective attention that can be learned at the real-world environment. In the study, the children acquired ability to direct their attention towards the cognitive recourses while the attention required for planning and performing of the motor task was decreased, and they were able to process and interpret the different feedback information including those pertaining to their performance and make an adequate corrective response, improving the efficiency of feedback [39,40]. In addition, the concurrent use of cognitive and motor tasks at the same time (dual-tasks) decrease gait velocity, which in itself is associated with a decrease in body sway. The slowing of the gait is to reduce the risk of falling in more difficult circumstances to perform a dual task [40]. Effects of concurrent cognitive tasks on locomotor performance in children can lead to larger steps when walking under dual task conditions; this improvement may be due to increased attention to step length as child attempts to reach to the pictures without falling [41].

The results of this study contradicted with those of Brauer *et al.* [42], who revealed that when the children with spastic CP performed two tasks simultaneously, it appeared that they directed their attentional resources primarily to the performance of the cognitive task, resulting in a decrement in the secondary task of postural control.

Limitations of the study

The sample size in the study was small due to limited inclusive criteria of selected children, and the study was limited to children who were unable to identify a picture for three trials.

Conclusion

When visual cognitive task was used concurrently with gait training for 3 successive months, lateral trunk lurching (body sway) decreased and stride length and stance time % increased, whereas velocity and cadence during walking decreased in children with spastic diplegic CP. Therefore, the concurrent use of visual cognition with gait training could increase postural control on trunk and lower limbs.

Acknowledgements

The author thanks Professor Kamal El Shokry, Professor of Physical Therapy in Pediatrics at Faculty of Physical Therapy, Cairo University, and also to Amira Y. El-Dwiny, MSc in Physical Therapy in Pediatrics.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Miller P, Osmotherly P. Does scapula taping facilitate recovery for shoulder impingement symptoms? A pilot randomized controlled trial. J Man Manipulative Ther 2007; 17:6–13.

2 Rosenbaum P, Paneth N, Leviton A. A report: the definition and classification of CP. Dev Med Child Neurol Suppl 2007; 109:8–14.

3 Reddihough DS, Collins KJ. The epidemiology and causes of cerebral palsy. Aust J Physiotherapy 2003; 49:7–12.

4 Bax M, Goldstein M, Rosenbaum P, Leviton A, Paneth N. Proposed definition and classification of cerebral palsy. Dev Med Child Neurol 2005; 47:571–576.

5 Berger W. Characteristics of locomotor control in children with cerebral palsy. Neurosci Biobehav Rev 1998; 22:579–582.

6 Panteliadis, C.P. Classification. in: C.P. Panteliadis, H.M. Strassburg (Eds.) Cerebral palsy: principles and management. Thieme, Stuttgart (Germany); 2004.

7 Tecklin JS. The infant and child with cerebral palsy. In: *Pediatric physical therapy*. 5th ed. edited by Beaman J, Kalisperis FR, Skomorucha KM. Philadelphia: Lippincott Williams & Wilkins, a Wolters Kluwer business; 2015. 196–246.

8 Morton, R, Benton, S, Bower, E. Multidisciplinary appraisal of the British Institute for Brain Injured Children, Somerset, UK. Dev Med Child Neurol 1999; 41:211–212.

9 Berker N, Yalçin S. *The help guide to cerebral palsy*. 2nd ed. Seattle, WA: Global Help Organization. Avrupa Medical Bookshop & Publishing, Istanbul (Turkey); 2010.

10 Dobson F, Morris ME, Baker R. Gait classification in children with cerebral palsy: a systematic review. Gait Posture 2007; 25:140–pp152.

11 Degelaen M, Leurs F, De Borre L, Kerckhofs E, De Meirleir L. Effect of ankle-foot orthoses in gait in typically developing children: development trend in segmental coordination. J Ped Rehab Med 2010; 3:163–170.

12 Warren M. A hierarchical model for evaluation and treatment of visual perceptual dysfunction in adult acquired brain injury, part1. Am J Occup Ther 1993; 47:42–54.

13 Schneck C. Visual perception. In Case-Smith J. & O'Brien J. (Eds.), *Occupational therapy for children* (6th ed.). Maryland Heights, MO: Mosby/Elsevier; 2010; 375–433.

14 Huang HJ. Effects of different concurrent cognitive tasks on temporal-distance gait variables in children. Pediatr Phys Ther 2003; 15:105–113.

15 Wright DL, Kemp TL. The dual-task methodology and assessing the attentional demands of ambulation with walking devices. Phys Ther 1992; 72:306–315.

16 Reilly DS, Woollacott MH, Donkelaar PV. The interaction between executive attention and postural control in dual-task conditions: children with cerebral palsy. Arch Phys Med Rehabil 2008; 89:834–842.

17 Diamond A, Taylor C. Development of an aspect of executive control: development of the abilities to remember what I said and "do as I say, not as I do." Dev Psychobiol 1996; 29:315–334.

18 Assainte C. Development of locomotor balance control in healthy children. Neurosci Biobehav Rev 1998; 22:527–532.

19 Mezzacappa E. Alerting, orienting, executive attention: develop-mental properties and sociodemographic correlates in an epidemiological sample of young, urban children. Child Dev 2004; 75:1373–1386.

20 Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther 1987; 67:206–207.

21 Palisano RJ, Rosenbaum P, Bartlett D. Content validity of the expanded and revised gross motor function classification system. Dev Med Child Neurol 2008; 50:744.

22 Hsue BJ, Miller F, Su FS. The dynamic balance of the children with cerebral palsy and typical developing during gait. Part 1: spatial relationship between COM and COP trajectories. Gait Posture 2009; 3:465–470.

23 Mulavara AP, Ruttley T, Cohen HS, Peters BT. Vestibular-somatosensory convergence in head movement control during locomotion after long-duration space flight. J Vestib Res 2012; 22:153–166.

24 Sethi V, Raja R. Effects of dual task training on balance & activities of daily livings (adls). Int J Biol Med Res 2012; 3:1359–1364.

25 Marshall SC, Grinnell D, Heisel B, Newall A, Hunt L. Attentional deficits in stroke patients: a visual dual task experiment. Arch Phys Med Rehabil 1997; 78:7–12.

26 Bensoussan L, Viton JM, Schieppati M, Collado H. Changes in postural control in hemiplegic patients after stroke performing a dual task. Arch Phys Med Rehabil 2007; 88:1009–1015.

27 O'Connor SM, Kuo AD. Direction-dependent control of balance during walking and standing. J Neurophysiol 2009; 102:1411–1419.

28 Reynolds RF. Visual guidance of the human foot during a step J Physiol 2005; 569:677–684.

29 Hallemans A, Ortibus E, Meire F, Aerts P. Low vision affects dynamic stability of gait. Gait Posture 2010; 32:547–551.

30 Levitt S. *Treatment of cerebral palsy and motor delay*. 5th ed. Blackwell Oxford; 2010. 73–74.

31 Cromwell RL, Pidcoe PE, Griffin LA, Sotillo T. Adaptations in horizontal head stabilization in response to altered vision and gaze during natural walking. J Vestib Res 2004; 14:367–pp373.

32 Harris LR. Visual–vestibular interactions. In: Squire LR, editor. *Encyclopedia of neuroscience*. Academic Press, Oxford 2009; 10:381–387.

33 Chen R, Hsieh W, Wei S, Kao C. Interactive wiimote gaze stabilization exercise training system for patients with vestibular hypofunction. J Neuroeng Rehabil 2012; 9:77.

34 Schweigart G, Mergner T, vdokimidis I, Morand S. Gaze stabilization by optokinetic reflex (OKR) and vestibulo-ocular reflex (VOR) during active head rotation inman. Vision Res 199737:1643–1652.

35 Bruijn SM, Meyns P, Jonkers MI, Kaat D, Duysens J. Control of angular momentum during walking in children with cerebral palsy. Res Dev Disabil 2011; 32:2860–2866.

36 Simoneau GG. Kinesiology of Walking. In: Neumann DA, editor. *Kinesiology of the musculoskeletal system: foundations for physical rehabilitation*. St Louis, Missouri: Mosby; 2002. 523–569.

37 Schmidt RA, Wrisberg GA. *Motor learning and performance: a problem-based learning approach*. Champaign, IL: Human Kinetics; 2008.

38 Massion J. Postural control system. Curr Opin Neurobiol 1994; 4. 877–887.

39 Larin H. Quantifying instructional interventions in pediatric physical therapy with themotor teaching strategies coding instrument (MTSCI-1): a pilot study. Internet J Allied Health Sci Pract 2007; 5:1–9.

40 Van Iersel MB, Ribbers H, Munneke M, Borm GF. The effect of cognitive dual tasks on balance during walking in physically fit elderly people. Arch Phys Med Rehabil 2007; 88:187–191.

41 Brauer SG, Woollacott MH, Lamont R, Clewett S. Single and dual task gait training in people with Parkinson's disease: a protocol for a randomised controlled trial (2011)

42 Brauer SG, Broome A, Stone C, Clewett S, Herzig P. Simplest tasks have greatest dual task interference with balance in brain injured adults. Hum Mov Sci 2004; 23:489–502.