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ORIGINAL ARTICLE

Effect of a new physical therapy concept on dynamic balance in children with spastic diplegic cerebral palsy

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KEYWORDS

Antigravity;
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Abstract *Background:* Treadmill gait training as a therapeutic resource in the rehabilitation of children with cerebral palsy (CP) has recently been the focus of many studies; however, still little is known regarding the effect of antigravity treadmill (AGT) on dynamic balance in children with spastic diplegia.

Aim of the study: This study aims to evaluate the effect of gait training using AGT on standing balance of the spastic diplegic cerebral palsy (SDCP) children.

Subjects and methods: 30 SDCP children (6–8 years old), from both sexes, participated in this study. They were divided randomly into 2 groups: control group (group A) and study group (group B). The control group received a specially designed therapeutic exercise program; while the study group received gait training using AGT, for 20 min, 3 times weekly, for 3 months, in addition to the same exercise program given to the control group. The Biodex balance system was used for the assessment of the dynamic postural control of all participants.

Results: The results revealed no significant difference when comparing the pretreatment mean values of the 2 groups, while significant improvement was observed in all the measured variables of the 2 groups when comparing their pre and post treatment mean values. A significant difference was also observed when comparing the post treatment results of the 2 groups in favor of the study group.

Conclusion: It can be concluded that gait training using AGT could be used as an effective method for improving standing balance for children with SDCP.

1. Introduction

Cerebral palsy (CP) is a group of permanent and non-progressive disorders of posture and movement caused by brain lesion or dysfunction occurring early in life [1]. The birth prevalence of cerebral palsy has significantly risen to 2.0 per 1000 life

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births over the last 40 years [2]. Spastic diplegia is one of the most common clinical subtypes of cerebral palsy. It is used when there is more motor impairment in the lower extremities than the upper extremities. Most children have significant weakness in the trunk and spasticity of the extremities [3].

Spastic diplegia accounts for about 44% of the total incidence of CP. It is the principal of cerebral palsy in preterm infants. It represents 80% of preterm infants and in a recent series it represents 18% of the overall CP children [4].

Postural control, specifically postural stability, is a fundamental prerequisite for motor development in children [5]. It means the ability of an individual to maintain his center of gravity over the base of support [6], when he is standing still (static balance), during motion (dynamic balance), initiating movement or preparing to end a movement [5]. The delicate integration of vision, vestibular and proprioceptive sensations, commands from the central nervous system and neuromuscular responses, particularly muscle strength and reaction time is fundamental for postural control [7,8].

Postural control abnormalities are a major limitation to the motor development in children with CP [9]. These children demonstrate a number of limitations caused by instability on the performance of static and dynamic tasks, such as sitting, standing and walking [9–12]. The clinical picture of CP includes neuromuscular dysfunctions, such as the loss of selective motor control and muscle tone disturbance, leading to an imbalance between agonist and antagonist muscles, coordination disturbance, sensory alterations and weakness[13]. Postural unsteadiness of children with CP is evident from the greater oscillations of the center of pressure (COP) in the anteroposterior (AP) and mediolateral (ML) directions, even with the use of the lower limb braces [14].

Different methods have been used to improve postural control in CP children [15–17]. In recent years, gait training on a treadmill has been used in the treatment of children with CP aiming to enhance postural stability [18–24]. Treadmill training is believed to improve postural control by allowing multiple repetitions of the steps of the gait cycle in a rhythmic pattern, thereby improving harmonization between agonist and antagonist muscles and resulting in improved static and dynamic balance [18–24]. Recent study, that compared treadmill training versus over ground walking effects on balance skills in children with CP from 3 to 12 years old, indicated that the treadmill group had higher Berg balance scale scores and showed lesser mediolateral oscillation with eyes open in comparison to the control group [25].

From the neurophysiological point of view, neuroplasticity in the damaged nervous system can be enhanced through walking on a treadmill with body weight partially supported (BWST) [26,27]. This reorganization is partly motivated by afferent somatosensory signals that are activated through the action of the treadmill belt [28–31]. Several investigations have shown that the sensorimotor experience from BWST can improve postural balance of children with CP [32–36].

The antigravity treadmill (AGT) consists of a standard treadmill but with an inflatable fabric enclosure that covers the treadmill. In the center of the enclosure is a hole through which the user steps onto the surface of the treadmill. The subject wears a special pair of shorts, and these shorts are zipped into the hole in the enclosure. The enclosure is filled with air by a blower. The pressure inside the inflated enclosure provides a lifting force against the body. The AGT provides a level of comfort while exercising unmatched by other unweighting systems. The percentage of body weight supported is determined by the air pressure in the bag, which provides a lifting force on the body [37].

Recent experiments have shown that AGT has similar biomechanical and physiologic responses as the more traditional harness-based body weight support systems [37,38]. No studies however, have investigated the possible effects of gait training using AGT on dynamic balance in children with SDCP. Therefore, the aim of this study was to verify whether SDCP children's balance was significantly affected by gait training using AGT.

2. Subjects and methods

Thirty spastic diplegic CP children from both sexes participated in this study. They were selected from the pediatrics out-patient clinic of the Hospital of Medical Rehabilitation, Almadinah Almonawara, Kingdom of Saudi Arabia. Their ages ranged from 6 to 8 years old. They were divided randomly into two groups: Group A (control group) included 15 children (9 boys and 6 girls). They received a specially therapeutic exercise program. Group B (study group) included 15 children (9 boys and 6 girls), and they received the same therapeutic exercise program in addition to gait training using AGT. Fig. 1 represents the flow chart of participation throughout the study.

2.1. Choice of sample

The subjects were selected according to the following criteria: (1) spasticity grades ranged from 1 to 1^+ according to modified Ashworth scale [39], (2) no hearing defects, (3) no fixed deformity of both lower limbs, (4) absence of cognitive or visual impairment that could compromise the performance of the tasks. Informed consent was obtained from all parents. This study was approved by the Hospital of Medical Rehabilitation, Almadinah Almonawara, Kingdom of Saudi Arabia. This study was carried out in accordance with The Code of Ethics of The World Medical Association (Declaration of Helsinki).

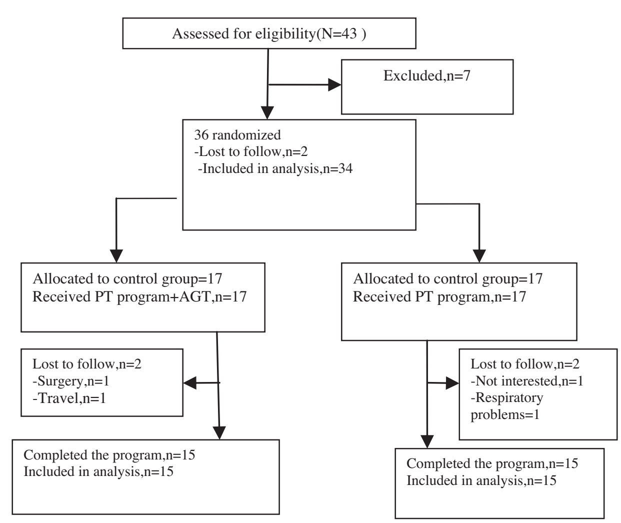

Figure 1 Flow chart of participation throughout the study.

2.2. Instrumentations

2.2.1. A. Equipment used for evaluation

1. *Modified Ashworth scale*: adapted from Bohannon and Smith, 1987 [39].

2. *Biodex Stability System*: the Biodex stability system, was used to test the balance of all the subjects. It consists of a movable balance platform which can be set at variable degrees of instability. The system is interfaced with computer software monitored through the control panel screen and with Cannon Bubble Jet Printer to print the test results.

2.2.1.1. The components of the Biodex stability system. The components of the Biodex stability system include:

1. The foot platform: It provides up to 20° of surface tilt in 360° range.

2.2.1.2. The control panel screen. Stability levels: Biodex stability system allows for eight stability levels, which range from stability level one to stability level eight. Stability level eight is the most stable level. On the other hand, stability level one is the least stable level.

Stability indices (SI): The system measures the subject's ability to control the platform's angle of tilt. The patient's performance is noted as stability index. The stability index represents the variance of the platform displacement in degrees. A high number is indicative of a lot of motion, which indicates balance problem. The system supplies the data regarding the balance of the tested subject. These data include (1) anteroposterior (AP) stability index which represents the variance of the foot platform displacement in degrees, from level, for motion in the sagittal plane. (2) Mediolateral (ML) stability index which represents the variance of the foot platform displacement in degrees, from level, for motion in the frontal plane. (3) Overall stability index: represents the variance of the foot platform displacement in degrees, from level, in all motions during the test.

2.2.2. B. Equipments used for treatment

2.2.2.1. Instruments used at treatment program. Mat, rolls, medical ball, wedges, balance board and standing bar were used in the treatment program.

2.3. Methods

2.3.1. For evaluation

2.3.1.1. Spasticity evaluation. Modified Ashworth scale was used [40]. The degree of spasticity was evaluated by passive movement for both limbs while the child was completely relaxed, lying supine on a mat with the head in mid position. The test was repeated 3 times and the mean record was taken to refer accurately to the degree of spasticity.

2.3.1.2. The Biodex stability evaluation. It was used for the assessment of the dynamic postural control of all participants before and after 3 months of treatment (using dynamic balance test). The aim of the evaluation was explained to every child and his parents before the start of the study. Each child was instructed to remove his or her shoes and step onto the foot platform of the device. The position and height of the handles of support were adjusted according to the subject height and comfort, to grasp it during learning the test procedures before starting the test.

2.3.2. Dynamic balance test sequences

All subjects were given an explanatory session before the evaluative procedure to be aware of the different test steps. Each child in both groups was asked to stand on the center of the locked platform with two legs stance. Safety support rails and biofeedback display were adjusted for each child to ensure comfort and safety. The display was adjusted so that the child can look straight at it.

2.3.2.1. The following test parameters were introduced to the device in this study. Child's height and chronological age, Platform firmness (stability level): All children were tested on the stability levels; level 8 (the most stable) and level 3 (less stable) during the same set of testing, beginning at level 8 and ending at level 3, for three time repetition for each trial. The mean of the three trials was calculated and recorded for each child individually before and after 3 months of treatment (all children were tested for 1 min for the three repetitions).

Patient centering steps: It was performed to position the center of gravity (COG) over the point of the vertical ground reaction force. Centering was achieved by asking the child to stand on both feet, while grasping the handrails. The child was instructed to achieve a centered position on a slightly unstable platform by shifting his feet position until keeping the cursor (which represents the center of the platform) centered on the screen grid while standing in a comfortable and upright position. Once centering was achieved and the cursor was adjusted in the center of the display target, instruction was given to the child to maintain his feet position till stabilizing the platform. This was followed by recording feet angles and heels coordinate from the platform. After introducing these angles into the Biodex system, the child was instructed to focus on the screen and the test then begins. At the end of each test trial, a print out report was obtained. This report includes information regarding overall, mediolateral and anteroposterior stability indices. Every child was assessed before the application of the treatment program and reassessment was done after 3 months of using the treatment program.

2.3.3. B. For treatment program

The control group: Children in the control group received a selected physical therapy program of one hour session, three times per week for three successive months. This program is based on the neuro developmental approach directed toward inhibiting abnormal muscle tone and abnormal postural reflexes and facilitation of normal movement patterns. The postural control was addressed through reflex inhibiting positions using proximal and distal key points of control. Treatment was conducted through a set of therapeutic activities as follows: approximation, as a proprioceptive training, was applied in a slow and rhythmic manner for upper limbs, lower limbs and trunk to control spasticity and stimulate the joint mechanoreceptors from semi reclined and quadruped positions; training of active trunk extension; facilitation of righting and equilibrium reactions to improve postural mechanisms, through using specific exercises; like tilting at different directions using therapeutic balls and balance board; facilitation of protective reactions by applying fast and large amplitude stimuli to prompt saving reactions from sitting on the roll. Protective reactions from standing position were promoted by pushing the child to improve the child ability to take protective steps forward, backward or sideways to regain balance. Facilitation of standing from supine and prone positions as well as facilitation of single limb support while standing facing the stand bar. Strengthening exercises for weak muscles particularly knee extensors, hip abductors and ankle dorsiflexors muscles. Gait training activities were also essential elements for balance training including; sideway, forward and backward walking between parallel bars in front of a large mirror and walking training using stepper. Gait training at open environment was used by placing obstacles; like rolls and wedges across walking tract. Also, walking training on different surfaces like soft mat, sponge, carpet, or hard surface was used [40].

2.3.4. C. The study group

The Alter G anti-gravity treadmill was used for gait training. It consisted of a treadmill that was enclosed in a pressurized bag (Fig. 2). Gait training program was performed for 20 min, 3 times per week for 12 weeks. This protocol was similar to the protocol developed by Dodd and Foley [20]. The exercise session passed through the following steps: (1) putting on the shorts: the child wore a pair of neoprene shorts, (2) stepping into the AGT: the cockpit was lowered so it compressed the bag against the treadmill surface then the child entered from the back and stepped into the opening in the fabric enclosure, (3) adjusting the height of the cockpit, (4) zipping into the fabric enclosure: neoprene shorts were zipped into the bag, (5) adjusting percentage of body weight with the (+) and (−) button. (6) Adjusting treadmill speed: Speed was incremented and decremented by pressing the (+) or (−) button controls. As it is difficult for children with cerebral palsy to reliably report their comfortable walking speed on a treadmill, therefore based on our pilot work and the work of others and the fact that comfortable speeds on a treadmill are slower than over ground walking [41], a comfortable treadmill speed was selected for all participants as 75% of their comfortable speed during over-ground walking [42].

Figure 2 Gait training using antigravity treadmill.

Our pilot work revealed that the selected speeds were comfortable across many visits to the out-patient clinic. As a warming up, children walked multiple times back and forth across the room for approximately 5 min. The treadmill was set at 0° inclination [43]. Verbal commands were given to children to keep the upright posture with their feet flat on the treadmill belt, (7) ending the exercise session by pressing the stop button.

3. Results

The collected data from this study represent the statistical analysis of the stability indices including overall stability index, antero-posterior (AP) stability index and medio-lateral (ML) stability index of the dynamic balance test that were measured before and after three months of treatment for both groups. The raw data of the measured variables for the two groups were statistically treated to determine the mean and standard deviation. Student's t-test was then applied to examine the significance of the treatment conducted for each group. Data were organized and tabulated using the Statistical Package for the Social Sciences (SPSS v.16.0).

As indicated from the pre treatment results of both the control and the study groups, all subjects were homogenous concerning age and sex (Tables 1 and 2). Also, the obtained results in this study revealed no significant differences when comparing the pre-treatment mean values of the two groups. Significant improvement was observed in all the measured variables of the two groups, when comparing their pre and post-treatment mean values. After treatment a significant difference was observed when comparing the post-treatment results of the two groups in favor of the study group.

As shown in Table 3 and Fig. 3, a significant reduction was observed in the mean values of stability indices for the control group at the end of treatment as compared with the corresponding mean values before treatment program. Also, Table 3 and Fig. 3, show a significant reduction in the mean values of stability indices for the study group at the end of treatment as compared with the corresponding mean values before treatment. Significant improvement was also observed when comparing the post-treatment mean values of the stability indices

Table 1 Age in years for both control and study groups.

Patient's group	Item	Mean ± SD	t Value	P value
Control group	Age in years	6.402 ± 0.68	1.492	>0.05*
Study group		6.799 ± 0.77		

SD: Standard deviation.
* Non significant difference.

Table 2 The frequency distribution of sex in both groups.

Patient's group	Male no.	%	Female no.	%	Total
Control group	9	60	6	40	15
Study group	9	60	6	40	15

No: Number.
%: Percentage.

Table 3 The pre and post treatment mean values of the measured variables in both groups.

Variable	Time of evaluation	Mean ± SD		t -value	P-value
		Control group	Study group		
Overall stability index	Pre treatment	5.4 ± 0.833	5.52 ± 0.657	0.436	> 0.05*
	Post treatment	5.087 ± 0.834	4.36 ± 0.423	3.012	< 0.05**
A–P stability index	Pre treatment	4.274 ± 0.818	3.96 ± 1.052	0.911	> 0.05*
	Post treatment	4.046 ± 0.79	3.4 ± 0.897	2.089	< 0.05**
M–L stability index	Pre treatment	4.744 ± 0.582	4.272 ± 0.526	0.360	> 0.05*
	Post treatment	4.276 ± 0.562	3.846 ± 0.453	2.253	< 0.05**

SD: Standard deviation.
P-value: probability value.
t-Value: paired *t*-test value.
* Non significant difference.
** Significant difference.

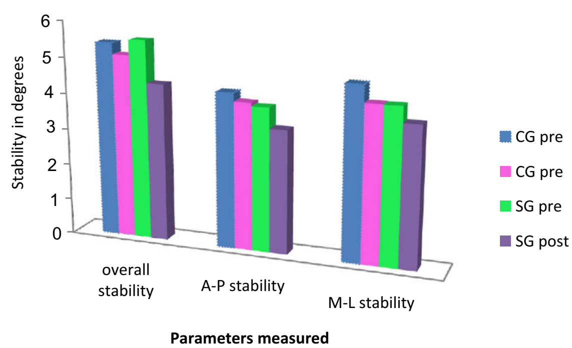

Figure 3 Pre and post treatment mean values of overall stability index, antero-posterior stability index and mediolateral stability index for both the control and the study groups.

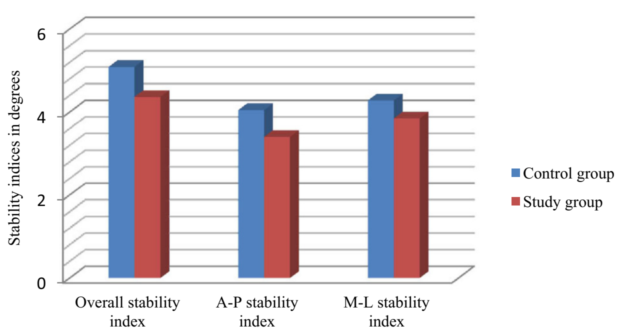

Figure 4 Post treatment mean values of overall stability index, antero-posterior stability index and mediolateral stability index for both the control and the study groups.

of the two groups in favor of the study group ($P < 0.05$) as shown in Fig. 4.

4. Discussion

One of the most common complaints in children with CP who have the ability to walk independently is frequent falls. Consequently, impaired balance is an important subject in the rehabilitation of these children and has been the focal point of many therapeutic interventions [44]. The present study compared dynamic balance in children with SDCP after a protocol of gait training using AGT or traditional physical therapy program. Results showed that the two protocols led to significant improvement in dynamic balance. However, more improvement was observed in the study group. These findings demonstrate that AGT gait training is an important tool for improving dynamic balance in SDCP children.

The improvement in the study group can be explained by the improvement in: first neuromotor control; second the balance control and strength; third the sensory integration.

The improvement seen in the study group may be due to stepping practice via AGT training which strengthens and stabilizes the neural network involved in producing this pattern and improves the specific postural control mechanism needed to maintain the balance during the weight shift from one leg to the other, so, treadmill as an example of stepping practice, facilitates and strengthens the neural connections that arise from the coupling of multimodal sensory input generated by the child through improving attention and awareness of the body position image in relation to his or her environment [45]. This comes in agreement with El-Meniawy 2012 [46] who attributed the improvement of balance in children with Down's syndrome to the practice of stepping via treadmill training.

AGT improved balance through: firstly, by reducing the uncomfortable pressure points that normally occur in more traditional body weight support systems [38], secondly, no support was provided around the child's trunk as would be the case with more traditional body weight support systems. This freedom allowed the child to practice controlling the displacement of the trunk's mass during the training sessions [47]. This comes in agreement with the findings described by Shimada et al. [48] who investigated the effects of unexpected perturbation on the prevention of falls among healthy elderly individuals. To facilitate postural reactions, one group used a treadmill for training and another group used an exercise protocol. After 6 months of training, the group that used the treadmill demonstrated more improvement in balance and reaction time when compared to the other group. The study revealed that the treadmill group had a greater reduction in falls when compared to the group that underwent the exercise protocol.

In addition, the improvement in the study group may be attributed to the increase in muscle strength. Treadmill training was used for children with motor impairment which helps them to improve balance and build strength of the lower limbs so they could walk earlier and more efficiently than children who did not receive any treadmill programs [49]. The treadmill stimulates repetitive and rhythmic stepping while the patient is supported in an upright position and bearing weight on the lower limbs [49]. A positive correlation exists between balance impairments and decreased lower-limb strength. In addition, poor trunk control negatively influences overall balance [50]. This comes in agreement with Olama [51]who found that a program of treadmill training has a positive effect on muscle strength and functional activities in hemiparetic cerebral palsy children.

Tanaka et al. [52] stated that a training program that aims to stimulate both sensory as well as motor function is effective in improving balance. AGT helped the diplegic children to organize sensory information from the visual, somatosensory and vestibular systems (sensory strategies) for postural control thus creating internal neural representation essential for coordinated postural abilities. This finding comes in agreement with Wernig et al. [53] who reported that proprioceptive awareness of postures and movements is very important during the learning of new tasks. They added that during slower movements, the proprioceptive system can monitor and adjust the movement as it occurs. This system is able to generate immediate, rapid and precisely tailored compensatory muscular contractions that occur in response to unexpected changes in external or internal forces, for example as required during standing balance.

This study was limited to 30 spastic diplegic children who were selected from the pediatrics out-patient clinic of the Hospital of Medical Rehabilitation, Almadinah Almonawara.

According to the results of this study, further investigations and research studies are recommended: similar studies should be done on other types of cerebral palsy with postural control abnormalities; longitudinal studies with a larger sample size and patients with different diagnosis are recommended; using more objective evaluative tools as electromyography (EMG) with gait training AGT training to record muscular activity; other studies aiming to investigate the effect of AGT training on hand function in spastic diplegic cerebral palsied children better to be applied; Further investigations are needed to determine the effect of dynamic postural control on cognitive development of spastic diplegic children.

5. Conclusion

Our results showed that, gait training using AGT for 3 months, enabled the children in the study group to gain more balance control and postural reactions so it can be added as an additional modality to improve balance and postural reactions of diplegic children.

Conflict of interest

No potential conflict of interest reveal to this article was reported.

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