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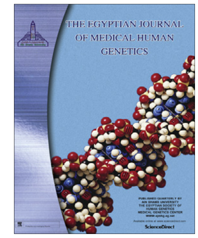

ORIGINAL ARTICLE

Integrated effect of treadmill training combined with dynamic ankle foot orthosis on balance in children with hemiplegic cerebral palsy

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KEYWORDS

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Abstract *Background and purpose:* Maintaining balance is a necessary requirement for most human actions. Most cerebral palsy children, who constitute a large portion in our country, continue to evidence deficits in balance, co-ordination, and gait throughout childhood. So, the purpose of this study was to determine the combined effects of treadmill and dynamic ankle foot orthosis on balance in spastic hemiplegic children.

Subjects and methods: Thirty spastic hemiplegic children from both sexes ranging in age from 7 to 11 years represented the sample of the study. The degree of spasticity ranged from 1 to 1+ according to the Modified Ashworth Scale. They were assigned randomly into two groups of equal number (A and B). Each child in the two groups was evaluated before and after 3 months of treatment for detecting the level of lower limb performance using the Peabody Developmental Test of Motor Proficiency and Stability indices using Biodex instrument system.

Both groups received a designed physical therapy program for treatment of hemiplegic cerebral palsy children for 60 min, in addition group B received treadmill training with dynamic ankle foot orthoses for 30 min.

Results: Significant improvements were observed in all measuring variables when comparing the pre and post-in the same group. Comparing the post-treatment variables, significant difference is revealed in favor of the group (B).

Conclusion: The obtained results strongly support the combined effect of dynamic AFO with treadmill training as an additional procedure to the treatment program of hemiplegic cerebral palsy children.

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1. Introduction

Cerebral palsy (CP) is a group of permanent disorders of the development of movement and posture, which are attributed to non progressive disturbances that occurred in the developing fetal or infant brain [1]. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition communication, and behavior. Secondary musculoskeletal impairments, pain, and physical fatigue are thought to contribute to changes in motor functions in children with CP [2]. Spastic hemiplegia accounts for more than a third of all cases of CP, and the resulting impairments to extremities affect functional independence and quality of life [3]. The most common patterns of spasticity during standing include flexion of the head toward the hemiplegic side and rotation. So that the face is toward the unaffected side and the upper limb is in flexion pattern with the scapula retracted and the shoulder girdle depressed [4]. The diagnosis of CP is based on a clinical assessment, and is typically based on observations or parent reports. Parents complain that their children had delayed motor milestones, such as sitting, standing, walking that play an important role in assessment of these cases. Evaluation of posture, deep tendon reflexes and muscle tone, particularly among infants born was done prematurely [5]. The treatment approaches used in management of cerebral palsy are neurodevelopmental treatment, sensory integration, electrical stimulation, constrained induced therapy and orthosis [6]. Balance control is important for performance of most functional skills and helping children to recover from unexpected balance disturbances due to self-induced instability [7]. Difficulties in determining individual causes of balance impairment and disability are related to decreased muscle strength, range of movement, motor coordination, sensory organization, cognition, multisensory integration and abnormal muscle tone [8].Treadmill training was used for children with cerebral palsy to help them to improve balance and build strength of their lower limbs so they could walk earlier and more efficiently than those children who did not receive treadmill training [9]. The treadmill stimulates repetitive and rhythmic stepping while the patient is supported in an upright position and bearing weight on the lower limbs [10]. A positive correlation exists between balance impairments and decreased lower-limb strength. In addition, poor trunk controls negatively influence overall balance [11]. Splinting is commonly used by both physical and occupational therapists to prevent joint deformities and to reduce muscle hypertonia of hemiplegic upper limbs after stroke [12]. Orthoses are commonly used to improve and correct the position, range, quality of movement, and function of a person's arm or hand [13]. It is proposed that inhibition results from the application of splint can be due to altered sensory input from coetaneous and muscle receptors during the period of splint or cast application. Immobilization is applying gentle continuous stretching of the spastic muscle at submaximal passive range of motion [14]. Ankle–foot orthoses (AFOs) are frequently prescribed to correct skeletal misalignments in spastic CP, and to provide a stable base of support which helps in improving the efficiency of gait training [15]. Dynamic AFO is a dynamic orthosis (articulated), which is used to facilitate body motion to allow optimal function [16]. A dynamic AFO provides subtalar stabilization while allowing free ankle dorsiflexion and free or restricted plantar flexion· So, dynamic ankle foot orthosis may be effective to gain balance and proper body alignment. The present study aims to evaluate the effect of the dynamic ankle–foot orthosis on standing balance of the spastic hemiplegic child.

2. Subjects, randomization and methods

2.1. Subjects

Thirty hemiplegic CP children participated in this study from both sexes. They were selected from the pediatrics out-patient clinic of the Faculty of Physical Therapy, Cairo University. Their ages ranged from 7 to 11 years old. They were divided randomly into two groups A&B: *Group A:* included 15 children (10 boys and 5 girls) with mean age of 9.801 ± 0.77 years. They received a designed physical therapy program for treatment of hemiplegic cerebral palsy children for 1 h, *Group B:* included 15 children (10 boys and 5 girls) with mean age of 9.401 ± 0.69 years, and they received the therapeutic exercise program for treatment of hemiplegic cerebral palsy children for 1 h as group A in addition to exercising on treadmill with the ankle–foot orthosis for about 30 min. The subjects were selected according to the following criteria: (1) Spasticity grades ranged from 1 to +1 according to modified Ashworth scale [17]. (2) They were able to follow simple verbal commands included in the tests. (3) All subjects did not have fixed deformity of both lower limbs. (4) All subjects were able to stand with support. Exclusion criteria (1) shorting or contracture (2) cardiovascular diseases, (3) surgery within the previous 24 months, (4) sensory defensiveness, and (5) inability to follow instructions. All procedures involved for evaluation and treatment, purpose of the study, potential risks and benefits were explained to all children and their parents. The work is carried out in accordance with the code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Parents of the children signed a consent form prior to participation as well as acceptance of the Ethics Committee of the University was taken.

2.2. Randomization

Randomization process was performed using closed envelopes. The investigator prepared 30 closed envelopes with each envelope containing a card labeled with either group A or B. Finally, each child was asked to draw a closed envelope that contained one of the two groups.

2.3. Methods

2.3.1. For evaluation

Stability indices and gross motor function were evaluated before and after three successive months of treatment, using Biodex Stability System and Peabody developmental motor scale II). A familiarity session occurred prior to the test session. This session was particularly necessary for the children to ensure their comfort with the research team and protocol. On this session, participant practiced Biodex Stability System and Peabody developmental motor scale II).

2.3.2. Balance evaluation

Biodex Stability System was used for evaluation using dynamic balance test which was performed at stability levels 8. At the first, certain parameters were fed to the device including: child's weight, height, age and stability level (platform firmness). Each child in the two groups was asked to stand on the center of the locked platform within the device with the two legs stance while grasping the handrails. The display screen was adjusted, so he could look straight at it. Then each child was asked to achieve a centered position in a slightly unstable platform by shifting his feet position until it was easy to keep the cursor (representing the center of the platform) centered on the screen grid while standing in comfortable upright position. Once the child was centered, the cursor was in the center of the display target, he was asked to maintain his feet position till stabilizing the platform. Heel coordinates and feet angles from the platform were recorded as follows: heel coordinates were measured from the center of the back of the heel, and foot angle was determined by finding a parallel line on the platform to the center line of the foot. The test began after introducing feet angles and heel coordinates into the Biodex System. The platform advanced to an unstable state, then the child was instructed to focus on the visually feedback screen directly in front of him while both arms at the side of the body without grasping handrails and attempted to maintain the cursor in the middle of the bulls eye on the screen. Duration of the test was 30 s (sec.) for each child and the mean of the three repetitions was determined. The result was displayed on the screen at the end of each test including overall stability index, anterior–posterior stability index, and medio-lateral stability index.

Peabody developmental motor scale (PDMS-2): was used for the detection of gross motor. Locomotive subtest of Peabody developmental motor scale was conducted before and after three successive months of training program.

It is composed of six subtests that measure interrelated motor abilities that develop early in life. It was designed to assess the motor skills in children from birth through 5 years of age. The six subtests included in PDMS-2 are:

Reflexes: Eight items of reflexes subtests, measure the child's ability to automatically react to the environmental events .because reflexes typically become integrated by the time a child is 12 months old, these subtests are given only to children from birth through 11 month of age.

Stationary: Thirty items of stationary subtests measure the child's ability to sustain control of his or her body within its center of gravity and retain equilibrium.

Locomotion: Eighty-nine items of locomotion subtests, measure the child's ability to move from one place to another. The actions measured include crawling, walking running, hopping and jumping forward.

Application of the scale included detecting entry point (in which 75% of children in the normative sample at that age passed), basal level (the last score of 2 on three items in a row before the 1 or 0 scores) and ceiling level (when the child scores 0 on each of three items in a row) for each child before and after treatment application. This scale is based on scoring each item as follows: Gross motor quotient (GMQ): It is a composite of the results of the subtests that measure the use of the large muscle system. Three of the following four subtests form this composite score:

Reflexes (birth to 11 months only) Stationary (all ages) Locomotion (all ages) Object manipulation (12 months and older).

(2) The child performs the item according to the criteria specific for mastery. (1) The child performance shows a clear resemblance to the item mastery criteria but does not fully meet the criteria. (0) The child cannot or will attempt the item, or the attempt does not show that skill is emerging.

2.3.3. For treatment

Both groups received a designed physical therapy program which was applied for 1 h, three times per week for three successive months. This program included the following:

(1) Manual standing on the mat grasping the child around his knees. (2) Manual standing on the mat with step forward and step backward grasping the child both knee (3) Kneeling and half kneeling on the mat to facilitate creeping position. (4) Changing position exercises from prone to standing and from supine to standing position. (5) Equilibrium, protective and righting reactions using balance board and medical ball. (6) Balance training exercise from standing on the mat by slightly pushing the child forward, backward and laterally to increase standing balance. (7) Strengthening exercises to weak muscles like dorsiflexors using manual resistive exercises. (8) Stooping and recovery exercising from standing position. (9) Squatting to standing exercise. (10) Gait training was performed: forward, backward, and sideways walking between the parallel bars (closed environment gait training). Obstacles including rolls and wedges with different diameters and heights, were put inside parallel bars. Gait training exercise between parallel bars using stepper. (11) Stretching exercises for tight muscles like hip flexors, hamstrings and calf muscles in lower limb and for wrist flexors, pronators and elbow flexors in upper limb.

In addition, group B received the following:

The children in this group received treadmill training for 30 min. Treadmill apparatus (En Tred) is a steel structure 2.4 meter (m) long, and ½ m width and is formed of a belt, two cylinders, and an axle along its width. The treadmill belt is a loop of synthetic rubber and nylon 3.75 m long that passes around 2 cylinders of 0.31 m in diameter. Parallel bars are attached on vertical beams at each side of the apparatus and its height was adjusted according to each child. The procedure and goals of exercise were explained to all children before starting walking on treadmill. Children grasped both parallel bars of the treadmill by both hands firmly and asked to look forward and not to look downward on their feet during walking as this may cause falling. At first the child must hold the hand rails by two hands then by one hand till he/she gained the self confidence, and walked on treadmill without support. The exercise training consisted of 5 min. of warm-up exercises involving light stretch and walking back and forth inside the room then dynamic aerobic exercise over treadmill was begun. A comfortable treadmill speed was selected for all children in both groups as 75% of their comfortable speed during over ground walking and zero degree inclination 20 min.[18]. The child was instructed to stop walking immediately if he felt pain, fainting, or shortness of breath. Finally, cooling down exercises for 5 min. involving light stretch and walking inside the room were performed.

The child was asked to wear the dynamic AFO during walking on the treadmill. Dynamic AFO is a very thin flexible supramalleolar orthosis with a custom contoured soleplate to include support and stabilization to the dynamic arches of the foot. The bottom of the posterior cut-out needs to be just above the level of the ankle fulcrum of movement to get complete coverage of the calcaneus and allow comfortable ankle movement. A narrow posterior opening provides more complete medial–lateral control. Forefoot strap provides integrity to the anterior portion of the orthosis to maintain total contact and support to the forefoot and toes. AFOs are externally applied and intended to control position and motion of the ankle, compensate for weakness, or correct deformities. This type of orthosis is generally constructed of lightweight polypropylene-based plastic in the shape of "L", with the upright portion behind the calf and the lower portion running under the foot. It is attached to the calf with a strap.

3. Statistical analysis

The collected data of the balance and Locomotive subtest of Peabody developmental motor scale of both groups were statistically analyzed to study the effects of treadmill training with dynamic AFO on hemiplegic CP children. Descriptive statistics were done in the form of mean and standard deviation to all measuring variables in addition to the age, weight and height. T test was conducted for comparing the pre and post treatment mean values of all measuring variables between both groups. Paired T test was conducted for comparing pre and post treatment mean values in each group. All statistical analyses were conducted through SPSS (statistical package for social sciences, version 20).

4. Results

4.1. Subject characteristics

Basic demographic data as well as the clinical characteristics of the 30 hemiplegic CP participants are presented in Table 1 There was no statistical significant difference between both groups as regards age, weight, height at the baseline of assessment as mean ± SD of the age of children in the group A was 8.11 ± 0.36, whereas that in the group B was 8.64 ± 0.48 years, also mean ± SD of the weight of children in the group A was 32.06 ± 4.54, whereas that in the group B was 32.66 ± 5.43 and mean ± SD of the height of children in the group A was 132.12 ± 4.54, whereas that in the group B was 136.33 ± 8.85, ($p > 0.05$).

4.2. Stability indices

The collected data from this study represent the statistical analysis of the stability indices including antero-posterior (A/P) stability index, medio-lateral (M/L) and overall stability index. The raw data of the measured variables for the two groups were statistically treated to show the mean and standard deviation. The obtained results in this study revealed no significant differences when comparing the pretreatment mean values of the two groups ($P > 0.05$). Also significant reduction was observed in the mean values of stability indices for the both groups A&B at the end of treatment as compared with the corresponding mean values before treatment ($p > 0.05$). As shown in Fig. 1 a significant difference was observed when comparing the post-treatment results of the two groups in favor of the study group B.

4.3. Peabody (locomotion subtest)

Mean values and standard deviations of locomotion subtest of the Peabody of the two groups A&B before and after 12-weeks treatment are presented in Table 3. The obtained results in this study revealed no significant differences when comparing the pretreatment mean values of the two groups ($P > 0.05$). There was a significant increase of locomotion subtest of both groups as compared with the corresponding mean values before treatment ($P < 0.05$). As shown in Fig. 2 there is a significant difference was observed when comparing the post-treatment results of the two groups in favor of the study group B (Table 2).

5. Discussion

Hemiplegic children may show a delay in the acquisition of various motor functions such as gross motor skills due to spasticity and motor weakness. This consequently will interfere with the gait function performance, so the current study was conducted to detect the effect of treadmill training with dynamic AFO on changing the affected lower extremity motor performance in those children. The pre-treatment mean values of overall stability index, anteroposterior stability index and mediolateral stability index of the dynamic balance test showed a significant increase in their values which indicated that those children had a significant balance problems. The pre-treatment mean values of locomotion subtest of the Peabody developmental motor scale II showed decrease in their values which indicated that those children had locomotion problems and difficulty. The dynamic postural control was impaired in cerebral palsied children due to the following: (1) Loss of selective muscle control. (2) Abnormal muscle tone. (3) Relative imbalance between muscle agonists and antagonists across joints, (4) Deficient equilibrium reactions. (5) Dependence on primitive reflex patterns for ambulation [19]. Comparing between mean values of pre-treatment results of dynamic balance test including overall stability index, anteroposterior stability index and medio-lateral stability index in both groups' revealed non significant differences but also showed significant increase in their values. Also, pre-treatment mean values locomotion subtest of the Peabody developmental motor scale in both groups showed non significant differences but showed a significant decrease in their values in comparison

Table 1 Mean ± SD of age, weight and height of both study groups.

	Study X ± SD	Control X ± SD	p-Value
Age (years)	8.11 ± 0.36	8.64 ± 0.48	0.79*
Weight (kg)	32.06 ± 4.54	32.66 ± 5.43	0.82*
Height (cm)	132.12 ± 4.59	136.33 ± 8.85	0.11*

X, Mean; SD, standard deviation; p-value, level of significance.
* Not significant.

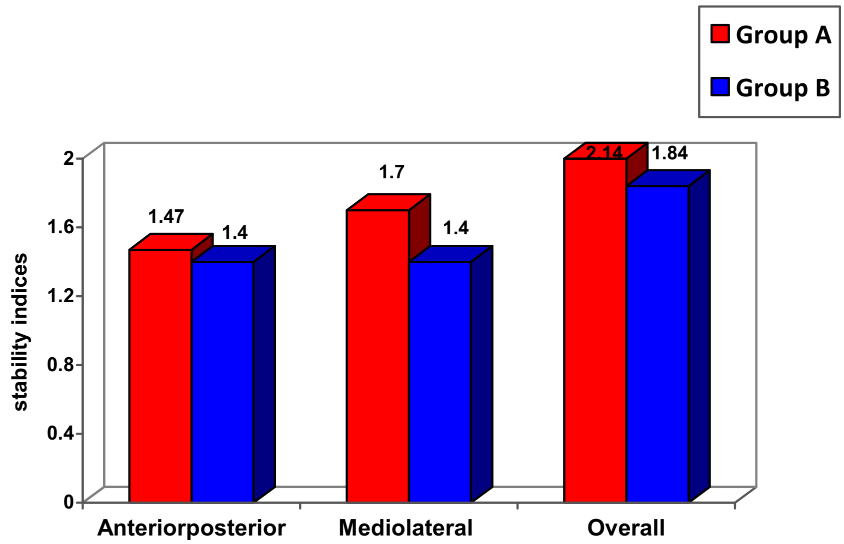

Figure 1 Post-treatment mean values of stability indices of both groups A&B.

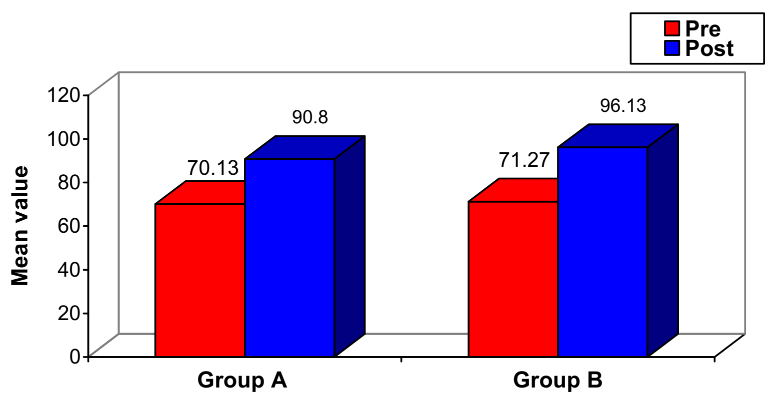

Figure 2 Pre- and post-treatment mean values of locomotion subtest of the Peabody within the same group and between the two studied groups.

Table 2 Pre and post-treatment mean values of the stability indices for the both groups.

	Overall stability SI		Anterior–posterior SI		Medio-lateral SI	
	Group A	Group B	Group A	Group B	Group A	Group B
Pre	3.8 ± 1.218	3.62 ± 1.349	2.679 ± 0.96	2.57 ± 0.756	2.95 ± 1.18	2.83 ± 1.192
Post	2.129 ± 1.094	1.84 ± 0.75	1.48 ± 0.66	1.4 ± 0.660	1.767 ± 0.41	1.432 ± 0.29
t-test	5.94	7.43	6.15	6.8	6.15	6.25
p-Value	0.05*	0.001*	0.05*	0.001*	0.001*	0.05*

Data are expressed as mean ± SD. *P*-value, level of significance; SI, stability index; %, percentage.
* Significant at $P < 0.001$.

to the normal values of the children in the same age group [20] which indicated that they had also balance problems.

This also could be explained by the work of Lepage et al. [21] who reported that spastic hemiplegic children exhibit abnormal synergies of movement including deficits that interfere with various motor functions such as gross and fine motor skills. These results were consistent with those reported previously by Mark et al. [22], who indicated that higher stability index was due to poor standing instability. Also the pre-treatment mean values of this study are in accordance with the findings of Roncesvalles et al. [23], who stated that one of the contributing factors in stability of children with spastic hemiplegia is a poor ability to increase muscle response amplitude when balance threats increase in magnitude. Comparing between pre and post treatment mean values of the balance and gross motor function in both groups showed significant improvement at the end of the treatment program. This improvement could be attributed to reducing in muscle tone

Table 3 Pre- and post-treatment mean values of locomotion subtest of the Peabody within the same group and between the two studied groups.

	Group A (n = 15)	Group B (n = 15)	t test	p Value
Pre	70.13 ± 2.23	71.27 ± 2.22	−0.164	0.871
Post	90.80 ± 3.10	96.13 ± 2.85	−5.826	0.001**
% improvement	−29.06	−37.69	–	–
t test	24.54	32.4		
p Value	0.05**	0.05**	–	–

Data are expressed as mean ± SD.
$p > 0.05$ = not significant.
** $p < 0.05$ = highly significant.

and improving joint ROM. This is supported by Karimi et al. [24] who stated that intensive reactive balance training which provided more stabilization to the child and minimized the displacement of COG under each foot, so keeping the center of gravity (COG) near the middle of base of support. Our results could be explained by the work of Carvalho and Almeida [25] who suggested that proprioceptive information is essential for the motor control system to select the appropriate motor strategy of reciprocal activation among the agonist and antagonist to efficiently maintain balance. High significant improvement was observed in group B when comparing its post treatment results with that of group A clearly demonstrated the evidence of using dynamic ankle foot orthosis with treadmill in addition to the physical therapy program for improving balance and gait in hemiplegic children. This combination leads to improvement of the child's ability to stand and walk in a nearly normal way. So, it allows better motor function, more postural control, increase self confidence and motivation. This agrees with Yamam et al. [26], who reported that there is a great importance of using the AFO in addition to gait exercise training in the early stages of rehabilitation of children with CP. This also comes in agreement with Morris and Bartlett [27] who reported that AFOs directly influence the alignment of the body segments. They can also influence hip and knee joint movements by manipulating the direction of the ground reaction force. Stabilizing the ankle and the foot therefore allows therapy to focus training on strengthening and encouraging better control over proximal joints. The improvement seen in the study group B may be due to reciprocal movement through treadmill training which strengthens and stabilizes the neurological network involved in producing this pattern and improves the postural control mechanism. [28]. The post-treatment results of the study group B also come in agreement with Matsuno et al. [29] who concluded that the treadmill is considered as a movable surface, so, the children needed to spend more time with both feet on the surface during the walking cycle than when they walked over ground. Also our results come in agreement with [30] who stated that treadmill has appositive effect on balance in Down's syndrome children. The additional improvement in group B could be explained by the work of [31] who studied the effect of dynamic AFO with treadmill training on spasticity in planter flexors and their effect on the range of motion of ankle joint, as dynamic splints have moving parts that improve the ability of voluntary controlled of the spastic muscle and to decrease pathologic loading forces on the structural components of the foot and lower extremity during weight bearing activities. Also our results come in agreement with Olma et al. [32] who stated that three side support ankle–foot orthosis improves balance in children with spastic diplegic cerebral palsy.

6. Conclusion

The data in the present study suggest that 12 weeks of intervention with dynamic AFO with treadmill training improve balance and gross motor performance related to standing and walking without any negative effects. So, it is recommended to include dynamic AFO with treadmill as a principle component in physical therapy programs directed toward improvement of balance and gait.

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