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ORIGINAL ARTICLE

Bicycle ergometer versus treadmill on balance and gait parameters in children with hemophilia

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KEYWORDS

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Abstract *Background and purpose:* Children with hemophilia often bleed inside the joints and muscles, which may impair postural adjustments. These postural adjustments are necessary to control gait and postural balance during daily activities. The inability to quickly recover postural balance could elevate the risk of bleeding.

So, the purpose of this study was to compare between the effects of bicycle ergometer and treadmill on balance and gait parameters in children with hemophilia.

Materials and methods: Thirty hemophilic boys with the ages ranging from 10 to 14 years had participated in this study. They were assigned randomly into two equal study groups. Group A received a designed physical therapy program and aerobic exercise training by bicycle ergometer. While group B received the same physical therapy program in addition to aerobic exercise training by the treadmill. Both groups received treatment sessions three times per week for three successive months. Stability indices and kinematic gait parameters were evaluated before and after three successive months of treatment.

Results: There were non significant differences between the pre-treatment mean values of all measuring variables for the two groups. Significant improvement was observed in the two groups when comparing their pre and post treatment mean values. Also, significant differences were recorded when comparing the post treatment results of the two groups in favor of the study group B.

Conclusion: Aerobic exercise, in the form of treadmill training for children with hemophilia, is an excellent supplement to regularly scheduled physical therapy intervention. It improves the degree of stability and gait parameters for those patients.

1. Introduction

Hemophilia an X-linked recessive disorder results from absence or deficiency of factor VIII as hemophilia A or factor IX as hemophilia B with incidences of approximately 1:10,000 and 1:60,000 people, respectively [1]. The incidence

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of hemophilia in Egypt is 1:10,000 live births [2]. Depending on the concentration of factor VIII or IX coagulant activity in blood, the disorders may be classified as severe (< 1% of normal activity), moderate (1–4%) or mild (5–25%) [3]. Patients may bleed for a long time after an injury. Also, they may experience internal bleeding, especially in the hinge joints (knees, elbows, and ankles) because these joints have less muscular padding [4]. Intra-articular bleeding of synovial joints in people with hemophilia triggers a degenerative process which is characterized by changes to articular cartilage, joint structures and muscles [5]. With the introduction of prophylactic clotting factor replacement therapy, patients had fewer bleeds and were able to participate in physical activities. It is now widely recognized that physical activity and sports are beneficial for patients with hemophilia [6]. Traditionally, balance has often been defined as a task of maintaining a person's center of gravity (COG) over the base of support (BOS) in an upright posture. Balance control is a complex process that requires the integration of multiple body systems (cognitive, sensorimotor, and musculoskeletal systems) [7]. Patients with hemophilia are often used to have a sedentary lifestyle, because of haemarthroses and subsequent synovitis and arthropathy [8]. There is increasing evidence of muscle atrophy, significantly reduced muscle strength, decreased range of motion (ROM) and altered walking patterns [9]. Hemophilics present a decrease of proprioception of joints which can provoke alterations in basic force development pattern. Likewise, stability is also impeded in certain positions of dynamic balance [10]. In addition to the implementation of exercise programs to maintain and improve joint ROM and muscle strength in hemophilic children, attention should be drawn to activities that help to develop coordination and improve proprioception. Exercises that improve balance and coordination are vital to any rehabilitation program [11]. There are small differences between walking on a treadmill and walking over ground without an effect on the symmetry [12]. The treadmill stimulates repetitive and rhythmic stepping while the patient is supported in an upright position and bearing weight on the lower limbs [13]. An improved gait pattern, with increased symmetry, can be obtained with treadmill training. There are significant increases in push-off power generation and in walking speed after 4 weeks of training on treadmill with program of muscle strength training [14]. Treadmills offer a continuous-controlled environment attractive to both clinicians and researchers. They are routinely used clinically, with the aim to improve over ground gait and have been used in research to imitate ground walking [15]. Pedaling is an aerobic exercise and a repetitive, functional activity, which requires reciprocal contraction of agonist and antagonist muscles of the lower limbs in a repeating pattern similar to that required for walking [16]. Cycling exercise is a functional treatment that is accessible for the relearning of motor skills required for locomotion [17,18]. Because cycling is practiced in the sitting position, it is safe, easy to perform, and can be widely applied regardless of the severity of motor impairment [19]. So, the purpose of this study was to compare between the effects of treadmill and bicycle ergometer on balance and gait parameters in children with hemophilia.

2. Patients, randomization and methods

2.1. Patients

Thirty hemophilic boys were selected from the Abu El-Rish Pediatric Hospital and Out-patient Clinic, Faculty of Physical Therapy, Cairo University. Their ages ranged from 10 to 14 years. Their medical management included factor replacement therapy (on demand), as determined by their treating haematologist. All children were clinically and medically stable. The children were selected with inclusion criteria including, children who were diagnosed as mild to moderate hemophilia. They understood and followed verbal commands included in both test and training. They had full and free pain ROM of upper and lower limb joints. They achieved grade 3^+ muscle strength according to Kendall et al. [20]. They were able to walk alone. The Children who had one or more of the following criteria were excluded from the study: children with advanced radiographic changes as bone erosions or destruction, bony ankylosis, joint subluxation or epiphysial fracture. Children who had any congenital or acquired skeletal deformities or cardiopulmonary dysfunction. Children who had abnormal motor development, neurological disease or receiving muscle relaxant that affect balance and gait. Those who had undergone previous orthopedic surgery. Children who had bleeding in joints or muscles in the 2 weeks prior to the pre-treatment assessment were also not included in the study.

The children were randomly assigned into two study groups of equal number: group A and group B. 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

Thirty-five children were assessed for eligibility. Three children were excluded as they did not meet the inclusion criteria, and two children were excluded as their parents refused to participate in the study. Following the baseline measurements, 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 gait parameters were evaluated by using Biodex Stability System and Biodex Gait Trainer 2TM, respectively. The evaluation was done before and after three successive months of treatment. A familiarity session occurred prior to the test session. On this session, the children practiced

Biodex Stability System and Biodex Gait Trainer 2TM. This session was particularly necessary for the children to ensure their comfort with the research team and protocol of evaluation.

2.3.1.1. Balance evaluation. Dynamic balance test of Biodex Stability System was used. It was performed on stability levels from 6 to 4. At 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 leg stance while grasping the handrails. The display screen was adjusted, so he could look straight at it. Then the 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, he attempted to maintain the cursor in the middle of the bulls eye on the screen. Duration of the test was 30 s (sec.). The result was displayed on the screen at the end of each test including overall stability index, antero-posterior stability index, and medio-lateral stability index. The mean of the three repetitions was determined. High values mean that the child had balance difficulty [21].

2.3.1.2. Biodex Gait Trainer 2TM. It is a modified treadmill technology which is provided by instrumented deck. It monitors and records specific gait parameters. At first, we fed the child's age and height to the device to automatically calculate the exact speed needed to achieve the desired step cycle. Each child was allowed to be familiar with the device before starting to record the gait parameters through instructing the child to walk over the device and to follow the tread belt movement for three to 5 min. This might be repeated two or three times till the child became adapted with the device. Each child was allowed to walk continuously for 3 min, then the evaluation session was finished and tread belt slowed gradually until it stopped. The result was displayed on the screen. This procedure was repeated three times (with a rest period in between) and the average was taken for each gait parameter. The gait parameters included time on each foot (%), average step length (meter) and average step cycle (cycle/second).

2.3.2. For treatment

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

- Gentle stretching exercises as a preparation for aerobic exercise training and as prophylactic against development of any tightness. Stretching was done for biceps brachii, hamstrings and calf muscles bilaterally. It was applied for 20 s stretch followed by 20 s relaxation and repeated five times for each muscle.
- Isometric muscle contraction for quadriceps, hamstrings, anterior tibial group, calf muscles, biceps and triceps. Each contraction was maintained 5 s then relaxed for another 5 s for five times [22,23].
- Balance and gait training exercises with obstacles.

In addition, both study groups received the following:

Group A: The children in this group were trained on the bicycle ergometer for 20 min, three times per week for 3 successive months [24]. Bicycle ergometer (Monark Rehab Trainer model 88 IE) is an electronically braked ergometer. It is equipped with an electronic meter showing pedal revolutions per min, the total pedal revolution and time function. The bicycle is supplied by a pedal strap to provide complete fixation of the child's foot and back support in order to support and prevent over exhaustion of the back muscles. The exercise training consisted of 5 min warm-up exercises involving a light stretch and walking back and forth inside the room. Then the child was asked to sit on the seat of the bicycle grasping the handles of the bicycle by both hands firmly with straight and supported back. Climb steady program was selected in which resistance has been increased gradually according to muscular force. This program was selected as it was the most suitable one for the present disorder of those children. Applying resistance comes in agreement with the results that confirmed the necessity of resistance training for children with hemophilia as they have demonstrated lower levels of anaerobic capacity and strength when compared with healthy children [25]. The child was asked to perform pedaling on a bicycle ergometer starting at lower intensity for 5 min as a warming up. Then, the child performed pedaling while gradually increasing resistance for about 10 min and end the treatment session with unloaded cycling for another 5 min as a cooling down exercise [24]. The child was instructed to immediately stop exercising if he felt pain, fainting or shortness of breath.

Group B: The children in this group received aerobic exercise in the form of treadmill training for 20 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. The exercise training consisted of 5 min of warm-up exercises involving a light stretch and walking back and forth inside the room. The child grasped both parallel bars of the treadmill by both hands firmly and asked to look forward on their feet during walking to avoid 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 speed of the treadmill was adjusted as the same obtained from the Biodex Gait Trainer 2TM. The practice on the treadmill was done at 75% of over-ground speed and zero degree inclination for 20 min, three times per week for 3 successive months [26]. 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.

2.3.2.1. Statistical analysis. The collected data of the balance and gait parameters of both groups were statistically analyzed to compare between the effects of aerobic exercise training by using treadmill or bicycle ergometer on all the measuring variables in hemophilic 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. Paired *t*-test was conducted for comparing pre and post treatment mean values in each group. Unpaired *t*-test was conducted to compare pre and post treatment mean values of all measuring variables between both groups. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analyses were conducted through SPSS version 20 and percentage of improvement was calculated according to:

$$\text{Percentage of improvement} = \frac{\text{post–pre}}{\text{pre}} \times 100$$

3. Results

3.1. Subject characteristics

Table 1, presented the mean ± SD of age, weight and height of both study groups. There was no significant difference between both groups in the mean age, weight and height ($P > 0.05$).

3.2. Stability indices

The collected data from this study represent the statistical analysis of the stability indices including overall stability index, antero-posterior stability index and medio-lateral stability index of the dynamic balance test at the levels from 6 to 4. The obtained results in this study revealed non significant differences when comparing the pre-treatment mean values of the two groups ($P > 0.05$). A significant improvement in the form of significant reduction was observed in all the measuring variables of the two groups, when comparing pre and post-treatment mean values ($P < 0.05$), as presented in Table 2. Also, significant differences were observed when comparing the post-treatment mean values of the stability indices of the two groups in favor of the study group B ($P < 0.05$) as demonstrated in Fig. 1.

Table 1 Subject characteristics.

Variable	Group A	Group B	*t*-Value	*P*-value
Age (years)	12.40 ± 1.37	12.8 ± 1.39	0.79	0.43
Weight (kg)	39.21 ± 3.95	38.16 ± 4.23	0.70	0.49
Height (cm)	134.11 ± 4.20	136.63 ± 5.96	1.34	0.19

Data are expressed as mean ± SD. *P*-value: level of significance.

3.3. Gait parameters

Mean values and standard deviations of gait parameters (time on each foot, average step length and average step cycle) in both groups before and after treatment are presented in Tables 3 and 4. Non significant differences were recorded when comparing the pre-treatment mean values of the two groups ($P > 0.05$). A significant improvement was observed for both study groups at the end of treatment as compared with the corresponding mean values before treatment. Also, significant differences were observed when comparing the post-treatment mean values of the gait parameters of the two groups in favor of the study group B ($P < 0.05$) as demonstrated in Figs. 2–4.

4. Discussion

Hemophilics have lower levels of fitness and strength than their healthy peers. The physical therapist, along with the hemophilia care team, can assist in preparing an individual to begin or progress to a physical activity program that enhances fitness level, body composition and overall well-being, so this study aimed to compare between the effects of treadmill and bicycle ergometer on balance and gait parameters in children with hemophilia. However, numerous studies evaluated the effects of treadmill and bicycle ergometer on hemophilic children, but to our knowledge, this study is the

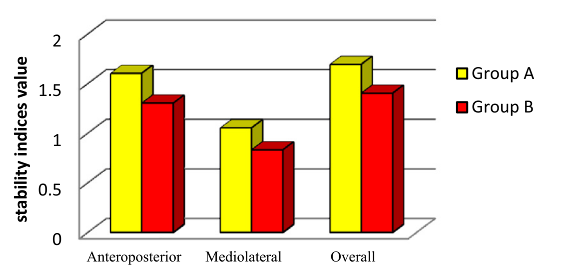

Figure 1 Post-treatment mean values of stability indices of both groups.

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

	Overall stability SI		Anterior–posterior SI		Medio-lateral SI	
	Group A	Group B	Group A	Group B	Group A	Group B
Pre	2.07 ± 0.24	2.03 ± 0.23	2.03 ± 0.35	2.08 ± 0.32	1.41 ± 0.32	1.43 ± 0.29
Post	1.69 ± 0.24	1.40 ± 0.20	1.60 ± 0.32	1.30 ± 0.27	1.05 ± 0.24	0.83 ± 0.20
% of improvement	18.36	31.03	21.18	37.5	25.53	41.96
t-value	16.358	20.873	8.293	6.951	10.557	11.015
P-value	0.01*	0.001*	0.01*	0.001*	0.01*	0.001*

Data are expressed as mean ± SD. *P*-value: level of significance, SI: Stability index, %: percentage.
* Significant at $P < 0.05$.

Table 3 Pre and post-treatment mean values of gait parameters for group A.

	Time on each foot (%)		Average step length (m)		Average step cycle (s)
	Rt	Lt	Rt	Lt	
Pre	41.83 ± 1.86	42.93 ± 2.05	0.34 ± 0.04	0.36 ± 0.03	0.63 ± 0.07
Post	43.43 ± 1.78	44.87 ± 2.23	0.39 ± 0.03	0.40 ± 0.02	0.68 ± 0.06
% of improvement	−3.83	−4.52	−14.71	−11.11	−7.94
t-value	−36.661	−12.614	−27.884	−11.529	−19.042
P-value	0.01*	0.01*	0.01*	0.01*	0.01*

Data are expressed as mean ± SD. *P*-value: level of significance, Rt = right, Lt = left, %: percentage, m: meter, s: seconds.
* Significant at $P < 0.05$.

Table 4 Pre and post-treatment mean values of gait parameters for group B.

	Time on each foot (%)		Average step length (m)		Average step cycle (s)
	Rt	Lt	Rt	Lt	
Pre	41.40 ± 1.76	42.47 ± 1.96	0.35 ± 0.04	0.35 ± 0.03	0.64 ± 0.07
Post	46.07 ± 1.87	51.87 ± 2.39	0.42 ± 0.03	0.43 ± 0.03	0.74 ± 0.06
% of improvement	−11.28	−22.13	−20.0	−22.86	−15.63
t-value	−18.520	−14.233	−24.333	−18.240	−20.073
P-value	0.001*	0.001*	0.001*	0.001*	0.001*

Data are expressed as mean ± SD. *P*-value: level of significance, Rt = right, Lt = left, %: percentage, m: meter, s: seconds.
* Significant at $P < 0.05$.

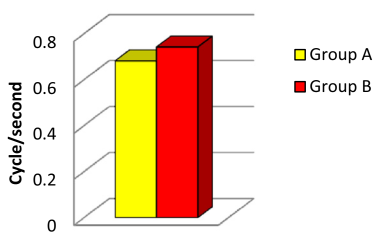

Figure 2 Post-treatment mean values of average step cycle of both groups.

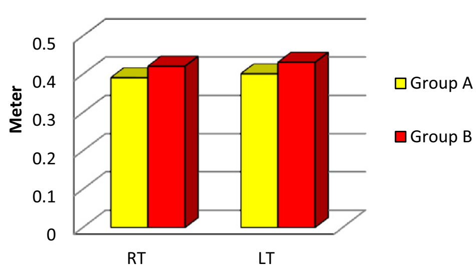

Figure 3 Post-treatment mean values of average step length of both groups.

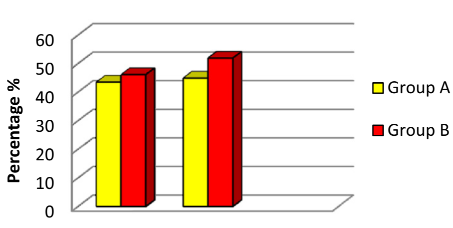

Figure 4 Post-treatment mean values of time on each foot of both groups.

first to compare the effects of treadmill to bicycle ergometer on gait parameters and balance in these populations.

Comparing between mean values of pre-treatment results of dynamic balance test including overall stability index, antero-posterior 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 of gait parameters including average step length, average step cycles and right-to-left time distribution (step symmetry) in both groups showed non significant differences but showed a significant decrease in their values in comparison to the normal values of the children in the same age group [27] which indicated that they had also gait problems.

Balance and gait impairments could be due to decreasing of the muscle strength, diminished proprioception and lack of coordination. This comes in agreement with Guskiewicz [28] who reported that, maintenance of postural balance includes a sensory process involving the articular mechanoreceptors, vestibular system and visual system. Sensorimotor information is then processed in the central nervous system. Finally, there is a motor response involving various muscle groups, including those around the ankle, thigh, trunk and neck. A child with hemophilia may experience impaired balance at both the sensory and motor levels. The position of the COG relative to the base of support may not be accurately sensed because of the destruction of the knee mechanoreceptors following injury. The automatic movements required to bring the COG to a balanced position may be compromised as a result of quadriceps inhibition. Tracy et al. [29] mentioned that, hemophilics present a decrease of proprioception of joints which can provoke alterations in basic force development pattern. Likewise, stability is also impeded in certain positions of dynamical balance. Gomis et al. [30] added that, in hemophiliacs, the physical condition, muscular strength, aerobic resistance, anaerobic resistance and proprioception have all diminished.

Comparing between pre and post treatment mean values of the balance and gait parameters in the both groups showed significant improvement at the end of the treatment program. This improvement could be attributed to increasing in muscle strength and enhanced coordination between both sides of the body. This is supported by Karimi et al. [31] who mentioned that an appropriate motor response for postural balance control requires an intact neuromuscular system and sufficient muscle strength to return the center of mass within the base of support when balance is disturbed.

Sharma and Gupta [32] studied the effect of cyclic ergometer exercise on improving gait parameters in ambulatory spina bifida children. They mentioned that, improvement in gait parameters could be due to increasing in muscle strength, although muscle strength was not specifically tested in this study, previous studies have shown that adult stroke patients showed significantly increased muscle performance. This effect on muscle strength is further confirmed by the fact that trained patients in previous studies usually experience a feeling of muscle fatigue after treatment, indicating that training on the ergometer not only acts as a passive guide for movements but also requires active involvement of the lower limb muscles. Benecke et al. [33] reported that, the gait generating circuitry in the spinal cord functions symmetrically. The symmetrical movement pattern imposed by the ergometer may allow this circuitry to orchestrate more effectively the muscles of the affected legs, facilitating them in a more nearly normal temporal rhythm.

The improvement seen in the study group B may be due to the stepping practice via treadmill training. Stepping practice strengthened and stabilized the neural network which was involved in producing this pattern. Also, it improved the specific postural control mechanism needed to maintain the balance when transferring the weight from one leg to the other. This is supported by Ulrich et al. [34] and Dal et al. [35] who stated that, treadmill intervention offered repeated opportunities to improve balance and build muscle strength in the lower limbs and stimulate neuronal connections that are involved in generation of independent balanced walking.

On the other hand, the previous results could be attributed to enhanced coordination between agonist and antagonist across joints. This comes in agreement with Tracy et al. [29] who believed that hemophiliacs have lack of intramuscular coordination. The agonist muscles actually being hindered from making maximum efforts through the unconscious force of the antagonist ones. When fluctuations reach unusual ranges, problems to reach the desired force and to control the path of certain movements take place. Likewise, stability is also impeded in certain positions of dynamic balance.

Also, these significant improvements could be attributed to effect of gait training by using treadmill on improving proprioception of hemophilic children and reinforced the effectiveness of treadmill training on improving balance by adopting a suitable program of treadmill walking. These results are also supported by Haven [36] who demonstrated that such synaptic reorganization occurs throughout a person's lifetime of adjusting to changing motion environs. With repetition, it becomes easier for motor impulses from brain stem to travel along a new nerve pathway and this process is called facilitation. The child is able to maintain balance during any activity.

Finally, comparing the post treatment mean values of all measuring variables of bicycle ergometer and treadmill groups showed that there are significant differences in favor of treadmill group. This is supported by Kubo and Ulrich [37] who stated that, treadmill training improves the spatio-temporal parameters of gait and produces more normal temporal pattern. Stickler and Greene [38] found that, weight bearing on a flexed knee not only increases the stress on the tibiofemoral and patellofemoral surfaces but also increases the quadriceps force required to maintain available extension against gravity. Despite the greater force required, hemophilic children with arthropathy and knee flexion contractures demonstrated significantly reduced knee extensor values. Matsuno et al. [39] concluded that, the treadmill is considered as a moving 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. One factor that contributes to improve stability and balance is the increase in the base of support. Tulchin et al. [40] added that, walking endurance will be increased to a greater degree in patients receiving treadmill training also gait stability, muscle function, aerobic fitness and balance will improve more in these subjects receiving treadmill also habitual activity levels will be higher.

5. Conclusion

In this study, we compared between the effects of treadmill and bicycle ergometer on dynamic balance and gait parameters in children with mild to moderate hemophilia. The obtained results showed a significant improvement in the post-treatment mean values of all measuring variables of stability indices and gait parameters of both groups in favor of treadmill. So, it is recommended to include treadmill as the principle component in physical therapy programs directed toward improvement of balance and gait in those children.

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