Effect of Treadmill Training with Body Weight Support on Energy Expenditure and Walking Velocity in Spastic Diplegic Children

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ABSTRACT

Cerebral palsy is classified as a static encephalopathy. It is a non progressive disorder affecting posture and movement and is commonly associated with a spectrum of developmental disabilities. Gait abnormalities in children with cerebral palsy have been showed to increase sub maximal walking energy expenditure almost 3-fold compared with healthy children. This study was designed to investigate the effect of treadmill training with body weight support on energy expenditure and walking velocity in spastic diplegic children. This study was conducted on 24 spastic diplegic cerebral palsy children of both sexes (15 boys and 9 girls). Their age ranged from 6 to 8 years and they were divided into two groups. The control group (A) received 60 minutes physical therapy program based on NDT for 12 weeks (3 times/week). The study group (B) received a program of body weight-supported treadmill training for 30 minutes in addition to conventional physical therapy program based on NDT for another 30 minutes three times weekly. The program was conducted for three successive months in both groups. ***Results:*** *no-significant difference was recorded between the two groups before treatment (P>0.05). A statistically significant increase in walking velocity and decrease in energy expenditure index were observed in both groups after treatment while significant difference was recorded between the two groups after treatment in favour of the study group (P<0.05).* ***Conclusion:*** *body weight supported treadmill training is shown to be an effective intervention in combination with physical therapy program based on NDT in improving energy expenditure and walking velocity in spastic diplegic children.*

INTRODUCTION

Cerebral palsy (CP) is a common clinical description of a sensorimotor dysfunction that result in increase muscle activity and abnormal posture and movement, and which has a prenatal, perinatal or postnatal aetiology[11].

Spastic diplegia is characterized by increased muscle tone, active movements are slow and stiff with abnormal patterns. Lower limbs are more affected than upper limbs. Head and neck are unaffected but there is weakness and limited rotation of the trunk[24].

Forward progression is disturbed in spastic diplegic children. The muscles can not produce the necessary force for moving the body forward. The body weight can not move over the stance leg because of muscle weakness and contractures that disturb the rocker mechanism[4].

Children with diplegic CP start walking at an older age than their healthy peer group. Usually, they will be able to walk with or without assistive devices depending on the severity of the disorder. The rate of energy expenditure required for walking, however, is increased and as a consequence the children often complain of fatigue[22].

Spasticity and the lack of motor control associated with spastic CP have long been recognized as sources of inefficiencies, especially during gait. It has been reported that the energy demands of walking for CP are 1.5 to three times that of healthy persons, depending on the degree and type of involvement. Energy expenditure during gait can be reduced in CP in at least three ways. These include reduction of spasticity, restoration of stance phase stability, and elimination of foot drag, all of which can be improved with strengthening of trunk and lower extremity[12].

The energy expenditure index (EEI) has been advocated as a means of using the heart rate response to assess energy cost during ambulation by relating changes in heart rate to velocity, and has been used in studies with children with CP[15].

Many different rehabilitation approaches for children with CP were adopted in clinics, each with a different philosophy. For example, according to the neurodevelopmental treatment (NDT) or the Bobath concept, gait training for walking should begin with the preparation of motor components that can be found in easier task (e.g., balance in standing)[19]. A different philosophy is that of the task-oriented approach. The approach stresses the importance of matching the training task with the functional goal of the target task. According to this approach, the best way of training walking is to practice walking itself. It has been demonstrated that the effect of training was specific to the particular characteristics of task being trained on[7].

One illustration of the task-oriented approach is body weight supported treadmill training (BWSTT). It consists of a motor-driven treadmill with a harness that suspends the patient's body weight. Because the needs for body weight support and balance control are released with such a system, training with repetitive gait cycles can be provided for patients with spinal cord injuries or strokes, even at the early stages of recovery[2]. Studies that have applied BWSTT for gait training in spastic diplegic children are limited in the literature. So, the present study was conducted to evaluate the effect of such training in addition to traditional physical therapy program on energy expenditure and walking velocity in spastic diplegic children.

SUBJECTS, MATERIAL AND METHOD

Subjects

Twenty-four spastic diplegic cerebral palsied children of both sexes (15 boys and 9 girls) participated in this study. They were selected from the out patient clinic of Faculty of Physical Therapy, Cairo University. Their age ranged from six to eight years. They were divided into two groups of equal number, each comprised 12 patients:

Control group (A) with a mean age of 6.71±0.78 years, 7 boys and 5 girls. Their mean weight and height are 21.08±3.05 kg and 114.08±8.75 cm respectively.

Study group (B) with a mean age of 7.20 ±0.72 years, 8 boys and 4 girls.

Their mean weight and height are 22.37±2.65 kg and 117.5±9.37 cm respectively.

Inclusion criteria were: (1) able to ambulate independently without an assistive device, (2) the degree of spasticity was determined according to the modified Ashworth scale, to be ranging from 1+ to 2 grades[5]. (3) Able to follow verbal directions for standardized testing. Exclusion criteria were: (1) orthopaedic surgery or neurosurgery in the past 12 months and (2) antispasticity medications orally or by injections in the past six months, (3) significant tightness or fixed deformity related to any joints of the lower limbs.(4) visual or auditory problems.

The control group (A) received traditional NDT program used in management of those patients' problems, three times per week for three successive months. The study group (B) received BWSTT in addition to the same physical therapy program given to the control group.

Evaluation procedures

Twenty-four diplegic children were subjected to follow up protocol for 12 weeks. Pre-test measures were performed before initiation of the treatment. Post test assessments were done after 12 weeks to assess effectiveness of the treatment and to determine impact on functional outcome.

- Clinical assessments included one measure of endurance (Energy Expenditure Index), one functional gait measure (Ten-Meter Walking Velocity) under the direction of a physical therapist.
- For the EEI measurement for diplegic children: The (EEI) in beats/meter is calculated as the ambulation heart rate (beats/min) minus the resting heart rate (beats/min) divided by the ambulation velocity (meters/min). Higher numbers indicate greater energy expenditure, while lower numbers reflect more energy efficiency[17].
- The child rested seated in silence for about five minutes and the mean heart rate of the

last 2.5 minutes was taken as the resting heart rate by using pulsometer (Japan model Tunturi TPN-400). The walking heart rate was measured on the treadmill using pulsometer and the mean heart rate was taken at the last three minutes of work. Treadmill walking was adjusted at the predetermined individual, self-selected speed, which was held constant throughout the test.

- Ten-Meter walking Velocity: walking velocity is a valid and reliable measure of walking ability in children with or without neuromuscular disability[6]. The twenty-four diplegic children were timed with a stopwatch as they walked a 10 meter walkway. The children were encouraged to walk as quickly as possible without running to calculate the walking velocity.
- Weight scale: for measuring weight : A valid and reliable weight (0 to 120 kilograms).

Treatment procedures

Body weight supported treadmill training (BWSTT) Apparatus and Protocol:

- Study group (B) received BWSTT as follows: The treadmill (En Tred, Holland) was attached to a weight support apparatus (Biodex Unweighing System, ETL listed CAN/CSAc, USA) which could be set at any level between 100% and 0%. The suspension system followed the vertical displacement of the body so set the selected body weight support level was held constant throughout the gait cycle. The child wore a harness with adjustable belt around pelvis and thighs. The shoulder straps of the harness were attached to a point centered above the child's head. The weight of each child was measured by using the weight scale before starting the treatment session. Then, the body weight support was adjusted as 30%, treadmill speed set at 1.5 to 1.9 miles/ hour with a gradual increase in the treadmill speed up to 2.3 to 3.1 miles/ hour and a gradual decrease of the support at the end of the training period[9]. The training period was three months. The training session was about 30 minutes walking divided into three 10- minutes walking interspersed with five- minutes rest periods. As the study progressed, rest breaks were more individualized and the child was allowed to continue walking on treadmill as long as he desire (up to the 30 minutes limit). During the session, physiotherapist provided stabilization at the hip of the child or assisted leg movement as needed in order to assist the child to achieve normal gait pattern. Children were encouraged not to hold the rail and freely move their arms gait training.
- Children of study group (B) received BWSTT for 30 minutes, in addition to physical therapy program based on NDT for 30 minutes three times / week for three successive months. The physical therapy program included: facilitation of postural reactions, strengthening exercises for antispastic muscles particularly, knee extensors, hip abductors and ankle dorsi flexors muscles. Stretching exercises to maintain the optimum length of the muscles especially the tendoachilis, hamstrings, hip flexors and adductors. Back and abdominal exercises to improve trunk control. Gait training, weight shifting exercises, ascending and descending stairs.
- While the control group (A) received the traditional physical therapy program based on NDT only for one hour three times /week for 12 weeks.

Statistical Analysis

The arithmetic mean and standard deviation of the mean, the student paired t-test (to determine level of significance in one group pre and post treatment), and unpaired t-test between two groups (to determine level of significance between two groups). Level of significance was assumed at 0.05 for all analysis.

RESULTS

The current study was designed to investigate the effect of BWSTT on energy expenditure and walking velocity in spastic diplegic children. The results of our study represented a statistical analysis of the following data:

1) Energy Expenditure Index data (beats/meter) (EEI):

The mean values of the EEI for the control group (A) were 0.58 ±0.07 before treatment and 0.49±0.05 after treatment which indicated a statistically significant difference decrease with P <0.05. On the other hand, the mean values of EEI for the study group (B) before and after treatment were 0.67 ±0.14 and 0.41±0.09 respectively. A highly significant difference decrease was recorded P<0.001 (table 1). Moreover as shown in figure 1 and table 2 there was no difference between the two groups before treatment (P>0.05). While a significant difference was found as P<0.05 after treatment in favour of the study group.

Table (1): Mean values of EEI of diplegic children for both groups (A and B) before and after treatment and difference in each group.

	Control group (A)		Study group (B)	
	Before	After	Before	After
Mean	0.58	0.49	0.67	0.41
SD	0.07	0.05	0.14	0.09
t-value	3.54		8.91	
P -value	< 0.05 *		< 0.001 **	

Values are mean ±SD 0.05 * Significant 0.001** Highly Significant

Table (2): Comparison of energy expenditure index between control and study group before and after treatment.

	Group A Control group	Group B Study group	t	P
Before treatment	0.58±0.07	0.67±0.14	1.824	0.09
After treatment	0.49±0.05	0.41±0.09	2.710	0.01*

0.01* Significant P >0.05 Non Significant

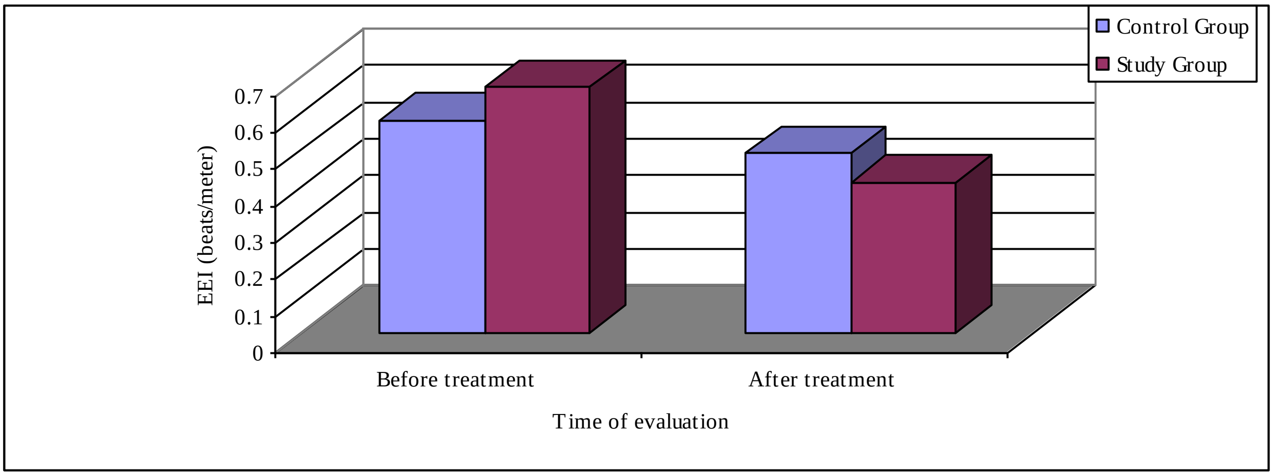

Fig. (1): Mean values of energy expenditure index for both the control and study groups before and after treatment.

2) Walking velocity data (m/sec):

The mean values of the walking velocity for the control group (A) were 1.38 ±0.26 before treatment and 1.48±0.32 after treatment which indicated a statistically significant difference with P <0.05. On the other hand, the mean values of walking velocity for the study group (B) before and after treatment were 1.51 ±0.14 and 1.92±0.23 respectively. A highly significant difference was found as P<0.001 (table 3). Moreover as shown in figure 2 and table 4 there was no difference between the two groups before treatment (P>0.05). While a highly significant difference was found as P<0.001 after treatment in favour of the study group.

Table (3): Mean values of walking velocity of diplegic children for both groups (A&B) before and after treatment.

	Control group (A)		Study group (B)	
	Before	After	Before	After
Mean	1.38	1.48	1.51	1.92
SD	0.26	0.32	0.14	0.23
t-value	3.941		6.016	
P -value	< 0.05 *		< 0.0001 **	

Values are mean ±SD 0.05 * Significant 0.0001** Highly Significant

Table (4): Comparison of walking velocity between control and study group before and after treatment and level of significance in each group.

	Group A Control group	Group B Study group	t	P
Before treatment	1.38±0.26	1.51±0.14	1.49	0.15
After treatment	1.48±0.32	1.92±0.23	3.76	0.001**

0.001** highly Significant P >0.05 Non Significant

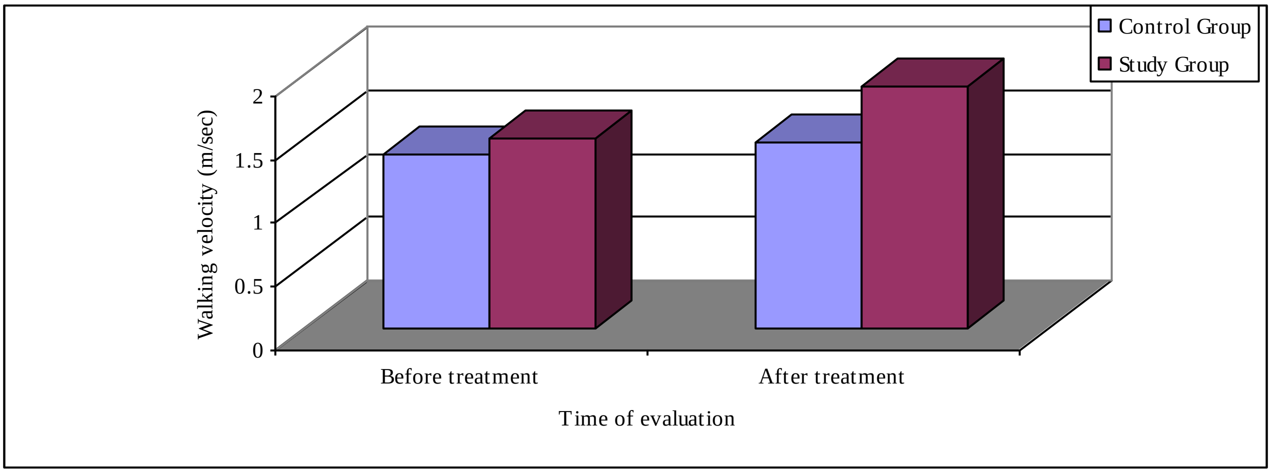

Fig. (2): Mean values of walking velocity for both the control and study groups before and after treatment.

DISSUSION

The diplegic children with CP in this study made statistically significant improvements in a measure of endurance (energy expenditure) and a measure of functional gait (walking velocity) after the BWSTT. Smooth advancement of the body during walking enables energy transfer between successive steps with the least mechanical and physiological energy expenditure. Walking efficiency is not only an expression of how well metabolic energy is converted to mechanical energy, but also of how well the neural system can control the energy transfer[25]. The metabolic cost of walking is determined by mechanical work and can be differentiated into; support body weight 28%, generation of propulsion 48%, swinging of legs 10% and lateral stabilization 6%. The remaining energy cost is accounted for by ventilation and circulation[13]. Excessive muscle contraction, increased muscle tone, co-contraction, work against gravity and altered joint moments means increased total mechanical work that can contribute to decreased walking efficiency and increase the energy expenditure during walking[9,10]. the common gait pattern seen in spastic diplegic starts with equinus/ calf dominance and ends with crouch /hamstring/hip flexor dominance. The most common bony problems seen in spastic diplegic are medial femoral torsion, lateral tibial torsion, mid foot breaching with foot valgus and abduction, which represented as "lever arm disease" which reduce the effectiveness of muscle action[16].

Other possible physiological mechanisms for the elevated energy expenditure during walking and lower endurance (lower maximal oxygen consumption) may include; higher ventilatory equivalent values for oxygen as a result of chest wall distortion caused by respiratory muscle spasticity. Also high muscle tone can reduce venous return and inhibit muscle lactate clearance during exercise with a resultant early fatigue and low endurance levels. In addition, high levels of co-contraction were observed to be highly related to elevated energy cost of walking at submaximal speed[20,21]. Energy expenditure or cost can be measured or estimated from measuring peak vo_2 during walking. As heart rate is related to oxygen consumption at submaximal levels, measurement of heart rate during exercise can therefore be used as an indirect method for estimating energy expenditure. Linearity between oxygen consumption (VO_2) and heart rate had been confirmed in healthy and CP children[18,23]. The physiological cost index or energy expenditure index used in the present study reflect the increased heart rate required for walking.

When comparing the post treatment results of both groups, a higher significant improvement was recorded in patients belonging to the study group. The recorded improvement in study group (B) comes in agreement with Begnoche et al., 2007[3] who concluded that, intensive traditional physical therapy treatment combined with partial body weight treadmill training may be effective in improving motor skills of children with spastic CP. The outcomes were measured using gross motor function measure, paediatric evaluation of disability inventory, and pedographs to measure the spatial gait parameters. Also, our results comes in consistent with Cherng et al., 2007[7] who examined the effect of treadmill training with body weight support on gross motor function and gait in eight children with spastic CP for 12 weeks training. The results showed an improvement in stride length and decreases in double limb support.

Concerning the improvement in the post treatment mean values of control group (A) could be explained by the effect of NDT program which focuses on inhibiting abnormal movement patterns and facilitating automatic patterns of movement and the foundations for normal functional movement. This finding comes in agreement with Adams et al., 2002[1] who reported improvements in gait patterns using a one hour program of NDT-based therapy twice a week for six weeks in children with cerebral palsy.

BWSTT might be a more effective or efficient means for many ambulatory children with CP because of safety factors (e.g, harness support eliminating fear/ potential of falling, walking in the safe environment of the clinic), velocity factors for endurance (e.g, treadmill speed maintains child's speed walking)[8,14].

The significant reduction of walking energy expenditure and improvement in the walking velocity noted in the present study may be attributed to; BWSTT allowing for manual guidance of foot and leg movements in a repetitive, task specific approach to walking on a moving treadmill. This explanation comes in consistent with Begnoche et al., 2007[3] who reported that facilitation of gait training by the therapist through stimulation of full hip extension and equal stance time on each limb, preventing premature initiation of swing phase, insuring heel strike at initial contact, and preventing knee hyperextension during midstance phase. The prolongation of the stance phase in combination with the backward movement of the treadmill belt during treadmill walking, believed to be an essential component in improving gait pattern and efficiency as reflected by reduction of energy expenditure.

Conclusion

According to the results of this study, it can be concluded that BWSTT represents an effective additional intervention to the traditional physical therapy program based on NDT in improving energy expenditure and walking velocity in spastic diplegic children.

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الملخص العربي

تأثير التدريب على جهاز السير المتحرك مع التحميل الجزئي لوزن الجسم على معدل استهلاك الطاقة و سرعة المشي عند الأطفال المصابين بالشلل التقلصى المزدوج

الهدف من هذا البحث هو بيان تأثير التدريب على المشي باستخدام سير الجري المتحرك مع التعليق الجزئي لوزن الجسم بنسبة قدرها 30% بالإضافة إلى برنامج التمرينات العلاجية التقليدي على معدل استهلاك الطاقة وسرعة المشي عند الأطفال المصابين بالشلل التقلصى المزدوج . تم إجراء هذا البحث على 24 طفلا من الأطفال المصابين بالشلل التقلصى المزدوج من الجنسين ، تتراوح أعمارهم من 6 سنوات إلى 8 سنوات . تم تقسيم العينة إلى مجموعتين متساويتين في العدد (كل منها 12 طفلا) المجموعة الضابطة (أ) : وقد تلقت برنامج العلاج الطبيعي التقليدي لهؤلاء الأطفال فقط . ومجموعة الدراسة (ب) : تلقت نفس البرنامج العلاجي بالإضافة إلى تمرينات المشي على جهاز السير المتحرك مع رفع الوزن بنسبة قدرها 30% لمدة 30 دقيقة في الجلسة الواحدة . كانت مدة العلاج لكلا المجموعتين 12 أسبوعا بمعدل ثلاثة أيام أسبوعيا . تم تقييم جميع الأطفال المصابين مرتين ، مرة قبل بداية العلاج والمرة الثانية في نهاية العلاج بقياس معدل ضربات القلب باستخدام جهاز البلثوميتر ومنها حساب معدل استهلاك الطاقة و قياس سرعة المشي عند هؤلاء الأطفال لمسافة قدرها 10 متر . وفى نهاية الدراسة تم مقارنة نتائج التقييمين إحصائيا . وقد أظهرت النتائج وجود تحسن ذي دلالة إحصائية واضحة في المتغيرات المقاسة لكلا المجموعتين وكانت نسبة التحسن الأكثر وضوحا في صالح مجموعة الدراسة . وهذه النتائج تدل على أن إضافة تدريبات المشي على جهاز السير المتحرك مع التعليق الجزئي لوزن الجسم إلى برنامج العلاج الطبيعي التقليدي المستخدم لتأهيل هؤلاء الأطفال ذات فائدة كبيرة في تقليل معدل استهلاك الطاقة وزيادة سرعة المشي عند الأطفال المصابين بالشلل التقلصى المزدوج .