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Effect of treadmill training with partial body weight support on spine geometry and gross motor function in children with diplegic cerebral palsy

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ABSTRACT

Back ground: Cerebral palsy children suffer from neuromuscular and musculoskeletal problems such as spasticity, muscle contractures, bony deformities, incoordination and muscle weakness that interfere with motor function. The aim of this study was to evaluate the effect of treadmill training with partial body weight support on spine geometry and gross motor function in spastic diplegic cerebral palsy children. Methods: 31 children with spastic diplegia (5-7 years) were recruited and randomly allocated to control group (15) and study group (16). Of these, 30 children completed training and testing. Both groups received a specially designed therapeutic exercise program. The study group additionally received treadmill training with partial body weight support (30% relief of total body weight). Treatment was provided 3d/w for 3 successive months. Assessment was performed before and after intervention. Trunk imbalance, pelvic tilt scores using formatric instrumentation system were recorded. Gross motor function (standing and walking) scores using gross motor function measurement scale were recorded. Results: children in both groups showed a significant improvements in the mean values of all measured variables post-treatment (p<0.05). The results showed significantly better improvement in the measured variables of trunk imbalance and pelvic tilt in favor of the study group (p<0.05). There were no statistically significant difference in GMFM of standing and walking between both groups. Conclusion: treadmill training with partial body weight support induced significant changes in spine which could be efficient in the rehabilitation of children with spastic diplegia.

Keywords: *Cerebral Palsy, Biodex Unweighing System, spine, GMFM.*

INTRODUCTION

Cerebral palsy (CP), a disorder of movement and posture attributed to non-progressive lesion of the immature brain [1], is the most common physical disability as the child grows the musculoskeletal problems changes [2,3]. Postural balance control in CP children deteriorates due to the combined effect of impaired neural motor control mechanisms and the secondary musculoskeletal abnormalities [4,5]. Spastic diplegia is one of the most common and prevalent clinical subtypes of cerebral palsy in which there is more motor impairment in the lower extremities than the upper extremities [6].

Spastic diplegic children suffer from abnormal back geometry, the contributing factors: 1-trunk imbalance due to functional leg length discrepancy (LLD), poor legs, pelvis and trunk alignment, weakness of the muscles of the trunk [7]. 2- pelvic tilt which refers to a high difference of the lumber dimples relative to horizontal plane and is one of the major problems because the pelvis transmitting vertical forces between the spine and the lower limbs as a part of the kinetic chain. So, the pelvis transmits the biomechanical disturbance of the lower limb to the trunk giving trunk imbalance [8]. There is a direct relation between decreased locomotor function and the limited capacity for participation, social and community interaction in CP children [9]. Children classified as level III by the

GMFCS (appendix 1), their walking energy expenditure is increased up to 3 times that of typically developing children [10].

Partial weight bearing therapy (unweighing) is a concept of rehabilitation that uses an external device to support a percentage of the patient's body weight allowing them to perform therapeutic activities in an upright ,proper biomechanics due to the control of center of mass in both horizontal and vertical direction [11].

In the absence of the higher brain center function the reciprocal walking motion on the treadmill is thought to be controlled at least in part by the spinal cord and is organized by the central pattern generators (CPGs), CPGs activated by lower brain centers, the brain stem and the basal ganglia, which activate muscles responsible for repetitive walking movements [12-14]. There is evidence of CPGs activity in human but with more complex activation process than that demonstrated in animals [15]. Reciprocal kicking motions appear as early as fourteen week of gestation, the abilities of newborns to step immediately after birth and the reciprocal kicking movement of the infants altogether provide additional evidence of a locomotion functional mechanism [16,17]. After neurological injury, activation of this automatic reciprocal mechanism can be achieved using partial body weight supported treadmill training (BWSTT) [15].

Treadmill training with partial body weight support as a therapeutic modalities in the rehabilitation of children with cerebral palsy has recently been the focus of many studies; however still little is known regarding its effect on spine. The purpose of this study was to assess the effect of treadmill training with partial body weight support on trunk imbalance, pelvic tilt and how these reflected on standing and walking in spastic diplegic children.

METHODS

Participants

The study was approved by the Ethical Committee of the faculty of Physical Therapy and parents signed a consent form authorizing the child's participation. The participating children were recruited from the outpatient clinic of the Faculty of Physical Therapy, Cairo University.

Sixty-two children with spastic diplegic cerebral palsy were initially screened and assessed to determine age, diagnosis and inclusion and exclusion criteria.The inclusion criteria were: the participated children had diagnosed spastic diplegic cerebral palsy in the prenatal, perinatal or post natal period confirmed by magnetic resonance images (MRIs), they aged 5-7 years of both sexes, spasticity grades ranged from 1+ to 2 according to modified Ashworth scale [18]; they were able to stand alone; walk with support with abnormal gait pattern; their average heights were one meter or more (because the horizontal line which appears on the computer screen when the camera is ready for recording should be below the scapula to avoid the undetection of the axillary points which will interfere with recording of the spinal image); they were categorized in levels II, III on the Goss Motor Function Classification System (GMFCS) [19] and the ability to comprehend commands.

The exclusion criteria were: lower extremity surgery within the past 6 months; nerve block or botulinum toxin injection within the past 3 months and fixed deformity of both lower limbs.

From the screened children only 31 children were fulfilled the aforementioned criteria, the children were distributed randomly into two groups. Of the 31 children 1 child in the study group withdrew after completing only 5 training sessions due to unexpected surgery. The control group (n=15) received a specially designed therapeutic exercise program. The study group (n=15) received the same therapeutic exercise program in addition to treadmill training with partial body weight support using the Biodex Unweighing System.

Evaluation

Formetric instrumentation system was used to assess the geometry of the spine (trunk imbalance, pelvic tilt) which based on non-contact three dimensional scan, the patient is positioned in front of the black back ground at a distance of 2 m away from the measurement system while keeping his neck in a slightly forward-bending posture to improve the presentation of the vertebral prominens, the scan time is 40 millisecond in order to eliminate movement artifact, full back shape three-dimensional analysis will be recorded and a spatial reconstruction of the spine derived from it by means of a specific mathematical model. Gross motor function assessed by Gross Motor Function Measure Scale (GMFMS) which is a standardized observational instrument designed and validated to measure change in gross motor function over time in children with cerebral palsy [20]. It consist of 88 items, the items are weighted equally and grouped into five dimensions, scores for each dimension is expressed as a percentage of maximum score for that dimension. The total score is obtained by averaging the percentage scores across the five dimensions.

Treatment

For both groups, the treatment program was three sessions /week, two hours each, for three successive months. The children in both groups received specially designed therapeutic exercise program composed of neuro-developmental approach directed toward inhibiting abnormal postural reflexes and facilitate normal movement pattern, stretching, strengthening exercises, gait training exercises for two hours for control group and for one and half hour for study group followed by around half an hour treadmill training with partial body weight support.

For the study group the Biodex Unweighing System used as a suspension system to reduce the amount of weight born by the child and provide proper upright posture as the child body weight is relieved by 30% of the total body weight [21]. Hesse [22] found that level greater than 30% of BWS can have adverse effect on gait pattern due to a significant reduction of the affected lower limbs muscles activity.

Treadmill protocol was developed from systematic reviews of literature assessing the effects of treadmill training on children with CP [23,24], children asked to walk with harness secured on the motor driven treadmill with speed of 0.01 m/sec and 0 degree inclination for 5 min firstly increased gradually to reach 2m/sec. and 10 degree inclination for 15 min of a maximum of 20 min.

Statistical analyses

Results were expressed as mean ± standard deviation (SD). T test was conducted for comparing subject characteristics between both groups. Paired t test was conducted for comparison of trunk imbalance, pelvic tilt, and GMFM between pre and post treatment conditions in each group. T test was conducted for comparing the pre and post treatment mean values of all measuring variables between both groups. The level of significance for all statistical tests was set at alpha < 0.05. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 19 for windows. (IBM SPSS, Chicago, IL, USA).

RESULTS

The demographic characteristics of the included children are illustrated in Table 1. The results of this study regarding to the mean values of the trunk imbalance, pelvic tilt, GMFM for standing and walking pre and post treatment showed significant improvement in both groups as illustrated in table 2 (p <0.05).

Comparing these results between both groups pre-treatment indicated no significant differences. While their comparison post treatment showed significant differences in trunk imbalance and pelvic tilt in favor of the study group (p < 0.05) and no significant differences in GMFM for standing and walking (p >0.05).

Characteristic	Control group n=15	Study group n=15
Age (years+SD)	6.01±0.77	6.11±0.67
Sex (boys/girls)	9/6	7/8
Height (cm)	112.3±5.99	112.5±5.88
Weight (kg)	19.12±2.28	19.09±2.18
GMFCS level		
II	9	8
III	6	7

Table 1. participant's characteristics

Parameters	control group	study group	p-value	Significance
Trunk imbalance (mm)				
Pre	13.8SD7.41	16.13SD8.31	0.42	Insignificant
Post	8.86SD6.57	3.66SD2.46	0.008	Significant
p- value	0.0001	0.0001		
	significant	Significant		
Pelvic tilt (mm)				
Pre	11.2SD4.32	14.26SD10.68	0.31	Insignificant
Post	7.6SD3.86	4.46SD3.18	0.02	Significant
P value	0.0001	0.003		
	significant	Significant		
GMFM standing (%)				
Pre	22.18SD11.73	22.36SD10.57	0.96	Insignificant
Post	32.13SD12.41	38.06SD13.54	0.22	Insignificant
p- value	0.0001	0.0001		
	Significant	Significant		
GMFM walking (%)				
Pre	16.44SD5	13.63SD5.28	0.14	Insignificant
Post	21.74SD4.66	20.89SD4.03	0.59	Insignificant
p- value	0.0001	0.0001		
	Significant	Significant		

Table 2: Comparison between the mean values of the trunk imbalance, pelvic tilt, GMFM standing and walking pre and post treatment within and between both control and study groups

Appendix1: Gross motor function classification system-descriptors

Level II	Can climb stairs with a railing. Has difficulty with uneven surfaces, inclines or in crowds. Has only minimal ability to run or jump.
Level III	Walks with assistive mobility devices indoors and outdoors on level surfaces. May be able to climb stairs using a railing. May propel a manual wheelchair and need assistance for long distances or uneven surfaces

DISCUSSION

Spastic diplegic children Standing posture is characterized by functional LLD due to hamstring and adductor spasticity in lower limbs, asymmetrical weakness of calf muscles, quadriceps and hip extensors, along with asymmetrical hip abduction and increased co-activation of back and abdominal, all leading to poor pelvis and trunk dissociation causing pelvic tilt and trunk imbalance[25].

In studies assessing the effect of BWSTT in children with CP, Schindl et al.[26] and cherng et al. [27] found that BWSTT resulted in improvements in GMFM and the Functional Ambulation Categories however, Willoughby et al. [23] evaluated the efficacy of 9 weeks of twice-weekly partial body weight-supported treadmill training (PBWSTT) for children with CP compared with overground walking and they concluded that PBWSTT found to be no more effective for improving walking speed, endurance, and walking function than practicing overground walking.

There are apparent discrepancy in the findings of previous studies also these studies do not address the possible effects of treadmill training with partial body weight support on spine. in this study we assessed the effect of treadmill training with partial body weight support on spine geometry (trunk imbalance, pelvic tilt) and how these can be reflected on motor function, the findings of this study reflected improvement in trunk imbalance, pelvic tilt, standing and walking in all participating children post-treatment. This improvement can be explained by various motor learning theories. Schmidt et al.,[28] confirmed that the learning processes of motor skill is a set of processes accompanied with practice and experience, that optimize the developmental motor skills potentials and leading to permanent changes for responding and producing skilled action also Magill [29] found that the motor learning three stages are strongly depend on the importance of intensive and repetitive practicing of any new learned skills to bring organization and develop an ingram by using of the same synaptic pathway and reach skill automaticity.

Also, Parasympathetic tones reduced either by neuro-developmental approach or BWSTT allowing for increased range of motion; Hesse [22] found that, there was less planter flexor spasticity and physiological activation pattern of erector spinae muscles during treadmill walking with partial body weight support also the qualitative analysis of the activation pattern of the tibialis anterior and the gastrocnemius muscles during treadmill walking with partial body weight support revealed less co-contraction and more timely correct activation of the dorsiflexors.

The difference in results of trunk imbalance and pelvic tilt, which were significantly better for the study group , can be explained by the combining effect of the partial weight bearing gait therapy as the Unweighing System allows symmetrical loading of the lower extremities which help in equal weight distribution over the base of support in turn provides the proper biomechanics with the least expenditure of muscle energy and postural tone also allows proper shift of the COG and proper pelvic rotation during gait, lateral pelvic tilt allows the body weight to be centered over the hip, allowing the non-weight bearing leg to swing through, the pelvis then rotates forward with the weight bearing hip acting as a fulcrum allowing forward movement of the non-weight bearing limb [11,30-32].

However, there were insignificant difference between both groups in GMFM, there are a number of possible explanations for that, treadmill training with partial body weight support does not provide task-specific approach and this potentially reduced the overall intensity of the intervention. The study group showed a significant improvement in trunk imbalance and pelvic tilt also they increased their GMFM for standing and walking as evidenced by the significant within group. However, these improvements did not carry over to overground providing opportunity for direct carryover of skills. Another possible explanation may be that we reduced the body weight by 30% for all children throughout the study and we did not systematically reduce body weight, which have been considered as key component of a successful training protocol in treadmill training for adults with spinal cord injury [33]. Also walking on a treadmill may be less challenging and comparatively easier for children challenging aspects of overground walking.

Some limitations were encountered in this study, including other important benefits to treadmill training with partial body weight support were not measured, such as changes to physiological outcomes such as cardiovascular fitness. Another limitation is that only children classified as GMFCS II, III were included in this study and so the results cannot be generalized to other GMFCS groups also lack of control over children's activities outside the training sessions and their follow – up several months post training to evaluate the long lasting effect of treadmill training with partial body weight support. Electromyography (EMG) is recommended to record muscular activities associated with treadmill training with partial body weight support also we recommended adding simultaneous overground walking practice to a treadmill training to intense the effect of BWTT.

Conclusion

The study has brought out that treadmill training with partial body weight support using the Unweighing Biodex System has better effect on spine however; it may be no more effective than therapeutic exercise program for improving gross motor function performance (standing and walking) in spastic diplegic children.

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Declaration of interest

The authors declare that there is no conflict of interest.

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