The Egyptian Journal of Medical Human Genetics (2012) **13**, 63–71

Ain Shams University

The Egyptian Journal of Medical Human Genetics

www.ejmhg.eg.net
www.sciencedirect.com

ORIGINAL ARTICLE

Modulation of back geometry in children with spastic diplegic cerebral palsy via hippotherapy training

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Received 27 August 2011; accepted 29 October 2011
Available online 29 November 2011

KEYWORDS

Cerebral palsy;
Diplegia;
Back geometry;
Hippotherapy

Abstract *Background and purpose:* Controlled hippotherapy environment provides a foundation for improved neurologic function and sensory processing. This foundation can be generalized to a wide range of daily activities, making the horse a valuable therapeutic tool for rehabilitation. The purpose of this study was to examine the effects of a once weekly, twelve-week hippotherapy program on back geometry in children with spastic diplegic cerebral palsy.

Subjects: Thirty spastic diplegic children from both sexes, ranging in age from six to eight years represented the sample of this study. The degree of spasticity ranged from 1 to 1+ according to the modified Ashworth scale. They were divided randomly into two groups of equal number A (control) and B (Study).

Procedures: Evaluation of back geometry parameters was conducted for each child of the two groups before and after three months of treatment via using Formetric instrument system. Group A received a designed exercise program, while group B received hippotherapy training in addition to the same exercise program given to group A.

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Peer review under responsibility of Ain Shams University.
doi:10.1016/j.ejmhg.2011.10.004

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Results: No significant difference was noticed when comparing the pre-treatment results of the two groups, while significant improvement was observed in all the measuring variables of the two groups when comparing their pre and post-treatment mean values. Significant difference was also observed when comparing the post-treatment results of the two groups in favor of group B.

Discussion and conclusion: Hippotherapy utilizes the movement of the horse to provide sensory feedback and may be used as a therapeutic intervention for improving back geometry in children with spastic diplegia.

1. Introduction

Cerebral palsy(CP) is the most common cause of physical disability in childhood and may affect the child on several health dimensions; the motor signs include primary neuromuscular deficits, such as spasticity, muscle weakness and decreased selective motor control, and secondary musculoskeletal problems, such as bony malformations and contractures [1].

Spastic diplegia is the most prevalent type of CP, it accounts for about 44% of the total incidence of CP and represents 80% of affected preterm infants [2].

Children with spastic diplegia have significant weakness in the trunk and spasticity of the extremities. They have some motor impairment of their upper extremities milder than lower ones [3]. The primarily functional problem includes difficulty with mobility and posture. Other problems include postural deviations such as inability to sit without support, inability to stand, and difficulty in movement transition [4].

Sitting is an important step for child to achieve the upright posture against gravity and also an essential activity to provide the postural background tone required for the functional movement of upper extremity. However, the spastic diplegic children with poor trunk control show rounded back while they are sitting. They often show the difficulty to achieve well-balanced sitting posture and display the poor sitting posture such as flexed trunk with kyphotic curvature of the spine and asymmetry of trunk [5].

The treatment goals of spastic diplegic children focus on the prevention of disability by minimizing the effects of impairments, and maximizing the gross motor function. Achieving these goals involves promotion and maintenance of musculoskeletal integrity, prevention of deformities, and enhancement of optimal posture and movement to promote functional independence [6].

Physical therapy is the main stay of treatment for postural deviations. Exercises program have been described to encourage adjustment of muscle tendon length, reposition of skeletal segments and produce static posture realignment. It has been reported that exercises program alone are insufficient to induce adaptive changes in muscle tendon length specially in severe spinal curves abnormalities, which need further combination with other physical therapy modalities [7].

Hippotherapy is a physical and occupational therapy that incorporates the movement of the horse into a treatment plan for patients who have neuromuscular impairments aimed at facilitative and rehabilitative goals. It is considered as a treatment strategy that utilizes equine movement as a part of an integrated intervention program to achieve functional outcomes [8].

The horse can be used as a dynamic treatment surface because a therapist can modify the direction, speed, and magnitude of postural displacement of a patient on a walking horse. With its proposed effect on postural control, hippotherapy has the potential to be an effective treatment intervention for children with CP with an expectation of carryover into functional activities [9].

The Formetric instrument system represents a reliable method for three-dimensional (3D) back shape analysis and reconstruction of the spinal deformities without ionizing radiation exposure [10]. It is a device used to analyze the back configuration based on the dimensional scan. It includes procedures for documentation and achieving patient's image data. Also it has the ability to compare new and old patient's data [11].

Therefore, the purpose of this study was to explore the effectiveness of hippotherapy training on back geometry in children with spastic diplegia.

2. Patients, instrumentation and procedures

2.1. Patients

Diplegic cerebral palsied children who had been referred from pediatric neurologist to out-patient clinic of the Faculty of Physical Therapy, Cairo University, were screened to select children who were possible to be included in this study. Thirty spastic diplegic children from both sexes were eligible for participation according to the following criteria: their ages ranged from six to eight years (X 7.02 ± 0.5 years), and their heights average were one meter or more. They were free from any associated disorders other than spasticity, with minimal non significant perceptual defects, but they were able to follow instructions given to them in both testing and training sessions. The degree of spasticity ranged from 1 to 1+ according to the Modified Ashworth scale [12]. All children were able to stand and walk independently with an abnormal pattern of gait. They were free from any structural deformities; however, children demonstrated variable degrees of tightness. They had no allergy to horses.

Children were subsequently excluded for any of the following reasons: they were medically unstable as determined by, history, or medical records, they had epilepsy, visual or auditory problems.

Children were randomly assigned into two groups of equal number (A and B), by asking each child to pick up an index card out of a box which contains 30 cards (15 card for each group) to determine which group he/she would be in.

Group A (control) received a designed exercise program for spastic diplegia with emphasis on posture correction, while group B (study) received hippotherapy in addition to same exercise program given to group A.

Back geometry for each child was evaluated before and after three months of treatment by using Formetric instrument system to assess lateral deviation, trunk imbalance, pelvic tilting and surface rotation of vertebra.

2.2. Instrumentation

2.2.1. For evaluation

2.2.1.1. Formetric instrument system. This system serves for the determination of the geometry of the spine of the human being based on non-contact three dimensional scan and spatial reconstruction of the spine derived from it by means of a specific mathematical model.

The Formetric instrument system contains the following major subassemblies

- *The scan system*: It is (optical column) with base plate contains a raster projector and a video camera mounted into a profile tube. A telescopic drive provides motorized vertical adjustment of the entire system.
- *The computer*: It is visual spine software which provides 3D-reconstruction of the spine based on measurement data of the system Formetric and allows individual image analysis of the carried out examinations.
- *The black background screen*: It is black to allow absorption of any light rays fall away of the patient body and prevents any reflection of the rays again to the recording camera to allow clear and accurate recording of the patient's back.
- *The laser printer*: Provides high-quality result presentation.

The results of shape analysis were plotted on the laser printer as graphic protocol. Each graphic protocol contains some anatomical parameters which are calculated from the anatomical landmarks. The anatomical landmarks are denoted as follows (Fig. 1):

VP: Vertebra prominence,
SP: Sacrum point,
DL: Left dimple,
DR: Right dimple, and
DM: Midpoint between both dimples, and, derived from it, a spatial reconstruction of the spine by means of a specific mathematical model [11].

2.2.2. For treatment

1. *Tumble forms objects*: (mat, tilting board, medical balls, stand bar and parallel bars).
2. *Trained horses*: Two well trained horses: these horses were owned by pyramids international school.

The horse saddle (Fig. 2) which was used in training consists of:

- *Leather seat*: The part of the saddle where the rider sits, is modified by removing the sponge layers to allow more feeling of the horse movement.
- *Stirrup*: It consists of :
  1- Iron stirrup which is the part of the saddle that the rider's feet rested on it, provides support and leverage to the rider.
  2- Adjustable leather stirrup which connects leather seat with iron stirrup.
- *Leather flaps*: The leather straps connecting the stirrups to the saddle tree and protecting the rider's legs from sweat.
- *Panel*, or *padding*: Cushioning on the underside of the saddle to prevent harm to the horse.
- *Surcingle*: A long strap that goes over a saddle and around the horse's barrel to hold the saddle on.
- *Monkey grip*: It is a handle that attached to the front of saddle. A rider may use it to maintain his or her balance or to assist in mounting (Fig. 3).
- *D-ring*: a "D"-shaped ring on the front of a saddle, to which certain pieces of equipment (such as the safety helmet) can be attached.

3- *Safety helmets*: (Fig. 4): It consists of two parts.
1. Adjustable waist belt made from cotton.
2. A stretch hard cotton strip with two hocks to be attached to the D-ring.

2.3. Procedures

2.3.1. For evaluation

All parents had been informed of all study procedures and objectives for their children with the absence of any risk. After signing a written consent form, instructions about evaluative procedures were explained for each child before the testing session to make sure that all children understood the steps of evaluation and familiar with the device.

Evaluation for each child in the two groups was conducted in a warm and quite room before and after three months of treatment using Formetric instrument system to measure back geometry as follows:

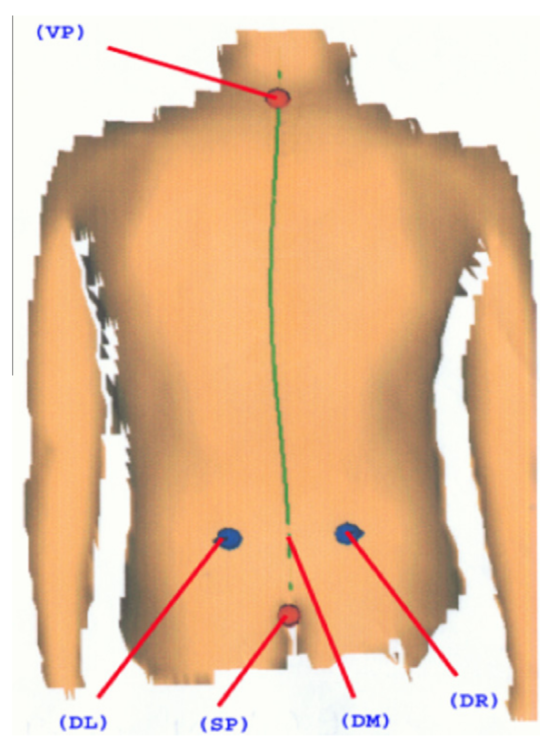

Figure 1 Illustrating the anatomical landmark (VP, SP, DL, DR and DM) which were detected automatically by the Formetric instrument system.

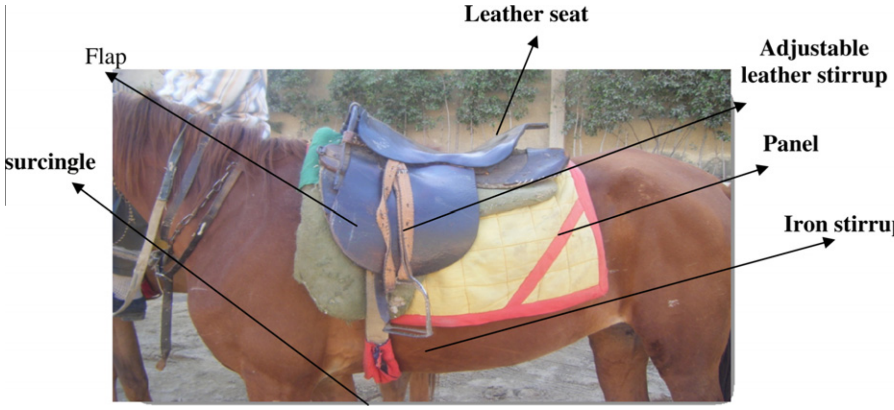

Figure 2 Representing the horse saddle for hippotherapy.

Child data were entered in his/her file on the computer including date of birth, name, sex, height and weight .Each child was asked to stand facing the black back ground screen at a distance of 2 m away from the scan system either on the ground or on the blocks (according to his/her height). The horizontal line of scan system should lie below the inferior angles of scapulae. It is important that the child's back (including buttocks) was completely bare to avoid disturbed image structures. Each child was asked to assume the usual natural standing attitude with chin in to improve the presentation of the vertebral prominence. The child was also asked to keep his/her both upper extremities freely extended beside the body as much as possible. Height adjustment of the optical column was done before capturing to obtain the suitable image. When the camera was ready for image recording, a green horizontal line appeared on the computer screen and the projector lamp was automatically switched. During capture, the child was asked to hold on breath for a period of 40 ms. Full back shape three-dimensional analysis was recorded and printed out for each child [11].

Through one capture, the following parameters were measured:

– Lateral deviation (rms).It represents the root mean square (rms) lateral deviation of the spinal midline from the line VP–DM. In a healthy person this figure should be zero (plus the rms error of measurement in the order of magnitude 3–4 mm).

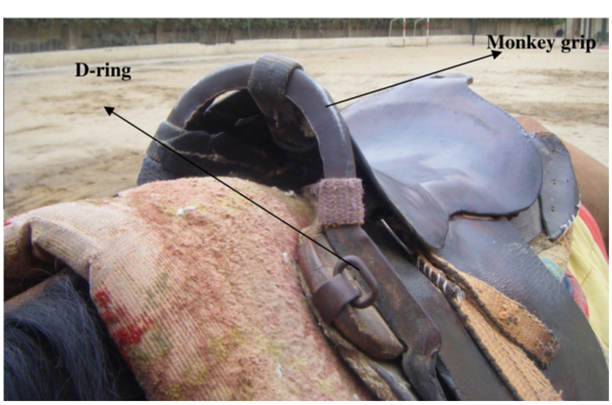

Figure 3 Showing monkey grip and D-ring.

– Lateral deviation (max)It gives with respect to the absolute values – the maximum lateral deviation of the spinal midline from the VP–DM, i.e., the apex value (in the frontal plane).
– Trunk imbalance VP–DM.It is defined as the lateral deviation of the vertebra prominence VP from the dimple midpoint DM. It is measured in millimeters and degrees.
– Pelvic tilt DL–DR.The pelvis tilt refers to a height difference of the lumbar dimples relative to a horizontal plane.
– Surface rotation (rms).It gives the rms value of the surface rotation on the symmetry line. In a healthy person this figure should be zero (plus the rms error of measurement in the order of magnitude 3°).
– -Surface rotation (max).It gives-the maximum surface rotation (generally at the apex).
– A positive or negative value in previous parameters indicates a deviation to the right or left, respectively.

2.3.2. For treatment

The thirty children representing the sample of this study were divided randomly into two groups of equal number (A and B). A designed exercise program for each child of the two groups was conducted for one hour, three times/week for three successive months, including:

- Stretching exercises for Achilles tendon, hamstrings, hip flexors and adductors of both lower limbs, upper abdominal and pectoralis muscles.
- Strengthening exercise for scapular retractors, spinal extensors, lower abdominal, hip and knee extensors, and dorsiflexors muscles.
- Facilitation of postural reactions, including: facilitation of righting, equilibrium and protective reactions from sitting on ball. Standing on balance board and tilting each child in different directions forward, backward and side-ways.
- Facilitation of standing and weight shift.
- Gait training: forward, backward, and side-ways walking between parallel bars (closed environment gait training).Open gait training was also conducted.

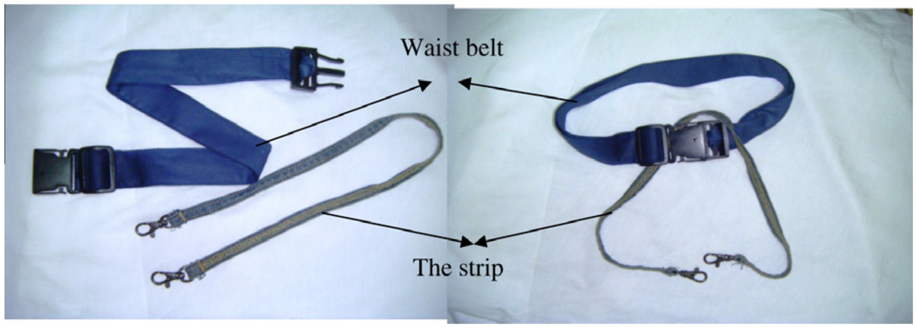

Figure 4 Representing the two parts of the safety helmets.

In addition to the selected exercise program, group B (study) received hippotherapy training. It was conducted once weekly for 13 times. The first one was considered as preparatory session for each child and his/her parent to emphasize on hippotherapy benefits and to explain every step of session to the child and how contact with horse to be familiar with it.

The selected horse gait in this study was four-beat gait which is called walk (6.4 km/h) [13], during each session the child horse walk in rectangular shape around the treatment arena in clock and anti-clock wise direction, directed by the handler who rides another horse walked in front of the child horse, holding the two rein lines together to direct the horses.

During this walk, the horse's legs follow this sequence: left hind leg, left front leg, right hind leg, right front leg, in a regular 1-2-3-4 beat. Also, the horse moves its head and neck in a slight up and down motion that helps maintain balance [13]. The child was almost always feeling some degree of gentle side-to-side motion in the horse's hips as each hind leg reaches forward. The physical therapist walked along the side of the horse to ensure child safety and to give verbal instructions to the child to maintain proper upright posture. Each child rode the horse for 30 min with 10 min rest in between [14]. The first 15 min, the child was encouraged to maintain postural alignment with symmetry of head, trunk, and pelvis while grasping the monkey grip in front of him for support and to prevent loss of balance. The second 15 min, the child sits independently, and was asked to conduct upper limb exercises in the form of bilateral upper limb elevation, extension diagonally and horizontal abduction.

3. Data analysis

The raw data were analyzed using the SPSS program to determine the mean ± standard deviation for each measuring variables of the two groups before and after three months of treatment. Tests included in this study were Levene's test, independent *t*-test and paired *t*-test.

4. Results

The baseline results of the Levene's test were not significant for all the measuring variables {the lateral deviation (rms) and (max), trunk imbalance, pelvic tilt and surface rotation, (rms) and (max)}, indicating homogeneity of the study sample for the two groups.

An independent *t*-test identified no significant differences when comparing the pre-treatment mean vales of the two groups.

As shown in Table 1 and Figs. 5 and 6, paired *t*-test was applied to reveal significant reduction in the mean values of all the measuring variables of the two group (A and B), when comparing their pre and post-treatment mean values. The independent *t*-test was also used to compare between the post-treatment results of the two groups, which revealed significant difference in the favor of the study group (B).

5. Discussion

Few scholars have defined the theoretical bases of hippotherapy and less about how psychological, physical, social and educational benefits can be achieved through hippotherapy in children with special needs [15].

Although hippotherapy treatment has been demonstrated to have therapeutic effects on children with cerebral palsy, the samples used in research studies have been very small [16].

Hippotherapy employs locomotion impulses that are emitted from the back of a horse while the horse is walking. These impulses stimulate the rider's postural reflex mechanisms [17]. It affects multiple systems such as the sensory, musculoskeletal, limbic, vestibular, and ocular systems simultaneously, leads to different therapeutic benefits that will be evidenced in behavioral patterns used in other environments [15].

The aim of this study was to determine the effect of hippotherapy on back geometry in children with spastic diplegia. This agree with Meregillano [18]who reported that hippotherapy refers to the use of the movement of the horse as a treatment tool by physical and occupational therapists to address impairments, functional limitations and disabilities in clients with neuro-musculoskeletal dysfunction such as cerebral palsy.

We focused in our study on the spastic diplegic type of cerebral palsy which develops abnormal muscle tone and abnormal movement control that may result in inability to maintain normal posture. This was conformed by the findings of Graham [19] who concluded that spastic diplegic cerebral palsied children are suffering from abnormal back geometry, poor postural reflexes and poor alignment of the trunk, so, the quality of sitting and standing postures is affected and reflected on their life and activity of daily living. This was also confirmed by Gillen and Burkhardt [20] who reported that diplegic children have been known to have difficulty with the timing of motor response to support surface perturbations as the muscle activation onset is frequently delayed. Abnormal timing of

Table 1 Pre and post-treatment mean values of back geometry for groups A and B.

Variables		Control group		Study group	
		Pre	Post	Pre	Post
Lateral deviation (rms)	Mean	4.9	3.8	4.85	2.75
	SD	±2.074	±1.704	±1.980	±1.292
	t-Test	5.581		6.242	
	P-Value	0 < 0.05		0 < 0.05	
	Sig.	Significant		Significant	
Lateral deviation (max)	Mean	9.35	6.75	9.3	4.7
	SD	±4.416	±3.850	±4.508	±2.202
	t-Test	4.155		5.054	
	P-Value	0 < 0.05		0 < 0.05	
	Sig.	Significant		Significant	
Trunk imbalance	Mean	11.35	10.3	12	7.3
	SD	±4.944	±4.824	±5.241	±4.329
	t-Test	2.926		6.443	
	P-Value	0 < 0.05		0 < 0.05	
	Sig.	Significant		Significant	
Pelvic tilts	Mean	3.4	2.25	3.5	1.5
	SD	±1.930	±1.118	±1.67	±1.192
	t-Test	3.359		7.646	
	P-Value	0 < 0.05		0 < 0.05	
	Sig.	Significant		Significant	
Surface rotation (rms)	Mean	3.3	2.85	3.2	2
	SD	±1.260	±1.387	±1.609	±1.076
	t-Test	2.438		4.485	
	P-Value	0 < 0.05		0 < 0.05	
	Sig.	Significant		Significant	
Surface rotation (max)	Mean	6.6	5.95	6.4	4.15
	SD	±2.479	±2.645	±3.299	±2.230
	t-Test	2.459		5.107	
	P-Value	0 < 0.05		0 < 0.05	
	Sig.	Significant		Significant	

X: mean; SD: standard deviation; *P* value: level of significance. Sig: Significance.

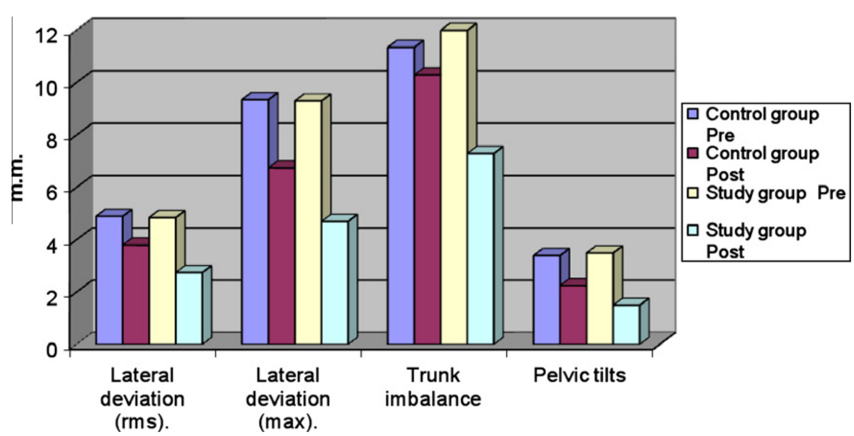

Figure 5 Illustrating the pre and post-treatment mean values of lateral deviation, trunk imbalance and pelvic tilt (mm) for groups A and B.

muscle activation is due to the activation of the proximal muscles before distal ones when responding to support surface perturbation. Also they have difficulty in organizing anticipatory postural adjustments associated with voluntary movements.

Selection of Formetric instrument system as an objective method for evaluation of back geometry in this study come in agreement with Saltikov et al., [21] who concluded that there is an increasing emphasis on objective assessment to monitor treatment effectiveness, which coincide with Hackenberg et al., [22] who reported that, Formetric system provides a reliable method for 3-dimensional back shape analysis and reconstruction of spinal deformities without radiation exposure.

The pre-treatment values of the Formetric system obtained from the two groups regarding the measured variables (lateral

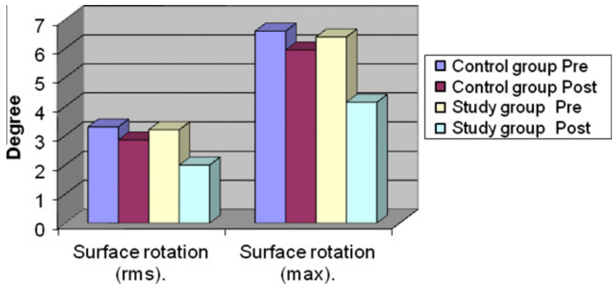

Figure 6 Demonstrating the pre and post-treatment mean values of surface rotation (degrees) for groups A and B.

deviation, trunk imbalance, pelvic tilt and surface rotation of vertebra) revealed non-significant differences and abnormal values of these variables. This may be attributed to neuromuscular impairments that interfere with the development of proper postural control as reported by Cook and Wollacott [23].

Choosing the measured variables for evaluation as a result of understanding the causes which might contribute to abnormal back geometry in spastic diplegic children as the following:

Lateral deviation of the spine is an attempt made by the spastic diplegic child to improve standing posture. Since pelvis is the link between lower limbs and spine, so, functional leg length discrepancy which is transmitted to the pelvis giving pelvic tilt is in turn transmitted to the spine using its mobility to give lateral deviation Chantraine et al., [24].

Presence of trunk imbalance in spastic diplegic cerebral palsied children may be due to functional leg length discrepancy, poor alignment of the legs, pelvis and trunk, weakness of trunk muscles and poor postural reflexes as reported by Graham [19]. He explained that functional leg length discrepancy occurs due to asymmetrical weakness of calf muscles, quadriceps and hip extensors, along with hamstring and adductor spasticity in lower limbs, asymmetrical hip abduction, and increased co-activation of abdominal and back muscles causing poor dissociation of the pelvis from the trunk, This leads to pelvic tit which reflect on the trunk giving trunk imbalance.

Pelvic tilt is one of the spastic diplegic children's major problems because pelvic attaches to the spine and the lower limbs transmitting vertical forces between them as a part of the kinetic chain. So, the pelvis transmits the biomechanical disturbance of the lower limb to the trunk James and Hardy [25].

Pelvic tilt leads to lateral deviation while pelvic torsion which occurs due to the combination of medial femoral torsion and lateral tibial torsion and foot equines leads to surface rotation of vertebrae Lippincott [26].

Improvement fulfilled in the control group (A) might be attributed to the effect of the therapeutic exercise program, which emphasized on a group of exercises for facilitation of normal erect posture. This comes in agreement with Kern et al., [27] who established that traditional methods of treatment for children with cerebral palsy are focused on the attainment of sequential developmental milestones and facilitation of normal movement patterns for the training of functional activities. The specific goals of sitting, standing and walking are part of an overall program that emphasizes postural alignment and quality of movement. This also agree with Park et al., [5] Who concluded that coordinated activation of extensors and flexors of trunk should be achieved for child to have a well balanced sitting position.

The significant improvement in the post-treatment results in the control group also comes in agreement with Sterba et al., [28] who recommended strengthening of the trunk and core muscles, promotion of postural and equilibrium reactions, and focus on postural alignment in sitting and standing as components of physical therapy treatment plans for pediatric therapists who rehabilitate children with neurological conditions.

The post-treatment results of the study group (B), receiving hippotherapy, revealed significant improvement which come in consistent with Vansant [29] who suggested that the child should be encouraged to engage in functional and meaningful activities that help the development of mature motor control and the transition from a lower stage of control to a higher stage. This is due to re-organization among the systems and sub-systems, as well as, flexibility of changes within the systems during contribution to specific tasks.

Duration of twelve sessions of hippotherapy training was selected based on other trial which was conducted by Haehl et al., [30] who investigated the effect of twelve sessions of hippotherapy on the function of two children with CP, the children demonstrated improvement in areas of general mobility and social domains.

Significant improvement in all the measuring variables in the study group was supported by the findings of Barnes [31] who concluded that the three-dimensional swinging motions of the horse back at the walk provide rhythmical movement that stimulates the rider's sensory processing. As the horse walk, his center of gravity is displaced with up-and-down, side-to-side, and rotational components of movement, which is similar to the normal trunk and pelvis patterns in human walking. Even when a horse turns toward one direction, the rider's body automatically compensates by leaning in the opposite direction. So, the child automatically learns to accommodate to the horse's particular gait pattern.

This improvement was also confirmed by Snider et al., [9] who reported that the proponents of hippotherapy suggest that the constantly moving, rhythmical sway of the horse back during riding challenges the rider's postural control via movement in all three planes, and variations in movements and perturbations encountered as the horse decreases or increases speed or changes direction while being led. In agreement with the dynamic systems theory of postural control development, these rhythms and variations in movement by the horse allow the rider to practice postural strategies and self-organize and re-organize balance strategies as with each step of the horse in walk, the center of mass of the rider is displaced while the trunk changes position in response to the horse's movements. He added that, changing the horse direction, contributes to the development of feed-forward and feedback responses necessary to control for unexpected perturbations in sitting. Learning to predict (feed-forward reactions) and control for (feedback reactions) unexpected perturbations lead to determinations of postural requirements for a selected task.

This explanation comes in agreement with Lovett et al., [32] who stated that as each fore-limb and hind-limb of the horse hit the ground, there is shifting of the rider's trunk in between impacts. This constant motion of the trunk would seemingly affect the rider's vestibular, proprioceptive, and neuromuscular systems, stimulating righting and equilibrium responses, and allowing enhancement of preparatory and anticipatory trunk muscle activity for proximal stability.

Improvement of the back geometry may be attributed to practice of upper limb exercises with hippotherapy training. This explanation comes in agreement with Thelen et al., [33] who reported that optimal motor control in dynamic sitting posture on the horse may be transferred to static and dynamic standing resulting in improvement of lumbo-pelvic alignment in the sagittal plane.

The post-treatment results of the two groups revealed significant improvement in the favor of the study group (B) receiving hippotherapy. This was confirmed by the findings of Benda et al., [34] who concluded that after hippotherapy for children with spastic cerebral palsy, significant improvement in symmetry of muscles activity was noted in those muscle groups displaying the highest asymmetry prior to hippotherapy.

Improvement observed in the study group may be attributed to the findings of Sterba [35] who found that during hippotherapy: (1) three-dimensional reciprocal movement of the walking horse produced normalized pelvic movement in the rider, closely resembling pelvic movement during ambulation in individuals without disability, (2) the sensation of smooth, rhythmical movements made by the horse improved co-contraction, joint stability, and weight shift, as well as, postural and equilibrium responses; and (3) that hippotherapy improved dynamic postural stabilization, recovery from perturbations, and anticipatory and feedback postural control.

6. Conclusion

Hippotherapy using the multidimensional movement of the horse may be used in conjunction with therapeutic exercise program for the improvement of back geometry in children with spastic diplegia.

Acknowledgments

This work was supported in part by the Faculty of Physical Therapy, Cairo University and pyramids international school. The critical comment offered on initial draft of this manuscript by my colleagues at the department of Physical Therapy for Growth and Developmental Disorder in Children and its Surgery are very much appreciated.

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