Research Article

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Geometrical analysis of back in response to spiral ankle foot orthosis in hemiplegic children.

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This study was conducted at the Faculty of Physical Therapy, Cairo University, Egypt in 2009 through 2010, to determine any possible effects of spiral ankle foot orthosis (AFO) on back geometry in spastic hemiplegic children. Thirty spastic hemiplegic children from both sexes ranged in age from six to eight years and ranged in degree of spasticity from grade 1 to grade 2 according to the Modified Ashworth Scale were participated in this study. Control group included fifteen children and received a designed rehabilitation program. Study group included fifteen children and received the same designed rehabilitation program of control group in addition to spiral ankle foot orthosis. The rehabilitation program was conducted 3 times/week basis for 3 successive months. This evaluation protocol was conducted for every child in both groups at his/her entry prior to the start of treatment, as well as after three months using Formetric instrumentation system to measure back geometry. The obtained results indicate that, back geometrical parameters showed no statistical differences following spiral ankle foot orthosis in addition to designed exercise program at three months (p>0.05). From the obtained results, it can be concluded that, this study gives support to no effect of spiral ankle foot orthosis (AFO) on back geometry in spastic hemiplegic children during study time.

Key words: Hemiplegic Children, Back Geometry, Spiral Ankle Foot Orthosis.

The term hemiplegic cerebral palsy comprises several pathological entities that result in limb weakness on one side of the body. In premature infants, the most common cause is periventricular hemorrhagic infarction. In term infants, the underlying causes are often cerebral malformation, cerebral infarction, and intracerebral hemorrhage. Imaging studies of the brain are useful to provide the family with a definitive diagnosis (Fenichel, 2009). Spastic hemiplegia is a unilateral paresis with upper limbs more severely affected than the lower limbs. It is seen in 56% of term infants and 17% of preterm infants (Sankar and Mundkur, 2005).

Hemiplegia is characterized by involvement of one side of the body, with the arm typically more affected than the leg. This is because of larger cortical representation (motor homunculus) of the hand and arm compared to a smaller leg area. (Shevell and Bodensteiner, 2004). Deformities of the spine (scoliosis, kyphosis, and lordosis) are associated with cerebral palsy. Although scoliosis can lead to serious outcomes, kyphosis and lordosis are not associated with significant co morbidity. The overall frequency of scoliosis in cerebral palsy is 25% (Thomson and Banta, 2001). The natural course of scoliosis in cerebral palsy differs from that of idiopathic scoliosis and is characterized by curve progression after skeletal maturity. Progression of scoliosis can lead to pain, interference with sitting, and, less commonly, cardiopulmonary compromise (Sarwahi et al., 2001). Scoliosis is common in children with cerebral palsy. The incidence and curve pattern depend on the degree of neurologic involvement. These children carry a higher risk of complications because of the increased presence of associated medical co morbidities (Rosenbaum et al., 2007). Typically, hemiplegia affects arm and hand, more than the leg. All children with hemiplegia walk later on toes of the affected foot because of a tight heel cord that may necessitate surgical lengthening. Growth arrest of the arm and leg is frequent in lesions that also involve the parital lobe. The arm and leg shorter and thinner and may be a compensatory scoliosis (Rowland and Pedley, 2010).

The spiral AFO consists of shoe insert; a spiral that starts medially, passes around the leg posteriorley and then passes anteriorly to terminate at the medial tibial flare where a calf band is attached the spiral AFO allow the rotation in the transverse plane while controlling ankle dorsiflexion and planterflexion as well as eversion and inversion (Kaplan, 2006). Spiral AFO is a design in which the single upright spirals from the medial aspect of the shoe insert, passes diagonally around the leg posteriorly, then passes anteriorly to terminate proximally where the calf band is attached. This design shows limited rotation in the transverse plane while controlling dorsiflexion/planter flexion and eversion/ inversion. Spiral AFOs are indicated in the presence of weak ankle dorsiflexors or planterflexors with moderate mediolateral instability and mild weakness of knee extensors (Tan, 2006).

Growth spurts occurring in 9 – 12 years old may cause widespread alterations in body shape and dimensions and have an effect on muscle tightness and flexibility, all of which may influence posture in children. Children have relatively larger heads and also a higher center of mass at about T_{12}, compared to L_5 – S_1 in adults. The combination of being shorter and having a higher center of mass may result in increased sway in children and difficulty in maintaining static balance. The stage of development of postural responses may influence the ability of the child to maintain a relaxed standing posture. Postural control development occurs sequentially in a cephalocaudad direction with head control first, followed by the trunk and then postural stability in standing. The motor and sensory systems involved in postural stability go through a transition period at 4 – 6 years and reach adult maturity by 7 – 10 years (Shumway-Cook and Woollacott, 2005).

The Formetric 3D measurement system dynamically scans and reconstructs human back surfaces with a frequency of up to 24 Hz. Automatically detectable fixed points and invariant features on the surface correlates to a high degree of accuracy with the spinal processes and pelvis. Thus, it is possible to calculate parameters derived from spine and pelvic position, displacement and rotation, things such as kyphotic and lordotic angles, pelvic symmetry and torsion, spinal rotation and displacement. Variations in postural movements in upright position of children may, however, lead to significant reduction of repeatability of examinations. A series of images taken with automatic calculation of the average values will solve this problem. In a dynamic examination, predefined movements are analyzed regarding symmetry and range of motion (Diers et al., 2009).

MATERIALS AND METHODS

Subjects: Thirty children of spastic hemiplegia (infantile type) between the ages of six years to eight years were studied. They were recruited from out clinic of Pediatrics, Faculty of Physical Therapy, Cairo University. The degree of spasticity of all subjects ranged from grade 1 to grade 2 measured according to the modified Ashworth scale. They had 100% of standing dimension percent score according to Gross Motor Function Measure (GMFMs). They were able to understand and follow verbal commands and instructions included in both testing and training. Children who had fixed deformities of upper and lower limbs or had significant perceptual, visual and auditory disorders were excluded. They were assigned into two groups of equal number control and study groups; each group consists of fifteen children. Control group received specially designed rehabilitation program while study group received the same specially designed rehabilitation program of group A in addition to spiral ankle foot orthosis which was used for successive 3 months.

Therapeutic procedures:

Children of both groups received especially designed therapeutic exercise program based on the neurodevelopmental technique principles of treatment on hemiplegic children. Each treatment session lasted one hour for each child and was conducted at 3 times/week basis for 3 successive months, around 36 sessions. Therapeutic procedures included: (1) Neurodevelopmental approach applied for the upper and the lower limbs from different positions. (2) Training of active trunk extension for improving posture control and balance. (3) Exercises for lower limbs. (4) Facilitation of postural mechanisms (5) Facilitation of balance from standing position (6) Gait training (7) Stretching exercises.

Spiral ankle foot orthosis (AFO):
Each child was fitted to orthosis for eight hours per day out of using it through exercise program.

Evaluative protocol:
Formetric instrumentation system:
Formetric instrumentation (AESCULAP-MEDITEC GMBH, Holland) system was used to measure back geometry of all children.

The following evaluation protocol of back geometry was conducted for every child in both groups at his/her entry, as well as after three months following the treatment program. All outcome measurements were performed by one experienced senior pediatric physiotherapist.

The preparatory procedure:

1. The procedure was explained to the patient.
2. The child was taught to take and hold deep breathing.
3. Care was taken not to interrupt the recording procedure to maintain the child in relaxed position.
4. Instruction was given to the child to take off the shoes before standing to avoid any spinal deviation.

The evaluative procedure:

1. The software program was started before the subject is positioned.
2. The patient's data was entered in his/her file on the computer including date of birth, name, sex, height, weight, any previous radiological findings and any comments on the case.
3. The child was asked to stand facing the black ground screen at a distance of 2 meters away from the measurement system (scan system). A freestanding posture was preferable.
4. Each child was asked to take normal breathing. The subject was asked to stop breathing for few seconds while image capture was released. Forced breathing in and out should be avoided, as it will affect his/her balance causing trunk imbalance.
5. The scanner was elevated for different subjects' heights as there is a green horizontal line appears on the computer screen when the camera is ready for recording.
6. Full back shape three-dimensional analysis was done, recorded, and printed out for each patient.

Statistical analysis:
The collected data of demographic and other baseline charac-teristics was statistically treated to show mean, range, standard deviation and standard error of mean for back geometrical parameters. The collected data for both groups were statistically analyzed using Graph pad instate software version 3.05.

Paired and un-paired t-test was conducted for back geometrical parameters to determine any statistically significant differences between data collected before and after treatment within each group and between groups respectively. P-value (<0.05) was considered significant.

RESULTS

Demographic and other baseline characteristics:
Table (1) presents a summary of children demographic data and clinical characteristics at entry as age, weight, height, frequency distribution of gender, frequency distribution of affected side and frequency distribution of spasticity grading.

Back geometrical parameters:
It was observed no statistical differences in back geometrical parameters including trunk imbalance, pelvic tilt, pelvic torsion, lateral deviation (max), lateral deviation (rms) and surface rotation (max) after three months of application of spiral ankle foot orthosis in addition to exercise program (p>0.05) when comparing between post treatment results of both groups but it is observed statistical differences in all measured parameters (p<0.05) when comparing pre and post treatment mean values for each group as shown in tables (2 and 3) and demonstrated in figure (1).

Table 1: The bio data of all involved children

Item		Control group	Study group
Age (year)	Mean±SD	6.967±0.462	6.833±0.506
	SE	0.1192	0.1306
	Range	6.25 – 7.75	6 – 7.75
Weight (Kg.)	Mean±SD	25.8±1.082	25.667±1.08
	SE	0.279	0.278
	Range	24 – 28	24 – 28
Height (meter)	Mean±SD	1.14±0.057	1.156±0.0683
	SE	0.0148	0.0176
	Range	1.05 – 1.23	1.05 – 1.25
Frequency distribution of gender	Male	8	9
	Female	7	6
	Total	15	15
Frequency distribution of affected side	Right side	9	10
	Left side	6	5
	Total	15	15
Frequency distribution of spasticity grading	Grade 1	5	6
	Grade 1^+	4	3
	Grade 2	6	6
	Total	15	15

SD: Standard deviation, SE: Standard error

Table 2: Comparing pre and post treatment mean values of all measured variables within each group.

Variable	Group	Mean ± SD		t-value	p-value
		Pre	Post		
Trunk imbalance	Control	17.2±5.046	16±5.099	5.392	<0.0001 **
	Study	17.4±4.517	16.333±4.483	5.87	<0.0001 **
Pelvic tilt	Control	15.467±5.37	14.667±5.26	3.595	0.0029 **
	Study	18.867±4.673	18.267±4.621	2.806	0.014 **
Pelvic torsion	Control	18.353±5.082	17.133±5.249	4.748	0.0003 **
	Study	14.373±5.698	13.813±5.78	4.049	0.0012 **
Lateral deviation (max)	Control	13.133±2.875	12.333±2.87	2.863	0.0125 **
	Study	11.733±2.631	10.6±2.473	3.9	0.0016 **
Lateral deviation (rms)	Control	9.467±1.922	8.333±2.193	4.432	0.0006 **
	Study	9.267±2.12	8.467±2.295	3.292	0.0053 **
Surface rotation (max)	Control	19.533±3.871	18.267±3.595	2.624	0.02 **
	Study	20.2±4.678	19.333±4.701	4.026	0.0013 **

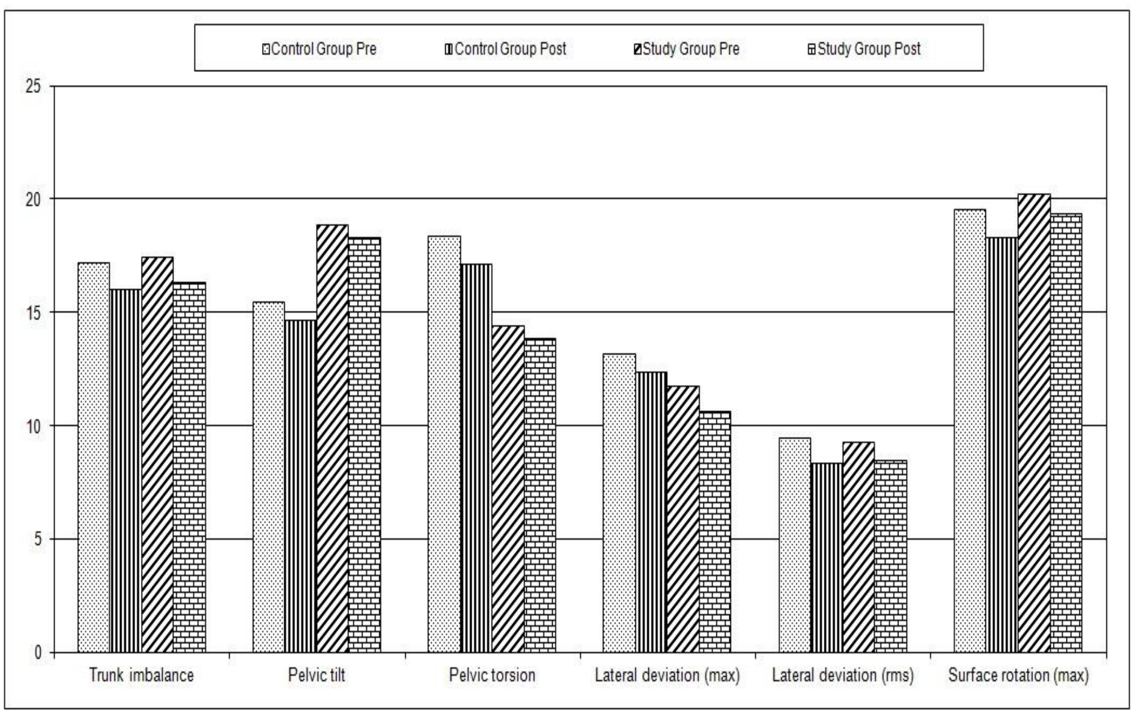
SD: Standard deviation. t-value: Paired t-test value.
Pre: Pre treatment. p-value: Probability value.
Post: Post treatment. **: Significant difference.

Table 3: Comparing pre and post treatment mean values of all measured variables between both groups.

Variable	Time of evaluation	Mean ± SD		t-value	p-value
		Control group	Study group		
Trunk imbalance	Pre	17.2±5.046	17.4±4.517	0.1144	0.9097 *
	Post	16±5.099	16.333±4.483	0.1902	0.8506 *
Pelvic tilt	Pre	15.467±5.37	18.867±4.673	1.85	0.0749 *
	Post	14.667±5.26	18.267±4.621	1.991	0.0563 *
Pelvic torsion	Pre	18.353±5.082	14.373±5.698	2.019	0.0532 *
	Post	17.133±5.249	13.813±5.78	1.647	0.1108 *
Lateral deviation (max)	Pre	13.133±2.875	11.733±2.631	1.391	0.1751 *
	Post	12.333±2.87	10.6±2.473	1.772	0.0873 *
Lateral deviation (rms)	Pre	9.467±1.922	9.267±2.12	0.2707	0.7886 *
	Post	8.333±2.193	8.467±2.295	0.1627	0.8719 *
Surface rotation (max)	Pre	19.533±3.871	20.2±4.678	0.4252	0.6739 *
	Post	18.267±3.595	19.333±4.701	0.6981	0.4909 *

SD: Standard deviation.
Pre: Pre treatment.
Post: Post treatment.
t-value: Unpaired t-test value.
p-value: Probability value.
*: No significance difference.

Figure 1: Pre and post treatment mean values of all measured variables within control and study groups.



DISCUSSION

Choosing the sample suffering from hemiplegia as a form of cerebral palsy as the majority of cases represent this type as recorded by Stanley et al., (2000) who stated that, Hemiplegia (unilateral involvement) affects 30 – 40 % of all cases. Choosing the sample suffering from hemiplegia to study the spinal geometry comes in agreement with Koloyan, (2004) who stated that, almost all hemiplegic children have slight atrophy and shortening of the involved lower extremity. The discrepancy is generally less than 15 mm. Shoe inserts or surgeries are not necessary. On the contrary, having a slightly shorter leg on the involved side helps toe clearance during swing. Consider a shoe insert in a discrepancy of over 15 mm to prevent pelvic obliquity.

Choosing the age of the children representing the study sample to be from six to eight years comes in agreement with Miller and Bachrach, (2006) who established that, during the age of four to six, AFO helps keep the Achilles tendon from becoming too tight. It can also help to control the foot that is rolling in. Heel cups and arch supports are usually less effective for this problem. This is an appropriate time in a child’s life to consider preparing him to enter school with as normal a gait as possible, without the need for bracing, and this may be the appropriate age to consider surgery on the Achilles tendon. But they recommend the start of using the AFO from one to three years as AFO can be helpful to children with hemiplegic involvement who are walking on tiptoe, usually more soon the side affected by the spasticity. The brace is applied if the foot can be brought to a neutral position. If the foot cannot be brought to a neutral position, then surgery or another kind of treatment needs to be considered.

Choosing age from 6 – 8 years was supported by Kubo et al., (2009) who suggested that posture control highly developed during the second grade to the third grade period, and that the development of posture control was different from other motor developments. Also using AFO at age from 6 – 8 years was supported by Hsu et al., (2008) who mentioned that the objectives of orthotic management for the standing child are the same as for the pre standing child, with the additional goal of facilitating an efficient upright posture with the minimum appropriate external support. Standing, even for the non-ambulant child, may be beneficial for the body structure by increasing bone density.

These obtained results come in agreement with Patricia et al., (2000) who demonstrated that, this study provides preliminary information about the effect of solid and spiral AFOs on stance balance control. It is important to note that children with CP tended to use the same muscle-recruitment patterns despite the use or design of AFO. Their preferred pattern for maintaining balance was well established and not altered by AFOs. However, use of spiral AFOs led to decreased activation of distal musculature as well as decreased recruitment of ankle strategies and increased joint angular velocity at the knee, the next most proximal joint. These trends were not found in trials with dynamic AFOs.

These preliminary findings suggest that, spiral AFOs are more advantageous for children with spastic CP when balance control is required during unexpected perturbations in stance. The results of this study also come in agreement with Özek et al., (2008) who demonstrated that; permitting small amounts of movement at the ankle may enhance standing balance and enable the child to move from sitting to standing more easily. Children who achieve independent standing can then focus on developing skills of walking, perhaps requiring ongoing assistance of orthoses and walking aids.

But the results of this study comes in contradict with Geboers et al., (2002) who mention that As the AFO corrects the mal-alignment in ankle and knee joint, there must be an improvement of power generation. It takes less energy to keep the upright position. The AFO corrects also the position of the foot. So the base of support will improve and make standing easier. As a whole, we can conclude that wearing an AFO improves the static postural control significantly. Also it comes in contradict with Romkes and Brunner (2002) who proved that, wearing an AFO gives a significant improvement in dynamic postural control.

Results on postural sway were more positive in the hemiplegic children. Again a better alignment and improved power generation, as well as a better base of support can be responsible for these results. Also it comes in contradict with Edelstein and Bruckner, (2002) who mentioned that, AFOs control the alignment and motion of the foot and ankle and thereby affect the entire body. They are less expensive, more cosmetically acceptable, and more energy efficient than more extensive bracing. In addition, they may enable the patient to achieve the same functional goals as would be possible with KAFOs and higher orthoses.

Conclusions:

From the previous discussion of the results of Formetric instrumentation used in this study and according to the reports of the investigators in the fields related to the present study, researcher considers no significant effect of using spiral AFO as complement to the traditional therapeutic exercises that are conducted for spastic hemiplegic children for the suggested period of study.

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