Effect of Neuromuscular Electrical Stimulation of Spinal Muscles on Back Geometry in Spastic Cerebral Palsied Children

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ABSTRACT

Background and purpose: *Cerebral palsy (CP) is the commonest cause of the neuromuscular spinal deformity. The incidence of spinal deformity in patients with CP is estimated in about 25% of the cases. The purpose of this study was to investigate the effect of Neuromuscular Electrical Stimulation (NMES) of spinal muscles on changing the degree of deviation of the spinal geometrical measurements in children with spastic diplegic cerebral palsy. Subjects and procedures: Twenty spastic diplegic cerebral palsied children from both sexes (nine girls and eleven boys) ranged in age between 5.2 to 9.6 years with mean age 7.25 ±1.14 years participated in this study. All children had a degree of spinal deviation including trunk imbalance, surface rotation and lateral deviation of the spine, pelvic tilt, and pelvic torsion according to formetric evaluation system. Patients were assigned randomly into two groups of equal numbers (ten patients in each group) represented control (A) and study (B) groups. A formetric (rasterstereography) system was used for selection of the sample and assessment of spinal geometry in both groups before and after treatment application. Control group A received a well designed physical therapy program based mainly on neurodevelopmental technique (NDT) directed towards improving posture and balance, modulation of muscle tone and correction of deformity while the study group B received the same program given to the control group in addition to the application of NMES on the back muscles for three successive months, three sessions weekly for one hour, while the NMES lasted for 30 minutes in each session.* ***Results:*** *The data was collected and statistically analyzed before and after the suggested treatment period showed a statistically non-significant difference between both groups before treatment application (P>0.05). While there was statistically significant difference (P<0.05) after treatment between the groups for all measured variables in favour of the study group except for pelvic torsion and surface rotation.* ***Conclusion:*** *NMES is an effective physical therapy modality to be safely used in the management of diplegic cerebral palsy children as an additional tool to improve back geometry.*
Key words: *Neuromuscular Electrical Stimulation, Spinal deformity, Back Geometry, Cerebral palsy.*

INTRODUCTION

Cerebral palsy (CP) is a sensorimotor disorder that affects the control of posture and movement[29]. It is a permanent but not unchanging neurodevelopmental disorder caused by non-progressive defect or lesion in single or multiple locations in the immature brain. The defect or lesions can occur in utero or during or shortly after birth and produces motor impairment and possible sensory deficits[6]. Characteristically, the child with cerebral palsy shows impaired ability to maintain normal posture because of lack of muscle co-activation and the development of abnormal movement compensation[24]. Cerebral palsy is the commonest cause of neuromuscular spinal deformity. The incidence of spinal deformity in patients with CP is estimated at about 25%[31]. Spastic diplegia is one of the most common clinical subtypes of cerebral palsy regardless of birth weight and gestation. It is the motor impairment in the upper extremities as well as the lower extremities, although it is milder in the upper extremities than the lower one. Most children have significant weakness in the trunk muscles and spasticity of the extremities[27].

Optimal posture is the state of muscular and skeletal balance that protects the supporting structures of the body against injury or progressive deformity, whether at work or at rest[30]. Postural problems play a central role in the motor dysfunction of children with CP. The performance of everyday activities is noticeably influenced by such postural deficits; the extent however, varies with the degree of the disability[7]. In the spastic diaplegia weakness has been recognized as clinical characteristics with less posture stability that leads to decrease balance and skill in activities of daily life[10]. Their mobility or gait may be impaired, and they may develop contractures and deformity in their spine and extremities[32].

The videorasterstereography (VRS) formetric system serves as an objective method to determine the geometry of the back of the human being based on non-contact three dimensions (3D) scan. A spatial reconstruction of the spine derived from it by means of a specific mathematical model. It provides a quantification and documentation of the abnormality in back shape before and after treatment[12].

There are many systems of treatment for spastic diplegia to improve functional performances, modulation of abnormal tone, facilitation of normal movement patterns and correction of deformity[20]. Physical therapy is the most traditional and principle non-surgical treatments of CP. Its aims are to promote functionally useful posture and movements[19]. Physical therapy program for spastic diplegic children should emphasis active trunk extension, increase trunk and pelvic mobility, which can lead to improve posture and balance[3]. Neuromuscular electrical stimulation (NMES) has been used for many years as an adjunct to the treatment of CP to reduce spasticity, increase muscle strength, range of motion (ROM), and muscle extensibility, promote the initial learning of selective control and improve functional activities such as gait[2,15,25]. The purpose of this study was to investigate the effect of NMES on changing the degree of deviation of the spinal geometrical measurements in children with spastic diplegic cerebral palsy.

SUBJECTS, MATERIALS AND PROCEDURES

Subjects

The study was conducted on 20 spastic diplegic cerebral palsied children, from both sexes (boys and girls), with age ranged from 5.2 to 9.6 years. They were selected from the outpatient clinic of the faculty of physical therapy, Cairo-University. They were divided randomly into two groups of equal number; each comprised 10 patients: Control group (A) with a mean age of 6.94 ± 1.196 years, six boys and four girls and study group (B) with a mean age of 7.56 ± 1.074 years, five boys and five girls.

Criteria of children selection: inclusion criteria

- Patients diagnosed as spastic diplegic CP.
- Degree of spasticity according to modified Ashworth scale ≥ 1+[4].
- All children had a degree of spinal deviation including trunk imbalance, lateral

deviation, surface rotation, pelvic tilt and pelvic torsion according to formetric evaluation system.
- Their average height around one meter or more as it is the suitable height for formetric measures.
- They were able to stand alone (independently).
- They were able to follow simple commands or instructions included in both test and training.
- They had neither visual nor auditory problems.

Exclusion criteria
- Severe spasticity.
- Severe and profound mental retardation.
- Evidence of fixed contractures deformity.

All children in both groups A and B received basically the same physical therapy program that was based on Neuro-Developmental Technique (DNT) three times / week for three months. While the child in group B had additional NMES applied on back muscles (on the convex side of spine lateral deviation according to their VRS formetric pre evaluation result).

Materials

Instrumentations for evaluation:
- Formetric instrument system:

It was used to evaluate back geometry. It contains the following major subassemblies: The scan system, the computer, the black background screen and the laser printer. Each graphic protocol contains some anatomical parameters which are calculated from the anatomical landmarks (i.e. VP: Vertebra prominence, DL: Left dimple, DR: Right dimple, and DM: Midpoint between both dimples).

The following parameters were measured:
- Trunk imbalance VP-DM: it represented the lateral deviation of the vertebra prominence from the dimple midpoint. It was measured in millimeters.
- Lateral deviation (RMS): The root mean square (RMS) lateral deviation of the spinal midline from the line VP-DM.
- Pelvic tilt DL-DR (in millimeters): The pelvic tilt refers to a height difference of the lumber dimples relative to a horizontal plane.
- Surface rotation (RMS): The RMS value of the surface rotation on the symmetry line.
- Pelvic torsion DL-DR (in degrees): It is the twisting of the pelvis about a transverse axis.

- Weight and height scales: A valid and reliable weight scale (0 to 120 kilograms) and height scale (0 to 200 centimeters) were used to measure weight and height of the participated children.

For treatment:

Neuromuscular electrical stimulator: Phyaction 787, made in Netherlands by Uniphy BV was used to delivered electrical stimulation over ipsilateral paraspinal muscle. It was adjusted with four rubber electrodes (30×50 mm), four viscous covers and a fixing tape.

Other materials:

Gymnastic mats, medical balls of different sizes, wedges, rolls, parallel bars and mirror were used to conduct the traditional physical therapy program.

Methods

Methods of evaluation:

The following evaluation procedures were conducted for both control and study groups of children, before and after three successive months of the treatment program using:

Formetric instrument system: The protocol of the work was explained to the children before conducting the study. The software program started, and then the child data was entered. The child was positioned in front of a black background screen in a distance of two meters from the measurement system. The child's back surface (including buttocks) was been completely bare in order to avoid disturbing image structures. The child was asked to keep his/her neck in a slightly forward-bending posture, just as in normal walking in order to improve the presentation of the vertebral prominence. Also, the child was asked to keep his both upper extremities extended beside his body. When the child and the system were correctly positioned, the image was captured. The best moment for releasing image capture was the slightly breathed-out state. The child was asked to stop breathing for some seconds while image capture was released. Finally, the device analyzed the data and compared it to the values of the normal person and printed out for each patient.

Methods of treatment:

Physical therapy program: patients of both groups practiced a well designed physical therapy program, based mainly on neurodevelopmental technique (NDT) and directed toward inhibiting abnormal muscle tone and abnormal postural reflexes in addition to facilitating the normal patterns of postural control and gait training plus postural correction exercises which include, stretching exercises for back muscles to increase the flexibility of tight structures and elongate the trunk, and strengthening exercises to symmetrically strengthen trunk muscles necessary for postural control and trunk stability[28].

Neuromuscular electrical stimulation:

Patients belonging to the study group were subjected to NMES to the uncovered back muscles from prone lying position. The child back was cleaned with alcohol and the electrodes were placed and fixed on the paraspinal muscles at the upper and lower end of the spinal curve on the convex side according to their VRS formetric pre evaluation result. The parameters of electrical stimulation was adjusted to rectangular pulse shape with pulse time 100 ms, pause time 200 ms, train time 10 seconds, rest time 20 seconds, and surge 67%. The intensity of electrical stimulation was adjusted to the tolerance of the child, which was kept at the intensity of muscle contraction felt and observed on the child's back. Each patient was treated for three successive months, three sessions weekly for 1 hour, while the NMES lasted for 30 minutes in each session.

Statistical Analysis

Statistical calculations were performed using graph pad software, Inc. San Diago, CA 92121 USA on a personal computer. Data were presented as means ± SD; with p-value < 0.05 were statistically significant. In comparing the improvement after the intervention in each group, paired t-test was used and for the difference between the two groups, independent t-test was used.

RESULTS

In the present study, the effect of NMES on back geometry in diplegic children were investigated for the measured parameters.

Trunk Imbalance:

Paired t-test demonstrated a highly significant reduction of the mean value of trunk imbalance after treatment in study and control groups, (P< 0.0001, 0.032) respectively, which means that trunk imbalance was improved in both groups, as shown in table (1) and figure (1).

Unpaired t-test demonstrated that before treatment there was no significant differences in the mean value of trunk imbalance between study and control groups, as (P>0.867). While after treatment, there was a significant differences in the mean value of trunk imbalance between both groups in favour of study group, where (P<0.0181), as shown in table (1) and figure (2).

Table (1): The mean values ± SD of trunk imbalance (in millimetre) for study and control groups before and after treatment.

Group	Before Mean ±SD	After Mean ±SD	MD	t value	P Value
Study	15.9 ±4.977	8.9 ±3.573	7	11.389	0.0001 HS
Control	15.5 ±5.543	13.7 ±4.620	1.8	2.529	0.032 S
t value	0.170	2.599			
P value	o.867 NS	0.018 S			

SD: standard deviation MD: mean difference S: significant HS: highly significant NS: non significant

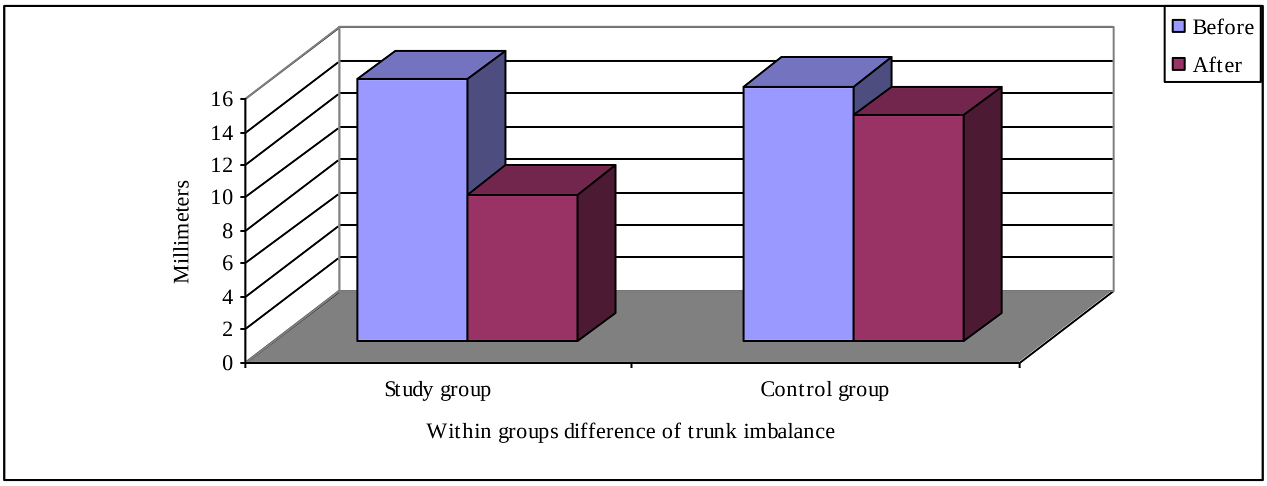

Fig. (1): The Means value ± SD of trunk imbalance between study and control group.

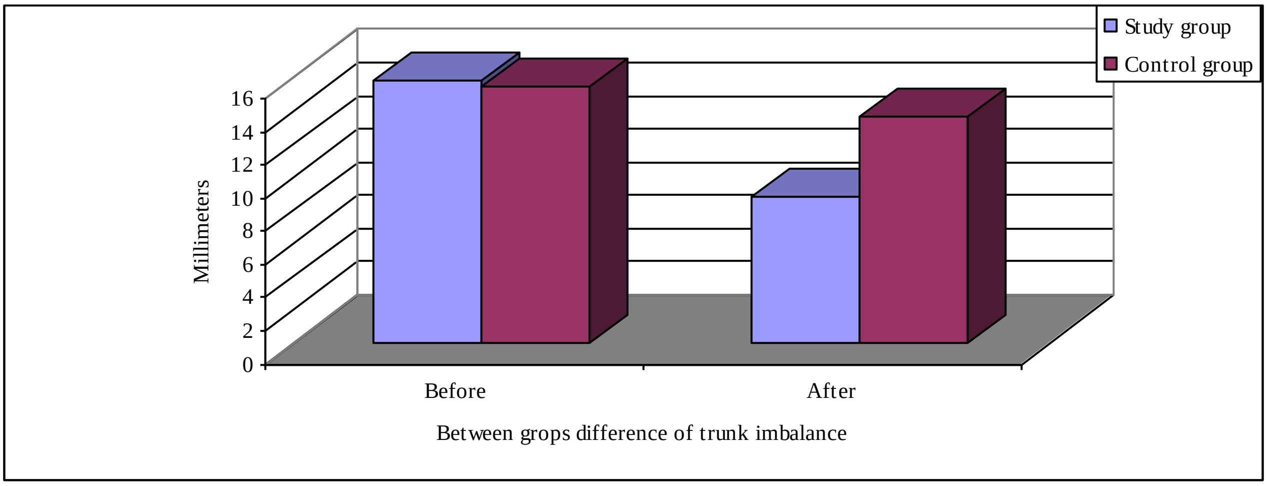

Fig. (2): Comparison of the mean values ± SD in the both groups before and after treatment.

Pelvic Tilt

Table (2) and figure (3) showed that the study and control groups demonstrated a significant improvement in the pelvic tilt after three month of treatment, where P < 0.0001, 0.0277 consequently.

Before treatment there was no significant difference between groups regarding the pelvic tilt as (P>0.456). While after treatment, there was a highly significant difference of pelvic tilt between study and control groups in favour of study group where (P < 0.001), as shown in table (2) and figure (4).

Table (2): The mean values ± SD of pelvic tilt (in millimetre) for study and control groups before and after treatment.

Group	Before Mean ±SD	After Mean ±SD	MD	t value	P Value
Study	7.8 ±2.573	3.4 ±1.265	4.4	6.736	0.0001 HS
Control	8.8±3.259	7.5 ±2.321	1.3	2.623	0.0277 S
t value	0.762	4.904			
P value	0.456 NS	0.001 S			

SD: standard deviation MD: mean difference S: significant HS: highly significant NS: non significant

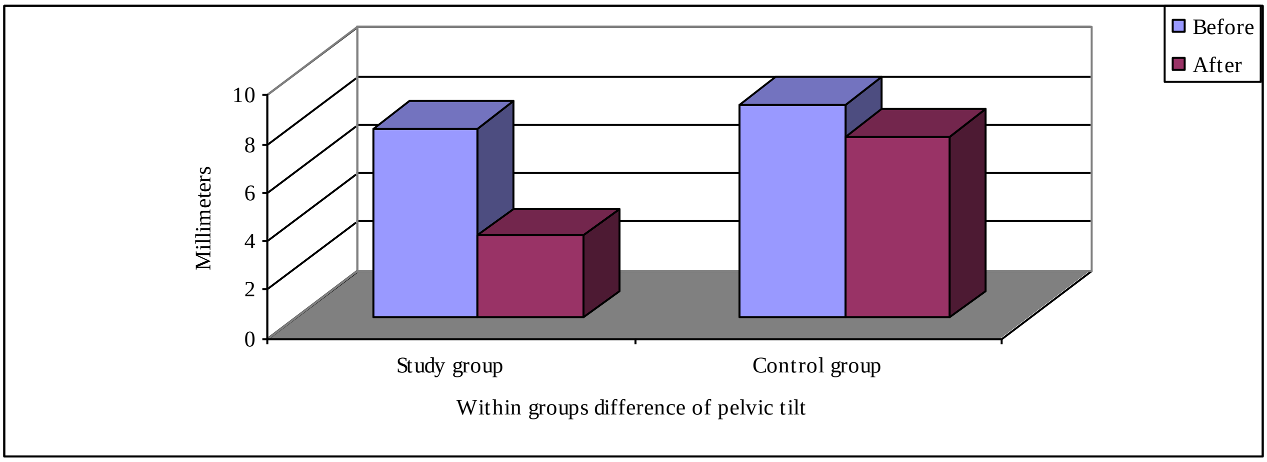

Fig. (3): The means ± SD of Pelvic tilt for the study and control group before and after treatment.

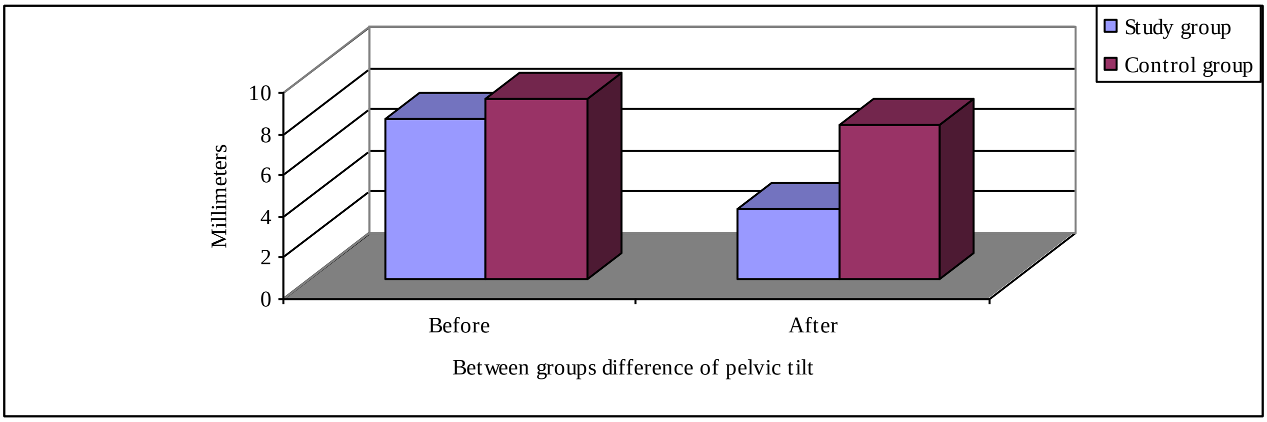

Fig. (4): Comparison of mean ± SD of pelvic tilt (millimetres) between study and control group.

Pelvic Torsion and surface rotation:

Table (3 and 4) and figure (5 and 6) showed a highly significant difference in study and control groups before and after treatment, where (P value < 0.0001, 0.0087, 0.0001 and 0.0063) consequently, which means that pelvic torsion and surface rotation was improved in both groups. While table (3 and 4) and figure (7 and 8) showed no significant differences in pelvic torsion and surface rotation between study and control groups before and after treatment as (P > 0.215, 0.078, 0.326 and 0.918) respectively.

Table (3): The of mean value ± SD of pelvic torsion for study and control group before and after treatment.

Group	Before Mean ± SD	After Mean ± SD	MD	t value	P Value
Study	8.34 ±1.655	4.86 ±0.838	3.48	8.464	0.0001 HS
Control	7.16±2.384	6.061.852±	1.1	3.340	0.0087 VS
t value	1.286	1.852			
P value	0.215 NS	0.078 NS			

SD: standard deviation MD: mean difference HS: highly significant NS: non significant

Table (4): The mean value ± SD of surface rotation for study and control group before and after treatment.

Group	Before Mean ± SD	After Mean ± SD	MD	t value	P Value
Study	6.6 ±2.757	4.1 ±2.685	2.5	9.303	0.0001 HS
Control	5.5±2.068	4.2 ±1.476	1.3	3.545	0.0063 VS
MD	1.1	0.1			
t value	1.009	1.103			
P value	0.326 NS	0.918 NS			

SD: standard deviation MD: mean difference VS: significant HS: highly significant NS: non significant
S: significant

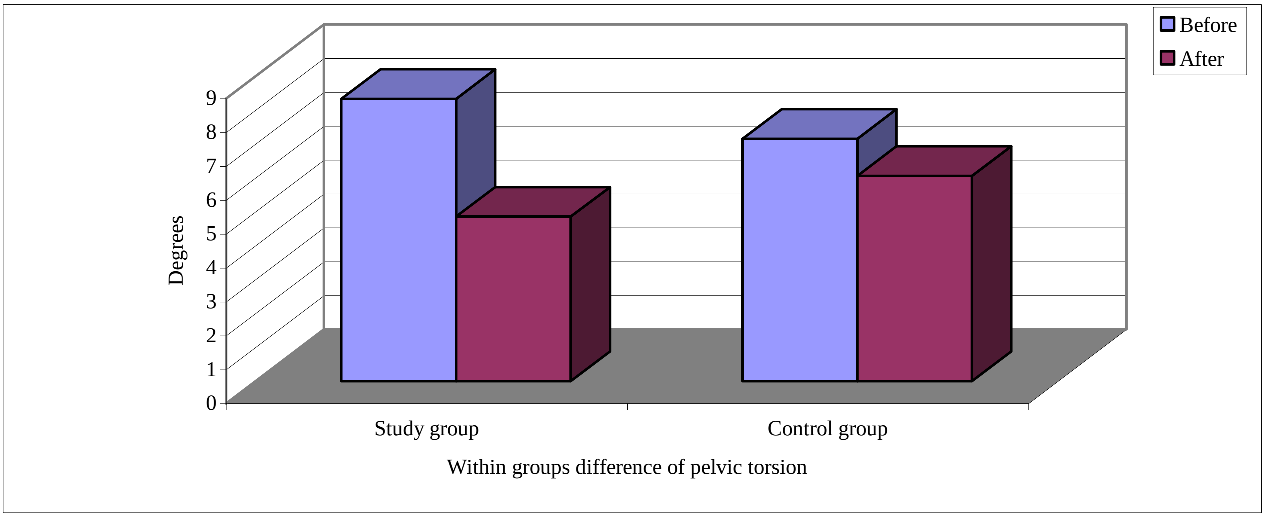

Fig. (5): The mean value ± SD of pelvic torsion for study and control group before and after treatment.

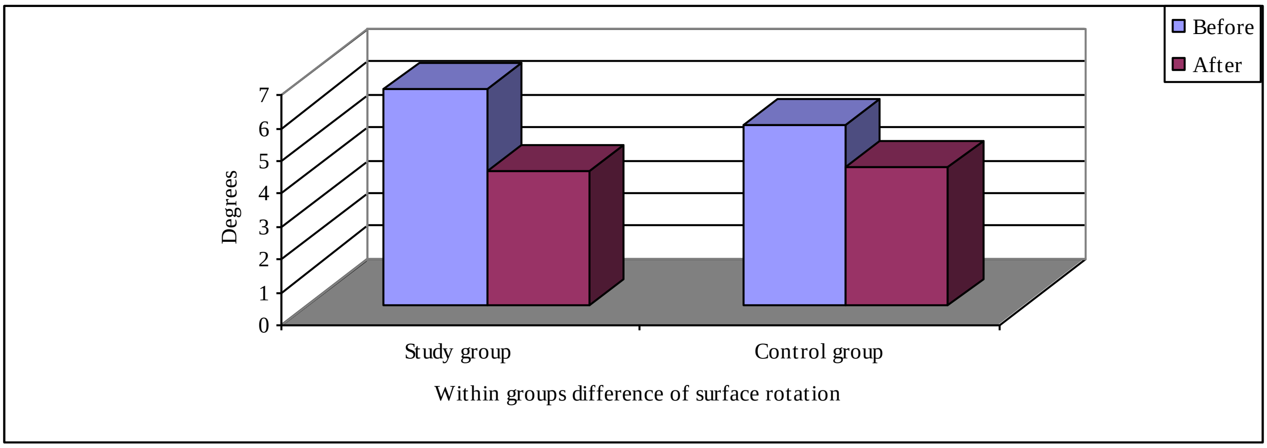

Fig. (6): The mean value ± SD of surface rotation for study and control group before and after treatment.

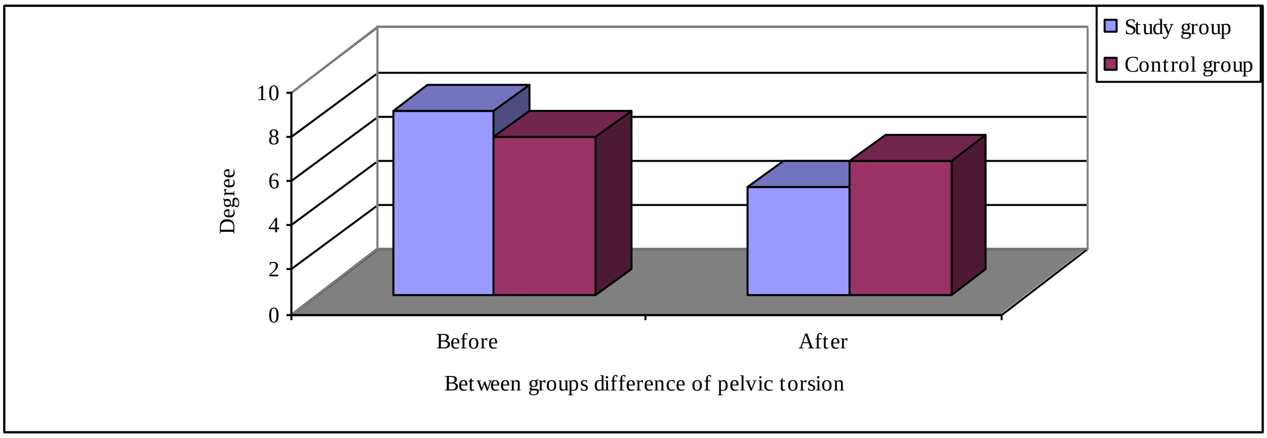

Fig. (7): Comparison of the mean value of pelvic torsion between study and control group.

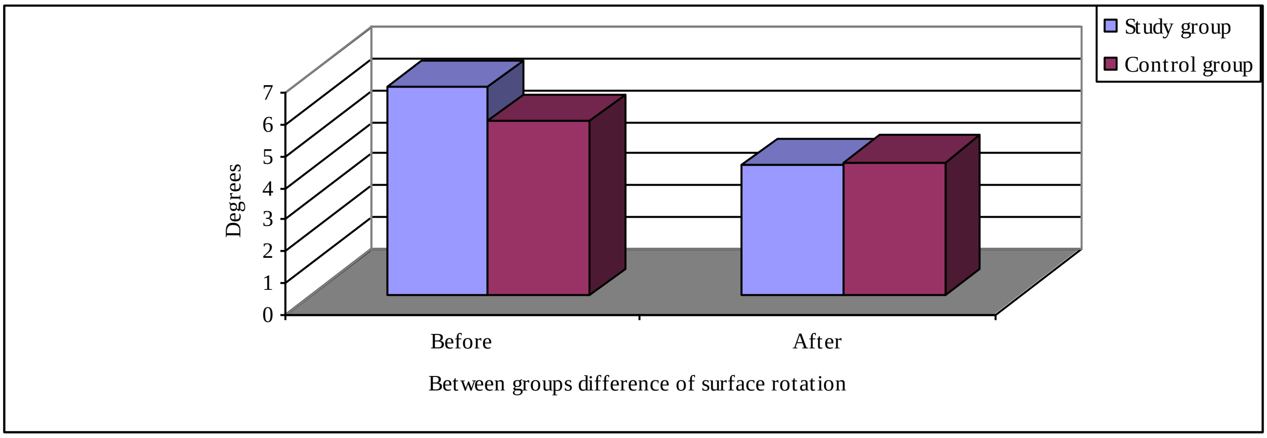

Fig. (8): Comparison of the mean value of surface rotation between study and control group.

Trunk Lateral Deviation:

Table (5) and figure (9) showed that the study and control group demonstrated a highly significant improvement in trunk lateral deviation after treatment, as P < 0.0001, 0.0086, consequently.

Before treatment, there was no significant difference between groups regarding the trunk lateral deviation as (P>0.595). While after three months of treatment, there was significant difference between study and control groups in favour of study group, where (P< 0.0149), as shown in table (5) and figure (10).

Table (5): The mean value ± SD of trunk lateral deviation for study and control group before and after treatment.

Group	Before Mean ±SD	After Mean ±SD	MD	t value	P Value	
Study	7.4 ±2.011	4.1 ±1.595	3.3	7.359	0.0001	HS
Control	8±2.867	6.8 ±2.741	1.2	3.343	0.0086	S
t value	0.542	2.693				
P value	0.595 NS	0.0149 S				

SD: standard deviation MD: mean difference HS: highly significant NS: non significant S: significant

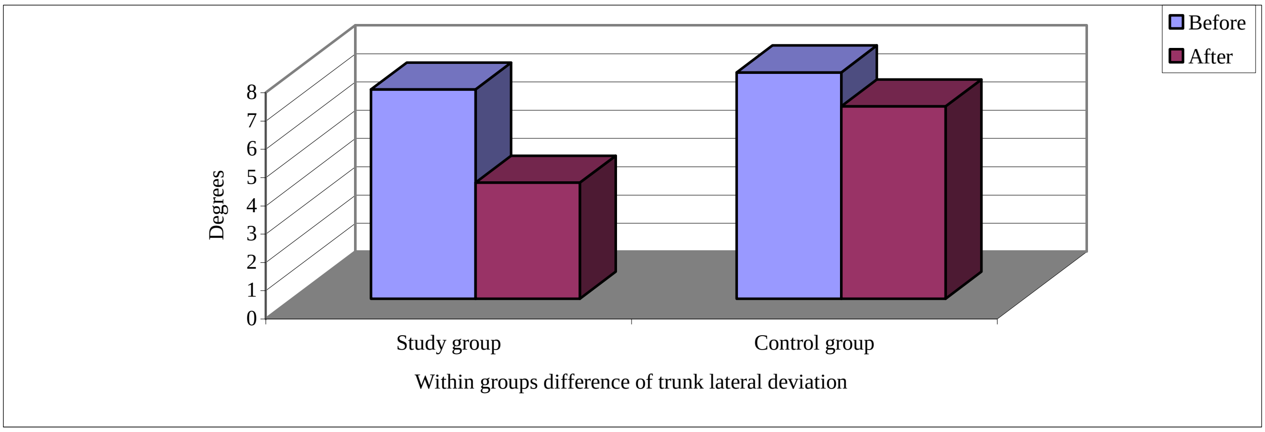

Fig. (9): The mean value ± SD of trunk lateral deviation for study and control groups before and after treatment.

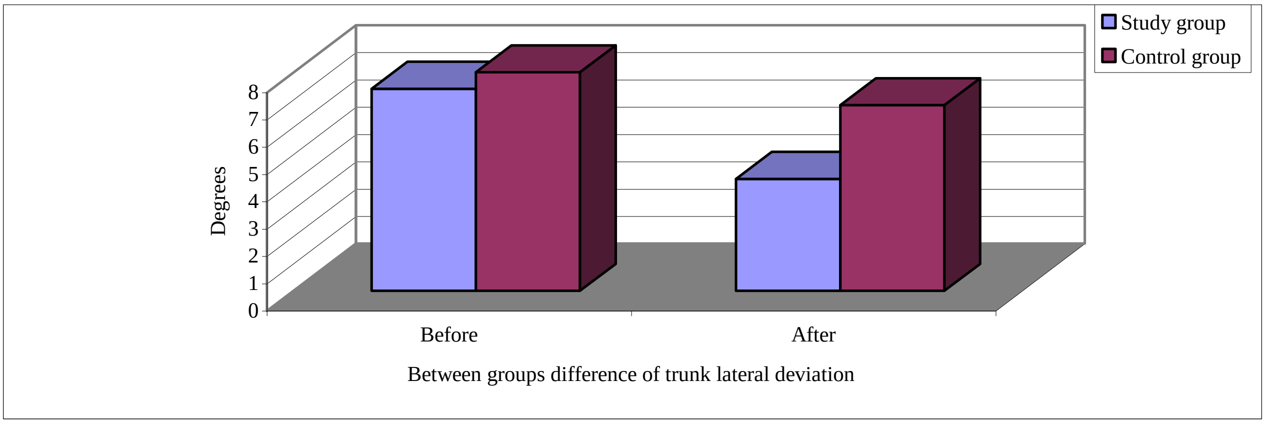

Fig. (10): Comparison of the mean value ± SD of trunk lateral deviation for study and control groups.

DISCUSSION

The aim of this study was to evaluate the effectiveness of NMES as an adjunctive tool with the traditional physical therapy program to change the degree of deviation of the spinal geometrical measurements in spastic diplegic children.

Formetric II system was used to measure back geometry in this study before and after three months of the treatment program in both groups. This comes in agreement with Hackenberg et al., 2003[12], they reported that, Rasterstereograph (formetric II system) represents a reliable method for three dimensional back shape analysis and reconstruction of spinal deformities without ionizing radiation exposure. The patient can be examined within seconds in standing posture without any markers on the surface of the back. As compared to other examination techniques, formetric system is relatively inexpensive, fast and largely objective.

The collected data from both groups (A and B) before starting the treatment program indicated that there was significant misalignment of the trunk, which was demonstrated by an abnormal back geometry, that may be attributed to musculoskeletal problems that constraint normal posture and movement patterns. This explanation comes in agreement with levitt 2004[17], who reported that, the development of skeletal deformities in cerebral palsied children may be due to poor postural control.

The statistical analysis of the pre treatment results of all measuring variables of spastic diplegic children of both groups (A and B) revealed a non significant difference ($P>0.05$). Spastic diplegic patients are likely to have neuromuscular impairments which interfere with the development of proper posture control in addition to changes in the structure and function of the skeletal muscles particularly in the lower extremities[7].

Misalignment of postural can reflect changes in the alignment of one body part to another or in the alignment of centre of mass relative to the base of support as stated by Shumway-cook and Woollacott, 2001[22]. All the previous impairments were the causes of the pre treatment results. Also, the pre treatment results come in agreement with the following explanations: According to Graham, 2003[11], spastic diplegic cerebral palsied children are suffering from abnormal back geometry and trunk imbalance which may be due to weakness of the trunk muscles, poor postural reflexes and functional leg length discrepancy (FLLD), and poor alignment of the legs, pelvis and trunk[21].

Pelvic tilt is one of major problems in the spastic diplegic children because pelvis attached to the spine and the lower limbs transmitted 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[14]. In addition, this is consistent with Chantraine et al., 1995[9], they mentioned that, lateral deviation of the spine is an attempt by the spastic diplegic child to improve standing posture. Since pelvis is the link between lower limbs and spine, so the functional leg length discrepancy which is transmitted to the pelvis giving pelvic tilt is in turn transmitted to the spine using its flexibility to give lateral deviation.

Spinal surface rotation in spastic diplegic is an attempt to assume a stable standing posture. Both pelvic tilt and pelvic torsion lead to functional scoliosis. Functional scoliosis has two components: lateral deviation and surface rotation. 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 equinus leads to surface rotation. Also weak trunk muscles and poor postural reactions both are reflected on the spine leading to surface rotation[18]. This is also come in agreement with Campbell et al. (2006)[6] and Brogen et al. (1998)[5], they reported that, in contrast to normal children, spastic diplegic children show a non selective activation of agonist and antagonist muscles with increased frequency of reversals (proximal to distal recruitment of leg and thigh muscles), increased recruitment of antagonist muscles and decrease activation of trunk musculature.

In respect to the results of the present study, there was significant improvement in the mean values of all measured parameters (i.e. trunk imbalance, pelvic tilt, lateral deviation, pelvic torsion, and surface rotation) in both groups. The well designed physical therapy exercise program encourages normal movement patterns as it inhibit the development of abnormal patterns of movement. Furthermore, the program aims at developing weight shift, providing postural adaptations and alignment to improve equilibrium in all positions. The improvements of trunk imbalance and trunk lateral deviation may be attributed to an improvement of the postural reactions.

Mechanically, improvements of trunk imbalance and lateral deviation of the trunk may result in improvement of pelvic tilting, surface rotation, and pelvic torsion. So, the significant improvement in the post treatment results of the control group may be attributed to the selective physical therapy program. Through this program there was improvement of trunk control, modulation of abnormal muscle tone, improvement of sensory and motor awareness, enhancement of postural re-adjustment and activation of the motor learning process. This study confirm the findings of Horak and Macpherson, (1996)[13], who stated that, the development of proper alignment of posture provided by the different exercises for facilitation of normal erect posture improves postural orientation of different body segment to each other, as well as to the environment.

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) may be attributed to the effect of NMES on improving sensory awareness and muscle strength, which results in improving coordination. The results of this piece of work were supported by those of Apkarion and Naurmann, (1991)[1], who compared the effect of neurodevelopmental therapy (NDT) alone and when combined with NMES on the motor activity of cerebral palsied children. Their results showed that using both approaches together provided better results than the results obtained by using NDT only. Similarly, the results of this study was supported by the clinical use of NMES in a two-part case report which has been investigated by Carmick, (1995)[8], part (I) results showed the usefulness of NMES as an adjunct to the physical therapy program for improving motor function in CP Children. The results of the second part of the study suggested that NMES may be a useful physical therapy tool for enhancing muscle strength, increasing sensory awareness, assisting motor learning and improving co-ordination.

The improvement in the post treatment results of the study group also comes in agreement with Thelen and Fisher, (1982)[26], who suggested that development of sufficient muscle strength is essential to support the body during static balance and improve pelvic alignment during standing. Also, the results agree with Smith and Rogers (1982)[23], who reported the importance of muscle strength to produce tension and control trunk movement. They were regulated by number of factors, included motor unit recruitment, motorneuron firing patterns, muscle fibre composition, type of contraction, length of muscle, velocity of contraction and movement arm. Finally, the results of this study come in agreement with Kluzik et al. (1990)[16], who stated that, children with spastic cerebral palsy may exhibit a change in quality of movement. These qualitative changes may include improvements in biomechanical alignment during voluntary movement and postural maintenance, improved gradation of movement with increased eccentric muscular control and improved stability at proximal body parts to allow distal body parts to move with greater control.

Conclusion

According to the results of this study which are supported by other related studies, it can be concluded that electrical stimulation of the muscles represents an effective and safely additional modality to the physical therapy program in improving back geometry of spastic diplegic children.

REFERENCES

1- Apkarion, J. and Naurmann, S.: Stretch reflex inhibition using ES in normal subjects and subjects with spasticity. J Biomed Eng. 13(1): 67-73, 1991.

2- Baker, L.L., Mc Neal, D.R. and Benton, L.A.: Neuromuscular Electrical stimulation: A practical guide. 3rd ed. Downey, calif: Rancho los Amigos Medical Center; 1993.

3- Binder, H. and Eng, G.D.: Rehabilitation management of children with spastic diplegic cerebral palsy. Arch Phys Med Rehab; 70: 482-489, 1989.

4- Bohannon, R. and Smith, M.: Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther. 67: 206-207, 1986.

5- Brogen, E., Haolders-Algra, M. and Forssberg, H.: Postural control in children with spastic diplegia: Muscle activity during perturbations in sitting. Dev Med Child Neurol; 38: 379-388, 1998.

6- Campbell, S.K., VanderLinden, D.W. and Palisano, R.J.: Physical Therapy for Children. Saunders, 625-635, 2006.

7- Carlberg, E.B. and Algra, M.H.: Postural Dysfunction in Children with Cerebral Palsy: Some Implications Therapeutic Guidance. Neural Plasticity. 12(3): 221-228, 2005.

8- Carmick, J.: Managing equinus in children with cerebral palsy: Electrical stimulation to strengthen triceps surae muscle. Dev Med Child Neurol, 31(11): 965-975, 1995.

9- Chantraine, A., Nusgens, B. and Lapiere, C.: Biomechanical analysis of heterotrophic ossification in spinal cord injury patients. Diplegia; 33: 398-401, 1995.

10- Damiano, D.L. and Abel, M.F.: Functional Outcomes of Strength Training in Spastic Cerebral Palsy. Arch Phys MedRehabil., 79: 119-125, 1998.

11- Graham, K.: The management of spastic diplegia. Current Orthopedics; 17: 88-104, 2003.

12- Hackenberg, L., Hierholzer, E., Potzlw, W., Gotze, C. and Liljenqvist, A.: Rastersteregraphic back shape analysis in idiopathic scoliosis after posterior correction and fusion. Clinical biomechanics. 18(10): 883-889, 2003.

13- Horak, F.B. and Macpherson, J.M.: Postural orientation and equilibrium. In: Shepard and Rowell L. (Eds). Hand book of physiology section 12. Exercise: regulation and integration of multiple systems. New York, Oxford University. 255-292, 1996.

14- James, H. and Hardy, M.: Spinal deformity in neurological and muscular disorders, st. louis; Mosby, 192-195, 1974.

15- Keshet, S.L., Tirosh, E., Mizrahi, J., Verbitsky, O., Isakov, E., Marmur, R. and Rabino, S.: The Effect of Therapeutic Electrical Stimulation in Children with Diplegic Cerebral Palsy as Measured by Gait Analysis. Basic Appl Myol., 11(3): 127-132, 2001.
16- Kluzik, J., Fetters, L. and Coryell, J.: Quantification of control: A preliminary study of effects of neurodevelopmental treatment on reaching in children with spastic cerebral palsy. Physical therapy; 70: 65-78, 1990.
17- Levitt, S.: The clinical picture for therapy and management. In: Treatment of cerebral palsy and motor delay. 4th edition, Blackwell publishing, 1-13, 2004.
18- Lippincott, W.: Fundamentals of pediatric orthopedics, children's hospital and regional medical centre. seattle, Washington, 3rd ed, 47-99, 2003.
19- Menkes, J.H., Sarnat, H.B. and Maria, B.L.: Child Neurology. Seventh edition. Lippincott, Williams and Wilkins, 400-410, 2006.
20- Russman, B.S.: Cerebral palsy: Curr Treat Option Neurol., 2(2): 97-108. 2000.
21- Samilson, R.: Scoliosis in cerebral palsy. Current practice in orthopaedic surgery, St.louis, Mosby, 183, 1975.
22- Shumway-cook, A. and Woolacott, M.: Motor control: Theory and practical application. 2nd ed., Lippincott, Williams and Wilkins, Baltimore, 164-165, 269-270, 2001.
23- Smith, G. and Rogers, M.: Factors contributing to the regulation and clinical assessment of muscular strength. Physical therapy; 62: 1283-1289, 1982.
24- Smith, J.C., Allen, A.S. and Pratt, P.N.: Occupational Therapy for Children. 3rd ed. Mosby; St. Louis, 1996.
25- Stanger, M. and Bertoti, D.: An overview of electrical stimulation for the pediatric population. Pediatric Physical Therapy, 9: 95-143, 1997.
26- Thelen, E. and Fisher, D.M.: New born stepping: an explanation for a disappearing reflex. Dev Psychol; 18: 760-775, 1982.
27- Tong-Wai, R., Webster, R. and Shevel, M.: A clinical and etiologic profile of spastic diplegia. Pediatric Neurology. 34(3): 212-218, 2006.
28- Turner, A., Foster, M. and Johnson, S.: Occupational Therapy and Physical dysfunction (principles, skills and practice), Churchill living stone, Edinburgh, 5th ed. In: Morgans L and Gething S:cerebrovascular accident. 477-488, 2002.
29- Umphred, D.A.: Cerebral palsy, Neurological Rehabilitation. 4th ed. 259, 767, 2001.
30- Weatherall, V.: Correcting faulty posture. Advance Chiropractic, 2005.
31- Williamson, J.: Management of the spine in cerebral palsy. 4th ed. Current orthopaedics. 17(2): 117-123, 2003.
32- Wilsdon, J.: Cerebral palsy. In: Turner A., Foster M., Johanson SE, and Steward AM: Occupational Therapy and Physical Dysfunction (principles, skills and practice), Churchill living stone, New York, 395-431, 1996.

الملخص العربي

تأثير التنبيه العصبي العضلي الكهربائي على جومتيرية الظهر في الأطفال المصابين بالشلل المخى التقلصي

يهدف هذا البحث إلى دراسة تأثير التنبيه الكهربائي على جومتيرية الظهر في الأطفال المصابين بالشلل التقلصى المزدوج . تم إجراء هذا البحث على 20 طفل من المصابين بالشلل التقلصى المزدوج (تسع بنات وإحدى عشرولد) تراوحت أعمارهم بين 5.2 إلى 9.6 سنه يعانون من درجة اختلاف في انحناءات العمود الفقري متضمنة عدم اتزان الجذع- درجة ميل الحوض- درجة التفاف الحوض- الدوران السطحي للفقرات- درجة الانحناء الجانبي للعمود الفقري . وقد تم تقسيم الأطفال إلى مجموعتين متساويتين في العدد (10 في كل مجموعة) . المجموعة الأولى (الضابطة) : تلقت برنامج العلاج التقليدي الذي يهدف إلى تحسين القوام والاتزان وتقويم النغمة العضلية وتعديل التشوهات . وتلقت المجموعة الثانية (الدراسة) : نفس البرنامج السابق مضافا إليه التنبيه الكهربائي لعضلات الظهر ثلاث جلسات أسبوعيا لمده ساعة وأضافه نصف ساعة للتنبيه الكهربائي . وقد تم تقييم العمود الفقري للأطفال باستخدام جهاز تشوهات العمود الفقري الثلاثي الأبعاد (جهاز الفورماترك) قبل وبعد ثلاثة أشهر من بدء العلاج . وأظهرت النتائج حدوث تحسن ذو دلالة أخصائية في جميع القياسات لدى مرضى المجموعتين؛ مع وجود مقدار تحسن أكبر لدى مرضى مجموعة الدراسة التي خضعت للعلاج التقليدي بالإضافة إلى التنبيه الكهربائي مما يستلزم التوصية باستخدام التنبيه الكهربائي في علاج مثل هذه الحالات .