Modulation of Foot Pressure in Juvenile Idiopathic Scoliosis Via Neuromuscular Electrical Stimulation Versus Myofeedback Training

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ABSTRACT

Background and purpose: *Neuromuscular electrical stimulation (NMES) and myofeedback training for the scoliotic spine provide foundations for improved foot planter pressure; so that more lower limbs, hence more spinal disorders can be avoided. The purpose of this study was to examine the effects of each of the treatment modalities for three times weekly, for three months; on the total static planter pressure distribution of the right foot in children with juvenile idiopathic scoliosis.* ***Subjects:*** *forty scoliotic girls, ranging in age from seven to nine years represented the sample of this study. Cobb's angle ranged from ten to twenty degrees. They were divided randomly into two study groups of equal number (A and B).* ***Procedures:*** *Evaluation of static right foot planter pressure was conducted for each child of the two groups before and after three months of treatment via using force distribution measurement system (FDMS). The study group A received neuromuscular electrical stimulation in addition to a specially designed exercise program, while the study group B received myofeedback training in addition to the same exercise program given to group A.* ***Results:*** *No significant difference was noticed when comparing the pre-treatment results of the two groups, while significant improvement was observed in the measured variable of the two groups when comparing their pre and post-treatment mean values. No significant difference was observed when comparing the post-treatment results of the two groups.* ***Discussion and Conclusion:*** *Neuromuscular electrical stimulation and myofeedback training may be used as a therapeutic intervention for improving the total static planter pressure distribution of the right foot in children with juvenile idiopathic scoliosis.*

Key words: *Juvenile idiopathic scoliosis, planter pressure distribution, neuromuscular electrical stimulation, myofeedback training.*

INTRODUCTION

Scoliosis is a lateral deviation of the normal vertical line of the spine greater than 10 degrees[16]. Scoliosis affects about 2-3% of the population. It can occur in adults but it is more commonly diagnosed for the first time in childhood[10].

Scoliosis is either functional which result from soft tissue imbalance or structural which includes bony changes as well as soft tissue asymmetries. If the functional deformity is not corrected, it will be structural one[15,22,34]. Scoliosis is a deformity in which there are one or more lateral curvatures of the lumbar or thoracic spine; the curvature may occur in the thoracic spine alone, in the thoracolumbar area or in the lumbar spine alone[19]. The most common curve of scoliosis arises in the thoracic segment with convexity to the right[30].

Scoliosis can transfer the center of gravity towards the convexity. Alteration in the center of gravity is reflected in the change of distribution of weight bearing on the feet; this is referred to as altered plantar pressure distribution. The shift of the gravity center is to the front and to the right in patients with right sided scoliosis; which leads to pathology not only in the right foot, but also in the whole right lower limb. The hip joint on the convex side may be similarly affected resulting in hip adduction contracture derived from growth and maturation of the joint in the abnormal posture; which causes increase of the right foot pressure[31].

The foot pressure alteration produces an adverse effect to the spine and becomes the direct cause of aggravation of spinal deformity. The gait pattern due to incorrect posture brings about physiological troubles, fatigues muscles and joints of the lower limbs, which causes increase of the primary problem which is vertebral disorder, this occurs due to repetitive and abnormal impact of feet which is transmitted back to the spine[23].

Locomotive behavior depends on the static posture and is not separate from it and the immediate goal of non-locomotive posture is to keep the center of mass of the body over the base of support with respect to relevant forces acting on it (i.e. gravity). The position of the upright static standing is required to allow the initiation of bipedal locomotion[29].

The correlation between the foot pressure and the degree of scoliosis was evaluated. It was found that; as the degree of scoliosis increases a difference in foot pressure also increases[23]. Force distribution measurement system performs a simple and fast measurement analysis of the static plantar pressure distribution in idiopathic scoliosis[11].

The treatment options for idiopathic scoliosis include bracing, exercises, electrical stimulation and surgery. While many other factors must be considered, the general goal is to keep curves under 50^{o} at maturity[12]. Myofeedback can also be used for the treatment of idiopathic scoliosis. It help the patient to develop greater voluntary control in terms of muscle reeducation; and thus increasing muscle-strengththrough improving the ability of a muscle or group of muscles to contract[26].

Application of previous findings regarding muscle strength and function in scoliosis suggests that curvature might result from unbalanced pull of spinal muscles oriented both longitudinally and transversely. Previously, most of attention has been given to the paraspinal muscles. Lately, attention has been also afforded to the major transverse muscles that attach on the concave side of the spine.

In the current study modulation of the back muscle efficiency was obtained through electrical stimulation, myofeedback, each of them was added to a specially designed exercise program. Electrical stimulation was attempted as a mean of stimulation of weak back muscles. The goal of myofeedback was to train the patient to perceive appropriate small changes in performance to be practiced independently. Exercise therapywas applied to maintain strength of muscles.

Neuromuscular electrical stimulation (NMES) can be used to strengthen or prevent disuse muscle atrophy, maintain or improve range of motion, facilitate voluntary motor control. Patients with musculoskeletal problems appear to demonstrate greater strength gains with NMES than with exercise alone. Combining NEMS with functional activity can further enhance gains. Electrical stimulation should not replace voluntary muscle contraction but is most effective when used as an adjunct to exercise and activity[1].

Biofeedback works by making the patient aware of his or her own sensations when there is dysfunction. Thus, in order to maintain control; the patient gradually learns the desired response with progressively fewer feedback reinforcements. Feedback is proportional to the response. Thus a strong muscle contraction produces a strong signal[18].

Therapeutic exercise prevents or reduces disabilities of the scoliotic patients and facilitates the neutralization of postural deficits[21]. Many studies demonstrated the efficacy of therapeutic exercise in reducing both the rate of progression and the magnitude of the Cobb's angle at the end of treatment. Exercises can be used effectively to reverse the signs and symptoms of spinal deformity and to prevent progression in children and adults[9].

As the spinal column alignment has a serious effect on the patient's life, the significance of this work was to compare the effect of neuromuscular electrical stimulation of the longitudinal back muscles "on the convex side", and the transverse muscle "on the concave side" of scoliotic curve, versus the effect of myofeedback, on the total right planter pressure distribution, in cases of dorsal right C shape "non-structural" juvenile scoliosis.

PROCEDURES AND METHODS

Procedures

Human samples

Idiopathic scoliotic children who had been referred from pediatric orthopedists 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. Forty girls with non-structural juvenile idiopathic right dorsal scoliotic deformity were eligible for participation according to the following criteria: their age ranged from 7 to 9 years, and their heights average was one meter or more.

The mean age of group A was (X7.92 ± 0.68 years), while the mean age of group B was (X 7.76 ± 0.6 years).They were free from any associated disorders other than scoliosis. The angle of scoliosis was determined by the Cobb's angle to be ranging from 10 to 20 degrees.

Girls representing the sample of this study were divided randomly into two study groups of equal numbers (A and B); each group is composed of twenty girls.

Group A (study) received neuromuscular electrical stimulation for the longitudinal back muscles (paraspinal muscles) on the convex side of scoliotic curve, and for the transverse back muscles (middle fiber of trapezius) on the concave side of scoliotic curve, in addition to a specially designed therapeutic exercise program, while Group B (study)received myofeedback, in addition to the same exercise program as in group A. The treatment procedures were applied three times / week for three successive months.

Evaluation for each girl of the two groups was conducted before and after three months of treatment by using the force distribution measurement system.

Instrumentation

Evaluative instrumentation

Stress X-ray. For selection of the patients with right dorsal non-structural idiopathic scoliotic deformity ranging from 10 to 20 degrees, an anterior-posterior plain x-ray film was taken in standing position (stress x-ray) to determine the Cobb's angle; also x-ray from lateral view was taken to exclude the presence of kyphosis.

Force distribution measurement system. Force distribution measurement system (Zebris Medical GmbH, Germany) was used to measure the static plantar pressure distribution of right feet using the FDMS measuring platform.

Treatment instrumentation

Neuromuscular electrical stimulation. Faradic stimulator was used for stimulation of back muscles; it is an electrical stimulator, four channels system, manufactured in Netherlands by Uniphy BV.

Electromyographic biofeedback (myo-feedback). Biofeedback unit was used; the unit provides both of visual and auditory feedback relative to the quantity of electrical activity. Raw activity is displayed visually on an oscilloscope as a line traveling across a monitor in response to the incoming integrated signal. Raw activity can also be listened. An increase in the pitch of the tone indicates an increase in the level of electrical activity.

Methods

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 the force distribution measurement system (FDMS) to measure the static plantar pressure distribution of right feet as follows:

Child data were entered in a file on the computer including date of birth, name, sex, height and weight. The child was instructed to stand barefeet and to be relaxed in the anatomical upright position on the platform with feet separated slightly. The device was switched on and chart was presented indicating foot pressures which were represented in Newton per square centimeter acting on the individual plate sensors. Comparison of the total right foot pressure for each patient was done before and after treatment.

Treatment

Electrical stimulation. This was applied in the study group A, as follows:

- Stimulation of the longitudinal back muscles on the convex side of scoliotic curve (paraspinal muscles): One electrode was put on the upper end of the curve on the convex side and other electrode was put on the lower end of the curve on the convex side[14].
- Stimulation of the transverse back muscles (middle fiber of trapezius) on the concave side of scoliotic curve: Both electrodes were put transversely on middle fibers of trapezius on the concave side at the level of apex of the curve[2].

- The intensity was raised slowly until palpable contraction was felt and observed on the patient's back.
- The faradic stimulation was applied for 30 minutes before exercises, three times / week for 3 successive months.

Myofeedback training. The electrodes (positive and the negative) were place at fixed distance on the paraspinal muscles of the convex side of the spine, one and half cm above one and half cm below the apex of the curve according to the Cobb's angle. The third 'indifferent', 'ground' or 'reference' electrode is placed somewhere else on the body. The skin under electrodes sites was cleaned by alcohol; the electrodes were applied with a conducting gel, and then were secured with adhesive tape. The procedure was explained to the child (contraction of paraspinal muscle at convex side), and the audio and visual feedback were adjusted. The treating session was for 20 minutes, then the electrodes were removed and cleaned and the child's skin was cleaned with alcohol[27].

Exercises. This was applied in both of the study groups, as follows:

- From standing, supine lying, prone lying, kneeling with hands over head on mat, and side lying position on the concave side; each girl was asked to move the trunk toward the convex side of scoliotic curve.
- Wall push-up; from standing position with feet shoulder width apart.
- Press-up; from sitting position on a chair.
- Protraction and retraction; from sitting position, with shoulders elevated 90^o.
- Each exercise was repeated 20 times.

Data Analysis

The raw data were analyzed using the SPSS program to determine the mean ± standard deviation for the measured variable 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.

RESULTS

The baseline results of the Levene's test were not significant for the measured variable (static pressure of the right foot), 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 study groups.

As shown in Table 1, paired t-test was applied to reveal significant reduction in the mean values of the measured variable of the two study groups (A and B), when comparing their pre and post-treatment mean values. As shown in Table 2, independent t-test was used to compare between the pre-treatment results, and post-treatment results of the two study groups, which revealed no significant difference between groups.

Table (1): Paired t-test for groups A and B.

Variable		Study group (A)		Study group (B)	
		Pre	Post	Pre	Post
Right total Static planter pressure distribution	X	55.42	52.01	56.45	52.19
	SD	± 2.404	± 1.555	± 3.051	± 1.59
	t test	12.012		10.846	
	P value	<0.0001		<0.0001	
	Sig.	Significant		Significant	

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

Table (2): Unpaired t-test for Pre and post-treatment mean values for groups A,B.

Variable		Study group (A,B)		Study group (A,B)	
		Pre (A)	Pre (B)	Post (A)	Post (B)
Right total Static planter pressure distribution	X	55.42	56.45	52.01	52.19
	SD	± 2.404	± 3.051	± 1.555	± 1.59
	t test	1.295		0.372	
	P value	0.203		0.65	
	Sig.	Not Significant		Not Significant	

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

DISCUSSION

Idiopathic scoliosis denotes a lateral curvature of the spine of unknown cause and is the most common form of scoliosis in children[24]. Idiopathic scoliosis was classified into three age related groups: infantile, juvenile and adolescent[5].

Juvenile idiopathic scoliosis develops between ages 3 and 9 years. The most common curve is right thoracic, occurring in males and females with equal frequency and most often recognized around 6 years of age. Juvenile idiopathic curves have a high rate of progression and result in severe deformity if untreated. Incidence of scoliosis in children younger than age 8 years is 1.3 %[24].

The issue of present study was conducted to compare the effect of neuromuscular electrical stimulation versus myofeedback on static planter pressure of the right foot in children with juvenile idiopathic scoliosis.

In this study; forty girls with juvenile idiopathic scoliosis were randomly selected from the outpatient clinic of the Faculty of Physical Therapy, Cairo University.

The mean chronological age of the selected children of both study group (A) and study group (B) equal X7.92(± 0.68) and X 7.76(± 0.6)years; respectively.

The treatment programs were conducted three times per week (every other day) for three successive months. Neuromuscular electrical stimulation was used in the first study group, in addition to a specially designed therapeutic exercise program. The other study group received training by auditory and visual EMG biofeedback (myofeedback), in addition to the same therapeutic exercise program as in the first group.

Results of the present study demonstrated that each of electrical stimulation and myofeedback added to exercises program is significantly effective for the treatment of juvenile idiopathic scoliosis, with no significant difference between each of them on decreasing static planter pressure of the right foot.

Selection of Force distribution measurement system for measurement of the static plantar pressure distribution in this study comes in agreement with Illyes and Kiss[11] and with Saltikov et al.,[28] who found that there is an increasing emphasis on objective assessment to monitor treatment effectiveness in cases of idiopathic scoliosis.

In this study Cobb method was selected to measure the degree of curvature. This comes in agreement with Poncet et al.,[25] who stated that the degree of the scoliotic curve is measured as the angle intersect between the most inclined lines of vertebral end-plates. Also it comes in agreements with Dangerfield[5] who reported that the level of the apex vertebra can be quantified by examining the spinal radiograph to reveal the most inclined vertebral end- plates at the end of curve. The angle between these points is Cobb angle.

The post treatment results of the group (A) come in agreement with Griffet and Leroux[7] who certified that, electrical stimulation is effective in halting progression of mild to moderate scoliotic curves. They concluded that, electrical stimulation with electrodes placed laterally on convex side of curve is a valuable and effective in the treatment of scoliosis in children and adolescents.

Also these results confirm results of Verzini and Parzini[33] who found that, electrical stimulation to muscles of the convex side is used to straighten the curve. This alters the direction of the deformity so that pressure is reduced on the concave side, and reducing asymmetric pressure leads to a more normal vertebral growth and development.

The findings come in agreement with Daliand Hansen[4] who applied electrical stimulation, in the form of low intensity electrical stimulation. Stimulation was applied to the convex side of the curvature in order to evoke muscle contractions causing curvature correction. It was found that electrical stimulation lead to increase back muscle strength and vertebral mobility.

The results confirm that of John[13] and Kathleen et al.,[14] who found that, NMES and exercises on convex side have been effective in treatment of idiopathic non-structural scoliosis.

Susan et al.,[32] reported thatelectrical stimulation has been used effectively in place of orthotics and in conjunction with bracing to increase patient motor control and to facilitate occupational performance. Because the use of electrical stimulation is to gain control of function of targeted muscle groups, it is often referred to as functional electrical stimulation (FES).

On the other hand, some studies contradict the post treatment results of group (A). Nancy[20] concluded that, both of exercises and ES of the back muscles on convex side of scoliotic curve don't have any beneficial effects for idiopathic scoliosis.

Gurpreets et al.,[8], contradict the post treatment results of group (A). They compared the outcomes of NMES on convex side of scoliotic curve with untreated patients (aged 5 to 8 years). They did not find significant difference between both groups.

However, these Studies are lacking the effect of modulation of transverse back muscle (middle fibers of trapezius) efficiency on concave side of scoliotic curve. In the present study, this balance between stimulation of both of the longitudinal and transverse back muscles had been applied.

The importance of transverse back muscles stimulation was also confirmed by Christa[3] found that,scoliosis is characterized by pronounced changes in the balance of forces of muscles. With greater the deviations from the midline, transverse muscles lose their supportive function. In other words, deviations of the trunk to the side can develop and progress if the corresponding supportive muscles give way and become weak.

There is imbalance of muscle pull on both sides of the scoliotic spine, so correction of both component of the spine is necessary. The post treatment results of group (A) confirm that of Burwell[2] who reported that, attempting to create balanced pull from the concave side of the transverse muscle groups is effective in reducing progression of scoliosis.

The significant improvement in the post treatment results of the study group (B) may be attributed to the development of proper alignment of posture provided by movement training using biofeedback. This explanation is in agreement with Robertson et al.,[27] who reported that feedback is proportional to the response caused by motor signals. Thus a strong muscle contraction produces a strong signal, which should be trained.

Biofeedback was preferred to be used in the current study as biofeedback is easily recognized and used by the patient. Prentice[26] and Robertson et al.,[27] described the mechanism of using biofeedback. They said that biofeedback unit receives small amounts of electrical energy generated during muscle contraction through an electrode. Once the electrical activity is detected by the electrodes, the extraneous electrical activity, or "noise" is eliminated (or at least minimized). This is achieved through using three electrodes; two 'active' electrodes over the muscle (they should be placed in close proximity to one another), and a third 'indifferent', 'ground' or 'reference' electrode that is placed somewhere else on the body. All connected to a differential amplifier. It then separates or filters this electrical energy from other extraneous electrical activity on the skin and amplifies the electrical energy. The amplified activity is then converted to information about electrical activity of the muscles.

Results of group (B) in the present study are also supported by Lewis and By blow[17] who stated that biofeedback is an effective intervention, which is typically used to assist patients in recruiting weak muscles.

The post treatment results of both groups coincides with Eva[6] who asserted that, physical exercise on convex side of scoliosis is beneficial when practiced in order to improve the muscle strength and tone, vital capacity and posture of scoliotic subject.

Treatment must improve posture so that the body can regain its original vertical axis through restoring muscular balance. This can only be achieved by developing and training the corresponding muscle groups responsible for upright posture. In order for these muscles to be able to hold the spinal column and ribcage in their normal vertical position again, short muscles need to be lengthened, and weak muscles need to be strengthened, so that exercise therapy was important to be applied in this study.

Conclusion

Each of neuromuscular electrical stimulation and myofeedback may be used in conjunction with therapeutic exercise program for the improvement of the total static planter pressure distribution of the right foot in children with juvenile idiopathic scoliosis.

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Conflict of interest

There is no conflict of interest for this paper.

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الملخص العربي

تعديل ضغط القدم في الجنف بالتنبيه الكهربائي مقابل التدريب على التنبيه الاسترجاعي للعضلات

يقدم التنبيه الكهربائي والتدريب على التنبيه الاسترجاعي للعضلات أساليب لتحسين ضغط أسفل القدم وبذلك يتم تجنب مشاكل أخرى بالطرف السفلي والعمود الفقري . تهدف هذه الدراسة إلى اختبار تأثير كلا من وسائل العلاج ، ثلاث مرات أسبوعياً لمدة ثلاث شهور ، على توزيع الضغط الكلي الثابت أسفل القدم ، للقدم اليمنى في الأطفال ذوي الجنف . تم إجراء هذا البحث على أربعين فتاة ممن تتراوح أعمارهن بين سبعة وتسعة سنوات . تتراوح زاوية الجنف بين عشرة إلى عشرين درجة . قسمت الفتيات عشوائياً إلى مجموعتين متساويتين في العدد ، المجموعة (أ) والمجموعة (ب) . تم قياس توزيع الضغط الكلي الثابت أسفل القدم لكل طفلة بالمجموعتين قبل وبعد ثلاثة أشهر من العلاج باستخدام جهاز قياس توزيع الضغط أسفل القدم . تلقت المجموعة (أ) التنبيه الكهربائي بالإضافة إلى مجموعة من التمرينات الخاصة ، بينما تلقت المجموعة (ب) التنبيه الاسترجاعي للعضلات بالإضافة إلى نفس التمرينات الخاصة بالمجموعة (أ) . أثبت التحليل الإحصائي عدم وجود فروق ذات دلالة إحصائية عند مقارنة نتائج ما قبل العلاج للمجموعتين (أ) ، (ب) ، كما أثبت وجود تحسن ذو دلالة إحصائية في المجموعتين عند مقارنة نتائج ما قبل وبعد العلاج ، كما أثبت التحليل الإحصائي عدم وجود فروق ذات دلالة إحصائية عند مقارنة نتائج ما بعد العلاج للمجموعتين . لذا فإنه يمكن استخدام التنبيه الكهربائي والتدريب على التنبيه الاسترجاعي للعضلات كوسائل علاجية لتحسين ضغط أسفل القدم الكلي الثابت للقدم اليمنى في الأطفال ذوي الجنف .

الكلمات الدالة : الجنف ، توزيع ضغط أسفل القدم ، التنبيه الكهربائي ، التدريب على التنبيه الاسترجاعي للعضلات .