INFLUENCE OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION EXERCISE PROGRAMS ON PAIN, FUNCTIONAL PERFORMANCE AND PULMONARY FUNCTIONS IN SCHOOL AGE CHILDREN DIAGNOSED WITH ADOLESCENT IDIOPATHIC SCOLIOSIS: RANDOMIZED CONTROLLED STUDY

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ABSTRACT

Study Design: Randomized controlled study. Objective: To investigate the influence of the proprioceptive neuromuscular facilitation exercise programs on pain, functional performance and pulmonary function in the school age children diagnosed with adolescent idiopathic scoliosis. Background Data: Evidence of declined respiratory function in patients with adolescent idiopathic scoliosis (AIS) has been well established in the literature. Rehabilitation program that includes proprioceptive neuromuscular facilitation exercise could help children with idiopathic scoliosis to regain their functional performance. Methods: A total of 60 children diagnosed with AIS have been enrolled in the study. They were randomized into two equal groups. Group A received the PNF program and respiratory exercise pulse the traditional treatment. Group B received only the traditional treatment program. Outcome measures (VAS, TUG test, FVC, FEV1, and FEV1/FVC ratio) were measured before and after application of rehabilitation programs. Results: Statistical analysis using MANOVA test revealed that there was a significant decrease in VAS and TUG of both groups post treatment compared with that pretreatment (p < 0.001). There was a significant increase in FEV1 and FVC of the study group (p < 0.001) and control group (p < 0.05) post treatment compared with that pretreatment; while there was no significant difference in FEV1/FVC ratio post treatment compared with pretreatment in both groups (p > 0.05). Conclusion: The obtained research results indicate the importance of proprioceptive neuromuscular facilitative program, with the application of breathing exercise and home exercise program, in treating children diagnosed with idiopathic scoliosis.

Keywords: Adolescent idiopathic scoliosis, Pulmonary function, Maximal voluntary ventilation, Forced vital capacity, TUG test.

1-INTRODUCTION

Skeletal malposition could affect the joint load transfer capabilities and, therefore weight-bearing process through the articular surfaces. Good posture secure both minimal muscle tension and minimal stress on the articular surface. Optimal alignment of the joints through good posture provides distribution of stress over wide area and reduce any overload. Optimum posture alignment could decrease joint surface compression and reduce risk of destruction and degeneration changes to joint (2,6,7).
One of the main posture deformities that affects both adults and children is Scoliosis. Scoliosis is the most common 3-dimensional deformation abnormality of the spine that has direct effects on the thoracic cage, with a reported prevalence in the general population varying significantly from 0.3% to 15.3% [3-6]. It is the result of a pathologic process which leads to lateral curvature of the spine. It can be acquired scoliosis that resulted from assuming bad postures for prolonged time through life spine especially during the puberty. And it could be congenital, due to vertebral or rib malformation as in Klippel-feil syndrome, secondary to a variety of systemic or neuromuscular disorders, and could be idiopathic. Idiopathic scoliosis accounts for approximately 85% of cases and it is defined as a structural scoliosis for which no specific cause can be established (10,14).

Idiopathic scoliosis is further categorized as infantile, juvenile, and adolescent, according to the age at which the spinal deformity is first noticed. Its diagnosis can be made after exclusion of a primary etiology such as vertebral anomaly, neuromuscular disorder, Marfan syndrome or other disorder. Another classification is based on the quantification of the severity of the scoliosis using radiographic measurements of the angle of the curvature in the spine (Cobb angle), as well as the level of the apex of the spinal curvature (cervical, high thoracic, thoracolumbar, lumbar), and the number of curves (single or double). These characteristics are used for comparison, prognosis, and development of treatment guidelines (8,9).

The effects of scoliosis on the chest cage diameter are important and quite complex. It was reported that changes in the morphology of rib cage in anteroposterior radiographs associated with proportional changes of thoracic viscera, mainly the heart and lungs and principally the lungs during development (11,12, 14).

As the lung fills the chest cage any changes in the diameter of this cage could affect the lung expansion and this will reflect on the physical performance of the subjects. So, monitoring pulmonary functions in children with idiopathic scoliosis is very important and targeting the respiratory functions and its training in the rehabilitation of children of idiopathic scoliosis is considered medical necessity. Measuring the respiratory functions in patients with idiopathic scoliosis is not clear in the literature (18,23,25).

The purpose of the current study is to investigate the effect of functional training as proprioceptive neuromuscular training PNF on pulmonary functions in children with idiopathic scoliosis. The current study enriches the literature with a randomized controlled research work that analyzed the effect of the proprioceptive neuromuscular facilitation exercise on functional performance and respiratory functions of patients with idiopathic scoliosis.

II- MATERIALS & METHODS

A sample of 60 students in 7th and 8th grades of Alagouza language school located in Cairo City, Egypt. They were male and female, and their age was between 14 and 17 years of age, were diagnosed with scoliosis. The subjects were all students, who were seated on a chair for more than 6 hours a day on average, listening to lessons. All the parents or caregivers of the children read and signed a consent form before the beginning of the study and the study procedure were approved by ethical committee of faculty of physical therapy of Cairo university. The patients were randomly assigned into two equal groups (study and control group) with the use of a computer-based randomization program. The study followed the consort follow system as a RCT and patient allocated to two equal group, there was no dropping out of participants from the study was reported after randomization and intervention (Figure 1).

Subjects were excluded from the study if they had any prior operative intervention for scoliosis or chest pathology and associated medical comorbidities. Also, if there are concomitant respiratory issues, such as asthma or shortness of breathing during exercises.

This study was approved by ethical committee of faculty of physical therapy Cairo University and this study is registered as a RCT at pan African clinical trials registry PACTR under this number (PACTR202108675488120). Subjects were randomly divided into two equal groups by using computer generated randomization system for two groups. Group A is the study group which received PNF exercises plus traditional scoliosis treatment and group B is the comparison group and received traditional scoliosis treatment.
The treatment procedure for group A:
The exercise programs in this study were composed of six therapeutic exercise programs, including home exercises, and considering the balancing ability, lateral asymmetry of the sway, distortion, and heights of the pelvis and scapular bones, the exercise was executed with the initial posture with a wider bottom plane changed to one with a narrow bottom plane. Also, all the exercise programs were based on the basic principles of PNF, its procedures, and philosophies. Moreover, the PNF patterns and techniques were appropriately used.

The PNF techniques that were used in the programs in this study also included the principle of combination of isotonic applied to the treatment of the patient. The PNF exercise programs, which were executed for a total of six weeks, consisted of three sessions a week, with each session lasting 30 min. It combined two to three exercise programs in accordance with the level of adaptation of the patient to the exercises. Before beginning the exercise in earnest, the overall progress of the exercise and how to breathe deeply were explained to the subject. Also, when the subject complained of pain or fatigue, the exercise was suspended, and a 2- to 3-min break was given. (The break was excluded from the exercise time.)

Fig. (1): Flow chart of the current study.
PNF Six exercises program:

The first drill includes Stabilizing lumbo-pelvic systems: patient lay crock-lying position and the therapist held the iliac crest in both of his/her hands. Patient is asked to suck his abdomen in the posterior rotate his pelvis while keep breathing as normal. This activity activates transferase abdomens TA muscles and activate the stabilization system. The second exercises include the amphibian position, in which the patient lay prone and flexion-adduction-external rotation with knee flexion was performed with the left leg while the left arm performed flexion-abduction-external rotation to stabilize the lumbo-pelvic system and to elevate the scapular and pelvic bones on the left side, depressing the right-side scapular and pelvic bones so that the cervical and thoracic spines’ arches towards the right and the lumbar spine’s arches towards the left could be aligned to the normal positions. Assuming this position counterforce the scoliotic curves and restore the proper alignment of vertebral segment and allow those muscles around the spine to work synergistically to maintain the normal alignment.

The third exercise consist of the patient lay in the supine position and with using both legs of each subject, the left-side pelvis (the convex side) was raised using combination of isotonic contraction of TA. The subject was also asked to move their left arms (same of pelvic side) in flexion-abduction-external rotation to improve the lumbar curve as well as the cervical curve. The fourth drill was performed in a side-lying position, where the patient lay side on the convex side and the upper most leg was doing extension-abduction-internal rotation while the lower most arm was doing flexion-abduction-external rotation in a closed-kinetic-chain exercise up (push against wall) to stretch the right arm of the patient.

The fifth drill performed from sitting position while the patient sitting at edge of the bed and the therapist supports him from posterior, they asked to raise the arms at concave side and put it over the bed and to practice breathing exercises from this position. The six drills include the same maneuver of fifth one, but it was performed in standing position.

The traditional treatment program for both groups A & B:

All subjects in both groups received the traditional treatment during the period of rehabilitation program. It includes heated pad for 15 minutes which the subjects lay prone-lying position. Stretching exercise for both hamstrings muscles to improve the flexibility of the lower extremity, this exercise performed as active stretch as the children asked from long sitting position to touch by both hands the tips of toes of both legs for 30 seconds for 5 sets.

The outcomes measures:

All the outcomes measure has been taken at base line before the treatment procedure to start as initial evaluation and after treatment procedure as post procedure measurement.

1-The TUG: test consists of rising from a chair positioned 3meters from a wall, walking 3m, turning around, returning to the chair, and sitting down again. The test was performed according to the modifications for children described in the study by Williams et al. For each TUG evaluation, three measures are recommended, and the result is the shortest time obtained. The verbal command included instructions about velocity such as: ‘walk as fast as possible’(21).

This adaptation was proposed because TUG results are less variable when instructions are given regarding velocity. The modifications for the use of the TUG test in pediatrics are (1) using a specific task of touching a target on the wall; (2) instructions may be repeated during the test, (3) the chair used for the test must have a back but no arms and the height will be accepted when the angle measured with a goniometer is 90º (SD 10º) of knee flexion, with the feet supported on the floor; and (3) counting time must begin when the child gets up from the chair, and stop when the child sit in the chair. TUG test evaluations were performed by the same rater, with more than 2 years of experience in pediatric physiotherapy, and the individuals were evaluated wearing comfortable clothes and shoes. First, the test was demonstrated to the participants who then performed it once as a training test to familiarize them with what was expected. As recommended, the individuals performed the TUG test three times and the test done in the shortest time was taken as the result.
2- The Visual analogue scale VAS: Numeric scale from 1 to 10 used to assess the intensity of pain during the research study (3,24).

3- Evaluation of FVC, FEV1, and FEV1/FVC ratio was guided by previously guidelines using a computerized electronic spirometer (Spiro-Sonic FLO). PC-based ultrasonic spirometry (Spiro-Sonic FLO): is a high-fidelity ultrasonic spirometry for pulmonary function assessment. Coupled with the spirometer reporter software.

   Based on half-duplex single path digital ultrasonic flow measurement, Spiro-Sonic FLO automatically calibrates itself before each measurement. The device consists of no moving parts and a continuous flow tube, making disinfection very effective and easy. Data are expressed as absolute values and as a percentage of the predicted normal values.

   Maximum effort was emphasized to gain the best results. For evaluation of FVC and FEV1, participants initially breathed normally for several cycles, followed by deeply inspiration then maximum forced expiration. FVC and FEV1 evaluation maneuvers were repeated three times where the best-recorded trial results were used.

   In measuring FEV1/FVC ratio via spirometry, the amount of air you exhale in one second is recorded, as well as the total amount of air you can exhale. Based on the FVC calculated for your age, height, and weight, the ratio of these two values is then evaluated. The ratio is expressed as a percentage: the percentage of the FVC expired in one second.

**Statistical analysis**

Descriptive statistics and unpaired t-test were conducted for comparison of subject characteristics between groups. Chi-squared test was used for comparison of sex distribution between groups. Normal distribution of data was checked using the Shapiro-Wilk test. Levene’s test for homogeneity of variances was conducted to ensure the homogeneity between groups. Mixed design MANOVA was performed to compare within and between groups effects on VAS, TUG, FEV1, FVC and FEV1/FVC. Post-hoc tests using the Bonferroni correction were carried out for subsequent multiple comparison. The level of significance for all statistical tests was set at p < 0.05. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

**III- RESULTS**

**Subject characteristics:**

Table 1 showed the subject characteristics of study and control groups. There was no significant difference between groups in the mean age, weight, height, and BMI (p < 0.05). Also, there was no significant difference in the distribution of sex between groups (p < 0.05).

| Table 1. Basic characteristics of participants. |
| MEAN ± SD | Study group | Control group | p-value |
| Age (years) | 13.93 ± 0.94 | 13.86 ± 0.97 | 0.78 |
| Weight (kg) | 46.46 ± 4.22 | 46.73 ± 4.83 | 0.82 |
| Height (cm) | 147.2 ± 4.13 | 146.86 ± 3.84 | 0.74 |
| BMI (kg/m²) | 21.48 ± 1.48 | 21.61 ± 1.29 | 0.72 |
| Sex | | | |
| Male | 14 (47%) | 15 (30%) | 0.79 |
| Female | 16 (53%) | 15 (30%) |

x̄, mean; SD, standard deviation; p-value, probability value
Effect of treatment on VAS, TUG, FEV1, FVC and FEV1/FVC:

Mixed MANOVA revealed that there was a significant interaction of treatment and time (F = 24.7, p = 0.001). There was a significant main effect of time (F = 94.5, p = 0.001). There was a significant main effect of treatment (F = 25.1, p = 0.001). Table 2 showed descriptive statistics of VAS, TUG, FEV1, FVC and FEV1/FVC and the significant level of comparison between groups as well as significant level of comparison between pre and post treatment in each group.

Within group comparison:

There was a significant decrease in VAS and TUG of both groups post treatment compared with that pretreatment (p < 0.001). There was a significant increase in FEV1 and FVC of the study group (p < 0.001) and control group (p < 0.05) post treatment compared with that pretreatment; while there was no significant difference in FEV1/FVC ratio post treatment compared with pretreatment in both groups (p > 0.05). (Table 2).

Between groups comparison:

There was no significant difference in all parameters between groups pre-treatment (p > 0.05). There was a significant decrease in VAS and TUG and a significant increase in FEV1 and FVC of the study group compared with that of control group post treatment (p < 0.01). There was no significant difference in FEV1/FVC ratio between groups post treatment. (Table 2).

Table 2. Mean VAS, TUG, FEV1, FVC and FEV1/FVC pre and post treatment of the study and control groups.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
<th>MD (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre treatment</td>
<td>3.02 ± 0.48</td>
<td>2.13 ± 0.27</td>
<td>-0.12 (-0.39: 0.14)</td>
<td>0.36</td>
</tr>
<tr>
<td>Post treatment</td>
<td>3.14 ± 0.56</td>
<td>2.66 ± 0.23</td>
<td>-0.53 (-0.66: -0.4)</td>
<td>0.001</td>
</tr>
<tr>
<td>% of change</td>
<td>0.89 (0.7:1.07)</td>
<td>0.48 (0.29:0.66)</td>
<td>p = 0.001</td>
<td></td>
</tr>
<tr>
<td>TUG (sec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre treatment</td>
<td>6.34 ± 0.15</td>
<td>6.38 ± 0.17</td>
<td>-0.04 (-0.12: 0.04)</td>
<td>0.32</td>
</tr>
<tr>
<td>Post treatment</td>
<td>5.41 ± 0.32</td>
<td>6.09 ± 0.24</td>
<td>-0.68 (-0.83: -0.53)</td>
<td>0.001</td>
</tr>
<tr>
<td>% of change</td>
<td>0.93 (0.82:1.03)</td>
<td>0.29 (0.18:0.39)</td>
<td>p = 0.001</td>
<td></td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre treatment</td>
<td>2.42 ± 0.17</td>
<td>2.44 ± 0.16</td>
<td>-0.02 (-0.09:0.07)</td>
<td>0.8</td>
</tr>
<tr>
<td>Post treatment</td>
<td>2.59 ± 0.18</td>
<td>2.48 ± 0.15</td>
<td>0.11 (0.01: 0.19)</td>
<td>0.01</td>
</tr>
<tr>
<td>% of change</td>
<td>-0.17 (-0.2: -0.12)</td>
<td>-0.04 (-0.09: -0.004)</td>
<td>p = 0.001</td>
<td></td>
</tr>
<tr>
<td>FVC (L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre treatment</td>
<td>2.82 ± 0.09</td>
<td>2.83 ± 0.07</td>
<td>-0.01 (-0.05:0.03)</td>
<td>0.57</td>
</tr>
<tr>
<td>Post treatment</td>
<td>2.97 ± 0.06</td>
<td>2.86 ± 0.11</td>
<td>0.11 (0.06: 0.15)</td>
<td>0.001</td>
</tr>
<tr>
<td>% of change</td>
<td>-0.15 (-0.18: -0.13)</td>
<td>-0.03 (-0.06: -0.009)</td>
<td>p = 0.001</td>
<td></td>
</tr>
<tr>
<td>FEV1/FVC (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre treatment</td>
<td>86.01 ± 5.13</td>
<td>86 ± 4.43</td>
<td>0.01 (-2.47:2.48)</td>
<td>0.99</td>
</tr>
<tr>
<td>Post treatment</td>
<td>86.96 ± 5.27</td>
<td>86.64 ± 4.04</td>
<td>0.32 (-2.1: 2.75)</td>
<td>0.79</td>
</tr>
<tr>
<td>% of change</td>
<td>-0.95 (-2.61: -0.69)</td>
<td>-0.64 (-2.29: -1)</td>
<td>p = 0.24</td>
<td></td>
</tr>
</tbody>
</table>

SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, Level of significance
The current study was conducted to investigate the effect of proprioceptive neuromuscular facilitation exercise programs on respiratory functions in children diagnosed with adolescent idiopathic scoliosis. The subject in current study is school-age children who has idiopathic scoliosis. Scoliosis in such age affects their growth and has negative impact on their cardio-pulmonary function and endurance. Up to our knowledge there are no RCTs in the literature studying the same procedure in the current study. The Statistical analysis of the current study revealed that there was a significant decrease in VAS and TUG and a significant increase in FEV1 and FVC of the study group. This result indicates the improvement in level of performance in the study group in compared with that of control group post treatment (p < 0.01). The increase respiratory function measure indicated the positive effect of PNF program on lung performance in children with idiopathic scoliosis. These results supported the initial hypothesis of the positive effect of PNF training program on restoring the good alignment of the spinal curves and improving the functional level of respiratory. Statistical analysis also revealed in results that compared between groups that their significant decrease of VAS and TUG and significant increase in FEV1 and FVC in study group in compare with group B. This result supports the use of PNF and breathing exercises as rehabilitation program during treating children diagnosed with idiopathic scoliosis.

To improve their postural alignment and regain the cardiopulmonary function the authors in the current study focused on the application of PNF exercise program and beside home exercise program as a plane of care that children followed it and the measurement has been taken to analysis the results of this POC. The main goal is to give these children the chance to practice their school daily activities with normal rhythm and without exhaustion or feeling of tiring and to make them in same performance level of their same age colleges. Also, to regain the static and dynamic posture alignment of their spine and prevent any psychological side effect of the scoliosis on these children.

Studying the effect of scoliosis in the development of student in such age is crucial as they are in the peak of skeletal functional development and any deformity could result in permanent disruption in their growth and being able to practice their ADL normally and without complaint or discomfort (6,7). Beside the physical and functional reflects of scoliosis on the lung functions and posture alignment it has an impact on the psychological aspect of these children. This effect could make them suffers from social stress and may lead to isolation and these complications made the treatment and prevention of scoliosis in early ages is mandatory (15,20).

The results of the current study supported by the study of Lee, Byung-Ki 2016. Lee studied the influence of the proprioceptive neuromuscular facilitation (PNF) exercise programs on one young female patient diagnosed with idiopathic scoliosis. Lee in his study focused on the restoration or both normal static and dynamic alignment of
spine curves. Lee used 6 PNF exercise program focusing on both static and dynamic balance control of the subject postural alignment. This study is considered case series study as the author included one patient in the treatment procedure however the current study considered a continuation of Lee and his college work, it has higher evidence level as it includes randomization producer of subjects during the treatment procedure which make the study more valid and liable for generalization (16).

Karaleic and his colleges 2014, studied the influence of corrective gymnastic exercises on correction of bad posture and changes of muscle performance in school-age children diagnosed with scoliosis. They concluded that scoliosis resulted from imbalance between muscles groups that support the spine and maintain its curves. During the rehabilitation program they provide strengthening exercises for weak muscles at convex side of the curve and stretching exercise for muscles at concave side. Breathing exercises has been included to the program to address the respiratory function and enhance it in such young, aged subjects (13).

The current study was conducted over 6 weeks, PNF exercise program and breathing exercises were provided to enhance both physical and respiratory performance. Subjects were both gender and at school-age and the statistical analysis confirmed that the PNF and breathing exercises are effective in enhancing the functional level of school age children diagnosed with idiopathic scoliosis.

Conflict of interest.
The there is no conflict of interest during application of the current study or receiving any funds from any organization.

V- CONCLUSION
The obtained research results indicate the importance of proprioceptive neuromuscular facilitative program, with the application of breathing exercise and home exercise program, in treating children diagnosed with idiopathic scoliosis.

REFERENCES