ORIGINAL REPORT

PULMONARY FUNCTION AND AEROBIC CAPACITY RESPONSES TO EQUINE-ASSISTED THERAPY IN ADOLESCENTS WITH IDIOPATHIC SCOLIOSIS: A RANDOMIZED CONTROLLED TRIAL

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Background: **Idiopathic scoliosis is a common spinal malalignment that negatively impacts the respiratory system and physical conditioning in adolescents. Equine-assisted therapy comprises therapeutic horseback riding that optimizes physical performance and mobility in a range of contexts. However, the influence of equine-assisted therapy on pulmonary function remains unclear.**

Objective: **To examine the impact of 10 weeks of hippotherapy combined with Schroth exercises on pulmonary function and aerobic capacity in adolescents with idiopathic scoliosis.**

Methods: **A randomized controlled trial including 45 patients, randomly assigned to experimental and control groups, was performed. Patients in the experimental group received 15 30-min sessions of hippotherapy over a period of 10 weeks. The 2 groups attended a 60-min session of Schroth exercises 3 times/week for 10 weeks. Pulmonary function and functional capacity were assessed before and after the intervention.**

Results: **Pre- and post-intervention variables (FVC, FEV1, FEV1/FVC, MVV and 6MWT) revealed significant improvement in both groups ($p<0.05$). The improvement in the experimental group was significantly higher than in the control group ($p<0.05$).**

Conclusion: **The addition of hippotherapy to Schroth exercises resulted in improved pulmonary function and aerobic capacity in adolescents with idiopathic scoliosis.**

Key words: equine-assisted therapy; pulmonary function; Schroth method; idiopathic scoliosis.

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LAY ABSTRACT

Scoliosis is a 3-dimensional spine deformation disorder that has direct consequences on the thoracic cage, resulting in lung constriction and functional difficulties in adolescents. Conservative therapy approaches are mostly designed to correct the spinal bony curvature rather than address adverse negative deteriorations. This study investigated the effect of hippotherapy (equine therapy) in combination with Schroth exercises on pulmonary function and aerobic capacity in adolescents with idiopathic scoliosis. The combination of hippotherapy with Schroth exercises had a significant benefit compared with Schroth exercises alone. Horseback riding therapy could be an innovative complementary physical therapy technique for improving respiratory and physical functioning in adolescents with idiopathic scoliosis.

Scoliosis is a 3-dimensional spinal deformity with an incidence of 0.3–15.3% (1); approximately 85% of cases are idiopathic (2). Scoliosis is categorized as infantile, juvenile, or adolescent idiopathic depending on the age of onset. Adolescent idiopathic scoliosis (AIS) accounts for 90% of cases, starts at approximately between the age of 10 years until the end of growth, affecting mainly females, with a sex ratio of 3.5:1 (3).

Vertebral rotation in AIS results in a deformed spine in the sagittal, frontal, and coronal planes (4), with rib cage structure deviations (5). The asymmetrical deformity of the thorax is caused by the twisted vertebral column component in the transversal plane, which creates a convex and concave side (6). The chest wall stiffens, due to the deformed thoracic cage, which reduces the tension of the respiratory muscles and causes mechanical diaphragm dysfunction (7).

Spinal rotation causes the ribs to move laterally, so that the midpoint of the sternum becomes lateral to the centre of the spine, further compressing and distorting the lungs by flattening them in the lateral plane (8). It has been reported that patients with AIS have a narrower rib cage than non-scoliotic healthy individuals (9). Patients with mild scoliosis may experience reduced exercise tolerance and pulmonary limitation as a result of rib cage deformation and vertebral rotation, along with respiratory muscle weakness (10–12).

Prior research concluded that respiratory muscle strength correlates positively with forced vital capacity (FVC) (13). Adolescents with mild idiopathic scoliosis have significantly reduced pulmonary function parameters compared with healthy adolescent controls (14). The degree of thoracic curve has a negative correlation with forced expiratory volume in the first second (FEV1) and FVC; and, as a consequence, the lung function declines with greater thoracic curve (2).

Schroth exercises are mainly a combination of scoliotic posture correction and breathing pattern alteration through mirrored self-monitoring (15, 16). Previous literature has reported positive therapeutic effects of Schroth exercises on the Cobb angle, pulmonary function, and functional movement screen scores when treating adolescents with idiopathic scoliosis (17, 18).

Equine-assisted therapy, also known as hippotherapy, involves specially trained physiotherapists using the horse as a therapeutic tool to deliver 3-dimensional stimuli to the musculoskeletal system of the rider (19). Equine-assisted therapy has been proposed as a physical rehabilitation method to stimulate the somatosensory, proprioceptive, and vestibular systems and, consequently, improve major motor function, balance, and stability (20). The movements of the horse are rhythmic, repetitive, and resemble the gait of a human; due to its simulation, horseback riding may facilitate the effects of gait therapy (21).

Maximal inspiratory and expiratory pressure values have been shown to be better among people who practice hippotherapy, and the older the individual the better the inspiratory respiratory muscle strength (22). Horse-riding simulator training has a positive impact on FVC and FEV1 in healthy adults after 4 weeks' intervention (23)

Previous research has focused on the impact of equine therapy on physical performance and mobility in children with cerebral palsy (CP), autism spectrum disorder, and in adults with multiple sclerosis and other neurological conditions (24). However, there is a lack of research into the impact of hippotherapy on pulmonary function and functional performance in adolescents with mild scoliosis. Therefore, this study investigated the additional effects of 10 weeks of equine therapy in combination with Schroth exercises on pulmonary function and aerobic capacity in AIS.

MATERIALS AND METHODS

Participants

A total of 45 patients (13 males and 32 females) were referred by paediatric orthopaedic surgeons from local clinics and medical centres and participated in the current study. Inclusion criteria were: age 12–18 years and diagnosed with AIS, having a thoracic or thoracolumbar primary curve, confirmed diagnosis of mild AIS (Cobb angle 10–20°) (25), Risser grade 2–4, and availability to participate in the study. Exclusion criteria were: adolescents with obstructive pulmonary diseases, associated neuromuscular diseases, recent infectious episodes in the previous 2 months, history of cardiovascular or psychological disorders, and any significant history of riding horses.

The study adopted a single-blind randomized controlled research design, and was conducted during the period February 2020 to December 2020. The participants were randomly assigned to 1 of 2 groups: an experimental group who received hippotherapy combined with Schorth exercises, and a control group who received only Schorth exercises. The method for concealing the allocation was to enclose the assignment in opaque, sealed envelopes with sequential numbers. The envelopes were opened in front of the participants by an independent person not involved in the study.

Data, including age, sex, height, weight, and body mass index (BMI), were documented. Each participant signed a written informed consent form. The research protocol was approved by the institutional ethics committee of Batterjee Medical College (RES-2021-0020); with Clinical Trial.gov ID (NCT04833868). The study was conducted following the principles of the Declaration of Helsinki.

Assessment procedure

Pulmonary function. Using a spirometer (Spiro Master PC-10, Chest M.I. Inc, Tokyo, Japan), the following indices were recorded FEV1, FVC, FEV1/FVC, and maximum voluntary ventilation (MVV). The results were presented as absolute values and as a percentage of the predicted normal values. To achieve the best results, maximum effort was emphasized. Participants breathed normally for several cycles before performing maximum forced expiration to determine FVC and FEV1. After a proper rest period, participants inhaled forcefully and rapidly as fast as they could for 15 s to assess MVV. In accordance with American Thoracic Society (ATS) and European Respiratory Society (ERS) standardization of spirometry, spirometric indices were measured using the best of 3 technically acceptable trials (26).

Aerobic capacity. According to the ATS guidelines, the 6-minute walk test (6MWT) is a practical, submaximal exercise test used to assess aerobic capacity and endurance through the global and interconnected responses of all the bodily systems involved in exercise, including the respiratory and circulatory systems, neuromuscular units and muscle metabolism. In this test, each patient was asked to cover as much ground as possible at his/her maximal cadence over a 30-m flat straight corridor without running, while keeping a steady pace over a period of 6 min, by which to compare changes in performance capacity. An increase in the distance walked indicates improvement in basic mobility and exercise tolerance (27).

Intervention procedures

The hippotherapy programme began with a physical therapy assessment to establish specific corrective movements to be performed when riding the horse, based on the direction of the spinal curvature. Interventions were conducted by a certified physical therapist experienced in hippotherapy at 2 nearby recreational riding centres. The participants received 15 sessions split into 2 phases over a period of 10 weeks (28). In the first phase, during the first 5 weeks, participants completed 30 min of walking and sitting trot training without a stirrup iron once a week. The frequency was then increased to twice a week for the remainder of the treatment programme. Before starting the intervention, 2 familiarization sessions were provided to explain safety rules, riding errors, and establish a riding rapport with the horse.

For each hippotherapy session, the participants wore safety helmets and rode a moving horse at a walk and trot in various positions, such as forward astride and backward astride, with frequent switching between positions during the downward transition from trot to walk and occasionally while the horse was moving (Fig. 1). In order to regain natural alignment of the spine, participants were also asked to ride without holding on with their hands, in order to execute self-correction movements. Examples of these movements include lifting both arms high to improve the flat-back position, turning the upper trunk towards the curve's convex side, and raising the arm on the concave side with scapular adduction in order to level both shoulders. To correct pelvic obliquity a small pad

Fig. 1. Hippotherapy training.

was placed under the hip on the side of the lumbar convexity. Under the physical therapist's instructions, a guide pulled the horse reins in front to control the horse's gait, gait velocity, and orient the horse in various directions. All of these movements activate the patient's neuromuscular and sensory reactions.

Schroth exercises, which are patient-specific asymmetrical exercises with rotational breathing practice, used for 3-dimensional corrections, were administered to both the experimental and control groups. For 10 weeks, the subjects performed the Schroth exercises 3 days/week. Each 60-min session included a warm-up (cat walking and breathing exercise: 10 min), stretching (chest part stretching: 5 min), the main exercises (laying right-click concave, laying aside static postural control training, sitting posture adjustment exercise, and muscle cylinder: 40 min), and a cool-down (moving ribs: 5 min) (18). A detailed description of Schroth exercises has been reported previously (17). During the therapy sessions, the Schroth method's postural correction principles, axial elongation, deflection, de-rotation, facilitation and stability were used (16).

Sample size calculation

G*Power (Universität Düsseldorf, Germany) software was used to calculate the sample size of the outcome parameter FVC, with an alpha of 0.05, power of 90%, and effect size of 0.5; a total sample size of

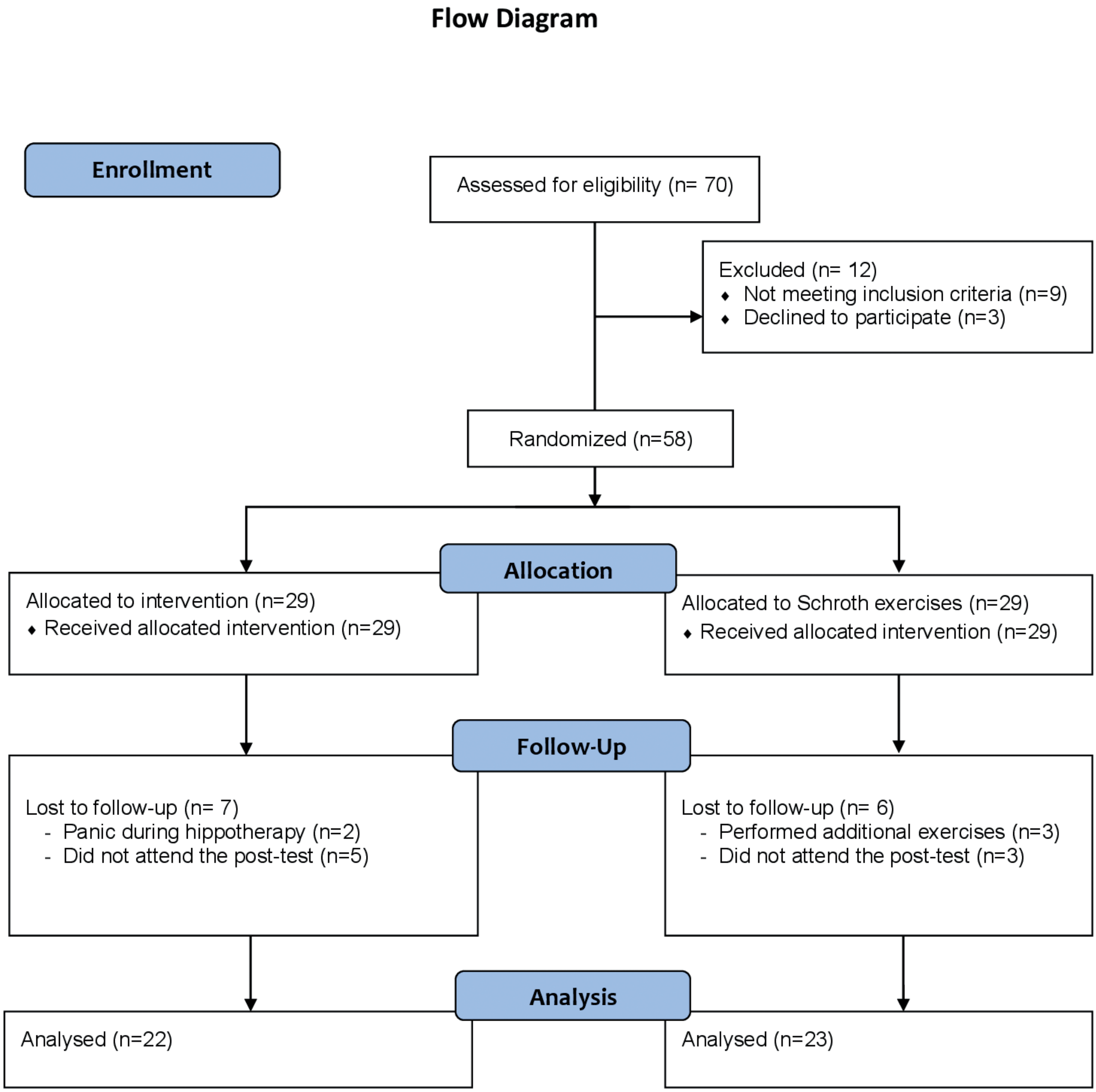

Fig. 2. Study flowchart.

45 patients was required for pre- and post- measurements of 2 groups.

Statistical analysis

Statistical Package for Social Sciences (SPSS, IBM Corp, Armonk, NY, USA) for Windows version 20.0 was used to analyse the collected data. An independent *t*-test was used to investigate the significant difference between the experimental and control groups regarding age, weight, height, BMI, or Cobb angle, and the χ^2 test was used to examine the significant difference between both groups regarding sex. The differences between FVC, FEV1, MVV, FEV1/FVC, and 6MWT of both groups were tested using multivariate analysis of variance (MANOVA). For subsequent multiple comparisons, post-hoc tests with the Bonferroni correction were performed. A $p<0.05$ was considered statistically significant with 95% confidence intervals (95% CI).

RESULTS

Of the 70 participants, 12 were excluded and 13 were lost to follow-up. A total of 45 patients' data were analysed. The flow of participants through the study is shown in Fig. 2.

Table I. Participants' demographic characteristics

Groups	Experimental group, $n=22$ Mean ± SD	Control group, $n=23$ Mean ± SD	*p*-value
Age (year)	14.68 ± 1.72	15.04 ± 1.66	0.479[a]
Weight (kg)	49.02 ± 5.17	51.18 ± 5.03	0.163[a]
Height (cm)	156.91 ± 6.74	158.65 ± 7.09	0.403[a]
BMI (kg/m²)	19.86 ± 1.02	20.30 ± 1.04	0.159[a]
Sex (male/female)	9/13	8/15	0.672[b]
Cobb angle (°)	15.59 ± 2.66	16.32 ± 2.39	0.332[a]

BMI: body mass index; SD: standard deviation.
Data are illustrated as mean±SD; *p*-values > 0.05 denote non-significant difference.
[a]Independent *t*-test; [b]χ^2 test.

Levene's test revealed that the data were homogenous and a normality test (Shapiro–Wilk) demonstrated that the data were normally distributed ($p>0.05$). Hence, the parametric data analysis approach was utilized. Regarding age, weight, height, BMI, and sex, there were no significant differences between the experimental and control groups ($p>0.05$), as shown in Table I.

Regarding the between-subjects effect, there was no significant difference (groups; F = 1.54, $p=0.199$), while there was a significant difference in the within-subjects effect (time; F = 3.76, $p=0.001$), and interaction effect (time*group; F = 16.79, $p=0.001$). Consequently, to determine the source of significance regarding group interactions (treatment interventions vs control) and time (pre- vs post-) factors the multiple pairwise comparison tests were carried out.

The pre- values of the FVC, FEV1, MVV, FEV1/FVC, and 6MWT of both groups were not significantly different ($p>0.05$). The pre-values were significantly lower than the post-values in each group ($p<0.05$). The post- values of the experimental group were significantly greater than those of the control group ($p<0.05$), as shown in Table II.

DISCUSSION

To our knowledge, this is the first study to investigate the effect of a combination of equine therapy and Schroth exercises on pulmonary function and functional capacity in patients with mild AIS. All variables, including FVC, FEV1, MVV, FEV1/FVC, and the 6MWT, improved significantly in both groups following the procedure, with more significant improvement in the experimental group.

These results can be attributed to multiple positive outcomes of hippotherapy. One such outcome is that, during the horse's movement, the rider experiences highly repetitive motion up 1,000 times over a 10-min period, producing an axial waving motion originating in the low back and spreading upwards (21). Locomotor waves from the horse's back are delivered to the rider at a frequency of 90–110 impulses per min (1.5–1.8 Hz) in 3-motion planes. Hippotherapy amplifies these effects by making the rider adjust their muscle tone to their body configuration, which is created by continuous proprioceptive and exteroceptive information (22). Repetition of these adjustments promotes strengthening of the pelvic, abdominal, and lumbar muscles, a process that improves trunk musculature, which itself is responsible for breathing mechanics (29). Furthermore, the 3-dimensional trunk sway resulted in continuous activation of the transverse abdominal muscles with increased activity in the paraspinal muscle after riding exercises (24).

Scoliosis decreases strength and disrupts the symmetry of muscle activation from lateral abdominal

Table II. Descriptive statistics of pulmonary function and aerobic capacity before and after intervention

Variables		Experimental group, $n=22$ Mean ± SD	Control group, $n=23$ Mean ± SD	*p*-value
FVC (L)	Pre-	2.62 ± 0.49	2.47 ± 0.45	0.309
	Post-	2.97 ± 0.57	2.65 ± 0.59	0.027*
	p-value	0.003*	0.039*	
FEV1 (L)	Pre-	2.28 ± 0.44	2.31 ± 0.41	0.306
	Post-	2.64 ± 0.58	2.56 ± 0.58	0.035*
	p-value	0.002*	0.023*	
MVV (L/min)	Pre-	71.78 ± 5.78	73.57 ± 5.48	0.291
	Post-	83.64 ± 4.50	79.14 ± 5.65	0.017*
	p-value	0.001*	0.01*	
FEV1/FVC %	Pre-	84.45 ± 4.22	83.72 ± 6.50	0.656
	Post-	94.13 ± 5.44	88.29 ± 8.45	0.013*
	p-value	0.001*	0.03*	
6-min walk test (m)	Pre-	600.77 ± 18.39	610.73 ± 18.57	0.078
	Post-	677.08 ± 20.92	663.22 ± 20.15	0.029*
	p-value	0.001*	0.021*	

Data are illustrated as mean±standard deviation (SD).
**p*-values < 0.05 denote significant difference.

muscles and the erector spinae muscles, which play a role in the reported reduction in respiratory function and aerobic physical performance in patients with AIS (30). Alves et al. (10) demonstrated that trunk rotation and rib cage distortion cause abnormal diaphragm and intercostal muscle configurations, primarily on the concave side. The torsion of the diaphragm may increase the radius of the diaphragmatic curvature, consequently lowering the force-generating capability and rendering it less effective, eventually resulting in respiratory disorders that prevent patients from participating in everyday activities (8).

Developing the core muscles is essential to optimize cardiopulmonary function. The core muscles control the synergistic action between the lateral abdominal muscles and the diaphragm for regulating or responding to abdominal pressure, providing stability to the trunk. The inner core muscles (multifidus, transverse abdominals, pelvic floor muscles, and diaphragm) play a vital role in the stability and postural control of the spine during whole-body exercise and in lung function (31).

Another important mechanism is the slow, rhythmic, and 3-dimensional sway of horseback movement, promoting bilateral symmetrical postural responses. This multisensory motion during horse riding helps to mobilize rigid pelvic and joints of the spine, normalize muscle tone, establish more equilateral head and trunk control, and enhance respiration, speech, and language (32). Constant adaptation of the rider to these movements through changes in trunk conformation necessitates the continuous use of muscles and joints, leading to increased strength and range of motion of the thorax (33).

The aligned skeletal system in the chest corresponds to the mobility of the chest wall, which is related to pulmonary function. Wang (34) has shown that stretching the dorsal spine can effectively reduce pain and enhance flexibility, range of motion, posture, and breathing function. In healthy people, increasing thoracic joint mobility increases lung function in the short term by improving bucket handle and pump handle movements of the ribs, which improves chest wall compliance, resulting in better pulmonary function (35).

In the current study, the experience of horseback riding can be regarded as a massed, but variable, practice of 2,000–3,000 repetitions of a forced-use postural challenge and trunk/head balancing exercise per 30-min hippotherapy session. This excessive number of repetitions exceeds typical physical therapy treatments by an order of magnitude. This intense practice condition accounts for the improvement of dynamic stability. Throughout the session, natural alignment facilitates the development of new movement strategies that may not have been adapted through conventional treatment methods.

The submaximal efforts during horseback riding may create a substantial overload on the cardiovascular system to induce adaptations indicating improved cardiovascular fitness, such as decreased heart rate, blood pressure, and pulmonary ventilation (36). Since horseback riding is weight-supported and there is less involvement of the lower limbs than for treadmill walking, it creates low to moderate physical exertion (37). Kim et al. (38) found that hippotherapy training increased the maximal oxygen consumption and metabolic equivalents of task, indicating that it could be used as an alternative to aerobic exercise.

Improvement in the 6MWT in the current study can be related to a range of factors; first, enhanced pulmonary function, since FEV1 and FVC had a strong positive relationship with absolute and percentage predicted 6MWT. Secondly, an association between trunk control and functional performance has been observed, since axial stability enhances balance, limb functionality, locomotion, and functional capacity (39).

The results of this study are in agreement with those from Costa et al. (22), who found that hippotherapy improves both inspiratory and expiratory muscle strength in people with Down syndrome, despite the fact that there was no statistically significant difference and that the results were best in the youngest subjects. The current study was recently supported by Seo et al. (23), who concluded that 4 weeks of horse-riding simulator training improved flexibility, FVC, and FEV1, but FEV1/FVC and peak expiratory flow (PEF) were not significantly different after training. It is believed that these benefits are due to stretching the paraspinal muscles, as they are repeatedly contracted and relaxed to maintain balance on an unstable surface.

In contrast to the current research results, Rigby et al. (37) found that 8 weeks of simulated horseback riding did not affect pelvic kinematic and cardiorespiratory responses and treadmill walking. Many functional outcomes, including gait, balance, posture, range of motion, and joint mobility, were significantly improved in children with CP, according to the same study. The difference may be attributed to the use of different samples and methodology, as the current study used real horseback riding.

The results from the control group showed that improvement could be accredited to rotational angular breathing and Schroth exercises that help strengthen respiratory muscles by correcting the distorted rib cage in the opposite direction. Stretching the rib cage during exercise has been shown to improve pulmonary function and rib mobility (17). After the Schroth exercises, Kim & Hwangbo (18) observed significant alterations in thoracic Cobb's angle, functional ability and thoracic rotation angle. The 3-dimensional rotational breathing turned the rib in the contrary direction, which widened the narrowed thoracic cage, resulting in a decreased trunk rotation angle. Furthermore, Kim & Hwangbo found that Schroth exercises were successful even in patients with a Cobb angle of 40° or greater who need operative treatment.

Study limitations

This study has some limitations; first, it only investigated patients with mild idiopathic scoliosis. Secondly, electromyography (EMG) assessment was not performed on primary or accessory respiratory muscles in the AIS; hence, the activation of muscles could not be verified. In addition, it was not possible to identify any causal relationships because the study only investigated the change in lung function and functional performance. Thirdly, energy expenditure and metabolic equivalents were not measured. Fourthly, the hippotherapy was added to only 1 type of physiotherapy scoliosis-specific exercise, which is a Schroth method. Hence, further study is required to examine the effect of adding the other PSSE, such as; the Scientific Exercise Approach to Scoliosis, the Dobosiewicz technique, and the Side-shift programme. Fifthly, changes in Cobb angle were not investigated post-intervention, hence improvement in pulmonary function could not be correlated with this measure. Finally, follow-up study is needed to examine the long-term effect of the current intervention.

CONCLUSION

This study showed that the addition of equine therapy to Schroth exercises improved lung function and aerobic capacity in adolescents with idiopathic scoliosis more than Schroth exercises alone. Therefore, in a clinical setting, the addition of equine-assisted therapy to conventional physical therapy programmes for individuals with AIS is recommended.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

The authors have no conflicts of interest to declare.

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