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REVIEW ARTICLE

Efficacy of exercise therapy for the treatment of adolescent idiopathic scoliosis: a review of the literature

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Abstract
Purpose Current evidence regarding the use of exercise therapy in the treatment of adolescent idiopathic scoliosis (AIS) was assessed with a review of published literature.
Methods An extensive literature search was carried out with commonly used medical databases. A total of 155 papers were identified out of which only 12 papers were deemed to be relevant.
Results There were nine prospective cohort studies, two retrospective studies and one case series. All studies endorsed the role of exercise therapy in AIS but several shortcomings were identified—lack of clarity of patient recruitment and in the method of assessment of curve magnitude, poor record of compliance, and lack of outcome scores. Many studies reported "significant" changes in the Cobb angle after treatment, which were actually of small magnitude and did not take into account the reported inter or intra-observer error rate. All studies had poor statistical analysis and did not report whether the small improvements noted were maintained in the long term.
Conclusions This unbiased literature review has revealed poor quality evidence supporting the use of exercise therapy in the treatment of AIS. Well-designed randomised controlled studies are required to assess the role of exercise therapy in AIS.

Keywords Adolescent idiopathic scoliosis · Physiotherapy · Exercise therapy · Rehabilitation · Literature review

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Introduction

The exact aetiology of adolescent idiopathic scoliosis (AIS) is unknown [1–3] but is deemed to be multi-factorial and includes genetic predisposition, imbalance between anterior and posterior spinal growth, abnormalities in connective tissue, skeletal muscle, muscle contractile mechanisms and neurology. While surgery is a well-recognised treatment of AIS, the role of conservative therapies including exercises, physiotherapy, intensive rehabilitation programmes and bracing has been the source of much debate [4]. Although it is rather difficult to explain how exercise therapy could correct a complex three-dimensional structural deformity that occurs in AIS, it has been promoted as an effective treatment [5]. However, this view is not shared universally, particularly in the US where bracing is a recognised form of conservative treatment [6, 7].

Lenssinck et al. [8] published a systematic review of all conservative interventions in the treatment of AIS and concluded that the effectiveness of exercise therapy is not yet established but might be promising. A number of papers have been published by some centres that heavily endorse exercise therapy as an effective treatment option and have purpose built rehabilitation centres specifically for this use. An initial review of 11 papers published by the Italian Scientific Spine Institute, concluded that there was no solid evidence in support of or against the role of exercise therapies in reducing curve progression in AIS [9]. A subsequent up-dated review included 8 more papers and concluded that all studies excepting one, confirmed the efficacy of exercises in AIS [10]. However, the results appear to be influenced by one randomised controlled trial [11] that reported on 80 patients split into two groups with 5 months follow-up. Each group had electrical stimulation, traction and postural training but the study group also underwent specific asymmetric strengthening exercise therapy. Although the exercise therapy group showed a greater reduction in Cobb angle, no statistical analysis was performed. It is interesting to note that the senior author of this review was also an author in 2 out of 8 [12, 13] additional papers reviewed. Another review from the Asklepios Katharina Schroth Spinal Deformities Rehabilitation Centre in Germany [14] found evidence to support physiotherapy and rehabilitation programmes in AIS and included several papers published earlier by the authors of this review [5, 15–18].

Clearly, there is a need for an independent review of current evidence on this topic to avoid inevitable reviewer bias. The aim of the current study was to provide an unbiased literature review regarding the use of exercise therapy in the treatment of AIS.

Materials and methods

An electronic literature search was performed using the following search engines

- Pubmed (end of December 2010)
- Embase (1980–December 2010)
- Medline (1950–December 2010)
- Cinahl (1981–2010)
- The Cochrane Library 2010, Issue 12.

The same search string was used for each database—'scoliosis AND (physiotherapy OR physical therapy OR exercises OR rehabilitation). Thesaurus mapping was also used to accommodate the variations in spelling of the search terms. Search limits were set to include only clinical trials, involving humans that were written in English. Table 1 shows the yield from each database using the above search string and limits set.

After elimination of 45 duplicated hits, the abstracts of remaining 110 were independently reviewed by the two authors. 98 studies were not relevant based on predetermined inclusion criteria outlined below:

- Treatment involving only exercise therapy
- At least level IV evidence

Table 1 Database yield using search string and limits

Database	Hits
Pubmed	75
Embase	27
Medline	18
Cinahl	2
Cochrane Library	33
Total	155

Table 2 Levels of evidence adapted from Centre of Evidence Based Medicine

Level I	Randomised controlled trials + systematic reviews of level I studies
Level II	Prospective cohort studies + systematic reviews of level II studies
Level III	Retrospective cohort studies + systematic reviews of level III studies
Level IV	Case series
Level V	Expert opinion

- At least 1 month follow-up
- Minimum of one defined outcome measure.

The 12 relevant studies were then categorised according to their level of evidence using a simplified adaption of the guidelines published by the Centre of Evidence Based Medicine, Oxford, UK [19] (Table 2).

Results

Table 3 highlights the key aspects from each paper. Paper 6a and 6b represent the same study that has been published in two separate journals. Overall, there were no studies representing level I evidence, nine studies representing level II evidence, two studies representing level III evidence and one study representing level IV evidence. Combining all the studies there was a total of 997 patients, mean age 15.8 years with an average follow-up period of 15 months.

Analysis

Prospective cohort studies (level II evidence)

Negrini et al. [20] reported on 74 consecutive patients with AIS, mean age 12.1 years and mean Cobb angle 15°. Patients were allowed to choose between two study groups [1], scientific exercises approach to scoliosis (SEAS) group or [2] usual physiotherapy (PT) group. There were 35 patients in the SEAS group and 39 patients in the PT group all of whom were followed up at 6 and 12 months. Outcomes were recorded by a neutral observer and included number of patients requiring a brace, Cobb angle and the angle of trunk rotation (ATR). Overall 6.1% of the SEAS group needed a brace versus 25% in the usual physiotherapy group. The average Cobb angle improved in the SEAS group but worsened in the PT group. The authors concluded that SEAS is more effective than usual PT in terms of the three measured outcomes. However, the actual average improvement in the Cobb angle was −0.67° in the

Table 3 Key aspects from the final paper selection

No.	Author	Year	Single/ ulticentre	Study type	Level of evidence	Follow-up	Outcome measure	Sample size	Age (years)	Females	Intervention	Conclusion
1	Negrini	2008	Single	Prospective	II	1 year	Brace prescriptions/ Cobb angle/ATR	74	12.4	52	SEAS	Pro exercise therapy
2	McIntire	2008	Single	Prospective	II	4–24 months	Curve reduction ? measurement	15	13.9 (10–16)	12	Trunk rotational strength (MedX)	Neutral
3	Weiss	2006	Single	Prospective	II	4 weeks	Formetric surface topography	36	15	36	Physio-logic exercises	Pro exercise therapy
4	Otman	2005	Single	Prospective	II	1 year	Cobb angle	50	14 .1 (11–17)	38	Schroth's 3D exercise	Pro exercise therapy
5	Mooney	2003	Single	Prospective	II	Unknown	Curve reduction ? measurement	20	13.6 (11–17)	18	Torso rotation training (MedX)	Pro exercise therapy
6a	Weiss	2003	Multicentre	Prospective	II	35 months	Cobb angle	222	12	222	Scoliosis intensive rehabilitation	Pro exercise therapy
6b	Weiss	2002	Multicentre	Prospective	II	35 months	Cobb angle	222	12	222	Scoliosis intensive rehabilitation	Pro exercise therapy
7	Weiss	1997	Single	Prospective	II	33 months	Cobb angle	181	12.7	156	Schroth rehabilitation	Pro exercise therapy
8	El-Sayyad	1994	Single	Prospective	II	12 weeks	Moiré topography angle	10	11.8	6	Exercise	Pro exercise therapy
9	Weiss	1992	Single	Prospective	II	4–6 weeks	Cobb angle	107	21.6 (11–49)		Schroth rehabilitation	Pro exercise therapy
10	Mamyama	2002	Single	Retrospective	III	4.2 years	Cobb angle	69	16.3 (11–27)	62	Side shift exercise	Pro exercise therapy
11	Dobosiewicz	2002	Single	Retrospective	III	6 months	Cobb angle–no actual values	208	14.2 (6–19)	187	Dobosiewicz—asymmetric trunk mobilisation	Pro exercise therapy
12	Chromy	2006	Single	Case series	IV	4 months	Cobb angle	5	14–18	5	Axial spinal unloading—LTX 3000	Pro exercise therapy

SEAS and +1.38° in the PT group. These changes are far too small to be conclusive because the reported error rate in measurement of Cobb angle ranges from 1.7° to 6.5° [21–23]. The choice of treatment was left to the patients whose compliance over the 6–12 month period was not assessed nor was there any mention of which criteria were used to prescribe a brace.

McIntire et al. [24] reported on 15 patients with average age of 13.9 years and an initial Cobb angle between 20 and 60° and Risser sign of III or less. Patients received 4 months supervised training consisting of 32 sessions using MedX Rotary Torso Machine followed by 4 months unsupervised training at home utilising a Thera-Band for resistance training. Patients were clinically evaluated at 4 and 8 months and until reaching skeletal maturity. Curve progression was defined as main curve progression of 6° or more. The three patients with initial curves between 50° and 60° all had curve progression. None of the remaining patients with curves between 20° and 40° showed curve progression at 8 months but this was not maintained at 24 months. Authors concluded that rotational strength was not effective for curves >50° and only stabilised curves between 20° and 40° for 8 months but not for 24 months. This was a well-designed study with a substantial follow-up period and clearly defined step-by-step treatment protocols. However, although initial Cobb angle measurements were given, it is questionable how subsequent measurements were made or how curve progression was established. A compliance rate of only 30% was also noted.

Weiss and Klein [17] conducted a controlled study of pairs of patients with AIS matched by sex, age, Cobb angle and curve pattern. 36 patients aged between 13 and 17 years were matched and divided equally into two groups each receiving a 4-week programme of Scoliosis Intensive Rehabilitation (SIR). The treatment group had the addition of five 90-min exercise sessions using the Physio-logic® exercise programme. Outcomes were measured after the 4 week programme using surface topography (Formetric® system) including changes in; lateral deviation (mm), surface rotation (°) and kyphosis angle (°). The results were that the Physio-logic programme significantly improved lateral deviation over the control group and had improved surface rotations after the course of rehab. There was no difference in the kyphosis angle between the groups. Although this was a well-designed controlled study, the surface topography system used to assess the curve dimensions has significant technical errors, which should be taken into account. The errors stated are 3 mm for lateral deviation, 1.5° for surface rotation and 2.5° for kyphosis angle. In all but one patient, the average difference after 4 weeks is smaller than the quoted errors rendering the majority of the results unreliable. Perhaps a longer follow-up period may have shown greater changes, which would have been significant. It is interesting that 13 out of the 18 patients in each group wore braces with some wearing it at night time.

Otman et al. [25] reported on 50 patients with an average age 14.1 years, treated with Schroth's 3D exercise therapy for 1 year. Average Cobb angle reduced from 26.10° pre-treatment to 17.85° after 1 year. Treatment required 4 h per day for 5 days a week. This was supervised for first 6 weeks and patients continued at home for the rest of the year. For such a time demanding therapy, compliance is a real issue yet there was no mention of how compliance was ensured suggesting that the changes observed may have been in part due to the natural history of the disease rather than the exercise therapy. Furthermore, although the reduction in Cobb angle is quoted as being significant, on closer examination of the standard deviations quoted, (4.69° pre-treatment and 3.58° after 1 year) which represents the spread of figures, the lower limit Cobb angle pre-treatment actually overlaps with the upper limit Cobb angle after 1 year which really questions their significance.

Mooney and Brigham [26] reported on 20 patients, 11–17 years old who underwent computerized MedX rotary torso machine with torso rotation strength training. Patients included had scoliosis ranging from 15° to 41° and were treated twice a week until curve reduction or skeletal maturity. 16 patients demonstrated curve reduction. Despite small sample size and lack of clarity on exact period of follow-up, the authors concluded that muscle imbalance can be corrected by a specific exercise programme and that the results are equal to or better than bracing. Only 12 patients were included initially and 8 more were added subsequently but there is no mention of how these patients were recruited. It is also not documented how or who measured curve reduction. It is interesting that the sex of patients has not been mentioned in this study in which a 17-year-old patient had curve reduction from 34° to 25° but in a 16-year-old the curve progressed from 60° to 67°. Lack of basic patient demographics, significant selection bias, small sample size, and exact period of follow-up bring the accuracy of results into question.

Weiss et al. [18, 27] reported on two independent patient groups with AIS matched by age and sex and measured the incidence of curve progression (≥5°). The treatment group (115 patients) underwent a 4–6 week scoliosis in-patient rehabilitation (SIR) programme followed by at home daily exercises to maintain postural balance and the control group (107 patients) had no treatment. They found statistically higher progression rates in the control group than the treatment group after 35 months follow-up. The authors concluded that exercise based therapies are effective when compared to natural history in reducing progression of AIS.

Although this is a controlled study, it is very difficult to match two separate prospective studies from different centres without significant confounding factors. These patients who are from distinct geographical locations with different genetic and cultural influences may have been better matched using Risser sign giving better indication of skeletal maturity than age. In addition, there has been much variation in the documented natural history of disease progression [28] and therefore it would not be accurate to just compare with one study reporting on untreated patients who had a comparatively high rate of progression.

Weiss et al. [29] in another study reported on 181 patients 11–15 years of age with idiopathic scoliosis and treated with exercise only. All the patients were from a single institute treated with the Schroth rehabilitation programme and followed up for average of 33 months. Overall average Cobb angle increased from 27° to 29°, an increase in curve of 6° or more was seen in 25% and a curve correction of 6° or more was found in 18%. The results suggest that more curves got worse than better as the overall average Cobb angle was increased. However, the authors state a positive outcome by comparing results to the natural history of AIS if left untreated. They state that a 25% curve progression seen in this study is a huge improvement on natural progression rate of around 62%. There is a huge variation in the reported natural progression rates of AIS largely depending on the initial Cobb angle. This paper does not specifically mention the initial Cobb angles for each of the patients and therefore cannot compare results against just one reported natural progression rate. Furthermore, the authors included a further 116 patients in the study who were asked to fill out a questionnaire regarding their exercise treatment. Even though the worst case results were assumed from the questionnaire, this is a very poor and unreliable source of evidence. These results were added with the initial 181patients in the prospective study which gave an overall better impression of the effectiveness of Schroth rehabilitation. Overall conclusions were made with the combined 297 patients thus combining different levels of evidence which is inaccurate and misleading.

El-Sayyad and Conine [30] reported on 30 children assigned to one of three groups—(a) exercise, (b) exercise and Milwaukee brace and (c) exercise and electrical stimulation. For the purpose of this review, only results of patients in group A are discussed. There were 10 patients with average age of 11.8 years. Spinal curve was measured before and after treatment with moiré topography by a single observer. The exercise programme consisted of daily activity, home exercise and exercise three times per week under supervision of a therapist for 12 weeks. Average curve reduced from 20.37° to 17.44° which the authors say was significant. Not only is the sample size and follow-up period too small, increasing the chance for type II error, but only a 2.93° average change was observed. It has been reported that the observer error using digital radiographs is 3.6° [31] but that of moiré topography has been shown to be even less accurate. Cobb angles between 16–25° as seen in this study would be diagnosed correctly using moiré topography in only 39.3% of cases [32].

Weiss [33] conducted a study on 107 patients with idiopathic scoliosis with an average age 21.7, who underwent a 4–6 week in-patient exercise program according to the Schroth method. Cobb angles before and after the programme were measured. Average Cobb angles reduced from 43.06° to 38.96° after treatment. A curve improvement of 5° or more was seen in 44%, 53% were unchanged and 2.8% had a curve increase of 5° or more. The author concluded that the Schroth exercise programme significantly improved scoliotic curve. However, 62% patients out of the 47 who showed improvement of 5° or more, were over 16 years of age and it is highly unlikely to see significant changes in Cobb angle in this age group over a 6-week period. 53% patients showed no change and in fact, 17.8% wore braces as well hence it cannot be concluded that any improvement was solely related to exercises.

Retrospective cohort studies (level III evidence)

Mamyama et al. [34] reported on 69 patients with idiopathic scoliosis who were treated only by side shift exercise after skeletal maturity. The average age of patients was 16.3 years with an average follow-up of 4.2 years. The average Cobb angle reduced from 31.5° to 30.3° at the end of the follow-up period. The authors concluded that side shift exercise can be a useful treatment for idiopathic scoliosis after skeletal maturity. Although this study specifically comments on skeletally mature patients the ages ranged from 11 to 27 years with no mention how many of them were under 16 years and probably skeletally immature. In addition, there was no mention of what treatment the patient had during skeletal immaturity and whether or not this may have affected their curve progression after skeletal maturity. In addition, 44 out of the 69 patients had no change in curve angle and the average 1.2° decrease observed is far too small to be of any significance.

Dobosiewicz et al. [35] reported on 208 children with a mean age of 14.2 years with AIS treated with asymmetric trunk mobilisation in strictly symmetric positions. Follow-up was at least 6 months with Cobb angle and angle of axial rotation being measured. Results showed a regression of Cobb angle in 33.6% for single scoliosis and 22.8 and 26.1% in double scoliosis for the thoracic and lumbar region, respectively. The progression rates of Cobb angle were very similar to the regression figures. The authors concluded that this rehabilitation method at least resulted in detention of scoliosis progression in most cases. Although this was a fairly large study, it has been described very briefly and the exact exercise regime used was not described neither is it mentioned if the same regime was used in all patients. The authors have not commented if any other conservative treatments (e.g. braces) were used simultaneously. It is important to bear in mind that no statistical analysis was performed and only percentage correction of Cobb angle was reported rather than the actual figure, which brings into question the reliability of this study.

Case series (level IV evidence)

Chromy et al. [36] conducted a pilot study of five adolescent girls (14–16 years) who underwent 3 months treatment of 10 min twice a day using the LTX 3000 Lumbar Rehabilitation System providing axial lumbar spine unloading. Lumbar Cobb angles were measured initially, at 3 months post treatment and again at 4 months. Initial mean standing Cobb angle of 13.7° reduced to 8° at 3 months but increased to 10.0° at 4 months. The authors concluded that the intervention resulted in significant reduction in Cobb angles immediately post treatment, which was also maintained 1-month post-treatment. Although this was just a pilot study, the conclusions are not sound enough to justify a further large scale study using LTX 3000. First, all the Cobb angles at 1 month, although still lower than the initial baseline angles had actually increased from the angles quoted immediately post treatment suggesting that the effects are only short lived. Second, a fixed Cobb angle measurement between T12 and L5 was used for each patient. Assuming all the patients had scoliosis limited to the thoracolumbar spine (although not specifically stated) this would still be a very inaccurate measurement of the Cobb angle which should ideally be centred over the maximal curve. Finally, an extremely long-winded method for Cobb angle measurement was used. The corners of the vertebral bodies were marked on a transparency laid over the radiograph, which was then scanned to a computer and analysed on Photoshop to give the Cobb angle. This is not a recommended or validated method for measuring Cobb angle and may have a significant error rate. In addition, going through so many steps increased the opportunity of observer and technical errors which would be particularly significant in this group where initial Cobb angles were quite small.

Discussion

The current literature review failed to identify any randomised controlled trials assessing exercise therapy in AIS. While such studies are difficult to perform, this finding reflects the paucity of good quality research on this topic. The Current review identified nine prospective cohort studies of which three were controlled studies and only one of these had observer blinding. Studies 6a and 6b in Table 3 represent the same study that has been published in different journals. 5 out of 10 studies were written by same authors who are affiliated to centres that heavily endorse exercise therapy.

Several weaknesses were identified in all studies including lack of clarity on recruitment of patients, or on indications or contraindications for treatment. Age, sex, respiratory function, age at menarche and radiographic parameters like Risser sign, or ossification of triradiate cartilage were not recorded in most studies. The data were not stratified according to age or sex and hence no correlation of these parameters was possible. None of the studies used standard functional outcome scores. Varied radiographic and clinical parameters were used with only 7 out of 12 studies reporting on changes in the Cobb angle [18, 20, 25, 29, 33, 34, 36]. However, the exact method used to measure the Cobb angle was not described and a non-standardised method was used in one study [36]. Most studies reported on “significant” changes in the Cobb angle which were actually of small magnitude and failed to take into account that the reported error rate in measurement is between 1.7° and 6.5° [21–23]. Two studies [17, 30] reported on Moire fringe topography, which has been shown to be inaccurate in detecting small changes in curve dimensions [32].

Different exercise therapy regimens were used in various studies with treatment periods ranging from 10 min to 4 h daily. There was poor use of statistical analysis and none of the studies reported on well-accepted measures like, numbers needed to treat (NNT), level of significance, confidence intervals, etc. The presence of confounding factors for example, patients wearing braces in addition to their treatment was also poorly documented as was compliance especially with some of the longer and more time-consuming exercise regimes. Many studies had short follow-up periods and hence none of the studies commented on long term results, thereby casting doubts on whether any changes observed would be maintained. If the changes were short lived then this suggests that the exercise regime would need to be continued lifelong requiring significant lifestyle modification. This contradicts the idea that exercise therapy is an effective treatment option that can restore normal lifestyle.

Previous literature reviews [9, 10, 14] have included several papers published earlier by the authors of these reviews [5, 12, 13, 15–18], clearly indicating the need for a more varied source of data incorporating different population groups. The current study is an un-biased review of literature on the effectiveness of exercise therapy in AIS, and has been performed by independent reviewers not affiliated in any way to rehabilitation centres or exercise therapy treatments. A limitation of this review is that only literature published in English was included using predetermined criteria, perhaps causing some selection bias. However, the inclusion criteria were not stringent and incorporated the basic expectations from a reasonable study. We also feel that any study with reliable methodology and sound conclusions would have been published in a well recognised and widely available journal. The current literature review failed to find robust evidence in support of exercise therapy in the treatment of AIS. Well designed and good quality studies are required to assess the role of exercise therapy in the treatment of AIS.

Conflict of interest None.

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