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Physical exercises as a treatment for adolescent idiopathic scoliosis. A systematic review

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Summary

Our purpose was, through an extensive and systematic review of the literature, to verify the effectiveness of physical exercises in the treatment of adolescent idiopathic scoliosis. We performed a search of different databases (*Medline*, *Cochrane Library*, *Embase*, *Cinhal*), and a hand-search of the non-indexed pertinent literature, and found 11 papers: none of the studies was randomized, six were prospective, seven were controlled, and two compared their results to historical controls; one paper had both a prospective design and a concurrent control group. The methodological quality of the retrieved studies was reviewed and found to be very poor. With one exception, the published studies demonstrated the efficacy of physical exercises in reducing both the rate of progression or the magnitude of the Cobb angle at the end of treatment. However, being of poor quality, the literature failed to provide solid evidence for or against the efficacy of physical exercises in the treatment of adolescent idiopathic scoliosis. Nevertheless, considering that exercises could also be proposed on the basis that benefits rather than to avoid progression have been shown in the literature, and that the results contained in published studies here reviewed suggest an effect on the primary goal of preventing progression, there is a basis for discussion of this option with patients and their families, which in turn allows decisions to be made according to their preferences.

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Introduction

Various treatments have been proposed for adolescent idiopathic scoliosis (AIS), including surgery, bracing, electrical stimulation, physical exercises (PEs), and simple observation. The effectiveness of surgery and bracing, in cases where these interventions are specifically indicated, has been demonstrated in some studies [1, 2], even though these were neither randomized controlled trials (RCTs) nor prospective studies with a long-term follow-up [1]; on the contrary, the technique of electrical surface stimulation, was found to be ineffective [3, 4], and has been abandoned.

While PEs as a form of therapy did enjoy a measure of popularity in the past [5–7], and are still applied in some countries like Italy, France and Germany [6–10], in more recent times the international scientific community has given them scant consideration [5, 11]. One reason for this may be the long absence—with the sole exception of one scientific study, which concluded that PEs are unable to alter the natural history of AIS [12]—of papers from peer-reviewed journals; however, studies appearing in the last few years have claimed that specific PEs, with clearly defined goals, are effective in the treatment of AIS [13–15], and some have identified a theoretical basis on the strength of which PEs might be proposed [9, 14]. Another possible reason for not using PEs could be that they target mild AIS—usually less than 30 Cobb degrees, a magnitude that, in fully grown subjects, has been considered significant [16], even if this point is under question. But PEs, once their effectiveness has been demonstrated, could be important during growth to delay or prevent the need for recourse to a brace and/or to keep the scoliosis as far under the 30° limit as possible.

In the light of all of this, it is possible that differences in the therapeutic behaviour adopted in different countries depend on the literature that is available in each of

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them (e.g. papers published in languages other than English, or in non-indexed sources). Additionally, pertinent and good-quality papers may not necessarily be the prerogative of peer-reviewed journals. In order to verify this hypothesis, we developed a method for systematically reviewing all the literature on PE treatment for AIS that, using all pertinent databases and conducting a hand-search of minor, non-English-language journals, we were able to identify and access. Our aim was, after reviewing all the literature and verifying its quality, to establish the current scientific knowledge on the effectiveness of PEs as a treatment for AIS and to reach on this basis an evidence-based clinical conclusion.

Methods

We searched the *Medline*, *Embase*, *Cinhal* and *Cochrane Library* databases, using both free text and the keywords of the relative thesauruses (*Mesh* and *Emtree*). We searched the databases from the date of their inception to December 2002 without applying any language restriction. For the free-text search, we used the following terms: 'idiopathic scoliosis AND exercise', 'idiopathic scoliosis AND exercises', 'idiopathic scoliosis AND sports', 'idiopathic scoliosis AND sport', 'idiopathic scoliosis AND rehabilitation', 'idiopathic scoliosis AND physiotherapy'. For the search in *Medline* we used the following *Mesh* terms: 'scoliosis' AND ('exercise therapy' OR 'rehabilitation'). We also searched the reference lists of articles retrieved. Finally we performed a hand-search of the journals listed in the table 1.

The inclusion criteria were the following: patients—diagnosis of AIS, patients treated exclusively with PEs; experimental intervention—control intervention, outcome measure; outcome—Cobb degrees; study design—any study design.

We evaluated the internal validity of the retrieved studies (methodological quality) considering the following factors: controlled study, random allocation vs other criteria to experimental and control intervention, prospective vs retrospective study, sample size, recruitment modality described, patient characteristics described, intervention described, blinded assessment of outcomes, identification of possible confounding factors, statistical control for the confounding factor [17–19].

Results

We retrieved 152 articles from the databases and reference lists, and 424 through hand-searching. From the titles and abstracts, we identified 19 articles that had a high probability, 32 that had a low probability, and 525 that had no probability of meeting the inclusion criteria: the last paper was excluded. Many of the articles identified were written in languages other than English (Italian, French, German, Russian, Polish, Japanese, Hungarian, Romanian, Dutch). We retrieved all 'high-probability' articles; we were not able to retrieve the full texts of 23 'low-probability' articles published in Russian, Polish and German. Upon reading the full texts of the retrieved articles, only 11 were found to meet the inclusion criteria [12–15, 20–26]: all were in the 'high-probability' group, while none of the 'low-probability' papers was included in the final review.

METHODOLOGICAL RESULTS

The results of the methodological evaluation are shown in table 2. The quality of the studies was found to be very poor: five studies [14, 21, 24–26] were uncontrolled, and involved only one evaluation of the outcome measure before and after the intervention. This kind of design produces results that are impossible to

Table 1 Journals in which hand-searching was performed

Journal	*Years searched*	*Language*
Annales de Kinésithérapie	1978–2002	French
Kinésithérapie Scientifique	1978–2002	French
Résonances Européennes Du Rachis	1994–2002	French
Cahiers de Kinésithérapie	1978–1997	French
Ginnastica Medica, Medicina Fisica e Riabilitazione	1953–2002	Italian
Chinesiologia Scientifica	1978–2002	Italian
Atti Gis, Giornate di Patologia Vertebrale	1978–2002	Italian
European Medical Physiology	1978–2002	English
European Spine Journal	1989–2002	English

Table 2 Methodological quality of retrieved studies

Study	*12*	*13*	*15*	*14*	*20*	*21*	*22*	*23*	*24*	*25*	*26*
Controlled study	Hc	Hc	Y	N	Y	N	Y	Y	N	N	N
Random allocation	N	N	N	N	N	N	N	N	N	N	N
Prospective study	Y	Y	Y	Y	N	Y	N	N	N	N	Y
Allocation criteria (other than random) described	Na	Na	N	Na	N	Na	Y: patient's decision	N	Na	Na	Na
Recruitment modality described	Y	Y	N	N	N	Y	N	N	N	N	N
Sample size: experimental group	42	44	89	12	422	34	100	160	43	107	181
Sample size: controls	57	120	107		165		50	50			
Patient characteristics described	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Intervention described	Y	Y	Y	Y	N	Y	N	N	Y	Y	N
Blinded assessment of outcomes	N	N	N	Na	N	Na	N	N	Na	Na	Na
Identification of confounding factors	N	Y	Y	Na	N	Na	N	Y	Na	Na	Na
Statistical control for confounding factors	N	N	N	Na	N	Na	N	Y	Na	Na	Na

Y: yes; N: no; Na: not applicable. Hc: historical control.

Table 3 Materials and methods of retrieved studies: populations and follow-up. Ref. [15] (Weiss *et al.*) has been divided, according to the original study, into two different age groups

Study	*Population*							*Follow-up*	
	Number			*Age*		*Cobb*			
	Total	*Exercise*	*Controls*	*Average*	*Range*	*Average*	*Range*	*Average*	*Range*
12	99	42	57		12–15	10°	4–22°	12 months	9–15 months
13	164	44	120	13.6	10–15	26°	20–32°	2.2 years	at least 4 months
15a	94	30	64	10	4–11	21°	5–52°	2.11 years	DS 1.11 years
15b	102	59	43	13	12–14	29.5°	5–68°	2.10 years	DS 3.1 years
14	12	12	No	13.1	11–16	33.5°	20–60°	4 months	
20	591	422	169	10.10	7–16	15.6°		4.7 years	
21	34	34	No	11.6	8.7–14.1	14.9°	10–24°	2 years	0.7–4.3
22	150	100	50	11	5–15	14°		3 years	1–7 years
23	210	160	50	10.8	10–15	16°		4.5 years	
24	43	43	No	12		19.5°		19.5 months	at least 3 months
25	107	107	No	21.6	10.9–48.8	43°	10–114°	6 weeks	4–6 weeks
26	181	181	No	12.7		27°		33 months	

interpret since it is impossible to conclude reasonably that the improvement observed was causally determined by the intervention: the positive change could have occurred naturally or might have been the result of other aspects of therapy being conducted contemporaneously [27].

Three out of the six controlled studies were prospective [12, 13, 15], but two of these used a historical control group [12, 13]: in such cases, there may be many factors, apart from the experimental intervention, in which the experimental and the control groups differ from one another. Of the four studies that did have a concurrent control group [15, 20, 22, 23], only one [22] specified the allocation criterion, which was patient preference. The method of recruitment was described in only two studies [12, 13]. None attempted to obtain a blinded assessment of the outcome, even though such an assessment should always be introduced as a means of limiting the possibility of detection bias when it is impossible to ensure the blindness of patients and of those administering the interventions [28]. Three studies [13, 15, 23] sought to identify possible confounding factors and sources of bias but only one [23] attempted to control for these through statistical analysis.

CLINICAL RESULTS

Tables 2, 3 and 4 and figures 1 and 2 summarize the methodology and results of all the included studies.

Table 4 Materials and methods of retrieved studies: exercises performed and compliance

Study	Exercises: Type	Aims	Characteristics	Compliance
12	Milwaukee method	Mobilization, strengthening, posture	Instructions from physios, exercises performed at home	about 50%
13	Side shift therapy	Side shift, posture	Instruction from physio, side-shift in daily living	95%
15	Schroth method	Actively straightening, auto-correction	Intensive in-patient exercise programme	
14	MedX Rotary Torso Machine	Strengthening	Daily	
20	Lyon method	Posture control, strengthening, balance	Twice a week with physio and other times at home	71%
21	Many methods	Active postural correction	Twice a week with physio and other times at home	see text
22				
23	Lyon method	Posture control, strengthening, balance	Twice a week with physio and other times at home	75%
24	Schroth method	Actively straightening, auto-correction	Three times a week with physio	
25	Schroth method	Actively straightening, auto-correction	Intensive in-patient exercise programme	
26	Schroth method	Actively straightening, auto-correction	Intensive in-patient exercise programme	

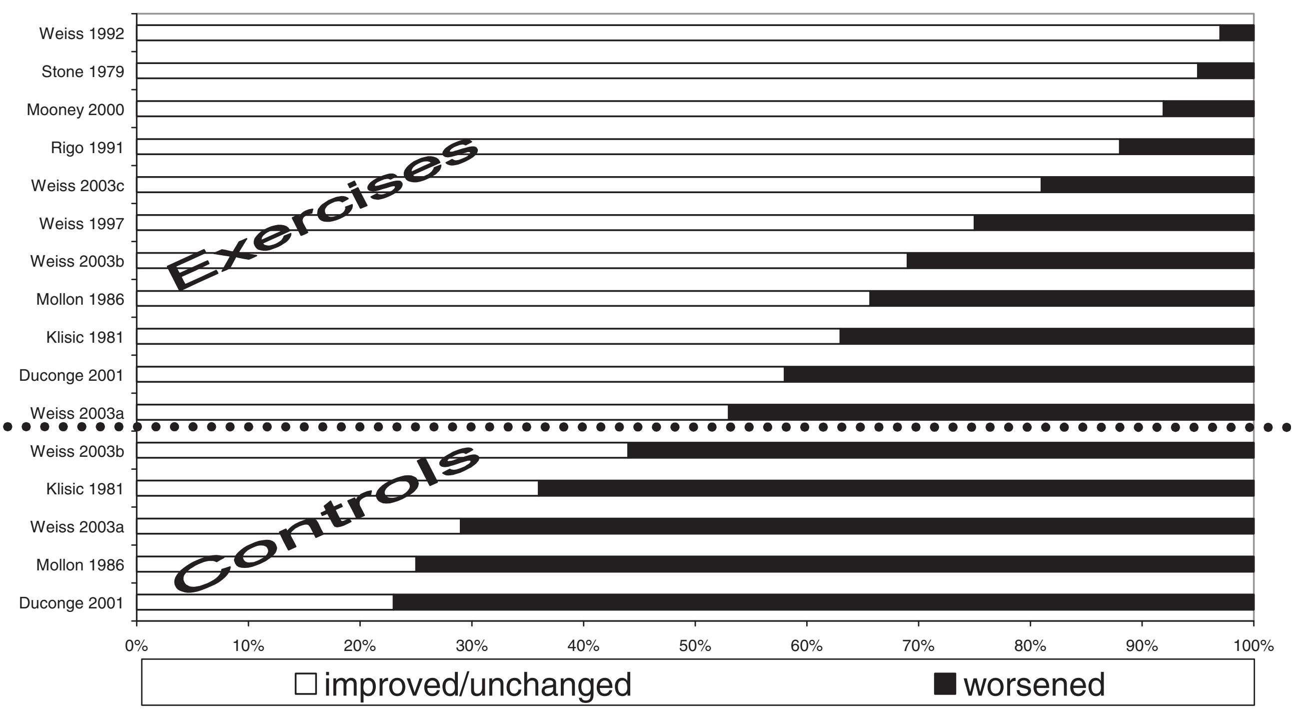

Figure 1 Variation of Cobb degrees after treatment in retrieved studies. Weiss et al. study (2003, ref. no. 15) has been divided, according to the original study, into two different age groups (a) and (b): the exercise group also included a sub-group (c) presenting the worst curves.

Studies with a control group

The oldest study was that of Stone *et al.* [12] and involved patients with 4–22° Cobb curves. After exercising at home (mobilization, strengthening and posture) for 12 months (range 9–15), with a compliance of 50%, curve progression and reduction rates of, respectively, 5% and 21% (variation: ±4° Cobb) were recorded in the treated group. No statistically significant difference emerged between the patients and a retrospective control group, or in relation to correct performance or frequency of PEs: after treatment, 48% of patients performed most of the PEs correctly.

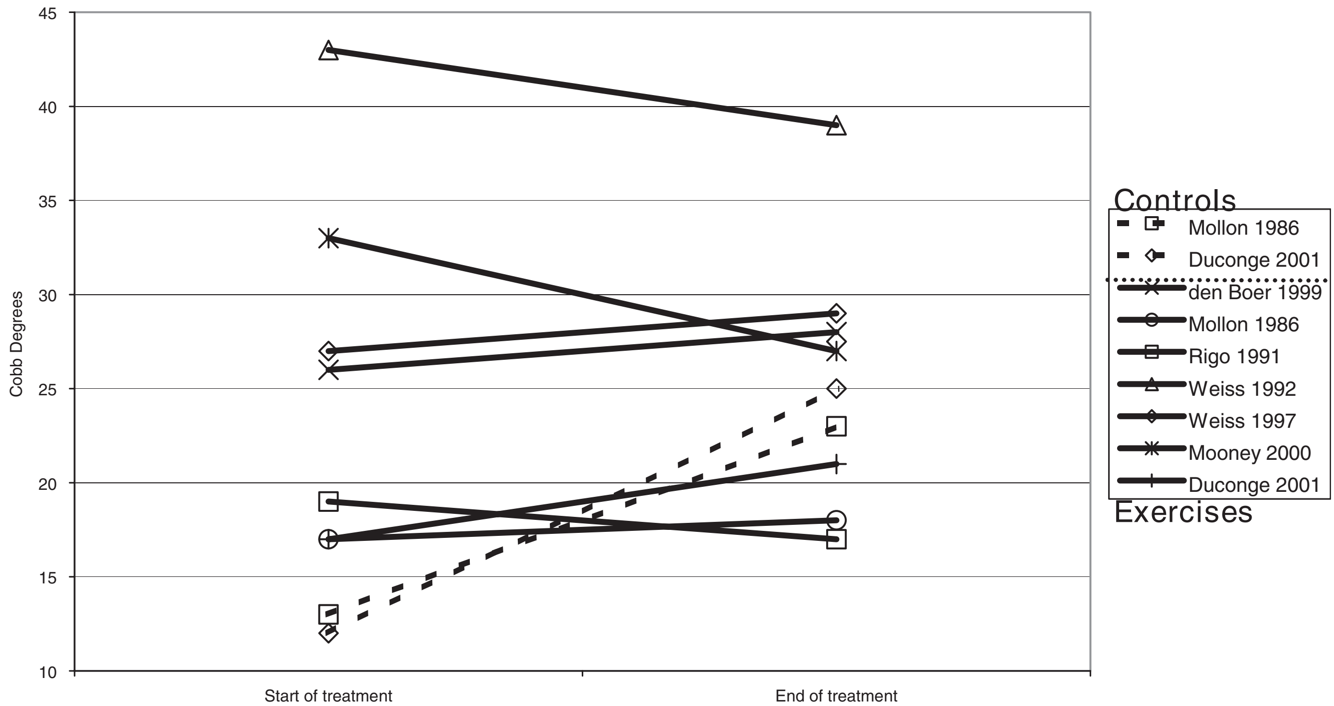

Figure 2 Cobb degrees pre and post treatment in retrieved studies. Data have not been grouped because retrieved studies were heterogeneous according to methods and quality. The results of each study are reported here as the results of one treatment in a case series study. The Den Boer control group is not considered because it was made up of braced patients and not non treated people.

Mollon and Rodot [23], and Klisic and Nikolic [22] proposed studies on 11-year-old patients with Cobb curves of less than 20° (average 17° and 15° respectively). Much more recently, Ducongé [20] increased the population of Mollon's original study [23]. Mollon and Rodot [23] considered retrospectively 160 patients who were 10 years old on average when they started therapy: they had complied with PE treatment (posture control, strengthening, balance training) performed continually until the completion of growth twice a week at hospital and then at home. They were compared to 50 non-compliant (non-treated) subjects: the only difference at baseline was the curve, which was 4° Cobb greater in the treated group. At the 4-year follow-up, the mean angle and the rib hump were 18.5° and 13.3 mm respectively in the treated group, versus 23.2° and 14.4 mm in the control group. Improvement and worsening (variation: ±3° Cobb) were statistically different: 62.5% and 44% of subjects respectively in the treated group, and 20% and 75% in the control group. No significant differences were found between the worsened and improved patients in terms of age, follow-up, pattern of the curve or sex. These results were confirmed by Ducongé [20] in 591 patients: 42% of the 422 treated cases worsened, as opposed to 77% of the control group. Klisic and Nikolic [22] compared 100 treated and 50 non-treated patients: no details were given on the PE regimen adopted. An improvement was recorded in 58% and 26%, and a worsening in 37% and 64% respectively: the efficacy of the treatment was found to be higher for thoracolumbar curves.

In a very recent, prospective study, Weiss *et al.* [15] compared two groups of patients from the same region in Germany, one treated with an intensive 4–6-week repeated in-patient rehabilitation programme, the other simply followed for a period of 52.4 months. Two sub-groups matched for sex (females only) and age (<12 and 12–14 years) were identified; the PE group of 12–14-year-olds contained a sub-set presenting more severe curves (30° or more). Statistically significant differences in AIS progression (worsening of 5° or more) were detected in all the analyses: the PE-treated patients always had better results than controls.

Den Boer *et al.* [13] compared PEs (side-shift constantly applied in everyday life and posture) with bracing in patients with 20–32° Cobb curves. Progression was recorded when there was a variation of at least 4° in 4 months, or 10° in the entire course of the treatment, or if the curves reached 35°. No difference was found between the groups in terms of intention to treat (66%

vs 68% in PE and brace group) and efficacy (85% vs 90% respectively).

Studies without control group

Weiss *et al.* [26] considered the effect of an intensive in-patient rehabilitation programme in a sample of 297 subjects. In the 181 patients, there was no relative progression (5° or more per year) in 33 months; while, in the whole group, a relative progression of 5% was found; considering all 'drop-outs' as therapy failure, the progression rate rose to 19.5%. Given that a rate of progression of 30% was expected (on the basis of the natural history, reported in the literature, of patients with similar curves), PE was, in this study, deemed effective.

Rigo *et al.* [24] proposed the same kind of PEs of Weiss [26], but they were organized as an out-patient, twice-a-week, 2-hour programme. Forty-three patients, 12 years old, with $19.5° \pm 10.5°$ Cobb angles, exercised for 19.5 ± 8.5 months (minimum 3 months) and were evaluated retrospectively: 11.6% progressed, while 44.2% improved. The progression group had significantly longer treatment time than the others, but similar starting angle, age and Risser sign. Again, data were compared to natural history and PEs were considered effective.

Ferraro *et al.* [21] recruited 34 scoliotic subjects, average age 11.6 years, initial mean Cobb angle 14.9°, who were followed for an average of 2 years (range 0.7–4.3 years). They performed a multiple linear regression analysis for the changes in Cobb angle as a function of compliance, physical therapist and potentially confounding variables. Maximal participation in PE therapy (>30 min/day), compared with minimal participation (<10 min/day), slowed down or even halted the progression of the deformity (difference between the groups of 9° Cobb).

Mooney *et al.* [14] studied 12 patients (11–16 years, curvatures: 20–60° Cobb) using a MedX Rotary Torso Machine for torso rotation strength training. Following a 4-month training programme, an improvement (at least 5° Cobb) was recorded in 41.6% of the patients, while just one (8.3%) worsened.

A further study by Weiss *et al.* [26] differs from the others in several factors: the age of the patients (average 21.6 years, range 10.9–48.8), the size of the Cobb angle (average: 43°), and the duration (brief) of the in-patient PE regime adopted (4–6 weeks). These authors found an improvement of at least 5° in 43.93% of the patients, no variation in 53.27%, and worsening in 2.8%. The mean angle of the primary curve fell from the initial 43.06° to 38.96°. There was no control group. It is not possible from the data available to calculate the percentage of progression in patients under 16 years of age.

Discussion

METHODOLOGICAL RESULTS

The RCT is the strongest research design on the basis of which to draw valid conclusions about the effectiveness of a therapeutic intervention, because, if well conducted, it keeps the risk of bias to a minimum. None the less, there are many clinical settings in which RCTs are difficult, impractical or unethical. In these situations, a controlled, non-randomized study, an observational controlled study or an uncontrolled study could constitute a valid alternative, providing confounding factors and sources of bias are carefully analysed [29]. Rehabilitation is one of the fields in medicine in which a researcher trying to conduct an RCT is most likely to run into difficulties: it is often difficult to collect a homogenous patient sample that is large enough to obtain adequate power for the study; it is often difficult to find a suitable placebo intervention, and it is sometimes impossible for ethical and practical reasons to include a 'no intervention control group'; moreover, it may often be impossible to distinguish between the specific effect of the intervention (PE, physical therapies or other) and the therapeutic effect (psychological) of the patient–therapist relationship; equally, the specific effect of the intervention could be modified by the therapist's expertise and faith in the given technique; finally it is almost always impossible to establish a double-blind condition. Nevertheless, evaluating the effectiveness of rehabilitative intervention through good-quality studies is not impossible; there are, in fact, many published studies that try to overcome the difficulties associated with the field of rehabilitation: the *Cochrane Library*, for example, contains many systematic reviews on various rehabilitative interventions, which include RCTs of acceptable quality that try to overcome the said difficulties.

None of the retrieved studies on the effectiveness of PE in AIS was randomized and the controlled and uncontrolled studies retrieved failed to meet even basic methodological criteria for observational studies. Consequently, it is impossible, on the basis of the data contained in these studies, to draw any valid conclusion on the effectiveness of PE in AIS.

Table 5 Results of retrieved studies

Study	*Groups*	*°Cobb*		*Variation*			
		Start	*End*	*°Cobb*	*Improved*	*Unchanged*	*Worsened*
12	Exerc	10°	8.5°	4°	21%	74%	5%
	Ctrl					no differences	
13	Exerc	26°	28°	5° (4 months)		no differences	
	Brace	27°	25°	10° (follow-up)			
15a	Exerc	21°		5°	53.3%		46.7%
	Ctrl	5–30°			28.8%		71.2%
15b	Exerc 1	29.5°		5°	69.5%		30.5%
	Exerc 2	42.3°			80.8%		19.2%
	Ctrl	5–30°			44.2%		55.8%
14	Exerc	33.5°	27.2°	5°	41.6%	50%	8.3%
20	Exerc	17°	21°	3°	58%		42%
	Ctrl	12°	25.5°		23%		77%
21	Exerc	14.9°	–9° (compliant)				
22	Exerc	15°			58%	5%	37%
	Ctrl	13°			26%	10%	64%
23	Exerc	17°	18.5°	3°	62.5%	3.5%	34%
	Ctrl	13°	23.2°		20%	5%	75%
24	Exerc	19.5°	17.2°	5°	11.6%	44.2%	44.2%
25	Exerc	43.06°	38.96°	5°	43.9%	53.3%	2.8%
26	Exerc	27°	29°	5°	18%	57%	25%

Exerc: exercises; Ctrl: controls. Ref. no. 15 (Weiss et al.) has been divided, according to the original study, into two different age groups (a) and (b); the group (b) included two sub-group (1) and (2): this presented the worst curves.

CLINICAL RESULTS

It must be borne in mind that these low-quality studies represent the source of the only data that our extensive search of the literature was able to produce. This being the case, we have no choice but to use them as a basis on which to draw some kind of clinical conclusion: should (or could) PEs be used to treat AIS?

Of the papers reviewed, only one gives negative results [12]. This study was controlled (but retrospectively, while the treated group was prospective) and published in an indexed English journal: this granted a big impact to this paper, which has been almost the only one cited in the indexed literature, where PEs effectiveness is usually denied [5, 11]. The patients included in this study showed less compliance than those considered in other studies (table 3), presumably because the PEs were performed only at home. Moreover, the PEs were proposed only for 12 months, and children were not considered until they had finished growing: these results should, consequently, be considered brief-term data and not final results as in most of the other studies considered in this review. Finally, this PE programme was the most ‘mechanical’ encountered: in fact, only after Stagnara [7, 8, 23] was there a shift from a ‘mechanical’ to a ‘neurological’ perspective as regards PEs for AIS: there is now a general consensus on this approach [9, 15, 20, 21].

All the other papers that included a control group [13, 15, 20, 22, 23] were more recent and proposed a more complex neuromotor PE programme than Stone’s; the results of these studies were, if compared with the natural history of the condition (figures 1 and 2), as favourable as the ones given by studies in which there was no control group [14, 15, 21, 24, 25]. From a clinical point of view, the most important papers are the ones proposed by den Boer [13], who obtained the same results in PE-treated and braced patients, the two that consider the Lyons method [20, 23]—these studies presented data collected throughout Europe, and considered only children who had reached the end of growth—and the one recently published by Weiss [15]; the results of this latter prospective controlled study, which are comparable to those obtained in adulthood [10], might be considered quantitatively surprising, but it should be borne in mind that they refer to an intensive in-patient programme.

As regards the percentages of patients worsening/remaining unchanged or showing an improvement (figure 1), the results are in favour of PEs; the degree of curvature in the PE groups seems to reduce or remain stable regardless of the baseline curvature (ranging in the different studies from 17–43° Cobb), while the results given by the various control groups, whose starting degrees were lower than those recorded in the PE groups, were worse (figure 2). In any case, these results should be considered preliminary, as they are not supported by the quality of the studies.

The theoretical basis of PE has recently been described [9]: postural collapse [30] could be reduced by resistance training of extensors in correct position, while postural control and equilibrium systems, which have been suggested to be involved in the aetiology and/or pathogenesis of AIS [31–33], could be improved by PEs. But these theories need to be proved in practice and demonstrated in higher-quality studies. We might conclude that the promising results given by these studies provide a basis for the hypothesis of effectiveness of PEs in AIS, a hypothesis that must, however, be verified by well-designed and carefully conducted RCTs involving samples large enough to guarantee adequate power of the study.

EFFECTS OF PHYSICAL EXERCISES IN ADOLESCENT IDIOPATHIC SCOLIOSIS

The rationale for applying PEs in AIS [9] includes other secondary outcomes beyond the primary goal considered in this paper that is avoiding progression: these effects include increasing neuromotor control and stability of the spine [31–33], reducing biomechanically the postural collapse [30], and increasing breathing function [34, 35]. The effectiveness of PEs in AIS patients in improving breathing function [34, 35], strength [14], and postural balance [36] has already been proved. So, beyond the results of the studies considered in this review, PEs could be proposed in AIS treatment on the basis that other benefits than to avoid progression can be expected.

Conclusions

Through an extensive review of the literature, we were able to show that the efficacy of PEs in the treatment of AIS to reduce progression of the curve remains to be demonstrated beyond doubt. On the other hand, it would be wrong to say that PEs proposed to obtain this primary outcome are useless: to date there is no definite proof either way. More research is needed in this field, and in the light of all this preliminary data, prospective randomized trials are to be recommended. In any case, PEs have been shown to influence positively parameters such as breathing function, strength and postural balance in AIS patients. With no doubt, even if PEs do not show stabilizing effects on scoliotic curves, their utility to reduce specific impairments and disabilities in AIS patients cannot be neglected.

Waiting for stronger data on the primary result of preventing progression, given the length of time needed in this field to complete studies such as randomized trials, and the difficulties involved, the option of treating adolescents with PEs can be discussed with patients and their families and decisions reached according to their preferences: the effectiveness data here proposed, the possible outcomes (the delaying or avoidance of recourse to a brace and/or the keeping of the scoliosis below (as far as possible) the limit of 30°, which is thought to be dangerous in adulthood, and all the other positive effects of PEs), as well as the costs involved in PE treatment, should be thoroughly discussed.

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