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SYSTEMATIC REVIEW

Physical exercises in the treatment of adolescent idiopathic scoliosis: An updated systematic review

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ABSTRACT

Two years ago we published an update of another of our previous systematic reviews about the effectiveness of physical exercises (PEs), and we found that the evidence on exercises for AIS was of level 1b. Now we have updated these results in the field of exercises for AIS with the final aim to find the strongest evidence as possible about PEs. Our goal was to verify if treatment with specific exercises for AIS has changed in these years. The study design was a systematic review. A bibliographic search with strict inclusion criteria (patients treated exclusively with exercises, outcome Cobb degrees, all study designs) has been performed on the main electronic databases. We found a new paper about active autocorrection (Negrini et al, 2008b), a prospective controlled cohort observational study on patients never treated before so the number of manuscripts considered in the systematic review was 20. The highest quality study (RCT) compared 2 groups of 40 patients, showing an improvement of the curve in all treated patients after 6 months. All studies confirmed the efficacy of exercises in reducing the progression rate (mainly in early puberty) and/or improving the Cobb angles (around the end of growth). Exercises were also shown to be effective in reducing brace prescription. Appendices of the popular exercise protocols that have been used in the research studies that are examined are included with detailed description and illustrations. This study (like the previously published systematic reviews) showed that PEs can improve the Cobb angles of individuals with AIS and can improve strength, mobility, and balance. The level of evidence remains 1b according to the Oxford Centre for Evidence-based Medicine, as previously documented.

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a particular topic of medicine involved in an epic discussion: to treat conservatively or not (Hawes, 2003; Hawes and O'Brien, 2006; Negrini et al, 2008a)? There are some physicians who believe it is not useful to treat scoliosis conservatively, and the best way is "to wait and see." That is to say, follow the patient without proposing conservative treatment until a Cobb degree threshold is achieved, which would indicate that spinal surgery is necessary (Hawes, 2003). There are others who believe conservative treatment should be started as soon as possible to avoid surgery (Maruyama et al, 2003a; Negrini et al, 2008a).

When we say conservative treatment for AIS, we mean a variety of interventions, such as physical exercises (PEs), bracing, electrical stimulation, manipulation, physical therapy, and insoles (Dobosiewicz, Durmala, Czernicki, and Jendrzejek, 2002; Lehnert-Schroth, 2007; Moen and Nachemson, 1999; Mollon and Rodot, 1986; Pirola, 1999; Souchard, 1982; Souchard and Ollier, 2002; Stagnara, Mollon, and De Mauroy, 1990). For some of these treatments there is insufficient evidence, and for electrical stimulation it has been recognized as ineffective for stopping or reversing curve increases. However, with PEs, there is a growing interest in the literature and there is also evidence about their effectiveness (den Boer, Anderson, Limbeek, and Kooijman, 1999; Lenssinck, et al, 2005; Negrini, 2007; Negrini, Antonini, Carabalona, and Minozzi, 2003; Negrini et al, 2001; Negrini et al, 2005;

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Rowe et al, 1997). Physicians who believe in using exercise appreciate not only their capability to influence positively the spinal curvature but also to increase neuromotor control and stability of the spine, reduction of postural collapse, and increase breathing function (Negrini et al, 2006a; Weiss, 1991; Weiss et al, 2006).

A key aim in this systematic review is to understand the real role played by exercise during conservative management of AIS to potentially improve the effectiveness of these exercise protocols.

Two years ago we published an update (Negrini et al, 2008a) of a previous systematic review about the effectiveness of PEs (Negrini, Antonini, Carabalona, and Minozzi, 2003) and found that the evidence on exercises for AIS was of level 1b. As part of this special issue we have been asked to update these results and to include appendices of popular exercise protocols that have been used in the research studies that are examined.

METHODS

We chose the method of a systematic review and performed an extensive search through all pertinent databases: Medline; Embase; Cinhal; PEDr; and Cochrane Library. We searched for manuscripts in any language from July 2007 to October 2009 using the Mesh terms "scoliosis AND ("exercises therapy" OR "rehabilitation"), and in free text we used "idiopathic scoliosis" followed by the operator "AND" and the terms "exercise," "exercises," "sports," "sport," "rehabilitation," and "physiotherapy," We did not apply any language restriction.

The inclusion criteria remained the same as the most recent systematic review on exercise and AIS (Negrini et al, 2008a), which were the following:

- Patients: diagnosis of AIS by a specialist, confirmed through X rays; we focused on patients in growing age (up to Risser 5);
- Experimental intervention: patients treated exclusively with PEs, without any other associated intervention;
- Control group: any kind of patients, either observed or treated;
- Outcome measures: only Cobb degrees: results could be reported in absolute terms or as percentage of patients improved/worsened;
- Study design: any study design.

As in the previous systematic review, we divided studies according to: methodological quality (e.g., RCT); type of exercise intervention (e.g., inpatient rehabilitation and outpatient rehabilitation); and type of exercises proposed. We divided this last subgroup (type of exercises) into exercise with autocorrection (AC) and exercises without autocorrection. Autocorrection is defined as the ability to reduce the spinal deformity through the patient's active postural realignment of the spine. It is the core of the exercise treatment for scoliosis. Autocorrection exercises are actively and autonomously performed by the patient to achieve the best realignment of the spine in three dimensions.

These exercises have to be performed as much as possible in three dimensions. The aim of autocorrection exercises is to make the vertebral column move in the desired direction and to establish maintenance in the corrected position. These exercises are actively performed by the patient. They consist of activation of muscles of the trunk and limbs resulting in movement of the vertebral column executed in the three planes of the space: 1) in the coronal plane the lateral deviation is corrected; 2) in the sagittal plane the physiological curvatures are promoted; and 3) in the transverse plane the axial plane deformity is reduced by a reduction in rotation of the vertebrae. Autocorrection is considered by SOSORT (Society of Scoliosis Orthopaedic and Rehabilitation Treatment) experts as the key technique in scoliosis physiotherapy. Without autocorrection is defined as no specified exercises or with movement only in one direction. Finally, for papers in which autocorrection was not used, we differentiated these between symmetric and asymmetric exercises.

RESULTS

We found one additional study Negrini et al (2008b) beyond the previous systematic review that met the inclusion criteria and adding this study to the 18 retrieved in the past, there is now a total of 20 pertinent manuscripts (Tables 1 and 2). There were no additional randomized controlled trials.

Clinical results

Randomized controlled trial (RCT)

The only RCT about this topic that included all of the inclusion criteria was by Wan, Wang, and Bian (2005). They treated 80 Chinese patients (40 per group) with an average age of 15±4 years old and 24±12° of curvature. All patients received electrical stimulation on lateral body surface, traction, and postural training, while patients in the treatment group also underwent specific asymmetric strengthening PEs for correction of scoliosis once a day. After 6 months of treatment the change of Cobb angle in the thoracic and lumbar

TABLE 1 Results of retrieved studies. Exerc: exercises; Ctrl: controls. Study by Weiss et al (2003) has been divided, according to the original study, into two different age groups (a) and (b); the group (b) included two subgroup (1) and (2): this presented the worst curves

Study			Groups		
Author	Year		Improved (%)	Unchanged (%)	Worsened (%)
Wan et al	2005	Gymnastic exercise and postural training			
		Postural exercises			
Weiss	1992	SIR–Schroth method	44	53	3
Weiss et al	1997	SIR–Schroth method	18	57	25
Weiss et al	2003	SIR–Schroth method	53		47
		Observation	29		71
Weiss et al	2003	SIR–Schroth method	70		31
		SIR–Schroth method	81		19
		Observation	44		56
Rigo et al	1991	Outpatient–Schroth method	12	44	44
den Boer & Anderson	1999	Outpatient–Side shift therapy	66		34
		Brace	68		32
Maruyama et al	2002	Outpatient–Side shift therapy	22	64	14
Maruyama et al	2003b	Outpatient–Side shift therapy			
Otman et al	2005	Outpatient–Scroth method	100	0	0
Mollon & Rodot	1986	Lyon method	63	4	34
		Observation	20	5	75
Ferraro et al	1998	Many methods			
Ducongé	2002	Lyon method	58		42
		Observation	23		77
Negrini et al	2006c	SEAS.02	29	68	3
		Usual physiotherapy	5	82	13
Mooney et al	2000	MedX Rotary Torso Machine	42	50	8
McIntire et al	2006	MedX Rotary Torso Machine	44	33	22
Durmala et al	2003	Asymmetric mobilization of the trunk	33	27	39
		Asymmetric mobilization of the trunk	39	26	35
Stone et al	1979	Milwaukee method	21	74	5
Negrini et al	2006b	SEAS.02	58	41	1
		Usual physiotherapy	46	44	10
Negrini et al	2008b	SEAS.02	24		12
		Usual physiotherapy	11		14
Weiss & Klein	2006	Integrated scoliosis rehabilitation			

segments were significant in both groups ($p < 0.05$), but in the PEs group the mean improvement of (15°) was significantly higher than in controls (7°).

Inpatient rehabilitation exercise program: Autocorrection

This subgroup includes four studies. Three studies used the Schroth methodology in an inpatient setting and one study that expanded the Schroth SIR program using physio-logic® exercises with the entire program (integrated scoliosis rehabilitation [ISR]).

Scoliosis intensive inpatient rehabilitation (SIR): Schroth program (Appendix 1)

This exercise approach consists of an intensive inpatient physiotherapy protocol originally proposed by Katharina Schroth (4–6 weeks of treatment, 5–6 hours per day, 6 days a week, and then a home exercise program using the same exercise regimen for 30 minutes per day).

TABLE 2 Exercise studies presenting the intervention type and the core and secondary exercises

Study	Type	Core exercises	Secondary exercises
Wan, 2005	Gymnastic exercises and postural training	Correction of essential S-shaped scoliosis	Maintaining symmetrical posture during normal activities
Weiss, 1997	Schroth method	Actively straightening, Autocorrection	
Weiss, 1992	Schroth method	Actively straightening, Autocorrection	
Weiss, 2003	Schroth method	Actively straightening, Autocorrection	
Rigo, 1991	Schroth method	Actively straightening, Autocorrection	
Den Boer, 1999	Side shift therapy	Side shift	Posture
Maruyama, 2002	Side shift therapy	Lateral shift-trunk during standing and sitting	
Maruyama, 2003b	Side shift therapy	Lateral shift-trunk during standing and sitting	
Otman, 2005	Schroth method	Actively straightening, Autocorrection	Realignment of the trunk
Mollon, 1986	Lyon method	Postural control	Strengthening, balance
Ferraro, 1998	Many method	Active postural correction	
Ducongé, 2002	Lyon method	Postural control	Strengthening, balance
Negrini, 2006c	SEAS.02	Active–self correction	
Mooney, 2000	MedX Rotary Torso machine	Strengthening	
Mc Intire, 2006	Trunk rotatioali strength training	Increase trunk strength	
Durmala, 2003	Asymmetric mobilization of the trunk		
Stone, 1979	Milwaukee method	Mobilization	Strengthening, posture
Negrini, 2006b	SEAS.02	Active–self correction	
Negrini, 2008b	SEAS.02	Active–self correction	
Weiss & Klein	Integrated Scoliosis Rehabilitation	Symmetric mobilization	Actively straightening, Autocorrection

Exercises consist of correction of scoliotic posture (through elongation, realignment of trunk segments, positioning of the arms, and specific corrective muscle tension), and the use of specific breathing patterns with the help of proprioception, external stimulus, and mirror control. The external stimulus might be the hand of the therapist or the wall that assists the patient to perform exercises, in contrast to proprioceptive stimulation, which is unconsciously induced. All papers reported in this group are performed by Weiss who first proposed two case series.

Weiss (1992) treated 107 patients of various age (10.9–48.8) with mean curves of 43° (range 10–114°), and evaluated the efficacy of SIR over 4–6 weeks. The patients underwent the intensive inpatient physiotherapy program 6–8 hours per day each day. He found an improvement in 44% and a worsening in 3%.

In another study Weiss, Lohschmidt, el-Obeidi, and Verres (1997) treated 181 adolescents (12.7 years) with an initial average curve of 27°. The initial program was again 4–6 weeks of intense physiotherapy for 5–6 hours per day each day. A 30-minute home program was established for continued treatment following the inpatient intervention. Their findings were that the curves did not progress in 33 months (end of treatment: 29°–25% worsened; 18% improved).

The third study was published in 2003 (Weiss, Weiss, and Petermann, 2003) and was a prospective cohort controlled study in two subgroups matched for sex and age (first subset had a mean age of 10 years old and mean curve of 21°, and the second subset had a mean age of 13 years old and mean curve of 29.5°). In both SIR groups (4–6 weeks on initial intensive inpatient physiotherapy intervention) the authors found in a follow-up of 33 months better results, with a statistically significant difference ($p < 0.05$), compared to control groups who performed no treatment. The first subset (younger group) had 53% improvement in Cobb degrees vs. 29% in controls; the second subgroup (older group) had 70% improvement vs. 44% in the matched control group.

Integrated scoliosis rehabilitation (ISR) (Appendix 2)

Integrated scoliosis rehabilitation, ISR "Best Practice," a multifaceted approach to scoliosis management evolved to complement Schroth, includes four specific modalities: 1) physio-logic® exercises; 2) 3D exercises made easy; 3) pattern-specific ADL; and 4) the Schroth method and where appropriate scoliosis-specific spinal mobilization performed by the physiotherapist on the patient.

Weiss and Klein (2006) conducted a prospective controlled trial of pairs of patients matched by sex, age, Cobb angle, and curve pattern. Eighteen patients were in the experimental group (ISR), and 18 patients were in the control group and received only SIR (description provided earlier). The average age was 15.3 ± 1.1 years old in the experimental group and 14.7 ± 1.3 in the control group. The average initial curve was $34.5° \pm 7.8$ in the experimental group and $31.6° \pm 5.8$ in the control group. Thirteen of the 18 patients in either group had a brace (different braces with different corrective effectiveness), but because these were matched, the change in the final outcomes was believed to be the effect of the exercise regimes. All patients were admitted for an inpatient rehabilitation program of 4 weeks. The control group underwent 5–6 hours per day, 6 days a week, and then a home exercise program using the same exercise regimen for 30 minutes per day. The experimental group had the same exercise regiment, but in the second or third week of the 4-week program performed 90 minutes per day of the physio-logic exercises. The physio-logic exercise program provides symmetric mobilizing exercises for both thoracic kyphosis and focused lumbar lordosis at the L2 level. The program also provides asymmetric 3D exercises to improve postural correction in the coronal and sagittal planes. Finally, postures are practiced during typical ADLs during standing and walking. The results were obtained through the Formetric system for surface topographic analysis: lateral deviation and surface rotation improved in the experimental group (2.3 mm and 1.2°, respectively) compared to the control group with smaller improvements of (0.3 mm and 0.8°, respectively). It appears that the physio-logic "add-on" to SIR may be helpful in reducing lateral deviation of the scoliotic trunk.

Outpatient rehabilitation exercise programs

This subgroup includes 12 studies. Two used the Schroth methodology in an outpatient setting, one study used the DoboMed exercise physiotherapy program focusing on asymmetric exercises, three studies used the side shift exercise program, and six used an active intrinsic approach (SEAS).

Outpatient: Schroth program

The exercises used in the Schroth approach (which was designed as an intensive inpatient rehabilitation program) have also been used in the outpatient setting. The modification is generally the frequency (anywhere from twice a week to 5 days a week compared to daily in the traditional inpatient Schroth program); amount of time (2–4 hours per day compared to 6–8 hours per day in the traditional inpatient Schroth program); and of course the setting (an outpatient clinic compared to a rehabilitation inpatient setting).

Rigo, Quera-Salva, and Puigdevall (1991) conducted a retrospective study with 43 patients. The average age was 12 years old with an average initial curve of 19.5°. The patients exercised twice a week for 2 hours per treatment session for a minimum of 3 months without a home exercise program. The results were that 11.6% worsened and 44.2% improved.

The second paper using Schroth methodology was conducted by Otman, Kose, and Yakut (2005). They prospectively followed a series of 50 adolescents with an average age of 14.1 years old (range 11–17) in an outpatient setting for 6 weeks (4 hours per day, 5 days a week). The patients also were prescribed a home exercise program using the same exercise regimen for 90 minutes per day. During the treatment the investigators observed a progressive improvement of Cobb degrees from an average angle of 26.1°–17.8° at 1 year. All 50 patients showed an improvement.

Dobomed program (Appendix 3)

The DoboMed is a method of physiotherapy applied to patients with idiopathic scoliosis. Introduced in 1979, it has been systematically used since 1982, under the supervision of Professor Dobosiewicz in Katowice, Poland. This method respects the three-dimensional nature of the scoliotic deformity and tends to correct the scoliosis by active movements of the vertebral column. The main corrective technique comprises an active three-dimensional autocorrection. The vertebrae belonging to the primary curve are mobilized from their pathologic position toward their normal position in the axial plane of the trunk. The exercises are carried on in closed kinematic chains and based on symmetrically positioned pelvis and shoulder girdle. The selective respiratory movements guide the derotation of the thoracic spine. Active stabilization of the achieved corrected position is then performed and endured as postural habit.

Durmala, Dobosiewicz, Kotwicki, and Jendrzejek (2003) evaluated a program of asymmetric trunk mobilisation and followed prospectively 136 AIS patients, 6–18 years old, for 12 months. Exercises were performed an hour daily in and out of the brace. They reported a 31–39% decrease of the Cobb angle according to the segment of the spine considered.

Outpatient: Side shift program (Appendix 4)

Side shift exercises were originally proposed by Mehta (1985). These exercises consist of autocorrection of the spine curve through a lateral shift of the trunk to the concavity of the curve. Lateral tilt at the inferior end vertebra is reduced or reversed, and the curve is corrected in the side shift position.

den Boer, Anderson, Limbeek and Kooijman (1999) compared prospectively side shift exercises (44 patients) with bracing (120 adolescents) in 13.6 (mean age)-year-old adolescents with 20°–32° Cobb curves, respectively. Side shift patients had 10–12 half-hour sessions once a week to learn to side shift. Patients were instructed to remember to shift as often as possible during the day and the exercise regimen lasted over a 2.2-year period, whereas brace patients wore their braces for a 3-year period. Mean progression in Cobb angle per group was 2.6° Cobb in side shift group and −.5° Cobb in brace group. The authors did not find statistically significant differences between the two groups.

Maruyama, Kitagawa, Takeshita, and Nakainura (2002) followed prospectively a series of 69 patients, with an average age of 16.3 years old with 31.5° curves who started exercising after skeletal maturity (Risser grade IV or V, postmenarche since more than 2 years). Two exercises were performed daily and included shifting their trunk to the concavity of the curve, to hold the side shift position for 10 seconds, and to return to the neutral position; and lifting their heel on the convex side of their curve while keeping their hip and knee straight, to hold the hitch position for 10 seconds, to return to the neutral position. Both exercises were done standing and were repeated at least 30 times per day. After an average follow-up period of 4.2 years, the authors observed that 22% of the curves progressed, while 14% improved (4% by 10° or more).

One year later Maruyama et al (2003b) confirmed retrospectively these results in a sample of 53 patients of average age of 16.3 with an average 33.3° Cobb angle at the beginning of the treatment and 32.2° Cobb after 41 months of treatment that consisted of side shift and hitch exercises as described above.

SEAS program (Appendix 5)

The active intrinsic (AC) approach is based on the former Lyon School methods of autoelongation exercise that was not three-dimensional (Mollon and Rodot, 1986; Stagnara, Mollon, and De Mauroy, 1990). Actually, this approach has been reinterpreted in terms of three-dimensional AC in the SEAS (scientific exercises approach to scoliosis) by ISICO (Negrini, 2007).

SEAS is an autocorrection program. Autocorrection should be done by the patient exclusively through the spinal deep paravertebral musculature in all three planes, without external help, thus pursuing the precise control of movement without using muscular contractions strategies that drive the spine into a passive alignment. Increasing spinal stability is one of a primary therapeutic goal of the SEAS approach because the scoliotic spine is characterized by an intrinsic instability. This is obtained by working on stabilizing muscles without reduction of spine ROM. In this context it is also possible to add a balance perturbation to elicit activity of the trunk muscles to enhance their stabilizing function. A distinctive element of SEAS is that it acts outside the typical precepts of exercise-based techniques and is founded on the principle of a cognitive-behavioral approach.

Mollon and Rodot (1986) studied the entire growth period of 210 AIS patients with a mean age of 10.1 years recruited throughout Europe. These 50 controls and 160 patients had been treated with PEs consisting of posture control, strengthening and balance training according to the Lyon method that is based on neuromotor control to be increased though external input, mainly proprioceptive. At the end of treatment (4 years) the authors found statistically significant differences, with 63% of treated patients improved (34% worsened and 3% unchanged), whereas in the control group the percentages were 20% improved, 75% worsened, and 5% unchanged.

More than 15 years later Ducongé (2002) confirmed these results: 42% of the 422 treated patients worsened vs. 77% of the 169 controls.

A similar treatment was applied in Italy by Ferraro, Masiero, and Venturin (1998), who treated 34 outpatients twice a week (plus custom home sessions). They found that when compared to the minimal compliance (<10 minutes a day), the maximal participation (>30 minutes a day) slowed down or even halted the progression of scoliosis (difference between the groups: 9°), which was statistically and clinically significant.

More recently Negrini et al (2006c) compared in a prospective study the SEAS protocol to usual physiotherapy. As mentioned earlier the SEAS protocol is based on active three-dimensional self-correction with the aim to improve spinal stability, develop balance reactions, and preserve/improve the physiological sagittal spinal curves. In this 1-year prospective controlled study of 48 patients with a mean age of 12.4 years and a mean curve of 15°, the number of braced patients (failure of treatment) was statistically significantly reduced by specific exercises (4.3% vs. 20%), whereas SEAS caused 28.9% improvement vs. of 5% in controls.

Two years later Negrini et al (2008b) published another paper, a prospective controlled cohort observational study on patients never treated before. Seventy-four patients, 12.4 years old with curves about

15° Cobb, at risk of bracing were divided into two groups; 34 were in the SEAS group, and the remaining 39 were treated with usual physiotherapy (physical exercises that take their source from different method, not strictly specific for scoliosis). Cobb angle in the SEAS group was 30 at the beginning and 25 after treatment, and in the control group it was 31 and 28, respectively. The primary outcome included the number of braced patients, Cobb angle, and the angle of trunk rotation. The angle of trunk rotation is the angle between the horizontal and the plane across the back at the greatest elevation of a rib prominence or lumbar prominence, as measured by an inclinometer (scoliometer). It is evaluated with the trunk flexed to the horizontal. Results showed 6.1% braced patients in the SEAS exercises group vs. 25.0% in the usual physiotherapy group. Failure of treatment (i.e., patients who needed a brace) in the worst case analysis was 11.5% in the SEAS group and 30.8% in the usual therapy group, respectively. In both cases the differences were statistically significant. Cobb angle improved in the SEAS group (23.5% improved and 11.8% worsened), but the results were not as good in the usual physiotherapy group (11.1% improved and 13.8% worsened).

We consider in this group also one paper that explored the usefulness of PEs in preparation to brace (Negrini et al, 2006b). The SEAS protocol of general mobilization (e.g., stretching of hamstrings and scapular musculature) and localized mobilization (e.g., spine stretching and manual therapy) demonstrated its efficacy in increasing the brace correction at 5 months in 40 patients vs. 70 controls 13.4 years old with 30.9° curves: 58% improvement rate and 1.5% worsening in PE treated vs. 45.8% improving and 10.3% worsening in controls.

Outpatient rehabilitation exercise program: No autocorrection

Asymmetric exercises

This subgroup includes three studies in which authors did not use autocorrection principles but used asymmetric exercises for trunk mobilization according to different theories. These are two pilot studies performed with the aid of a rehabilitation device: the MedX Rotatory Torso Machine for trunk rotation strength training.

Mooney, Gulick, and Pozos (2000) performed a pilot study in 12 patients 13.1 years old (mean value) with 33.5° ± 12.2° curves. The patients underwent two training sessions per week until equal strength was achieved between sides and then the sessions were reduced to once per week for 4 months using the MedX Rotary Torso Machine (MedX 96 Inc, Ocala, FL). The patients curves improved 19% with the mean curves reduced to 27.2° ± 14.7°, whereas only one patient worsened.

McIntire, Asher, Burton, and Liu (2006) studied 9 patients 14 years old (mean value) with an average of 29° curves. The patients underwent two training sessions (25–30 minutes for each session) per week for 4 months for at least 30 training sessions using the MedX Rotary Torso Machine (MedX 96 Inc, Ocala, FL). The patients performed repeated trunk rotational isometric strength training and reported a statistically significant reduction of 5°.

Symmetric exercises

This last group is composed of studies performed by authors who did not use autocorrection principles. This subgroup includes only one paper.

Stone et al (1979) conducted a study in which 42 patients, 12–15 years old, 10° curve (range 4–22), followed a 12-month home program of mobilization, strengthening, and posture control according to the Milwaukee method that is based on autoelongation and obtained no differences between the prospective PE group and 57 retrospective controls.

DISCUSSION

After 2 years from the previous review, a study has been published that adds new encouraging data to the previous ones. The paper has been written by the same authors that reported in the past review. This shows a growing interest in PEs and demonstrates the real need among those individuals who treat AIS to clarify usefulness of PEs to focus the confused field of scoliosis rehabilitation. PEs, if correctly administered, can prevent a worsening of the curve and sometimes can result in not having to brace the patient, which is demonstrated by this review. Another important message that results from this review is the need to use specific exercises for scoliosis chosen according to strong scientific sources. Using "usual physiotherapy" often based on older outdated theories may lead to mistakes in the treatment of patients. Publications using unsound methodology and interventions can suggest that PEs in general are not effective, while in reality appropriate scientifically based PEs appear to be efficacious.

There has been an evolution with several of the approaches described in the appendices. Schroth inpatient evolved to outpatient intervention, and with the further development and need for a patient-focused approach some techniques have incorporated a cognitive-behavioral approach (SEAS), and patients are empowered to develop their own individual treatment protocol via experiential learning (integrated scoliosis rehabilitation). The goal in these newer techniques is for the patient and professionals to work together as a team. These new techniques aim to stimulate a new direction of research that constantly reflects, evaluates, and alters practice and does not simply accept the previous ideas and concepts.

Unfortunately, we have found only one short-term RCT (Wan, Wang, and Bian, 2005) that is the strongest research design from which to draw valid conclusions about the effectiveness of a therapeutic intervention (Reilly and Findley, 1989). This is due, probably, to the fact that rehabilitation is one of the fields in medicine in which a researcher trying to conduct an RCT is most likely to run into difficulties (ethical and logistic). So the level of evidence remains at 1b according to the Oxford Centre for Evidence-based Medicine (Phillips et al, 2001), as described in a previous systematic review.

CONCLUSION

The study published in 2008 about this topic demonstrated the capability of PEs to treat AIS in terms of Cobb angles and also secondary outcomes, such as strength, mobility, and balance. Nevertheless, there remains a need for further studies, especially RCTs that may improve the level of evidence regarding PEs. However, the present evidence is enough to consider PEs as an appropriate intervention for AIS, even if it is not possible to support a specific exercise regimen. We presently do not know if inpatient or outpatient, intrinsic or extrinsic autocorrection exercise, and symmetric or asymmetric exercise are more effective.

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APPENDIX 1

Rehabilitation in patients with spinal deformities: A description of the Schroth method

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ABSTRACT

Based on typical physiotherapeutic principles, the Schroth method was founded by Katharina Schroth in 1920. This three-dimensional scoliosis treatment is based on sensorimotor and kinesthetic principles, and its primary goals are to facilitate correction of the asymmetric trunk and the ability to maintain this in activities of daily living. Patients are assigned to groups, and their progress is closely supervised by on-site physicians. According to the Schroth classification, the appropriate individual exercise program is adapted. In-house counselling and cognitive behavioural therapy are also provided. The treatment program consists of specific exercises and postural techniques and bracing depending on curvature pattern, skeletal maturity, risk of progression, and compliance of the patient. The therapists use exteroceptive stimulation to facilitate the corrections and apply passive detorsional forces to enhance three-dimensional corrections. Corrective breathing technique enables detorsion of the rib cage to correct the collapsed areas of the trunk.

INTRODUCTION

Based on typical physiotherapeutic principles, the Schroth method was founded by Katharina Schroth in 1920 (Lehnert-Schroth, 2007). In Germany the Asklepios Katharina Schroth Spinal Deformities Rehabilitation Centre provides training courses in German and English language for physiotherapists and physicians to become certified Schroth therapists. The cooperation with these therapists creates a therapeutic network to enable the continuation of specific and intensive treatment as a combination between inpatient rehabilitation and outpatient treatment approach.

The inpatient rehabilitation (scoliosis inpatient rehabilitation [SIR]) uses an individualised exercise program combining corrective behavioural patterns with physiotherapeutic methods (Weiss, 2000; Weiss and Rigo, 2001). The three-dimensional scoliosis treatment is based on sensorimotor and kinesthetic principles, and its goals are to facilitate correction of the asymmetric trunk and posture (Figures 1A–C), and to teach patients to consciously maintain the correct posture (Figures 2A–C) in daily living activities.

Referrals are received from spine centres, general orthopaedic surgeons, paediatric physicians, and general practitioners. A 4-week minimum stay is required for initial treatment and may be extended up to 6 weeks. Follow-up treatments are 3–6 weeks in length, depending on symptoms and prognosis.

OUTLINE OF THE GENERAL TREATMENT

Patients in the clinic are assigned to groups, with the first day of the program devoted to diagnosis and evaluation of the three-dimensional deformity, supervised by physicians who observe each patient‘s medical program. A physical examination performed by trained physiotherapists assesses the typical scoliosis classification according to the Schroth classification (Figures 3A and B), and an individual exercise program is assigned.

Following this the patients are instructed in basic human anatomy and spinal deformity, and the principles of postural rebalancing therapy are provided to the patients in group lessons. Evening

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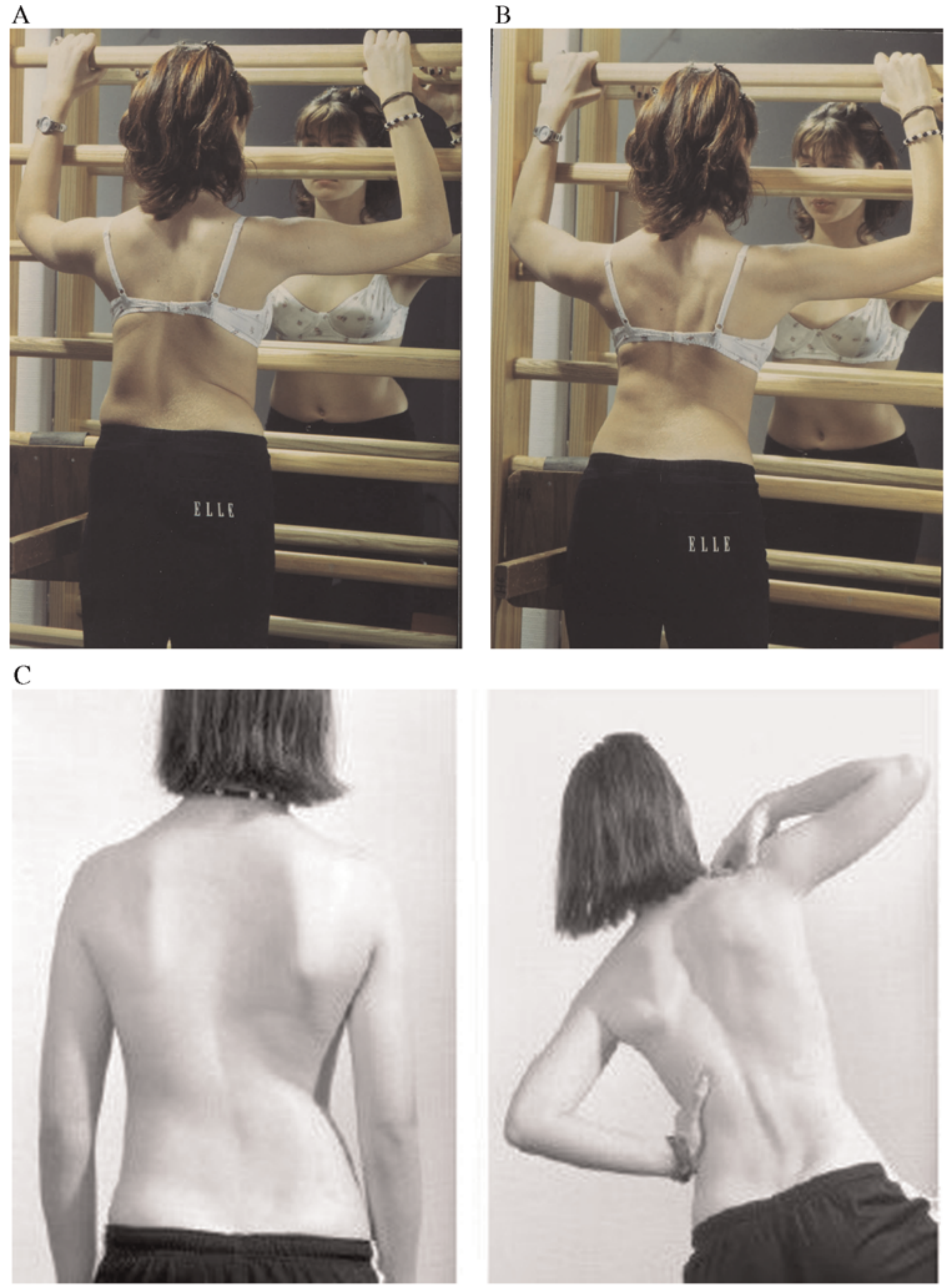

FIGURE 1 Correct posture in the exercise. (A) Hip resistance starting position. (B) Hip resistance corrected position. (C) Muscle cylinder correction effect.

social activities provide a sense of community and foster the development of psychological support systems that can be maintained after treatment.

Each weekday the patients are given a 10-minute outdoor group warm-up session (Figure 4). The patients exercise in matched groups (Figures 5A and B) for 1.5 hours in the morning and this is repeated in the afternoon. They receive shorter individual training sessions in between. The groups are matched depending on individual curve patterns of the patients. In addition to the group lessons, patients have to practice their individual exercise program in the "functional exercise" session. This takes 1.5 hours in the morning and this session is also repeated in the afternoon (Figure 6).

Massage therapists provide biweekly mobilisation and relaxation for each patient, using myofascial release, ischemic pressure, and classic massage techniques. Respiratory therapists are available to meet on a

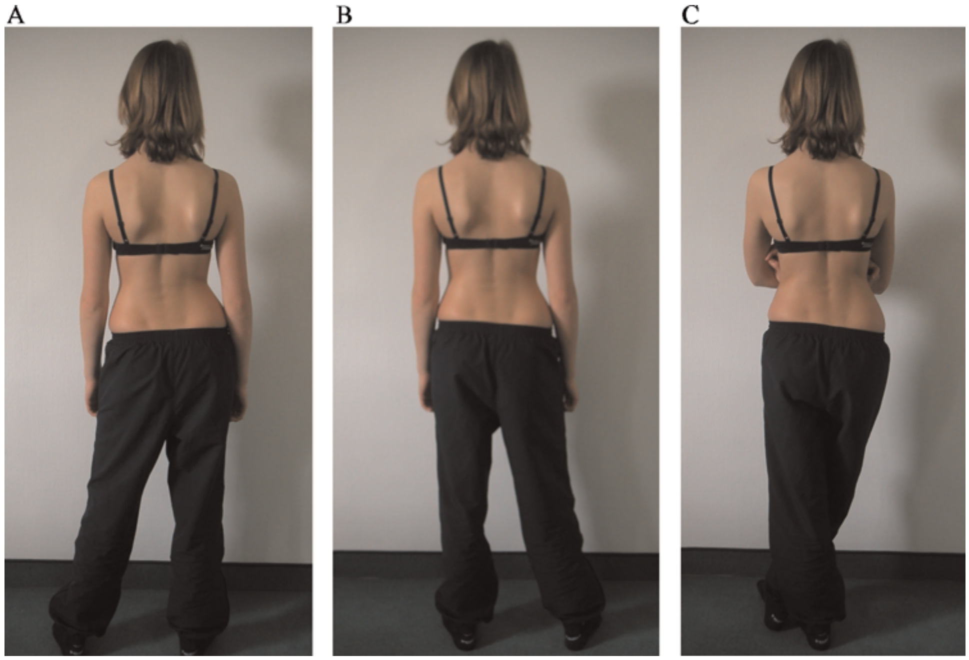

FIGURE 2 Posture variations. (A) Habitual posture. (B) Conscious posture. (C) Relaxed posture.

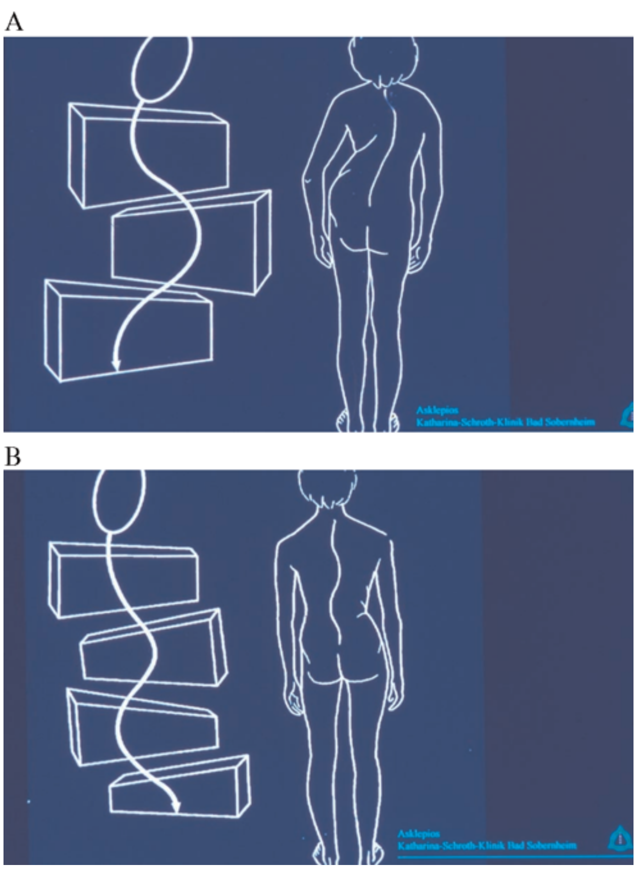

FIGURE 3 Schroth classification. (A) Body blocks three curves. (B) Body blocks four curves.

FIGURE 4 Warming up (outdoor).

one-to-one basis with each patient to monitor the learning process and to provide training in corrected breathing patterns.

Psychological counselling is provided by psychologists to help patients cope with the diagnosis as well as the impact of treatment, as needed. Patients can also request individual psychotherapy in response to anxiety, depression, or other psychological distress. For patients with chronic pain they can volunteer to participate in cognitive behavioural therapy in a small group session.

A

B

FIGURE 5 Group lesson. (A) Elastic band. (B) Mirrors.

Optional evening group sessions devoted to relaxation therapies including meditation and visualisation approaches are also available. Osteopathic and manual manipulation and acupuncture by on-site therapists to treat symptoms such as pain are again available, when necessary.

TREATMENT PROGRAM

The treatment program emphasises the correction of the scoliotic posture, once patients have detected their asymmetric posture and revealed the asymmetric loading in their typical habitual scoliotic postures. Bracing (since 1992) is applied as needed, depending on prognosis, curvature pattern, maturity, flexibility, and magnitude of the curve. Also the willingness of the patient to wear and accept the brace has to be part of the educational process within the therapy.

FIGURE 6 Functional exercise session: auxiliary handhold.

Central to the individual and group exercise program is therapist assistance. Experienced and certified physical therapists and sports therapists deliver active and passive measures and exercises to create a comprehensive educational process in which the patients learn to cope with scoliosis.

Development and maintenance of the corrected posture is supported by using asymmetric positioning designed to use targeted stretching of the collapsed areas of the concave trunk. The exercise position approaches the functional/structural threshold. Schroth therapy takes advantage of the overcorrected (mirroring changes to the opposite direction) positions. Basic corrections are installed and reviewed, by using mirrors in front and at the back of the patient. This posture requires concentration and coordination, applying the correct breathing, and well-adapted muscle length and tension. The therapists provide support by guiding resistances, auxiliary handholds, auditory feedback, and specific verbal instructions. The exercise technique develops along the patients‘ well-balanced body symmetry.

Corrective breathing technique is integrated into most individual exercises. The mobilization of the restricted thoracic concave side ribs enables corrections from "inside the body" by improving selective expansion and derotates the attached vertebral bodies. From a biomechanical point of view the main problem involves a loss of thoracic mobility followed by restrictive respiratory dysfunctions/impairments and a decrease in vital capacity. Breathing therapy in the Schroth context includes rib mobilization as well as intercostal massage techniques and stretching. The primary focus during therapy is to develop corrective breathing patterns with the help of manual resistances.

Rice bags provide localised sustained pressure during floor exercises to adjust and derotate the body blocks: pelvis, loin (lumbar block), rib cage, and shoulder girdle. These pressure zones stimulate the patient for the corrective movement. The object is to focus and concentrate on the convex side features of the curve (especially rib hump, lumbar prominence) and to reduce the contact to the rice bag.

On completion of the treatment the primary goal is for patients to be able to assume their individual corrected postural variations, independent of the therapist or mirrors, and to be able to maintain this position in their daily activities. Further self-management at home includes three to four exercises for 30 minutes daily to maintain the improved postural alignment. In the case of increased pain, curvature progression, or pulmonary symptom development, repeat Schroth treatment is available by referral from primary care physicians.

A new ADL (activities of daily living) approach in scoliosis rehabilitation has been designed to improve time efficiency. The ADL approach uses thoracic side shift, shoulder and pelvic tilt maneuvres, sagittal corrections (Weiss and Klein, 2006), and 3D-ADL exercises (Weiss, Hollaender, and Klein, 2006) according to current standard. With the help of these easy exercises, patients are able to integrate these elements in their activities from the beginning.

DISCUSSION

The Schroth clinic has used an exercise-based approach to treat spinal deformity for decades, with a continuous history of both positive subjective and objective feedback from patients who now exceed 3,000 per year in the German clinic alone. Though the use of postural exercises for scoliosis therapy is grounded in scientific principles that relate directly to known aetiologies and symptoms of spinal deformity, its effectiveness has remained a topic debate within the scientific community. During the past decade a systematic analysis has been undertaken with the long-term goal of examining scientifically the efficacy of this treatment approach.

The specific issue of the Schroth concept is to deliver a therapeutic network of effective treatment for the patients and training and education measures for physiotherapists, orthosists, and physicians. The treatment approach can be intensive inpatient rehabilitation or residential outpatient physiotherapy provided by certified Schroth therapists.

CONCLUSION

SIR is in essence an inpatient treatment approach, but when combined with the outpatient Schroth therapists and orthotists teams, it has become an all-encompassing multidisciplinary conservative treatment for patients with IS. The treatment program provides an individualised exercise-based approach combining behavioural patterns with physiotherapeutic methods. It is based on neurophysiological principles of locomotion/motor control and spatial orientation and emphasises on facilitation of a corrective and conscious posture to reverse the asymmetric loading on the spine and to enable patients to practise these postural changes in daily activities.

To treat the patients with the best quality and up-to-date treatments available, the clinic research continues to develop and improve the current best practise (Weiss, 2007). SIR has been proven to be a suitable and effective treatment option for the conservative management of scoliosis.

Declaration of interest: The authors declare that they have no competing interests. The authors alone are responsible for the content and writing of the article.

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APPENDIX 2

The Integrated Scoliosis Rehabilitation/ISR Scoliologic™ Best Practice program: A synthesis of four approaches of physiotherapy for the treatment of scoliosis

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ABSTRACT

Scoliosis is a three-dimensional condition involving spinal changes in the sagittal, coronal, and transverse planes. The torsional forces of this deformity also involve the rib cage, shoulder, and pelvic girdle. Common practice of treatment for scoliosis in the United States has loosely followed a wait and watch approach, leading to bracing and surgical intervention. Treatment that has involved physical exercise/rehabilitation techniques has largely been unrepresented in the literature. In Germany, the Schroth method, which consists of specific exercises and breathing techniques approaching the patient with a cognitive behavioral methodology, has existed for decades (1921). Numerous studies validate the efficacy of this approach demonstrating its effect on improved outcomes in respiratory function, cosmetic improvement, pain reduction, and halting or reducing the progression of scoliotic curve(s). Integrated Scoliosis Rehabilitation – ISR Best Practice program, a multifaceted approach to scoliosis management evolved to complement Schroth, includes four specific modalities: 1) physio-logic® exercises; 2) 3D exercises-made-easy; 3) pattern-specific ADL; and 4) the updated Schroth Method[2010] and where appropriate scoliosis-specific spinal mobilisation. An overview of the Integrated Scoliosis Rehabilitation—ISR Best Practice philosophy is presented.

INTRODUCTION

A new concept called integrated scoliosis rehabilitation (ISR) (Weiss, 2010) is currently applied in new modern centres in Gensingen (Germany), Istanbul (Turkey), Sydney (Australia), Hong Kong, Palo Alto (United States), and the Ukraine. “Integrated” is used to describe the teamwork of all professionals “acting as one.” The physician, physical therapist, and psychologist are integrated into each others’ work and act together in synchronicity in the diagnosis and treatment. In addition, integration applies to the multiple treatment methods that are brought together in a manner to optimise the management of each individual patient.

The ISR program uses an individualised exercise program combining corrective behavioural patterns with physiotherapeutic methods, following principles described by Lehnert-Schroth (2007) and Weiss (Weiss, 2003; Weiss and Maier-Hennes, 2008). The three-dimensional scoliosis treatment is based on sensorimotor and kinesthetic principles and its goals are 1) to facilitate correction of the asymmetric posture and 2) to teach the patient to maintain the corrected posture in daily activities (Weiss and Maier-Hennes, 2008).

The treatment program consists of correction of the scoliotic posture with the help of proprioceptive and external stimulation. Central to the individual and group exercise programs are the therapists who supervise all exercises and provide external stimulation needed to obtain the desired corrections. Depending on individual curve patterns, the patients are assigned to special exercise subgroups designing the program to suit the individual patient’s needs. Development and

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maintenance of the corrected posture is facilitated by using asymmetric standing exercises designed to use targeted traction to restore torso balance and mobility.

The ISR program follows a variety of methods to address all clinical aspects of the patient's deformity:

- Physio-logic® exercises (correcting the sagittal profile; Weiss and Klein, 2006)
- 3D made-easy exercises (3D program easy to acquire for small curves; Weiss, Hollaender, and Klein, 2006)
- Spine-specific exercises incorporated into ADLs (Weiss and Maier-Hennes, 2008)
- Schroth-specific exercises (Lehnert-Schroth, 2007.)

The individual methods used within the Scoliologic™ ISR Best Practice program (Weiss, 2010) are described below:

THE PHYSIO-LOGIC® EXERCISE PROGRAM (FIGURE 1)

The physio-logic® exercise program consists of:

- Symmetric mobilizing exercises to improve lordosis mobility of the lumbar spine and kyphosis mobility of the thoracic spine
- The physio-logic® ADL posture in sitting, standing, and walking.

The aim of the exercises is to improve the mobility of the lumbar spine and improve the lordosis capability specifically. The apex of the lordosis should be at the level of L2. First, lumbar lordosis is adopted actively and the pelvis is tilted forward whilst the upper trunk is reclined backward to improve thoracic kyphosis by a reciprocal reflex.

The symmetric mobilising exercises are performed repeatedly. It is *not* the aim of the exercises to increase lumbar lordosis at the L5/S1 level because increased stress in this region can cause low back pain. We can ensure perfection of the exercise by ventralising the lower ribs in the exercising positions (Figures 1A and B).

Activities of daily living (ADL) are very important to change the scoliotic stereotyped posture, and for this reason the physio-logic® ADL posture is trained in standing and walking (Figure 1B). Therefore, the patients are taught to perform the "Catwalk," which includes the basic principles of the physio-logic® program addressing the sagittal plane and ADL postures.

There is no angle and range of thoracic kyphosis and lumbar lordosis actually defined when performing or maintaining the physio-logic® exercises. Muscle groups used for the exercises are not yet fully identified; therefore, research into this may be beneficial.

The physio-logic® program can be used for the treatment of small curves (15–20°) and for the treatment of back pain as well, when the sagittal profile shows a malalignment. Asymmetric postures to correct (ADL) are also taught in standing, sitting, and in ambulation as well.

3D EXERCISES-MADE-EASY (FIGURE 2)

The "3D exercises-made-easy" program is derived from activities of daily living (ADL). These exercises can be performed in the sitting and standing position. Thoracic and lumbar exercise can be performed to address the different curve pattern in 3D. The thoracolumbar curve patterns can be addressed by applying the thoracic exercise (high thoracolumbar curve with apex TH 12) (Figure 2) or the lumbar exercise (low thoracolumbar curve with apex L1).

The exercises "3D made-easy" have been demonstrated to be easy to teach (Weiss, Hollaender, and Klein, 2006) and can be used for the treatment of small curves (15–30°) together with the physio-logic® program (Weiss and Klein, 2006).

SPINE-SPECIFIC EXERCISES INCORPORATED INTO ADLs (FIGURE 3)

The spine-specific exercises incorporated into ADLs in some ways are similar to the side shift exercises (Metha, 1986), as described by Maruyama, Takeshita, and Kitagawa (2008). These have been applied in two different exercises: one for thoracic curves and one for lumbar curve patterns during standing and sitting.

In the ISR program (Weiss, 2010) there are three key patterns:

- Thoracic curve pattern
- Double major curve pattern
- Lumbar/thoracolumbar curve pattern.

The spine-specific exercises incorporated into ADLs should accompany every other approach as described here.

THE SCHROTH PROGRAM (FIGURE 4)

The cognitive behavioural exercise program according to Schroth is described at length in several publications (Lehnert-Schroth, 2007; Weiss, 2003; Weiss and Meier-Hennes, 2008), and the idea of inpatient rehabilitation has been the subject of many scientific investigations (Weiss, 2003). The advantage of this program is the specificity of postural corrections designed for different curve patterns and the introduction of effective mechanisms to increase 3D postural correction in scoliosis.

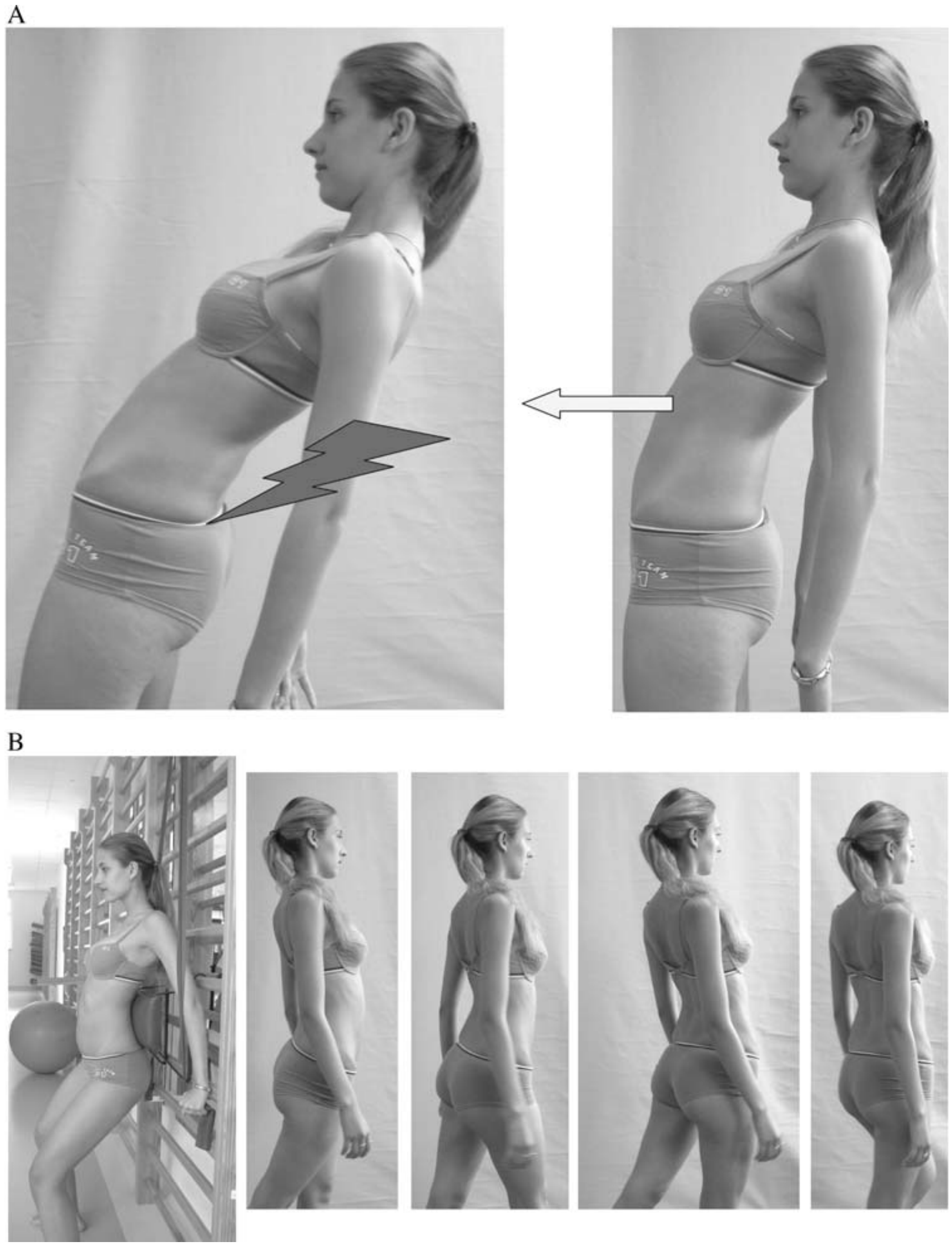


FIGURE 1 (A) Simply reclining the trunk leads to an increased thoracic kyphosis and also to stress in the lumbosacral region. This can be prevented by ventralizing the lower ribs to increase lordosis at the L2 level (right). (B) Lateral aspect of the physio-logic® exercise "Snake in the mountains" on the left and on the right the "Catwalk."

Within the Schroth exercise program, pattern-specific correction mechanisms are taught, depending on the clinical findings of the patient. Although the number of possible curve patterns seems quite high, in the Schroth system four basic curve patterns are considered:

- Functional three-curve pattern with neutral pelvis
- Functional three-curve pattern with decompensation
- Functional four-curve pattern, and as a special form of the four-curve pattern the
- Thoracolumbar curve pattern.

According to the magnitude of the curve, the application of Schroth-specific exercises is increased or lessened because this method is most effective in curvature of more than 30° (Weiss, Lohschmidt, el-Obeidi, and Verres, 1997). Curvatures between 15

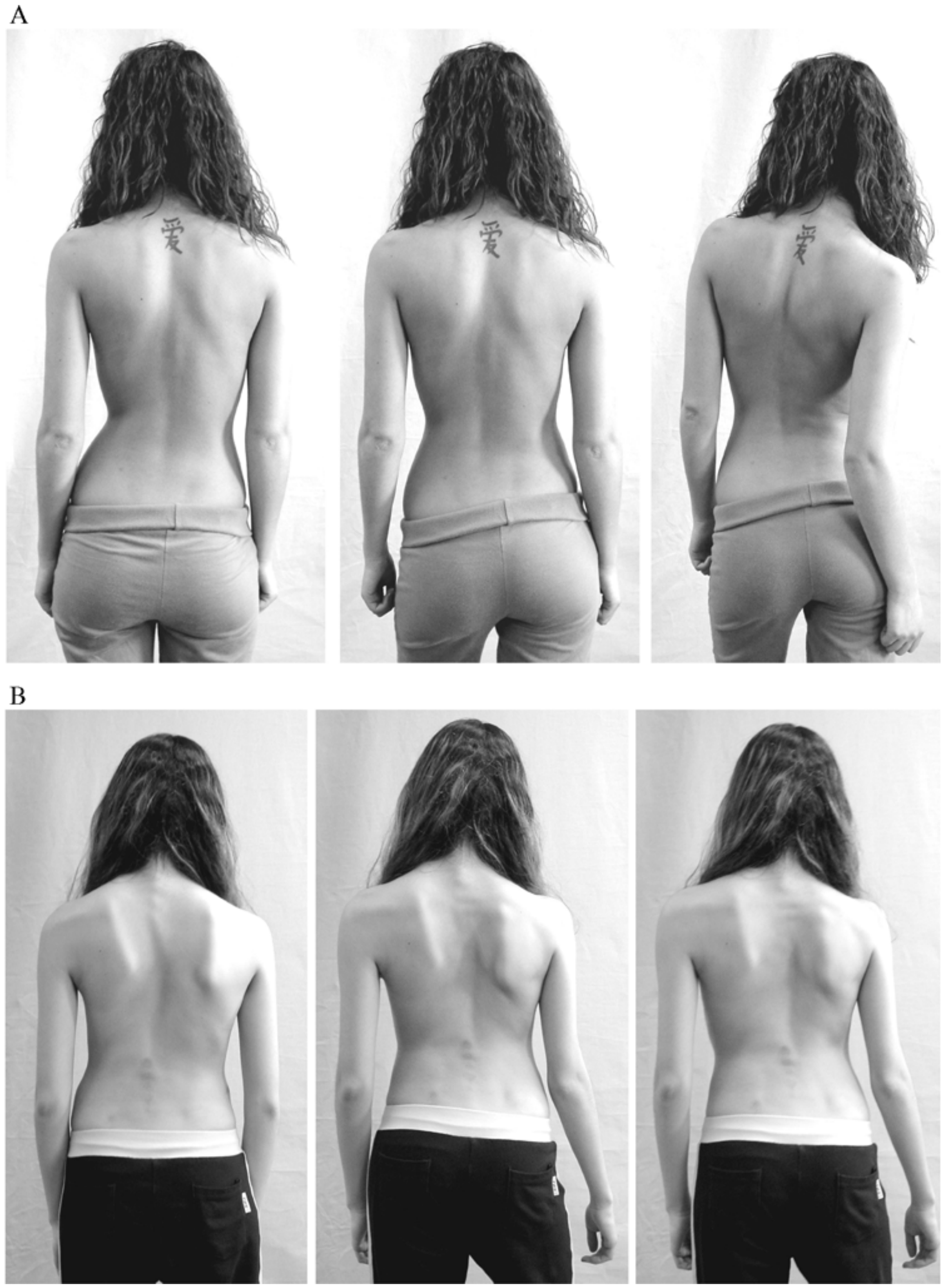


FIGURE 2 (A) Patient with high thoracolumbar curve treated like thoracic, according to the concept "3D exercises-made-easy": 1) pelvic overcorrection; 2) shoulder retraction with simultaneous alignment of the sagittal profile; 3) breathing; and 4) stabilisation via trunk muscle tension in the corrected position. (B) Patient with double major curve with both curves corrected according to the concept "3D exercises-made-easy": 1) pelvic overcorrection; 2) shoulder retraction with simultaneous alignment of the sagittal profile; 3) breathing; and 4) stabilisation via trunk muscle tension in the corrected position.

and 25° do not necessarily need the Schroth program, which is rather complex and takes time to learn well, when there are other specific approaches that are easier and already have been tested in the environment of an inpatient rehabilitation centre (Weiss, Hollaender, and Klein, 2006; Weiss and Klein, 2006).

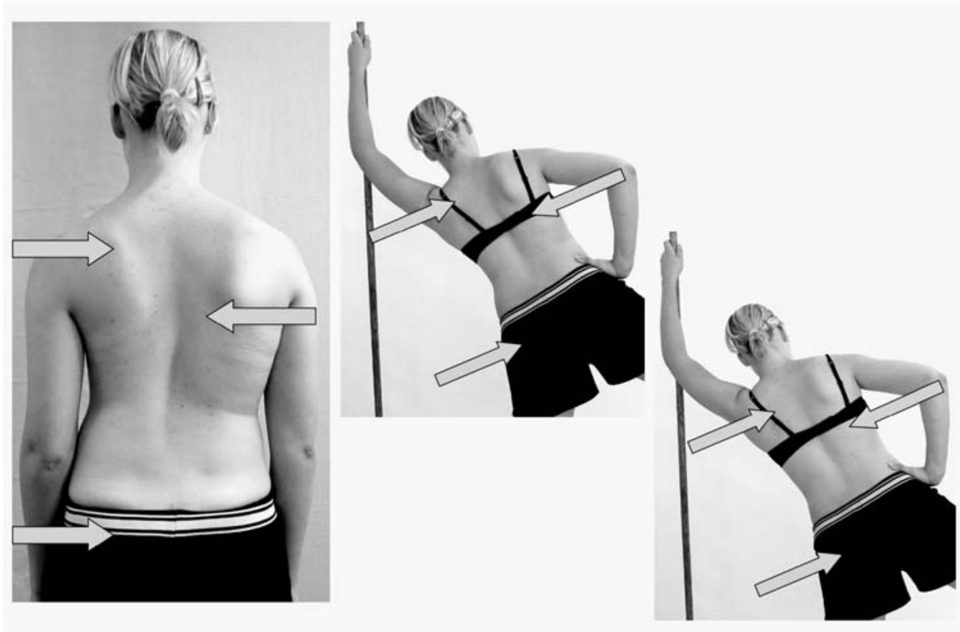
DISCUSSION

The basic aim of physiotherapy is to enable the patient to attain postural corrections themselves, with the exclusive use of trunk muscles, although dynamic passive forces (manual help by the therapist) and static

FIGURE 3 (A) ADL in standing and sitting in a functional three-curve scoliosis according to Schroth. The corrective movement ends in a clinical overcorrection as far as possible. (B) ADL in standing and sitting in a functional four-curve scoliosis according to Schroth. The corrective movement ends in a clinical overcorrection as far as possible. (C) ADL in standing and sitting in a single lumbar scoliosis. The simple corrective movement ends in a clinical overcorrection as far as possible. It‘s just pushing the pelvis to the opposite side.

forces (passive correction using bean bags) are applied. To train the patient, the various types of assistance offered by the therapist are essential. First, the therapist instructs the patient. The patient is also taught how to make slight corrections or adjustments to his or her posture in different parts of the body by means of exteroceptive stimulation or by provoking a reaction of balance. Equally important are the proprioceptive stimulations, both through manual passive corrections on the deformed trunk and through

A



B

FIGURE 4 (A) Example of an exercise for a functional three-curve scoliosis with decompensation. To recompensate the pelvic shift is crucial. The arrows indicate lateral forces as well as derotation forces directed ventrally. (B) Example of an exercise for a thoraco-lumbar scoliosis. The arrows indicate lateral forces as well as derotation forces directed ventrally.

changes in articular position, passive traction compression movements or manual relaxation, activation, or elongation tests of elastic structures.

The application of spine-specific exercises incorporated into ADLs alone cannot be regarded as the most important factor for a successful outcome and a preservation of the results achieved after exercising. The best exercise program available can only realistically be performed for up to 30, sometimes 60 minutes at home, which seems to be a small amount of time compared to 24 hours of each day (Weiss and Goodall, 2009).

The aim of successful therapy is to restructure the individual's activities of daily living (ADL). For a patient with scoliosis, maintaining their scoliotic posture is much more comfortable and therefore more desirable than the corrected curve and related posture. Therefore, a patient will not automatically acquire the corrected posture easily, and time is needed to become accustomed to this new postural schema (Weiss, Hollaender, and Klein, 2006). To unload the curve consistently during the day the postures taken during ADLs have to be changed according to the curve pattern of the individual patient in lying, sitting, and standing postures.

For the patients with significant curvatures, clinical appearance can be a problem. Specific rehabilitation, outpatient or inpatient, therefore provides a safe space to learn to cope with the deformity and thereby to improve self-esteem (Freidel et al, 2008; Weiss, 2003). The physical therapist should therefore also have some psychological skills while guiding treatment and be well aware of the patients' problems.

The role of the physical therapist has developed into that of a catalyst able to empower the patients who have now become a more active participant in the learning process than the earlier submissive role. This change from the classical 'teacher-pupil' roles to the more modern concepts of learning seem to allow a reduction of total training time of inpatient scoliosis rehabilitation to 5 days or even less, without reducing the effectiveness of treatment (Weiss, Hollaender, and Klein, 2006; Weiss and Seibel, 2010). Ultimately, this fosters the patients' ability to develop their own individual treatment protocol via experiential learning.

As mentioned earlier, a primary goal of physical therapy and specfically that of the ISR program is to enable the patient to assume their personal corrected posture independently of the therapist or mirror control and to maintain this position in their daily activities.

Thus, general aims of conservative scoliosis treatment according to the ISR program (Weiss, 2010) include the following:

- Alteration/correction of ADL
- Coping with the deformity
- Coping with treatment
- Coping with pain.

Finally, why use the term "ISR Best Practice" (Weiss, 2010) for this program? The Schroth program (Lehnert-Schroth, 2007) has been used for decades and has been developed further and documented extensively. The Schroth program has been proven in a prospective controlled study (untreated controls), and evidence has been achieved on level II in the environment of a 6-week inpatient program. According to the latest scientific publications on the sagittal profile (Weiss and Klein, 2006; van Loon, Kühbauch, and Thunnissen, 2008), the program has been updated with the latest biomechanical knowledge, and according to the latest publications on learning approaches, the program has been updated with the latest teaching strategies (experiential learning) as well (Weiss, Hollaender, and Klein, 2006). It has been shown that these additional approaches led to an improvement compared to the earlier program alone.

Today, inpatient programs have been reduced in treatment intensity, and outpatient approaches can be regarded as efficient as inpatient programs (Weiss and Goodall, 2009; Yilmaz and Kozikoglu, 2010). However, the results of the Schroth inpatient program have been improved by the addition of: physio-logic® exercises (correcting the sagittal profile) (Weiss and Klein, 2006); 3D made-easy exercises (Weiss, Hollaender, and Klein, 2006); and spine-specific exercises incorporated into ADLs (Weiss and Maier-Hennes, 2008) in prospective controlled studies. As has been shown, the Schroth inpatient program has been tested in a prospective controlled study (Weiss, Weiss, and Petermann, 2003). Therefore, the modules of the ISR Best Practice program (Weiss, 2010), tested against an evidence-based program, can be regarded as being evidence-based as well.

Declaration of Interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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APPENDIX 3

Physiotherapy for idiopathic scoliosis according to DoboMed

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ABSTRACT

The DoboMed is a method of physiotherapy applied to patients with idiopathic scoliosis. Introduced in 1979, it has been systematically used since 1982, under the supervision of Prof. Dobosiewicz in Katowice, Poland. This method respects the three-dimensional nature of the scoliotic deformity and tends to correct the scoliosis by active movements of the vertebral column. Thoracic kyphosis is restored in the hypokyphotic regions by active flexion of the spine. Thorax derotation results from an active, specific, respiration-guided movement of the rib cage, consisting of concave expansion followed by convex depression. During the inpatient stay the patient is carefully taught to perform corrective movements while keeping the pelvic and the shoulder girdle stable. The parents participate in the physiotherapy program to be able to control the home exercises. The DoboMed can be used with corrective bracing; it also helps to increase the curve flexibility in the immediate preoperative stage. When used as an exclusive treatment for the small and moderate idiopathic scoliosis in adolescence, the method has been shown to stop the progression of the Cobb angle and to improve the spirometric parameters and evaluated exercise efficiency.

INTRODUCTION

Mrs. Prof. K. Dobosiewicz introduced her method in 1979, initially for the adolescent girls in an outpatient clinic. Since 1982 she used the method as the main therapeutic option in the field of physiotherapy for small-angle progressive idiopathic scoliosis. It was used in the Department of Rehabilitation of the Medical University of Katowice, Poland, for a scoliosis-intensive inpatient rehabilitation.

GENERAL DESCRIPTION

The DoboMed (Dobosiewicz Method) represents a method of conservative management of idiopathic scoliosis for both the trunk deformity and the respiratory function impairment. The essential of the method is identification and application of active corrective movements of the spine that are executed by a trained patient, aware of her/his deformity. In the preparatory phase the nonspecific physiotherapy or physicotherapy may be used as a warm-up prior to the spine-specific exercises for each session. The main corrective technique comprises an active three-dimensional self-correction. The vertebrae belonging to the primary curve are mobilized from their pathological position toward their normal position in the transverse plane of the trunk. Because thoracic hypokyphosis is a constant feature of idiopathic thoracic scoliosis, increasing thoracic kyphosis can be elicited by the movements of flexion of the thoracic spine. The exercises are carried on in closed kinematic chains and based on symmetrically positioned pelvis and shoulder girdle. The selective respiratory movements guide the derotation of the thoracic spine. Active stabilization of the achieved corrected position

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is then performed and endured as postural habit (Dobosiewicz, Durmala, and Kotwicki, 2008).

MECHANISM OF CORRECTION

The DoboMed is a method of three-dimensional (3D) correction of idiopathic scoliosis that is based on the knowledge on the pathomechanism of idiopathic scoliosis (Burwell et al, 1992; Dickson, 1992). Because the thoracic scoliosis is the most frequent pattern, it seems essential to debate the case of a single thoracic curvature. The displacement of the thoracic vertebrae in the 3D space during the development of idiopathic scoliosis comprises an anterior displacement resulting in the decrease of the normal physiological kyphosis, axial rotation, and lateral deviation in the frontal plane. The DoboMed aims to reverse this displacement by performing an active movement of the thoracic vertebrae toward their normal position in the middle sagittal plane. This movement consists of flexion of the thoracic spine and derotation. The objective of flexion of the thoracic spine is to make the thoracic vertebral bodies glide forward in the sagittal plane to normalize the hypokyphosis. The objective of the derotation is to mobilize the axial rotation of the vertebrae. It is interesting to note that the frontal plane correction is obtained automatically, once the two other planes are corrected (no active movement of the lateral flexion is required).

TECHNIQUE OF EXERCISES

The DoboMed is characterized by exclusively symmetric positioning of the pelvis and the shoulder girdle during all exercises. Such a position is believed to facilitate the active correction in between the two symmetric stable girdles and to support the consolidation of the correct postural habit beyond the therapeutic session. The exercises are designed to be performed in closed kinematic chains, by the fixation of the pelvis and the shoulder girdle with the upper and lower limbs against the floor.

POSITIONS FOR EXERCISES

All exercise positions require strict symmetric arrangement of the trunk, which is achieved by fixation of the pelvis and the shoulder girdle. This stable symmetric position is ensured with the upper and lower limbs during all phases of the respiratory cycle (Figure 1).

The positions for exercises are presented in Figure 2. At the beginning of the session, exercises in low positions are performed. These positions leave the back muscles partially discharged from the influence of

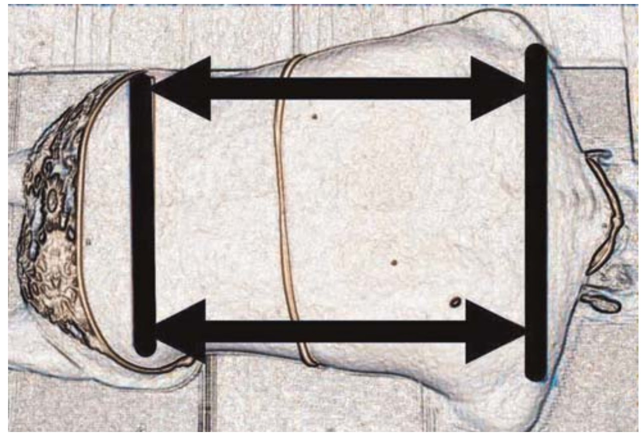

FIGURE 1 Top view of initial position for exercises (position 1): strict symmetric position of the pelvis and the shoulder girdle.

gravitation force. Probably because of that, the largest clinical correction of scoliosis can be observed in low positions. There are three main low positions (Figures 2A, B, and C). In between the exercises in each low position there is a difficult intermittent exercise: the break (Figure 2D). The break consists of active maximal flexion of the thoracic spine and extension of the lumbar spine with simultaneous 3D correction of scoliosis. After the full course of the low positions, the active 3D autocorrection exercises are performed in high positions. Thus, the spine is oriented vertically, so the gravitation affects the trunk muscles (Figures 2F–H, Figure 3). The course of action focuses on the vicinity of the apical vertebra. On the concave side of the curvature a strong local pressure is applied, whereas on the convex side a subtle facilitation is added. The pressure and the facilitation are phase-locked with the particular phases of the respiratory cycle; during inspiration a strong local pressure is applied on the concave side (Figures 3B and C), and during expiration a subtle facilitation is applied on the convex side (Figure 3E). During expiration, the achieved correction or hypercorrection is stabilized by isometric contraction of trunk muscles (Figure 3F).

INDICATIONS

The principal aim of the method is to 1) stop the progression of scoliosis, measured radiologically with Cobb angle and clinically with Bunnell scoliometer, and 2) improve the function of the respiratory system. The method has been used as exclusive or combined therapy with bracing exercises (Cheneau brace), when brace is indicated. Best results are observed when exercises are used 1 hour per day. Additional in-brace exercises are used when patients are ordinate bracing

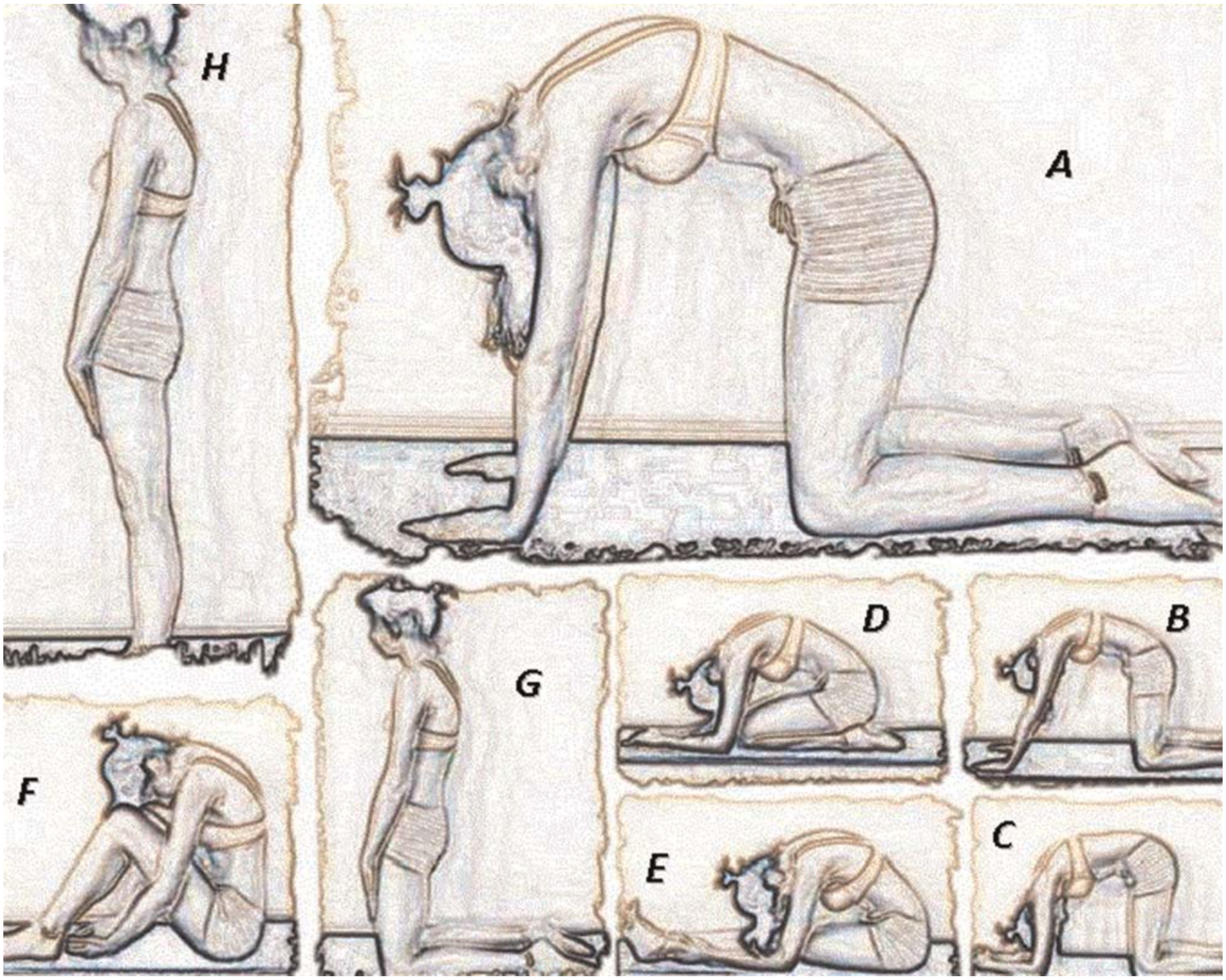

FIGURE 2 Side views of exercises positions. (A–E) Gradual progression of increasing neck, trunk, and hip flexion. (D) The break that is inserted between A, B, and C to achieve a maximal kyphotic position. (F–H) Transition from the low positions to the higher positions ending with standing H, representing the ability to carry over the outcomes achieved in the previous positions to a standing position.

(in-brace exercise are performed only in standing position). In our observation, small, moderate, and significant curves can benefit from the DoboMed; however, the effectiveness of the therapy depends on the curve flexibility and patient compliance (frequency and correctness of home exercises). According to the SOSORT guidelines (Weiss et al, 2006) Cobb angle for the curves is between 15 and 30° for nonmatured adolescents and children, who are candidates for physiotherapy alone. The combination method with the brace treatment is ordered when curves are significant.

If possible, the patients are admitted to the Department of Rehabilitation for a 3-week period. They have a complete clinical, radiological, respiratory, and functional evaluation, and they undergo an intensive rehabilitation comprising learning of the active corrective movement. The patients continue specific exercises at home and are systematically controlled in an outpatient clinic. Active cooperation is the basic requirement; therefore, DoboMed is not recommended for small children (Dobosiewicz, Durmala, and Kotwicki, 2005).

On the basis of retrospective (Dobosiewicz, Durmala, Czernicki, and Jendrzejek, 2002; Dobosiewicz, Durmala, Czernicki, and Piotrowski, 2006; Durmala, Dobosiewicz, and Czernicki, 2007; Durmala, Dobosiewicz, Kotwicki, and Jendrzejek, 2003; Durmala, Dobosiewicz, and Piotrowski, 2007) and prospective (Szota, 2006) radiological studies, the DoboMed has been shown to inhibit curve progression in small and moderate idiopathic scoliosis. The improvement of respiratory functions, assessed by the vital capacity and the forced expiratory volume in 1 second was noted (Dyner-Jama and Dobosiewicz, 2000). The exercise efficiency increased significantly during therapy (V_{O2max} evaluation) (Durmala, Dobosiewicz, Jendrzejek, and Pilis, 2002).

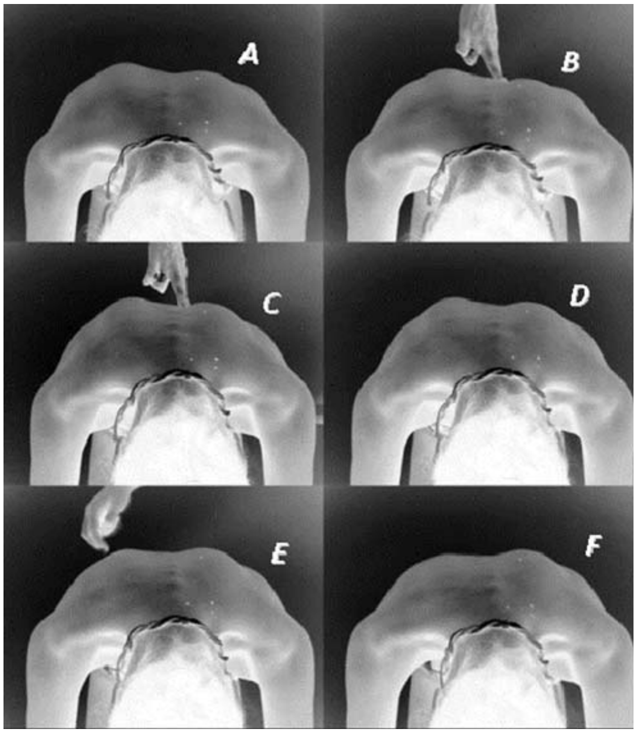

FIGURE 3 Transverse plane derotation of the apical area in low position is phase-locked with the respiratory cycle: (A) Start position. (B–C) Concave expansion during inspiration with facilitation by pressure on the concavity. (D) End of inspiration. (E) Convex depression during expiration with tactile facilitation on the convexity. (F) End of expiration. The hypercorrection obtained is fixed by isometric contraction.

The reduction of the Cobb angle and/or rotation angle of the apical vertebra depended on the correctness of exercising and their regularity.

CONCLUSIONS

The following are the principal distinctive features of the DoboMed: 1) symmetrical positions for exercising; 2) asymmetrical active movements to accomplish 3D scoliosis correction; 3) thoracic spine mobilization to increase thoracic flexion; 4) transverse plane derotation; 5) specific treatment emphasis is focused on the area of the curve apex; 6) concave rib mobilization to expand and derotate the ribs; 7) external facilitation; 8) respiration-directed movements of the thorax and spine to improve respiratory function; and 9) 3D displacement of vertebrae to obtain 3D scoliosis correction. The DoboMed may be considered a difficult method; therefore, frequent checking of the correctness of practicing is mandatory. The best effectiveness was achieved by daily exercises, actively supervised by the parents, who were educated during the initial inpatient rehabilitation period.

Declaration of Interest: The authors report no conflicts of interest. The authos alone are responsible for the content and writing of the article.

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APPENDIX 4

Side shift exercise and hitch exercise

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ABSTRACT

We use side shift exercise and hitch exercise for treatment of idiopathic scoliosis. These physical therapies can be indicated regardless of the curve magnitude or patients' skeletal maturity. Results of side shift exercise used in combination with part-time brace-wearing treatment or used for the curves after skeletal maturity are better than natural history. Side shift exercise and hitch exercise are useful treatment options for idiopathic scoliosis.

INTRODUCTION

Side shift exercise was first described by Mehta (1985), who reported the results of side shift exercise of 35 patients (33 girls and 2 boys) whose average age was 14.1 years and average Cobb angle was 23.8° at the beginning of the treatment. After a mean treatment period of 1.9 years, their average Cobb angle changed to 24.8°. Of 42 curves in 35 patients, nine curves (21.4%) improved of 5° or more and change of 21 curves (50%) were less than 4°.

We learned side shift exercise and another specific exercise, hitch exercise, directly from Dr. Mehta and have adopted these exercises as physical therapy for idiopathic scoliosis since 1986.

As we prescribe part-time wearing of brace for most of the patients who have an indication for bracing (e.g., Cobb angle>25°, Risser sign 0–IV), physical therapy is conducted in combination with part-time bracing in such patients. Other indications for physical therapy are patients whose curve is too small for bracing (e.g., Cobb angle<25°) or patients after skeletal maturity that include after weaning of the brace (e.g., Risser sign IV or V, postmenarche >2 years).

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METHODS OF TREATMENT

Side shift exercise

Side shift exercise consists of the lateral trunk shift to the concavity of the curve. Lateral tilt at the inferior end vertebra is reduced or reversed, and the curve is corrected in the side shift position (Figure 1). In the standing position, patients are instructed to shift their trunk to the concavity of the curve, to hold the side shift position for 10 seconds, to return to the neutral position, and to repeat this exercise at least 30 times a day. Attention should be paid that patients shift their trunk properly, not to bend nor rotate it (Figure 2). If C7 plumb line lies to the convexity of the curve at the level of the sacrum, large shift is indicated. Conversely, if C7 plumb line lies to the concavity of the curve at the level of the sacrum, small shift is indicated. In addition, in the sitting position, patients are instructed to maintain the side shift position for as long as they can. Side shift is indicated for any single curve at any location (i.e., thoracic, thoracolumbar,

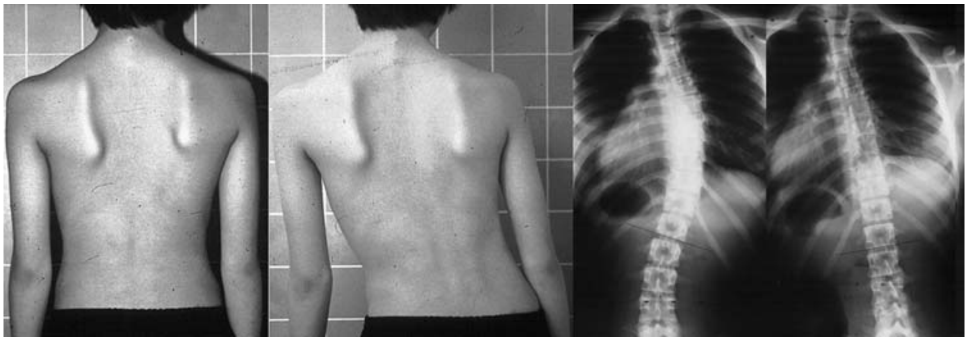

FIGURE 1 A patient standing in the neutral and side shift position. She is instructed to shift her trunk to the concavity of the curve. Note that lateral tilt at the inferior end vertebra is reversed, and the curve is corrected in the side shift position.

FIGURE 2 A patient standing in the neutral (A) and side shift (B) position. Attention should be paid that the patient does not bend (C) nor rotate (D) her trunk.

or lumber). For a double major curve, the larger curve is the subject of the treatment.

Hitch exercise

For lumbar curve or thoracolumbar curve, another option is hitch exercise. In the standing position, patients are instructed to lift their heel on the convex side of their curve while keeping their hip and knee straight (Figure 3), to hold the hitch position for 10 seconds, to return to the neutral position, and to repeat this exercise at least 30 times a day. In the hitch position, pelvis on the convex side is lifted, lateral tilt at the inferior end vertebra is reduced or reversed, curve is corrected, and asymmetry of the indented waist line is reduced.

Hitch shift exercise

Hitch shift exercise is an option for a double major curve. Patients are instructed to lift their heel on the convex side of the lower curve as the hitch exercise, to immobilize the lower curve by their hand, to shift the trunk to the concavity of the upper curve, to hold the position for 10 seconds, to return to the neutral position, and to repeat this exercise at least 30 times a day (Figure 4).

RESULTS

Exercise combined with the part-time brace treatment

Results of a total of 39 female patients with adolescent idiopathic scoliosis, whose Cobb angle was larger than 25° and whose Risser sign was 0–3 at the start of the treatment, were analyzed (Maruyama, Miura, Sasaki, and Kitagawa, 2007). The patients followed up for more than 1 year and at least until Risser sign of IV or deteriorated in this period and discontinued the brace treatment. At the start of the treatment, patients' mean age was 12.8 years and mean Cobb angle was 37.1°. The average Cobb angle changed to 45.4° after an averaged follow-up period of 2.8 years. Of 39 patients,

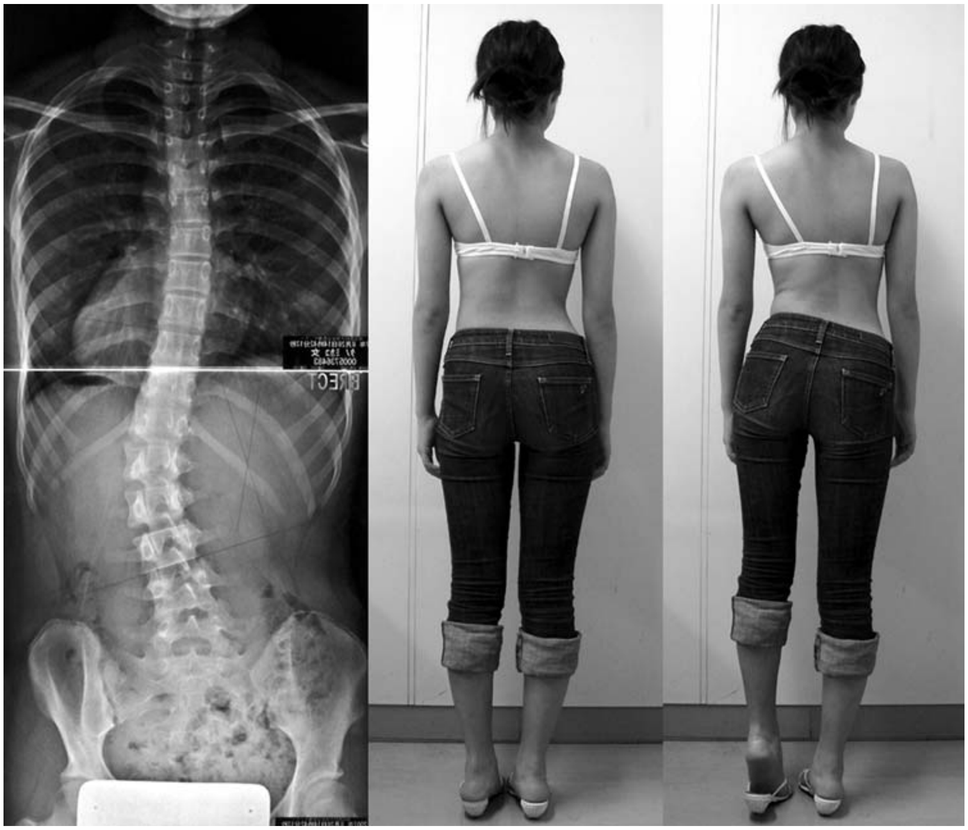

FIGURE 3 A patient with left thoracolumbar curve (A), standing in the neutral (B), and hitch (C) position. She is instructed to lift her heel on the convexity of the curve while keeping her hip and knee straight. Note that asymmetry of the waistline reduced in the hitch position.

FIGURE 4 For double curve, hitch shift exercise is indicated. A patient is instructed to lift her heel on the convex side of the lower curve as the hitch exercise, to immobilize the lower curve by her hand, and shift her trunk to the concavity of the upper curve.

28 (72%) were classified as unchanged because the change of their Cobb angle was within 10°, and 11 (28%) were as progressed because their Cobb angle increased of 10° or more.

Curves after skeletal maturity

Results of a total of 69 skeletally mature patients with idiopathic scoliosis treated only by side shift were analyzed (Maruyama, Kitagawa, Takeshita and Nakamura, 2002). The average age at the beginning of the treatment was 16.3 years, and the average follow-up period was 4.2 years. The average Cobb angle was 31.5° at the beginning of side shift and 30.3° at the follow-up. Of 69 curves, magnitude of 33 curves ranged from 30° to 40°: the average Cobb angle of these 33 curves changed from 36.6° to 36.1° during an average follow-up period of 4.3 years.

DISCUSSION

Physical therapy can be indicated for patients with idiopathic scoliosis regardless of the curve magnitude or patients' skeletal maturity. In the current study, patients treated with physical therapy and part-time bracing showed progression of 10° or more in 28%. According to natural history before skeletal maturity, 48% of curves of 30–40° progressed 10° or more in a follow-up period from 13.6 to 15.3 years of age (Bunnell, 1986). Comparing our results with natural history of the identical sized curve, follow-up period was longer in our study, while prevalence of progression more than 10 degrees was lower in our patients.

Most of the long-term follow-up studies reported that idiopathic scoliosis progressed even after skeletal maturity. Thoracic and thoracolumbar curves of 30–50° progressed in 0.25° per year with 40.5 years follow-up (Weinstein and Ponseti, 1983) and progressed in 0.36° per year with 33.5 years follow-up (Ascani et al, 1986). However, in our results, 33 curves of 30–50° in skeletally mature patients showed 0.1° per year decrease during the follow-up period of 4.3 years.

CONCLUSION

Physical therapy can be indicated for patients with idiopathic scoliosis regardless of the curve magnitude or patients' skeletal maturity Side shift exercise and hitch exercise are useful options for idiopathic scoliosis.

Declaration of interest: The authors report no conflicts of interests. The authors alone are responsible for the content and writing of the paper.

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APPENDIX 5

The SEAS concept of exercises for scoliosis

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ABSTRACT

The main characteristics of the Scientific Exercises Approach to Scoliosis (SEAS) approach is self-correction exercises and spinal stabilisation. As we are used to seeing with software products, after the acronym there is a dot followed by a number, to indicate the protocol version and the year in which substantial changes were introduced. Today, we have version .06. SEAS regulates its changes according to evidence coming from new developments proposed by scientific research. A distinctive element of SEAS is that it acts outside the typical precepts of exercise-based techniques and is founded on the principle of a cognitive-behavioural approach, which in our view is an indispensable element in chronic disease rehabilitation. In our field, this goal is pursued through regular moments of family counselling. Besides the possibility of reassuring the patient and his/her family and the ability to encourage compliance, family counselling must let the patient feel that we are close to him/her and that the entire team (physician, physiotherapist, trainer, and orthotist along with the patient and his/her family) is working together to obtain the best possible result.

MAIN CHARACTERISTICS OF THE SEAS APPROACH

Active self-correction

Active self-correction on the three spatial planes is the most important individualised therapeutic intervention directed toward one's own deformity.

Active self-correction should be done by the patient exclusively through the spinal deep paravertebral musculature, without external help, thus pursuing the precise control of movement without using superficial trunk muscular contraction strategies. The goal is to drive the spine into alignment by using the deep paravertebral muscles (e.g., contraction of concavity-side psoas muscles to reduce lateral flexion component in a lumbar scoliosis).

The first phase includes becoming aware of curve apex translation toward concavity on the frontal plane. The phase immediately following includes becoming aware of the correction of the sagittal plane. Finally, we associate active self-correction movements of the frontal and sagittal planes. According to Dickson, Lawton, Archer, and Butt (1984), an action done on two spinal planes (frontal translation and increased thoracic mobility in the sagittal plane and/or lumbar increase of lordosis) causes an involvement of the third plane (cross-sectional derotation).

Spine stabilisation

Increasing spinal stability is one of a primary therapeutic goal of the SEAS approach. The importance of this rehabilitation aspect is derived from a series of fundamental studies. Duval-Beaupère (1992) showed that scoliotic curve magnitude is not only the result of a structural deformation but that there is also a postural component signifying a difficulty of the stabilizing system in the spine to counterbalance the alignment loss. The importance of improving spinal stability derives not only from scientific experiments but also from clinical evidence. A scoliotic spine can be seen as a structure whose constituent elements, being subject to stimuli causing a loss of balance, are no longer able to maintain their physiological alignment and prescoliosis stability.

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The natural history of a progressive scoliosis could therefore be a postural collapse on several planes that afterward becomes a bone deformity in accordance with the "vicious cycle" theory ideated by Stokes, Burwell, and Dangerfield (2006). Muscle strengthening aims to develop paravertebral, abdominal, lower limbs, and scapulo-humeral girdle muscle endurance through isometric contractions. We ask the patient to execute an active self-correction movement and to hold it for the entire duration of isometric contraction (at least 10 seconds) of the chosen muscles.

Activation of stabilizer muscles can be enhanced by different ways. All of the following are done to strengthen the patient only if he/she is able to maintain the active self-correction while exercising:

- A weight (from 0.5 to 2 kg) on the head of patient to stimulate paraspinal muscles activation to prevent postural collapse
- Imbalance exercises that use gravity to enhance muscle activation (Figure 1)
- Adding drives, pressures (Figure 2), and weight lifting that patients perform, maintaining autocorrection. With these exercises the spine is stressed to keep alignment; the aim is to stimulate paraspinal muscle contraction that counters malalignment.

Development of balance reactions and neuromotor integration

This is aimed at improving axial, static, and dynamic balance of the trunk (Figure 3). Proposed exercises are always done in active self-correction, even on unstable planes (Figure 4), developed with growing difficulties to obtain a progressive integration of best spine support skills. We propose exercises that associate active self-correction with global movements, (e.g., walking with a simple gait and oculomanual education exercises, even on unstable planes). All these exercises are designed to train the patient to maintain autocorrection even in unfavorable conditions of attention.

FIGURE 1 Patient holds active self-correction and stays on one foot in forward overhanging position to enhance contraction of back stabilisation muscles.

FIGURE 2 In sitting position the patient holds active self-correction and pushes a stick with great force into the ground to enhance contraction of abdominal stabilisation muscles.

FIGURE 3 In standing position the patient holds active self-correction. He/she falls forward and catches self on wall and still keeps active self-correction and pushes back to standing.

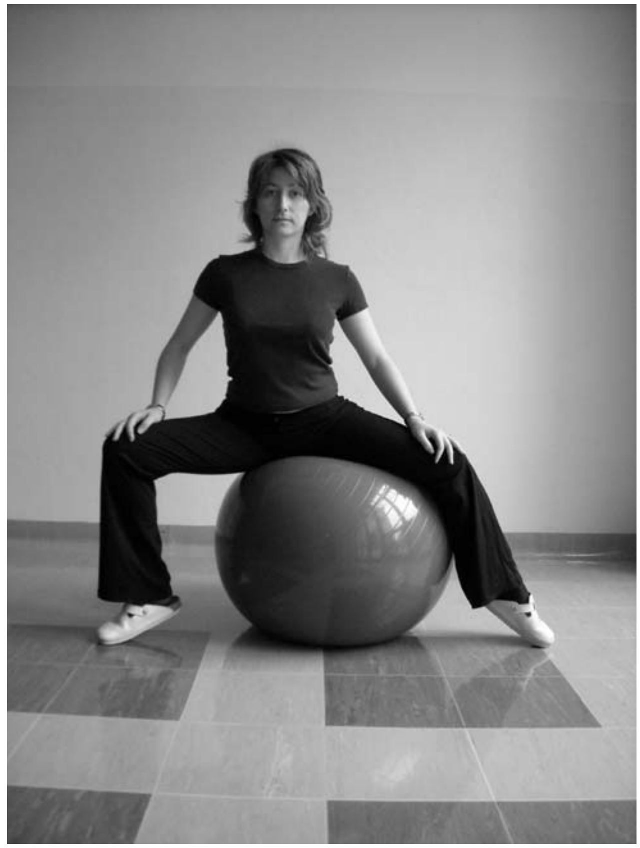

FIGURE 4 In sitting position on a fit ball the patient holds active self-correction and slides in the coronal plane.

PRACTICAL APPLICATION OF THE SEAS CONCEPT

Scientific research has shown that scoliosis is associated with functional impairments at a neuromotor, biomechanical, organic, and psychological level (Negrini, Negrini, and Sibilla, 1996; Negrini et al, 2001). On the basis of the knowledge of these impairments, we derive therapeutic goals to be pursued through exercises to prevent and reduce them in the treatment of both low-degree scoliosis and progressive forms in association with bracing. Furthermore, exercises allow us to slow down and in some cases stop progression in low-degree scoliosis (Mollon and Rodot, 1986; Negrini et al, 2006). During bracing this type of exercise therapy is useful to increase the orthosis corrective action and avoid side effects.

Exercises in low-degree scoliosis treatment

Goals at the neuromotor and biomechanical levels are directed toward postural control and spinal stability, whereas the goals at the bodily and psychological levels are directed toward aerobic functioning and development of a positive body image.

The therapeutic modalities to obtain postural control and spinal stability are active self-correction, muscular endurance strengthening in a correct posture, development of balance reactions, and neuromotor integration while being stimulated with posturally challenging activities (Figure 5). To develop a better corrected and balanced spinal posture to support the different requirements of social life, we propose exercises that associate active self-correction with global movements (e.g., walking with a simple gait and oculomanual education exercises, even on unstable planes).

Aerobic functioning and development of a positive body image are not specific goals to the therapeutic field; we are discussing, in particular, motor and sport activities that stimulate aerobic functioning (vital capacity and oxygen uptake and consumption) and help develop a positive body image. When the patient does not wear a brace, we advise against competitive sports that require an increased range of motion of the spine, particularly in maximum thoracic extension

FIGURE 5 Patient holds active self-correction and walks in place.

FIGURE 6 Active spine mobilization in the transverse plane to increase the range of motion. In this way, when the patient wears the brace the pressure of the brace's pads will exert the maximum possible correction.

and/or lumbar flexion. According to Stagnara (1974), for a scoliotic patient every motor activity done at a recreational level is beneficial; our everyday experiences (and some published results) continue to fit with this statement. Such activities, for their limited duration and intensity over time, cannot determine structural changes but offer huge benefits at the bodily and psychological levels.

Exercises in brace treatment

The main goals of exercises in brace treatment are elimination or reduction of side effects caused by immobility (muscular hypotrophy), or the brace itself (reduction of sagittal curves, mainly kyphosis, and breathing impairment), and accentuation of brace corrective pushes obtained by vigorous movements of the trunk inside the brace (Nachemson and Peterson, 1995; Romano et al, 2006). Such goals are pursued through specific therapeutic modalities, subdivided into treatment phases:

- Preparation for bracing: We request the execution of exercises aimed at increasing the range of motion of the spine on all planes (Figure 6) to allow the brace to exert the maximum possible correction (Negrini et al, 2006). We also continue proposing mobilisation and trunk flexibility exercises in the first phase of brace wearing, when it is worn for at least 21 hours per day. These exercises are performed actively by the patient. The aim is to allow a better modelling action of the brace that can work on a more flexible trunk.
- Brace wearing period: We initially propose exercises of "wriggling out of supports" by using the upper and lower limbs to facilitate adaptation to brace usage for the recommended number of hours.

We require the execution of modelling exercises to increase brace pressure on humps (Figure 7) using muscular endurance strengthening exercises, requiring lumbar lordosis and thoracic kyphosis preservation, while frontal and cross-sectional plane correction is guaranteed by brace pushes. We propose specific breathing activation exercises only when we detect some significant reductions of vital capacity.

During brace treatment, it is of fundamental importance to pursue continuatively these other two

FIGURE 7 The patient is on all fours and wears the brace. The physiotherapist's hand lays on the brace at the level of the hump. The patient exerts a vigorous push to allow a maximum thoracic kyphosis. In this way the hump is pushed into the brace pad, while at the same time the physiotherapist exerts a push in the opposite direction.

goals: 1) aerobic functioning and 2) development of a positive body image. For that reason, we recommend intensifying participation in motor and sport activities, both agonistic and/or recreational, even with a brace that must be worn full time.

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