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NARRATIVE REVIEW

Bracing and exercise-based treatment for idiopathic scoliosis

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Review

Summary *Background:* Various conservative therapies are available for treating adolescent idiopathic scoliosis (AIS), however, the disparities between them and the evidence of their efficacy and effectiveness is still unclear.
Objectives: To evaluate the effectiveness of different conservative treatments on AIS.
Methods: A literature-based narrative review of the English language medical literature.
Results and conclusions: The most appropriate treatment for each patient should be chosen individually and based on various parameters. Bracing has been found to be a most effective conservative treatment for AIS. There is limited evidence that specific physical exercises also an effective intervention for AIS. Exercise-based physical therapy, if correctly administered, can prevent a worsening of the curve and may decrease need for bracing. In addition, physical exercises were found to be the only treatment improving respiratory function. Combining bracing with exercise increases treatment efficacy compared with a single treatment. Additional, well-designed and good quality studies are required to assess the effectiveness of different conservative methods in treating AIS.

Introduction

Scoliosis is a spinal deformity consisting of lateral curvature, rotation of the vertebrae and a flexible or rigid deformity in the frontal plane (de Baat, 2012; Janicki and Alman, 2007). It was first described by Hippocrates and the term "scoliosis" was first used by Galen (AD 131—201). Generally, patients present with a spinal deformity or more

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likely chest wall and back asymmetry (Janicki and Alman, 2007). There are several types of scoliosis, each with its own specific characteristics. Adolescent idiopathic scoliosis (AIS) comprises approximately 80% of diagnosed scoliosis cases. Other known types of scoliosis are congenital (10%) and neuromuscular (5%—7%) (Thomson and Lehnert-schroth, 1992).

Prevalence of scoliosis in the general population is 0.3%—15.3%. The significant difference in the prevalence is due to different testing techniques, samples and definitions of scoliosis (Kowalski et al., 2001). The prevalence of AIS is 2%—3% in children 10—16 years of age. The female to male ratio is equal to one in adolescents with spinal curvatures of 10°; in spinal curvatures $> 30^{\circ}$, the ratio increases to 10 females to every male. Scoliosis in females tends to progress more often (Lenssinck et al., 2005). In adolescents diagnosed with mild AIS (Cobb angle $< 25^{\circ}$), only 10%—15% have progressive curves and only 2%—4% of the diagnosed patients progress to severe scoliosis (Cobb $> 45^{\circ}$) (Asher and Burton, 2006; Reamy and Slakey, 2001).

The risk of curve progression in AIS and hence its treatment and prognosis is based on remaining spinal growth (Janicki and Alman, 2007). The most reliable method of monitoring growth is simple height measurements. It is also important to look at other markers of growth and maturity (chronological age and skeletal age measured by the Risser sign), including signs of puberty (Bunnell, 1986; Tanner and Whitehouse, 1976).

Although the clinical manifestations of AIS have been well described, the etiology and pathogenesis remain unknown (Machida, 1999). Recently, investigations into the cause of AIS have focused on the structural elements of the spine, spinal musculature, collagenous structures, the endocrine system, central nervous system, and genetics. At present, no convincing mechanism has been established as to the cause of AIS (Machida, 1999).

Genetic factors are known to play a role, as observed in twin studies and singleton multigenerational families (Miller, 2007). A similar curve pattern was observed in twins with scoliosis (Inoue et al., 1998). A recent study of monozygotic and dizygotic twins from the Swedish twin registry estimated that overall genetic effects accounted for 38% of the observed phenotypic variance, leaving the remaining 62% to environmental influences (Grauers et al., 2011). In addition, Kindsfater et al. (Kindsfater et al., 1994) reported that the level of platelet calmodulin in skeletally immature patients with a progressive spine curve is significantly higher than in those with a stable curve. Machida et al (Machida and Imamura, 1996) found significantly decreased nighttime melatonin levels in adolescents with progressive curves, whereas normal levels were shown is adolescents with stable curves. To date, the dominant hypothesis states that the etiology of AIS is multi-factorial with significant genetic predisposition, imbalance between anterior and posterior spinal growth, abnormalities in connective tissues and skeletal muscles, muscle contractile mechanisms and neurological disturbances (Dickson et al., 1984; Murray and Bulstrode, 1996). Due to genetic predisposition, with a higher incidence of AIS in siblings (seven times) and offspring (three times) of scoliosis patients, children with a familial history of scoliosis should be carefully screened.

Various conservative treatments of AIS are available; however evidence of their efficacy and effectiveness is still unclear. Therefore, herein we summarize the present knowledge of two conservative treatments of AIS: exercise-based physical therapy and brace treatment. Since aesthetics is an important aspect in AIS, it will also be discussed.

Methods

PubMed, Google Scholar and PEDro databases were searched from inception until September 2014 using a predefined search strategy. Databases were searched for the following key words: "scoliosis"; ''spine'', "spinal deformities", "idiopathic"; "adolescent"; "etiology"; "treatment"; "aesthetics"; "exercise"; scoliosis-specific exercises; "physiotherapy"; rehabilitation"; and various combinations. Titles and abstracts of all articles mentioning at least one of the key words were reviewed. Included in this review were studies in the English language of any design or methodology dealing with conservative treatments of AIS. There were no search limitations. Reference lists of all articles retrieved in full were also searched.

Excluded were articles reporting on spinal surgery, alternative and integrative medicine or pharmacological interventions for scoliosis. Study protocol articles and articles without available full text were also excluded.

All published material was critically analyzed. We are aware that this traditional approach to narrative reviews has much more potential for bias than systematic reviews or meta-analyses; however, we endeavored to be inclusive and open-minded.

Results

Goals of AIS management

Adolescents with AIS experience no or a few complaints at a young age. Less than 35% of patients experience a certain degree of back pain (de Baat, 2012). In these patients back pain reduction is an initial and primary goal. Improvement of pulmonary function (vital capacity) is also crucial (de Baat, 2012; Weiss et al., 2006).

Because AIS is primarily a cosmetic deformity, it is important to identify the patient's thoughts as to their appearance. The self-perception of a patient and whether they are happy with their appearance is important in the decision-making process (Janicki and Alman, 2007). Treatment is based on the desire to change the shape of the back or prevent the deformity from worsening. Therefore, the primary aim of AIS management is to halt curvature progression.

According to a consensus by Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) experts, esthetic improvement is one of the main goals of scoliosis treatment. In a recent study on the importance of physical deformity in patients with AIS, "severity of deformity" consistently ranked as the most important clinical consideration when proposing surgical treatment (Zaina et al., 2009b).

There are many ways to evaluate and monitor esthetic changes such as including questionnaires (Asher et al., 2003; Sanders et al., 2007, 2003), general evaluations of the therapist (Buchanan et al., 2003) and high-tech instruments (Hackenberg et al., 2003; Liu et al., 2001; Negrini et al., 1995a, 1995b; Rigo, 1999; Theologis et al., 1993; Weisz et al., 1989, 1988), but none of the above have been used extensively or achieved a wide consensus (Zaina et al., 2009b).

Although many researchers have agreed that AIS patients with disturbed perceptions of body image experience greater problems in their psychological and social development (Lenssinck et al., 2005), most studies recorded no data as to the patient-centered outcomes of quality of life (QoL), back pain, psychological and esthetic issues (Lenssinck et al., 2005; Negrini et al., 2010; Romano et al., 2013). These and the other aforementioned issues have to be addressed in future well-designed and good quality studies with a long term follow up.

Treatment options

There are following major treatment options: a conservative approach involving mainly bracing and/or exercise therapy; and surgery. The choice of a specific approach is determined by the probability of spine deformity progression. Hassan et al. (Hassan and Bjerkreim, 1983) followed 100 patients with AIS who had been treated conservatively for a mean period of 10.6 years after completion of treatment. The majority of curves had increased; 70% between 16 and 20 years of age and 60% after age 20. The mean progression per year was 3° and 2° for single and double curves, respectively during the first four years after completion of treatment and 1° and 0.5°, respectively, in adulthood. Curves $> 40°$ significantly increased. It was concluded that curves $> 40°$, especially thoracic single curves, should be treated operatively in adolescence. Conservative treatment of smaller curves should be continued until age 20, subsequently followed up during early adult life.

Typically, exercise therapy without bracing and follow up is recommended for immature patients with mild curves of $< 25°$. Orthotic management is recommended for immature patients with progressing curves between 25° and 50° (Janicki and Alman, 2007). Moderate curves measure from a 25°–45° Cobb; severe curves measure $> 45°$Cobb angle (Romano et al., 2013). Surgical correction of AIS is considered for severe curves $> 45°$ in immature patients and for curves $> 50°$ in mature patients. Trunk deformity and balance are also taken into account in the decision-making process (Janicki and Alman, 2007). If scoliosis reaches a critical threshold, usually considered to be a 30° Cobb at the end-stage of growth, the risk of health problems in adulthood significantly increases. Difficulties include a decrease in QoL, disability, pain, increasing cosmetic deformity, functional limitations, occasional pulmonary problems and possible progression during adulthood (Janicki and Alman, 2007).

Exercise-based physical therapy

The first reviewed approach of conservative treatment is exercise-based physical therapy. It should be emphasized that currently physical therapy for scoliosis is not solely general exercises but rather specific exercises tailored individually for each individual patient. The following methods are designed to address the particular nuances of spinal deformity (de Baat, 2012; Weiss et al., 2006).

Scoliosis specific exercises (SSE). Scoliosis specific exercises (SSE) consist of individually adapted exercises taught to the patients at a scoliosis center. The patients are given a personalized exercise protocol according to his/her medical and physiotherapy evaluations. SSE include a series of specific movements intended to reduce the deformity. The exercises mechanically balance the musculature and other soft tissues of the spine. It is also believed that SSE can alter the motor control of the spine by affecting neurological changes that interact with each other. The overall aim of SSE is to reduce the progression of the scoliotic deformity and postpone or avoid braces (Romano et al., 2013).

There are four main SSE approaches to the treatment of AIS: The Dobosiewicz method; the side-shift method; the Schroth method, and the scientific exercise approach to scoliosis (SEAS) (de Baat, 2012; Weiss et al., 2006).

The Dobosiewicz technique. The Dobosiewicz technique was developed in 1979 and comprises active 3-dimensional auto-correction: a symmetrically positioned pelvis and shoulder girdle; primary curve mobilization towards the normal posture, with special emphasis on the kyphotization of the thoracic spine, carried on in closed kinematic chains; and active stabilization of the corrected position and instillation as postural habit (Dobosiewicz, 2008; Dobosiewicz et al., 2005). Fabian (Fabian, 2010) evaluated the effects of asymmetric breathing exercises according to the Dobosiewicz method on ventilation capability of lungs in girls with scoliosis. The research group consisted of 30 girls aged 9 to 18 with AIS. The spine's development was assessed by the Risser test and degrees of its ossification were marked. Body posture was evaluated at the beginning, a functional examination of the respiratory system was carried out and chosen parameters were marked. After 4–5 weeks, the tests were repeated. In between tests, the patients engaged in the special method of asymmetric breathing exercises. The authors found that therapeutic, asymmetric breathing exercises in accordance with the Dobosiewicz method, significantly improved the examined functional parameters of the respiratory system even over a short period of time (Fabian, 2010). These finding were confirmed by recent study from the same research group (Fabian and Rozek-Piechura, 2014). In this study authors found that asymmetric breathing exercise therapy by Dobosiewicz caused significantly higher improvement in maximal voluntary lung ventilation than symmetric remedial exercises.

In 2006 Dobosiewicz et al. (Dobosiewicz et al., 2006) retrospectively analyzed x-rays of 152 patients with AIS treated by Dobosiewicz method. Authors concluded that the radiological results demonstrated prevalent stabilization of scoliotic curves in children treated with this method.

The Schroth method. The Schroth method was developed by Katharina Schroth in 1921 (Thomson and Lehnert-schroth, 1992). The Schroth's 3-dimensional exercise therapy is based on sensorimotor and kinesthetic principles. The treatment program consists of postural corrections using proprioceptive and exteroceptive stimulation and mirror control in the sagittal plane together with specific breathing patterns. Katharina Schroth divided the trunk into three blocks which could be shifted against one another. She recognized that the pelvic and shoulder girdles are rotated in the same direction and that the middle block, the rib cage, shifts in the opposite direction (in the sagittal plane as well as the frontal plane). The more these blocks shift against each other, i.e. the more they deviate from a vertical line, the more they also rotate in the transverse plane. The body becomes less and less upright because all parts of the body which deviate from the vertical line are drawn downwards by gravity. For this reason, active extension is a prerequisite of successful exercising. An active elongation of the spine followed by curve correction and realignment of the three trunk segments in the coronal plane (deviated laterally) and completed by active derotation of the trunk segments. The explanations are always presented in detail to the patients, improving their self-confidence and convincing them of the value of practice, which subsequently encourages their motivation to perform the exercise.

Patients' motivation and cooperation are essential components in the Schroth method. The initial external force involved in every Schroth exercise is elongation. Using sensorimotor feedback mechanisms, the patients learn an individual correction routine. Subsequently, the patients use corrective active trunk muscle forces and learn to raise themselves as far as possible from a slumped position to an upright position. Subsequently, they need to maintain the corrected posture in daily living activities.

It has been shown that Schroth's rotational breathing leads to a significant increase in rib mobility and thus vital capacity (Weiss, 1991b) and sagittal respiratory excursion (Weiss, 1991a). In Otman et al's Turkish study (Otman et al., 2005), 50 patients (aged 14.15 $\pm$ 1.69 years) were treated by the Schroth's method, 5 days a week, 4 h a day for 6 weeks. Subsequently, patients continued with the same program at home. The Cobb angle, vital capacity and muscle strength of the patients were evaluated before treatment and after 6 weeks, 6 months and one year. The Cobb angle, measured on average 26.10° before treatment was 23.45° after 6 weeks, 19.25° after 6 months and 17.85° after one year ($p < 0.01$). Vital capacities were on average 2795 ml before treatment, reaching 2956 ml after 6 weeks, 3125 ml after 6 months and 3215 ml after one year ($p < 0.01$). Additionally, increased muscle strength and recovery of the postural defects in all patients were observed ($p < 0.01$) (Otman et al., 2005).

The side-shift program. The side-shift program employs active 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 then corrected in the side shift position (Fusco et al., 2011). This method was introduced in 1985 by Mehta (Mehta, 1985). Accordingly, the frequent repetition of a lateral shift of the trunk can stabilize and even correct early AIS. Den Boer et al. (den Boer et al., 1999) studied a group of 44 patients with AIS (mean age 13.6 years) with an initial Cobb angle between 20° and 32° who had received side-shift therapy (mean treatment duration 2.2 years). A group of 120 patients with braces (mean age 13.6 years) and an initial Cobb angle in the same range (mean brace treatment 3.0 years) was the historical reference group. Failure was defined as either as an increase of the Cobb angle > 5° within 4 months, a Cobb angle > 35° or a total increase of the Cobb angle > 10°. The chance of success was not significantly different between the side-shift and the brace groups, whether tested for efficiency (66% vs 68%) or efficacy (85% vs 90%). The difference in the mean progression of the Cobb angle for the respective groups was small. The authors concluded that side-shift therapy should be considered as an additional treatment for AIS with an initial Cobb angle between 20° and 32° (den Boer et al., 1999).

SEAS. SEAS is a system of customized exercises designed for treating scoliosis (Zarzycka et al., 2009). Increasing spinal stability is a primary therapeutic goal of the SEAS approach (Romano et al., 2008). SEAS originated approximately 30 years ago and since then has been continuously updated. The therapeutic strategy proposed by SEAS is based on improving reactions to the force of gravity and on enhancing the function of those muscles that have a major stabilizing vocation (Keller et al., 2007; Torell et al., 1985). The search and preservation of a physiological sagittal orientation in the scoliotic spine is also a main therapeutic goal. The practical application of SEAS includes postural control, spinal stability, postural rehabilitation, active self-correction (the first phase includes an awareness of a curve apex translation towards concavity in the frontal plane; the next phase includes an awareness of correction in the sagittal plane, and finally in the frontal and sagittal planes together), muscular endurance strengthening of the correct posture, development of balance reactions, neuromotor integration aerobic functioning and development of a positive body image (Romano et al., 2008). Therapy includes at least two weekly exercise sessions lasting 40 min each, performed at home. The patient becomes aware of pathology consequences and recovery possibilities for postural collapse. Active self-correction exercises aim to strengthen muscles and stabilize the spine.

Negrini et al. (Negrini et al., 2006) studied 69 patients at risk for brace treatment. They were divided into two groups with a one year follow up period. Among the SEAS group, bracing was prescribed in one out of twenty cases (6%), while in the control group treated with standard exercises, bracing was prescribed in one out of four cases (25%). This result is statistically significant and demonstrates how correctly designed exercises can guarantee scoliosis stability in most cases, thus avoiding more invasive treatments. Follow-up after two years of treatment in 38 patients confirmed the differences already highlighted at one year (10% SEAS vs. 27% other group), even with a reduction of the gap between the two treatments. The conclusion was that correct exercises may reduce the number of prescribed braces or at least delay their prescription.

Reviews on exercise-based treatment and comparison between methods. Several review papers evaluated and compared the efficacy of exercise-based treatment methods of AIS. A recent review by Romano et al. (Romano et al., 2013) compared SSE vs. no treatment, SSE plus another treatment vs. the other treatment, SSE vs. other treatments, SSE vs. usual physiotherapy, different SSE vs. each other, or different doses/schedules of SSE vs. each other. Results indicated that SSE as an adjunctive to other conservative treatments to increase the efficacy of these treatments in avoiding scoliosis progression. There is very low-quality evidence from a prospective controlled cohort study that SSEs structured within an exercise program can reduce brace prescription as compared with "usual physiotherapy" (many different kinds of general exercises according to the preferences of the single therapists within different facilities). No data were found as to the patient-centered outcomes of QoL, back pain, psychological and cosmetic issues.

Negrini et al. (Negrini et al., 2003) reviewed studies employing physical exercise as treatment for AIS (posture control, strengthening, mobilization, balance training). They found that physical exercise positively influences parameters such as breathing function, strength and postural balance in AIS patients.

Mordecai and Dabke (Mordecai and Dabke, 2012) reviewed 12 papers evaluating SEAS, physical therapy, resistance training, MedX Rotary Torso Machine, scoliosis intensive rehabilitation (postural balance), physiologic exercise programs, Schroth therapy, exercise, Milwaukee brace, electrical stimulation, side shift exercise, asymmetric trunk mobilization in strictly symmetric positions, and the LTX 3000 Lumbar Rehabilitation System providing axial lumbar spine unloading. All studies endorsed the role of exercise therapy in AIS but several shortcomings were identified: lack of clarity in the method of assessment of curve magnitude, poor record of compliance, and lack of outcome scores. Many studies reported "significant" changes in the Cobb angle after treatment, which were actually of small magnitude and did not take into account the reported inter or intra-observer error rate. All studies had poor statistical analysis and did not report whether the small improvements noted were maintained in the long term. Authors concluded that poor quality evidence make difficult to support the use of exercise therapy in the treatment of AIS.

Fusco et al's review (Fusco et al., 2011) tested autocorrection exercises, Schroth therapy, integrated scoliosis rehabilitation, SEAS, Dobomed (Dobosiewicz) method, side shift method, the Milwaukee method, and the MedX Rotatory Torso Machine, finding that physical exercise is an appropriate intervention for AIS, even though there is insufficient evidence supporting a specific exercise regimen. An additional review by Negrini et al. (Negrini et al., 2008) compared scoliosis intensive rehabilitation (Schroth method), extrinsic autocorrection-based methods (Schroth, side-shift), intrinsic autocorrection-based approaches (Lyon and SEAS), and no auto-correction. The authors found that all studies confirmed the efficacy of exercises in reducing the progression rate (mainly in early puberty) and/or improving the Cobb angles (near the end of growth). Exercises were also shown to be effective in reducing brace prescription.

Brace treatment

The second mode of conservative treatment is brace treatment (bracing). It appears that brace treatment may reduce the prevalence of surgery, restore the sagittal profile and influence vertebral rotation (de Baat, 2012; Weiss et al., 2006). Various studies have defined bracing as the application of external corrective forces to the trunk, usually achieved through rigid supports and occasional use of elastic bands (Coillard et al., 2003; Rigo et al., 2003). Braces should generally be worn full-time (at least 20 h per day) with treatment lasting from two to four years until cessation of bone growth (Brox et al., 2012; Katz and Durrani, 2001; Landauer et al., 2003; Lou et al., 2012; Rahman et al., 2005). The mechanical forces and the external and proprioceptive input due to bracing changes the unnatural loading, asymmetrical movements and neuromuscular control which facilitates proper spinal growth, neuromotor re-organization, and change of motor behaviors (Castro, 2003; Coillard et al., 2002; Lupparelli et al., 2002; Negrini and Marchini, 2007; Odermatt et al., 2003; Smania et al., 2008; Stokes et al., 2006; Weiss and Hawes, 2004). The indication for braces is progressing idiopathic scoliosis with curvature angles between 25° and 45° in skeletally immature patients.

There are many types of braces. The thoraco-lumbosacral orthosis (a TLSO brace) has been used since 1969 as an upper or lower back brace, depending on the curvature type. It is constructed out of plastic and available in different designs. The Boston brace (one of the TLSOs) is the most popular, used since 1975. It is an individually fitted plastic brace with mid to low-back corrective pads according to the patient's needs. The corrective pads place pressure on the curve, and correct scoliosis as well as helping maintain a proper posture. The plastic brace is fitted to the child's body and by applying three-point pressure to the curvature, prevents progression. It can be worn under clothing and is almost unnoticeable. The brace is usually worn 23 h a day and can be taken off to swim/play sports. This type of brace is usually prescribed for curves in the lumbar or thoraco-lumbar part of the spine.

The Cheneau TLSO brace is especially designed for use with Schroth therapy by utilizing large sweeping pads to push the body against its curve and into blown out spaces. The brace helps the patients to continue performing their exercises throughout the day. It is asymmetrical, used for patients with all degrees of severity and maturity and often worn 20–23 h a day (McAfee, 2002; Zarzycka et al., 2009).

Another type of Cheneau brace is the Rigo System Cheneau (RSC) (Rigo and Weiss, 2008), permitting sagittal normalization because of its physiological profile in the sagittal plane. Every trunk section is aligned to allow a normal sagittal profile. Its aim is to create forces to derotate the spine in the transversal plane, correct the lateral deviation in the frontal plane and normalize the sagittal profile of the spine. Breathing mechanics can be used to improve the thoracic structural flat back.

The Milwaukee brace or cervico-thoraco-lumbo-sacral orthosis (CTLSO) forces the patient to remain in an erect position, thus preventing curve progression during spinal growth. The Milwaukee brace is similar to the TLSO, but also includes a neck ring held in place by vertical bars attached to the body of the brace. It is usually worn 23 h a day, and can be taken off to swim and play sports. This type of brace is often prescribed for curves in the thoracic spine (Maruyama et al., 2011; McAfee, 2002).

The Charleston bending brace, worn only at night, keeps the spine in an over-corrected position while the patient sleeps and works mainly on the lumbar spine. This brace is also called a "nighttime" brace since it is only worn while sleeping. The Charleston back brace is molded to the patient while they are bent over to the side thus applying more pressure and bending the child against the curve. This pressure improves the corrective action of the brace.

Studies on bracing alone. van Rhijn et al. (van Rhijn et al., 2002) evaluated 50 AIS patients treated with a thoracic Boston brace. Bending radiographs showed more flexibility of the lumbar curves than that of the thoracic curves. However, after initial application of the brace, the mean lumbar correction in degrees was less than the mean thoracic correction. After brace treatment, a slight statistically significant increase in the mean lumbar curve was found, but with no significant change (positive result) in the mean thoracic curve. Their findings suggest that a thoracic Boston brace does not stop progression of the lumbar curve but stops progression of the thoracic curve. Although the lumbar curve was more flexible, it seemed to respond less to conservative treatment.

Several studies have shown that the Charleston nighttime brace is effective in controlling curve progression (Gepstein et al., 2002; Howard et al., 1998; Price et al., 1997; Trivedi and Thomson, 2001). Curves must be in the 20°—40° range and the apex of the curve needs to be below the level of the shoulder blade. In addition, the psychosocial effects of bracing on the AIS population are significant and by wearing the nighttime-only brace may improve patient acceptance and compliance with treatment, although this has not been shown (Climent and Sanchez, 1999; Zhang et al., 2011).

Brace plus exercise studies. A retrospective observational study by De Giorgi et al (De Giorgi et al., 2013) described an intervention of 48 girls with documented progressive AIS treated with the Cheneau brace. The average curve angle measured in Cobb degrees decreased from $27^\circ \pm 6.7^\circ$ at the beginning of treatment to $7.6^\circ \pm 7.4^\circ$ wearing the brace (72% of correction), and to $8.5^\circ \pm 8.6^\circ$ (69% of correction) at the end of treatment. No patient needed surgery. The authors concluded that conservative treatment with the Cheneau brace and physiotherapy was effective in halting scoliosis progression in 100% of patients (De Giorgi et al., 2013).

Rivett et al. (Rivett et al., 2014) evaluated the effect of the RSC brace and a specific exercise program on AIS curvature. Fifty-one girls, aged 12—16 years, with Cobb angles of 20°—50° participated in the study. Subjects were divided into two groups: a compliant group who wore the brace ≥ 20 h daily and exercised three or more times a week and a non-compliant group who wore the brace > 20 h a day and exercised less than three times a week. Cobb angles, vertebral rotation, scoliometer readings, peak flow, QoL and personality traits were compared between groups. The results showed that the compliant group significantly improved versus the non-compliant in all outcome measures. The compliant group showed improvement in the Cobb angle ($10.19^\circ \pm 5.5$). Spinal deterioration ($5.52^\circ \pm 4.3$) was significantly higher ($p < 0.0001$) than in the non-compliant group. Compliant subjects had a significantly better QoL than the non-compliant subjects ($p = 0.001$). The authors concluded that good compliance of the RSC brace and a specific exercise regime resulted in a significant improvement in curvatures; the poor compliance resulted in AIS progression/deterioration.

In a study of 68 AIS patients treated with brace (Zaina et al., 2009a) was found that after 2.7 years of wearing brace patients that performed exercises (according the specific protocol or other exercises) showed no change in Cobb angle, whereas in patients that did not performed exercises Cobb angle increased. Authors concluded that exercises can help reduce the correction loss in brace weaning for AIS.

In a recent prospective cohort study of 73 patients who satisfied Scoliosis Research Society criteria on the effectiveness of bracing for AIS (Negrini et al., 2014) were treated with brace, performed exercises and were managed according to SOSORT criteria. Results of the study showed that bracing in patients who satisfy SRS criteria is effective in reducing progression, and preventing surgery. Combining bracing with exercises according to SOSORT criteria increases treatment efficacy.

Reviews on efficacy of bracing. A meta-analysis by members of the Prevalence and Natural History Committee of the Scoliosis Research Society collected data from twenty studies of 1910 patients who had been managed with bracing (1459 patients), lateral electrical surface stimulation (322 patients), or observation (129 patients) because of idiopathic scoliosis (Rowe et al., 1997). Three variables — type of treatment, level of maturity, and criterion for failure — were analyzed to determine which had the greatest impact on the outcome. The authors also examined the effect of the type of brace used and duration of bracing on the success of treatment. The number of treatment failures in each study was determined by calculating the total number of patients with an unacceptable progression of the curve (as defined in the study), who could not comply with or tolerate treatment, or who had undergone an operation. The percentage of patients who completed a given course of treatment without failure, adjusted for the sample sizes of the studies in which that treatment was used, yielded the weighted mean proportion of success for that treatment. The weighted mean proportion of success was 0.39 for lateral electrical surface stimulation, 0.49 for observation only, 0.60 for bracing for 8 h per day, 0.62 for bracing for 16 h per day, and 0.93 for bracing for 23 h per day. The 23-h regimens were significantly more successful than any other treatments ($p < 0.0001$). The difference between the 8 and 16-h regimens was not significant. The weighted mean proportion of success for the six types of braces was 0.92, with the highest proportion (0.99) achieved with the Milwaukee brace (Rowe et al., 1997).

In Lenssinck et al's systematic review (Lenssinck et al., 2005), the effectiveness of bracing, electrical surface stimulation, exercises and behavioral treatment for AIS, was evaluated. Based on 13 studies, the authors concluded that the effectiveness of bracing and exercising is promising, but as yet not established.

Negrini et al. (Negrini et al., 2010) evaluated the efficacy of bracing in patients with AIS in a Cochrane systematic review. Using strict inclusion criteria, only two studies were included in the review. The authors found very low quality evidence from one prospective cohort study of 286 girls that a brace curbed curve progression at the end of growth was more effective than observation and/or electrical stimulation. Also, in a randomized controlled trial of 43 girls, low quality evidence was found that a rigid brace is more effective than an elastic one (SpineCor) at curbing curve progression when measured in Cobb degrees, however there were no significant differences between the two groups in the subjective perception of daily difficulties associated with wearing the brace.

Conclusions

This review confirmed that there is still no unanimous consensus among researchers as to the effectiveness of one conservative treatment approach over the other. It is commonly accepted that the most appropriate treatment for each patient should be individually chosen and based on parameters such as the Cobb angle, age at diagnosis, potential of spinal growth (by clinical and radiological markers of growth and maturity), motivation and compliance to treatment of the patient.

Bracing, regardless of its type, is probably the most effective conservative treatment of AIS, although additional high quality studies are needed to solidify this conclusion (Lenssinck et al., 2005; Negrini et al., 2010; Rowe et al., 1997).

Exercise-based physical therapy is also an appropriate intervention for AIS. There is initial evidence that exercises may be efficient in reducing the progression rate (mainly in early puberty) and/or improving the Cobb angles (near the end of growth). Exercises were also shown to be effective in reducing brace prescription. There are some common features in most exercise based methods. The scoliosis specific exercise incorporates correcting therapeutic exercises, special breathing techniques and re-education of the neuromuscular system. The common basis of all exercise methods is passive and active correction of the curvatures in coronal, sagittal and horizontal planes in combination with asymmetric breathing exercise. Another primary principal of scoliosis specific exercise is using active elongation of the spine. Using sensorimotor feedback mechanisms, the patients learn an individual correction routine (active self-correction). With treatment progression, patients need to maintain the corrected posture in daily living activities. The motivation and cooperation are essential components in those methods.

Moreover, exercise-based physical therapy is the only approach assisting in improving the respiratory function. This review demonstrates a growing interest in exercise-based physical therapy and substantiates the need among health professional that treat AIS to clarify the effectiveness of exercise-based physical therapy. Exercise-based physical therapy, if correctly administered most probably can prevent a worsening of the curve and occasionally can result in not having to brace the patient at all.

Combining bracing with exercise according to the SOSORT increases treatment efficacy and presents better results compared to a single treatment (braces or exercises) (Negrini et al., 2014). Bracing and exercise is recommended for primary curve angles between 25° and 40°, especially when the Risser sign is between 0 and 2. During brace treatment, specific exercises are recommended in order to avoid secondary effects of bracing, such as spinal stiffness and muscular strength loss, as well as improve brace efficacy (active correction on the side of passive correction of the spine).

Most reviewed studies had methodological flaws, were of poor quality and low power. Therefore, well-designed and good quality studies with a long term follow up are required to assess the effectiveness of different conservative methods in treating AIS.

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