Research Report

Effect of Bracing and Other Conservative Interventions in the Treatment of Idiopathic Scoliosis in Adolescents: A Systematic Review of Clinical Trials

Background and Purpose. Many conservative treatments are available for adolescents with idiopathic scoliosis, but the evidence for their accepted use is still unclear. The purpose of this study was to evaluate the effectiveness of braces and other conservative treatments of idiopathic scoliosis in adolescents by systematically reviewing the literature. Methods. The literature was searched in the PubMed, CINAHL, Cochrane, and PEDro databases. Studies were selected if the design was a randomized clinical trial or a controlled clinical trial, if all patients had an idiopathic scoliosis, if all patients were less than 18 years of age during the intervention, and if the type of intervention was a conservative one. Two reviewers independently assessed the methodological quality using the Delphi list and performed data extraction. Analysis was based on the levels of evidence. Results. Thirteen studies met the final inclusion criteria, showing a wide range of interventions such as bracing, electrical surface stimulation, and exercises. Discussion and Conclusion. The authors conclude that the effectiveness of bracing and exercises is not yet established, but might be promising. They found no evidence of the effectiveness of electrical stimulation. [Lenssinck M-LB, Frijlink AC, Berger MY, et al. Effect of bracing and other conservative interventions in the treatment of idiopathic scoliosis in adolescents: a systematic review of clinical trials. *Phys Ther.* 2005;85: 1329–1339.]

Key Words: *Back pain, Bracing, Evidence-based practice, Exercise movement techniques, Idiopathic scoliosis, Immobilization, Pediatrics, Rehabilitation, Scoliosis, Spinal curvatures, Systematic review, Treatment outcome.*

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According to the Scoliosis Research Society, *scoliosis* is a lateral deviation of the normal vertical lines of the spine greater than 10 degrees or an in-potency, 3-dimensional–form deviation from the spine, which is accompanied by lateral curvature of the spine with or without a change in the sagittal and axial surfaces.[1] The idiopathic form is a scoliosis with no clear underlying cause.[2] The age of the patient when scoliosis is first identified determines the classification of idiopathic scoliosis. Adolescent idiopathic scoliosis is found between 10 years of age and skeletal maturity. This form accounts for the majority of cases of idiopathic scoliosis.[2]

The prevalence of adolescent idiopathic scoliosis is 2% to 3% of children between 10 and 16 years of age. The ratio of girls to boys is equal in adolescents with spinal curvatures of 10 degrees. With spinal curvatures greater than 30 degrees, the ratio increases to 10 girls for every boy, and the scoliosis in girls tends to progress more often. Only 10% of adolescents diagnosed with scoliosis have curve progression requiring medical intervention.[2] More than 90% of diagnosed cases require only observation with repeated examination during the growing years.[1,3]

Treatment of idiopathic scoliosis is indicated for patients with spinal curvatures greater than 20 degrees.[4] Possible consequences of untreated idiopathic scoliosis in adults are social isolation, limited job opportunities, and lower marriage rates.[2] There is no indication that life-threatening effects occur in adolescent idiopathic scoliosis.[5]

Treatment strategies for idiopathic scoliosis include conservative treatment and surgery. There is consensus about surgical treatment in a minority of patients with spinal curvatures greater than 45 degrees, especially in patients with severe rotational abnormalities.[3] The vast majority of adolescents with idiopathic scoliosis receive conservative care. The most common interventions used in conservative treatment of adolescent idiopathic scoliosis are bracing, electrical stimulation, and exercise therapy.[1,3,6] Overall, the rationale for the choice of type of conservative care is unclear. Recently, the use of bracing to alter the progression of scoliosis or reduce surgery rate has been questioned.[7–9] The literature shows that bracing does not seem to alter the natural history of progressive idiopathic scoliosis or to reduce surgery rate.[7,9]

In a study by Fällström et al,[10] more than 50% of patients with adolescent idiopathic scoliosis initially denied their diagnosis. Several authors[10–12] reported that adolescents with scoliosis seem to have a poorer body image perception compared with a control group without scoliosis. Many researchers[11–13] agreed that people with scoliosis experience problems in their psychological and social development. It appears that quality of life, although measured differently in various studies, is affected not only by the presence of but also by the treatment (especially bracing) for adolescent idiopathic scoliosis.[11,13]

Although the majority of adolescents with idiopathic scoliosis are treated conservatively for years with interventions that have a major impact on their quality of life (eg, bracing), no systematic review concerning the effectiveness of conservative care in adolescent idiopathic scoliosis exists. One review[14] has been done, but it cannot be regarded as valid according to the accepted standards of the Cochrane Collaboration.[15] In that review, 20 studies were included, of which just 1 was a controlled trial; all of the other studies were retrospective patient series or case studies. No other reviews on this topic exist. Therefore, we believe that the current evidence for conservative treatment in patients with idiopathic scoliosis is insufficient. The aim of this study

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Dr Bierma-Zeinstra and Dr Verhagen designed the study. Ms Lenssinck and Ms Frijlink provided data collection and analysis and wrote the draft manuscript. Dr Berger and Ms Verkerk were involved as content experts. Dr Verhagen provided project management and facilities/equipment. All authors critically read the manuscript.

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was to evaluate the effectiveness of braces and other conservative interventions used in the treatment of adolescent idiopathic scoliosis by systematically reviewing the literature.

Method

Literature Search

The literature was collected using the Cochrane,[15] PubMed,[16] CINAHL,[17] and PEDro[18] databases from inception to December 2003. With the search strategy for identifying randomized controlled trials (RCTs) as described by Robinson and Dickersin,[19] we used the following key words or combination of words to identify the study population and intervention: "braces," "exercise," "exercise movement techniques," "exercise therapy," "exertion," "human activities," "musculoskeletal manipulations," "orthotic devices," "physical therapy techniques," "scoliosis," "spinal curvatures," and "treatment." Two junior reviewers (ML and AF) and 1 senior and experienced reviewer (AV) independently conducted this search. First, titles and abstracts of identified published articles were reviewed.

Selection

The following criteria were used to select studies:

1. The study had to be designed as an RCT or as a controlled clinical trial (CCT). In this review, a study was considered to be a CCT when there was an intervention group, 1 or more control groups (groups not created by randomization), and a baseline measurement and an outcome measurement.

2. Patients were diagnosed with idiopathic scoliosis.

3. The age of the patients was less than 18 years.

4. The treatment included the use of a conservative intervention (which was defined to exclude surgical and pharmacological interventions).

There were no language restrictions. Abstracts, conference reports, and unpublished studies were excluded. For the final selection of the studies, a selection form was used. The 3 reviewers (ML, AF, and AV) independently applied criteria on the full text of all articles that had passed the first eligibility screening.

Quality Assessment

Two reviewers (ML and AF) independently assessed the methodological quality of the studies using the Delphi list[20] followed by a consensus meeting. The Delphi list is a generic criteria list for quality assessment of RCTs and CCTs for conducting systematic reviews developed by Delphi consensus[20] (Tab. 1). *Quality* was defined as "the likelihood of the trial design to generate unbiased results that are sufficiently precise and allow application in clinical practice."[21(p651)] We choose to use the Delphi list because this criteria list appeared to be valid and reliable and is often used in systematic reviews on musculoskeletal disorders.[21] The Delphi list consists of 9 items. All items have a "yes," "no," or "don't know" answer option. A score of 1 point is given to each item assessed with a "yes" answer. Equal weights were applied, resulting in a maximum score of 9 points for the overall methodological quality score. For feasibility reasons, the assessment was not performed under masked conditions.[22] When disagreement between reviewers concerning the scoring of an item persisted, the third reviewer (AV) made the final decision.

Data Extraction

For each study, a data extraction form was used to make a summary of the study characteristics and outcome measures used. Two reviewers (ML and AF) independently collected the data.

Data Analysis

A quality score was calculated using the Delphi items that scored positive, resulting in a score ranging from 0 to 9. With reference to the influence of different scales used to assess quality and its effect on the conclusion of the systematic review,[23] we used 2 different ways of defining "high-quality" studies. We defined *high quality* as: (1) presenting a concealed randomization procedure and adequate blinding or (2) a positive score on 5 or more Delphi items (50% of the maximum attainable score). This way, we tried to minimize the possibility that our conclusion was flawed by misclassification.

We calculated relative risks (RRs) with 95% confidence interval (CIs) for dichotomous variables. Relative risk is a ratio and can vary between 0 and infinity, where an RR of 1 represents no difference between the 2 interventions under study. An RR less than 1 represents a better outcome for the first-mentioned comparison group, and an RR higher than 1 represents a better outcome for the second-mentioned comparison group (often the control group). Statistical pooling was limited to clinically homogeneous studies for which the study populations, interventions, and outcomes were considered to be similar by the reviewers. In case of clinical heterogeneity, or if data were lacking, we analyzed the results using a rating system with levels of evidence.[24] The rating system consisted of 5 levels of scientific evidence, based on the quality and the outcome of the studies: (1) strong evidence—consistent findings among multiple (2 or more) high-quality RCTs, (2) moderate evidence—consistent findings among 1 high-quality RCT and multiple (2 or more) low-quality RCTs or CCTs, (3) limited evidence—1 low-quality RCT or CCT, (4) conflicting

Table 1.
Overview of Methodological Quality: Delphi List

	Randomization	Concealed Allocation	Baseline Similarity	Eligibility Criteria	Outcome Assessor Masked	Care Provider Masked	Patient Masked	Data Presentation	Intention-to-Treat Analysis	Sum Score
Athanasopoulos et al[27]	Yes	No	Yes	Yes	DK[a]	DK	DK	Yes	Yes	5
el-Sayyad and Conine[33]	Yes	DK	Yes	Yes	Yes	No	No	Yes	No	5
den Boer et al[29]	No	No	Yes	Yes	No	No	DK	Yes	Yes	4
Birbaumer et al[28]	No	No	Yes	No	DK	No	No	Yes	Yes	3
Carman et al[30]	No	No	Yes	Yes	DK	DK	DK	Yes	No	3
Gepstein et al[35]	No	No	DK	Yes	DK	DK	DK	Yes	Yes	3
Nachemson and Peterson[38]	No	No	DK	Yes	DK	No	No	Yes	Yes	3
Dickson and Leatherman[32]	Yes	DK	Yes	No	DK	DK	DK	No	DK	2
von Deimling et al[31]	No	No	DK	No	DK	DK	No	Yes	Yes	2
Fiore et al[34]	No	No	Yes	No	No	No	No	No	No	1
Mulcahy et al[37]	No	No	No	DK	No	No	No	Yes	No	1
Schlenzka et al[39]	No	No	Yes	No	DK	DK	DK	No	No	1
Minami[36]	No	No	DK	No	DK	No	No	No	DK	0

[a] DK = "don't know."

evidence—inconsistent findings among multiple RCTs or CCTs, and (5) no evidence—no RCTs or CCTs found. Findings were regarded as consistent when more than 75% of the studies came to the same conclusion.[25]

Results

Study Selection

A total of 436 titles and abstracts were found in the literature search. The Cochrane database brought 1 new title and abstract, but the full text of the article was not retrievable[26] (Figure). After eligibility screening, 13 articles (3 RCTs and 10 CCTs) were included in the systematic review,[27–39] including 1 CCT in which the data of the control group were gathered retrospectively.[29]

Methodological Quality

There was disagreement between the 2 independent reviewers in 12% of the criteria. After the consensus meeting, no disagreement persisted. The quality score varied between 0 and 5 points out of the maximum of 9 points. The results of the methodological assessment are presented in Table 1.

No studies performed a concealed randomization procedure, and only 1 study[33] performed blinded outcome assessment. Therefore, no studies fulfilled the first criterion of high quality (concealed randomization and adequate blinding). Only 2 studies[27,33] achieved a quality score of 5 or higher and, therefore, were considered to be high quality according to the second criterion. The most prevalent shortcomings of the trials were: allocation procedures not randomized and no attempt to mask the outcome assessor.

Study Characteristics

Table 2 presents a short description of the study design, study population, intervention, control group, outcome measures, and quality score for each article included in the systematic review. None of the studies described what was considered idiopathic scoliosis. Only the characteristics of the scoliosis were sometimes described in the inclusion and exclusion criteria of the studies.

The studies showed a wide range of interventions (eg, bracing, electrical surface stimulation, exercises, behavioral treatment). Often, a combination of interventions was compared with another combination of control interventions. In all except 2 studies,[28,32] a brace was part of 1 or both interventions. Four studies[29,33,38,39] evaluated the effect of a brace by comparing it with no treatment, exercises, or electrical stimulation. The effect of training as add-on therapy upon wearing a brace was evaluated in 2 studies.[27,30] Different braces were compared in 5 studies.[31,34–37] In the remaining 2 studies, the effect of behavioral treatment was compared with no

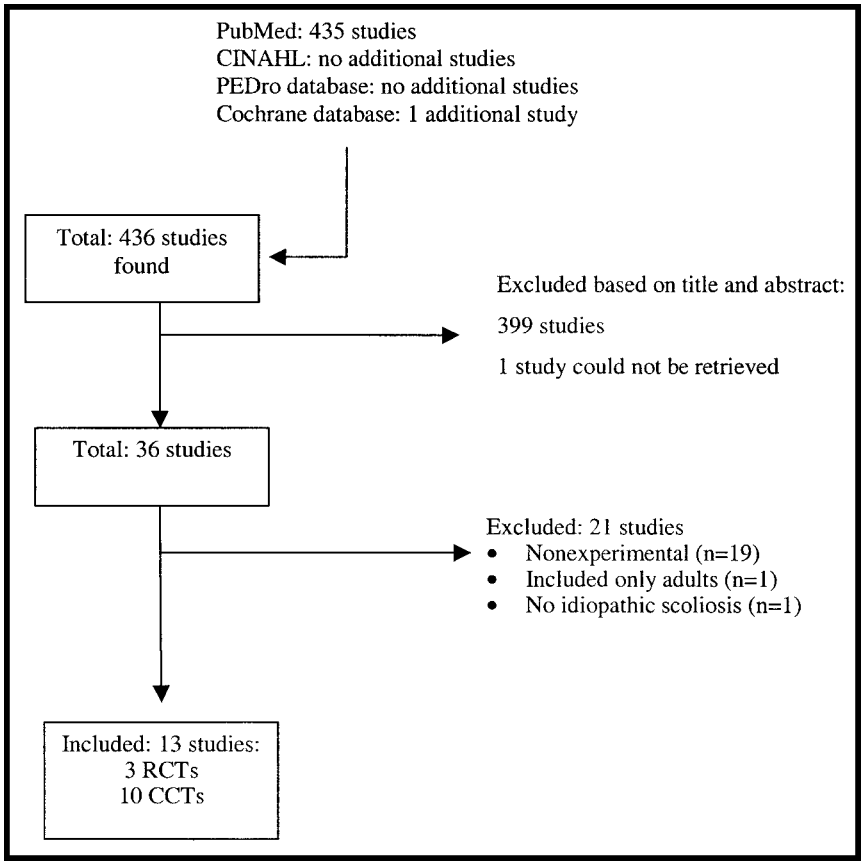

Figure.
Trial flow chart. RCT=randomized controlled trial, CCT=controlled clinical trial.

treatment[28] and Cotrel traction was compared with exercises.[32] Treatment duration varied enormously between 8 days and 7.8 years, but often the treatment duration is unclear especially in studies of bracing. Optimal duration of treatment is unknown.

The size of the study groups ranged from 4 to 129 subjects. In 9 studies, 1 or more study groups were smaller than 25 patients, indicating an overall low power. The effect of therapy was mostly measured by degrees of change in spinal curvature or Cobb angle. This measure is regarded the best determination of the curve magnitude, which is derived from a standard posteroanterior standing radiograph of the spine.[2] Other outcome measures were pulmonary function, "rumpfüberhang" (or torso overhang), rotation component of the spine, and loads on instrumented pads. The follow-up period appeared to be short, or there was no follow-up. Only 4 studies[28,34,36,37] had a follow-up period ranging from 4 to 24 months.

One study[29] was ambispective, meaning that the researchers used a retrospective reference group as a control group, while the remainder of this study was prospective. This ambispective study was included as a CCT because full descriptions of the control and intervention groups were given. Both groups were similar at baseline regarding age at onset of treatment and initial spinal curvature. Six studies[29–31,35,37,38] presented success or failure rates or surgery rates, which allowed us to calculate between-group differences.

Analysis

The studies were not considered clinically comparable with regard to interventions, study populations, and treatment duration. Because of this heterogeneity, we refrained from statistical pooling. Using a threshold of 50% of the maximum available score on the Delphi list (5 or more positive items), only 2 studies were considered of acceptable quality. Three subgroups concerning different interventions could be found: braces, exercises, and electrical stimulation. Table 3 presents the results of the included studies.

Bracing

Versus no treatment. In one low-quality study,[38] an underarm plastic brace was compared with no treatment, and the researchers found a significant reduced failure rate in favor of the brace group of approximately 50% to 80%.

As add-on treatment. Concerning the effectiveness of a Milwaukee brace as an add-on treatment to exercises, 1 high-quality study[33] showed no additional effect of bracing, but no data were available to be able to calculate RRs. In addition, the mean change of the spinal curvature (pretreatment-posttreatment) in all groups was small ($<5°$).

Versus exercises. One low-quality study[29] evaluated the effectiveness of a brace compared with side shift exercises and showed no difference.

Versus electrical stimulation. Two low-quality studies[38,39] compared bracing and electrical stimulation. Nachemson and Peterson[38] found in their low-quality study significant differences in favor of an underarm plastic brace of approximately 40% to 80%, and Schlenzka et al[39] mentioned an 11% difference in favor of the Boston brace but provided no data to calculate RRs.

Table 2.
Study Characteristics[a]

Study	Design	Study Sample	Intervention	Outcome Measures	Details
Athanasopoulos et al[27]	RCT QS: 5	Scoliosis: curves 20°–50° Primary curve in thoracic region to the right N=40 Mean age: 13.5 y (I), 13.6 y (C) Mean curve: 27.4° (I), 29.5° (C) Girls only	I: Boston brace + training, n=20, mean bracing 0.3 y, 2-mo training period, 4 times a week, 30 min C: Boston brace, n=20, mean bracing 0.24 y, 2-mo measurements	Pulmonary function Aerobic capacity	Scoliosis remained unaffected during 2-mo training period
el-Sayyad and Conine[33]	RCT QS: 5	Scoliosis: curves 15°–45° N=30 Mean age: 12.1 y (I), 11.8 y (C1), 10.8 y (C2)	I: exercise program + Milwaukee brace, n=8, bracing minimal, 18 h/d, 12 wk C1: exercise program, n=10 C2: exercise program + electrical stimulation, n=8 Exercise program: instruction for daily activity, home exercise, 3 times a week physical therapy for 12 wk	Angle of spinal curve	Loss: n=4; 2 (I), 2 (C2)
den Boer et al[29]	CCT, ambispective QS: 4	Scoliosis: Cobb angle 20°–32° N=164 Mean age: 13.6 y (I, C)	I: side shift therapy, n=44, mean treatment duration=2.2 y, 10–12 times a week, 30 min, follow-up every 4 mo C: brace therapy, n=120, mean treatment duration=3 y, bracing 23 h/d	Cobb angle (degrees)	Failure: nonadherence, or progression Cobb angle >5° in 4 mo, or progression >10° during treatment, or Cobb angle >35°
Birbaumer et al[28]	CCT QS: 3	Scoliosis: curves 15°–38° N=19 Mean age: 12.6 y (I), 10.7 y (C) Mean curve: 25.8°	I: behaviorally posture-oriented training, acoustic signal when patient assumed incorrect posture, n=15, mean wearing time=15.88 h/d, treatment period=8–39 mo C: Noncompliers, n=4, mean wearing time=4.23 h/d (SD=7.88), treatment period=4–13 mo	Cobb angle (degrees)	Follow-up 4–8 mo posttreatment, n=5
Carman et al[30]	CCT QS: 3	Scoliosis: right thoracic, left lumbar curves of <60° Eligible N=37 Mean age: 13.3 y (I), 12.4 y (C) Mean curve: 39.0° (I), 37.0° (C)	I: Milwaukee brace + exercises, n=21 C: Milwaukee brace, n=16 Bracing for 23 h/d	Spinal curvature (degrees)	Loss I: n=6 surgery, n=3 other brace Loss C: n=3 surgery, n=1 other brace
Gepstein et al[35]	CCT QS: 3	Scoliosis: adolescent type, single curvature N=122	I: Charleston bending brace, n=85, bracing at least 8 h at night C: thoraco-lumbo-sacral orthosis, n=37	Spinal curvature, success rate, surgery rate	Adherence: 80% Only complete case analysis, no information on dropouts

Table 2.
Continued

Study	Design	Study Sample	Intervention	Outcome Measures	Details
		Age range: 10–16 y Mean age: 12.8 y (I), 13.0 y (C) Mean curve: 30.4°	Bracing for 18–22 h/d		
Nachemson and Peterson[38]	CCT QS: 3	Scoliosis: single curve, apex between T8 and L1 N=286 Mean age: 12.6 y Girls only	I: underarm plastic brace, n=111, bracing for at least 16 h/d C1: night-time electrical surface stimulation, n=46 C2: no treatment, n=29 Treatment duration for all groups until maturity or until failure of treatment	Cobb angle (degrees)	Loss: n=39 (13.6%) I: n=23 C1: n=7 C2: n=9
Dickson and Leatherman[32]	RCT QS: 2	Scoliosis: adolescent onset N=20 Mean age: 13.1 y (I), 13.6 y (C) Mean curve: 42° (I), 40° (C)	I: traction, n=?, fixed traction at night, auto-elongation traction during the day, treatment duration=8 d C: exercises, n=?, exercises 2 times a day, 1 hr, 20 exercises, 15 times, treatment duration=8 d	Spinal curvature (degrees)	
von Deimling et al[31]	CCT QS: 2	Scoliosis: no information N=47 Mean curve: 33.3° (I), 30.5° (C)	I: Chêneau corset, n=21, mean follow-up=4 y C: Milwaukee brace, n=26, mean follow-up=7.8 y	Cobb angle (degrees) "Rumpfüberhang"	Correlation "rumpfüberhang" and Cobb angle is low (±0.3)
Fiore et al[34]	CCT QS: 1	Scoliosis: lumbar or thoracolumbar curve N=30 Mean age: 14.4 y (I), 14.0 y (C) Mean curve: 30° (I), 23° (C)	I: 3-valve orthosis, n=15, mean treatment duration=11.1 mo C: Boston brace, n=15, mean treatment duration=11.8 mo	Spinal curvature correction, rotation component (degrees)	Follow-up: 12–17 mo
Mulcahy et al[37]	CCT QS: 1	Scoliosis: no information N=37 Mean age: 14.5 y (I), 12.7 y (C) Girls only	I: Milwaukee brace, throat mold design, n=7 C: conventional Milwaukee brace, n=30	Loads on instumented pads (kilograms) Spinal curve (degrees)	3 patients changed from C group to I group Follow-up seems to be 6 mo
Schlenzka et al[39]	CCT QS: 1	Scoliosis: no information N=40 Mean age: 10.9 y (I), 11.9 y (C) Mean curve: 26° (I), 34° (C)	I: lateral electrical surface stimulation, n=20, less than 8 h/d, at night, mean treatment duration=1.5 y C: Boston brace, n=20, mean treatment duration=2.2 y	Cobb angle (degrees)	Loss I: n=5 surgery, n=9 Boston brace
Minami[36]	CCT QS: 0	Scoliosis: no information N=509 Mean age: 12.7 y	I: Milwaukee brace C: thoraco-lumbo-sacral orthosis, Boston-Milwaukee brace Mean treatment duration for all groups=3.3 y	Spinal curvature (degrees)	Follow-up 24 mo posttreatment, n=60, change: −1.6°

[a] Degrees with "−" sign indicate a decrease of the spinal curvature; degrees with "+" sign indicate an increase of the spinal curvature. Failure is >5 degrees progression of spinal curvature. RCT=randomized controlled trial, CCT=controlled clinical trial, QS=quality score, I=intervention, C=control.

Table 3.
Results of the Studies Included in Systematic Review[a]

Study	Intervention	Results	RR as Calculated by the Reviewers
Athanasopoulos et al[27]	I: Boston brace + training, n=20 C: Boston brace, n=20	I: increased ability to perform aerobic work 48.1% C: decreased ability to perform aerobic work 9.2%	
el-Sayyad and Conine[33]	I: exercise + Milwaukee brace, n=8 C1: exercise, n=10 C2: exercise + electrical stimulation, n=8	I change: −4.05° C1 change: −2.93% C2 change: −3.76°	
den Boer et al[29]	I: side shift therapy, n=44 C: brace therapy, n=120	I change: +2.6°, failure=34.1% C change: −1.5°, failure=31.7%	Failure I versus C: RR=1.08 (0.66–1.75), meaning no differences in failure rate between I and C
Birbaumer et al[28]	I: behaviorally posture-oriented training, n=15 C: noncompliers, n=4	I change: −6.14° C change: +8.20°	
Carman et al[30]	I: Milwaukee brace + exercises, n=21 C: Milwaukee brace: n=16	I (n=12) change: −3.7° C (n=12) change: −3.4°	Surgery I versus C: RR=1.52 (0.45–5.18), meaning no difference in surgery rate between I and C
Gepstein et al[35]	I: Charleston bending brace, n=85 C: thoraco-lumbo-sacral orthosis, n =37	Success: I=80%, C=81% Surgery: I=12.3%, C=11.8% Failure: I=7.4%, C=5.4%	Surgery I versus C: RR=1.09 (0.36–3.25), meaning no difference in surgery rate between I and C Failure I versus C: RR=1.31 (0.28–6.17), meaning no difference in failure between I and C
Nachemson and Peterson[38]	I: underarm plastic brace, n=111 C1: night-time electrical surface stimulation, n=46 C2: no treatment, n=129	Failure: I=15%, C1=48%, C2=45%	Failure I versus C1: RR=0.3 (0.16–0.56), meaning failure rate in I significantly lower compared with C1 Failure I versus C2: RR=0.28 (0.16–0.48), meaning failure rate in I significantly lower compared with C2 Failure C1 versus C2: RR=0.93 (0.62–1.41), meaning no difference in failure rate between both control groups
Dickson and Leatherman[32]	I: traction, n=? C: exercises, n=?	I change: standing curve in cast +3°, curve on lateral bending +1° C change: standing curve in cast +1°, curve on lateral bending −4°	
von Deimling et al[31]	I: Chêneau corset, n=21 C: Milwaukee brace, n=26	I change: +1.2°, 19% success C change: +2.9°, 3.8% success	Success I versus C: RR=0.84 (0.67–1.05), meaning no difference in success rate between I and C
Fiore et al[34]	I: 3-valve orthosis, n=15 C: Boston brace, n=15	I angle change: −6° C angle change: −3°	
Mulcahy et al[37]	I: Milwaukee brace, throat mold design, n=7 C: conventional Milwaukee brace, n=30	I: 42.85% remain in brace, 14.3% surgery C: 36.7% remain in brace, 16.7% surgery	Surgery I versus C: RR=0.86 (0.12–6.23), meaning no difference in surgery rate between I and C
Schlenzka et al[39]	I: lateral electrical surface stimulation, n=20 C: Boston brace, n=20	I (n=6) change: posttreatment +5°, follow-up (2.3 y) +8° C change: posttreatment −6°, follow-up (2.7 y) −2°	
Minami[36]	I: Milwaukee brace C: thoraco-lumbo-sacral orthosis, Boston-Milwaukee brace	No information about results of different treatment groups; results in curve and age groups	

[a] Degrees with "−" sign indicate a decrease of the spinal curvature; degrees with "+" sign indicate an increase of the spinal curvature. Failure is >5 degrees progression of spinal curvature. RR=relative risk (95% confidence interval); RR <1 means effect in favor of first-mentioned comparison. I=intervention, C=control.

Comparison of different types of bracing. Five studies,[31,34–37] all of low quality, evaluated the effectiveness of different braces. No data were provided for 1 study,[36] and small changes of the spinal curve were found in both treatment and control groups in another study.[34] In 3 studies,[31,35,36] we were able to calculate RRs and no significant differences were found in favor of a certain brace.

Exercise

One low-quality study[28] evaluated the effectiveness of exercises between subjects who adhered and those who did not adhere to the exercise program ("compliers" versus "noncompliers") and showed a difference of 14 degrees in spinal curvature in favor of behaviorally posture-oriented exercises, but this study had exceptionally low power (control group: n=4).

As add-on treatment. Two studies[27,30] evaluated exercises as add-on treatment to wearing a brace. One high-quality study[27] showed no additional effect of exercises on the spinal curves but did not present data to calculate RRs. In another low-quality study,[30] no difference in surgery rates were found and only small changes in spinal curvature (<5°) were found in both treatment and control groups.

Versus other interventions. One low-quality study[32] was found that evaluated exercises versus traction during the night. Only small changes in spinal curvature (<5°) were found in both groups.

Electrical Stimulation

Versus no treatment. When electrical stimulation was compared with no treatment in 1 low-quality study,[38] no difference in effect was found. Failure rates were high (45%–48%) in both treatment and control groups.

As add-on treatment. When electrical stimulation was evaluated as an add-on treatment to exercise therapy in 1 high-quality study,[33] no difference in effect was found; only small changes of the spinal curve were found in both treatment and control groups.

There is limited evidence of the effectiveness of braces when compared with no treatment. In addition, limited evidence was found for the effectiveness of bracing in reducing the spinal curve when compared with electrical stimulation. An additional effect of bracing as an add-on treatment to exercises, of exercises as an add-on treatment to braces, or of electrical stimulation as an add-on treatment to exercise therapy cannot be justified. No difference in effect could be found for electrical stimulation when compared with no treatment, for a brace when compared with exercises, or between different braces.

Sensitivity Analysis

When using only our first criterion of high quality (randomization and masking), no studies were considered to be of high quality. In that case, our conclusion concerning the effectiveness of different braces would not change. Next, we followed a suggestion by Chalmers et al[40] to evaluate different possibilities as "threshold" based on the methodological quality. When using the mean quality score of 2.5 or a median score of 3 as a "threshold," the number of high-quality trials increased to 7. In this case, as well, our conclusions remained unaffected.

Discussion

Overall, no statistical differences between groups could be found, but a large percentage of patients with a decrease of the scoliotic curve were found while wearing a brace when compared with other interventions. The only study that showed statistically significant differences was the study by Nachemson and Peterson,[38] but this study was of low quality and was nonrandomized. In this study, bracing was found to be superior when compared with no treatment or electrical stimulation. In addition, no differences among different braces or between braces and exercises could be found. Therefore, we conclude that the effectiveness of bracing and exercises is not yet established.

This systematic review might have some limitations. Most studies found were of low quality and low power. There was heterogeneity in treatments found, and the duration of treatments and follow-up period also varied enormously.

The methodological quality of the majority of the trials was disappointingly low. We found only 3 RCTs, and the size of the study groups was too small to reach an adequate power. A randomization procedure often was not performed because the researchers considered it unethical to withhold therapy from patients. We do not consider randomization an ethical problem, because the effectiveness of any conservative treatment for adolescent idiopathic scoliosis is not yet proven.

There is difficulty, however, in masking the care provider and the patients during conservative treatment for idiopathic scoliosis. Masking of outcome measurement, especially when measuring Cobb angles, seems to be possible, but was mentioned only once. Using different criteria or cutoff points for quality, our conclusions did not change. Therefore, we regard our conclusions as rather robust.

Most included articles did not mention a follow-up period. A long follow-up period is recommended in order to obtain insights into the long-term effects of treatment, especially bracing. Because of the expected physiological changes, such as developing a poorer body image perception[10–12] or quality of life,[11,13] we believe it is necessary to follow up until maturity.

Most studies did not address the measurement of treatment adherence. It is difficult to estimate teenagers' adherence to orthopedic bracing treatments in the absence of objective measurements of the wearing time, as opposed to the patient's reported value. According to Vandal et al,[41] the adherence rate reported by the participants appeared to be much higher than the actual rate determined by an objective measurement.

The risk of publication and language bias in our review is probably small, because we performed an extensive search and no study was found that could not be included because of language. Some rather well-known studies were excluded because of the design. Most designs were retrospective and did not have a control group, although this was not always clearly stated, such as in the studies by Noonan et al[7] and Fernandez-Feliberti et al.[42] In some studies, such as the studies by Rowe et al[14] and Weiss et al,[43] the results of the intervention group were compared with data from a control group of another study. Most studies claimed beneficial effects of braces or exercises, but controlled studies did not yet clearly confirm these claims.

Cobb angles were used as an outcome measure in all studies except the study by Athanaspoulos et al.[27] In that study, pulmonary function was used as an outcome measure. We do not consider pulmonary function especially relevant for the effect of conservative treatment for idiopathic scoliosis. Pulmonary function is relevant only in patients with thoracic curves over 60 degrees.

None of the studies included quality-of-life outcome measures, although many researchers[11–13] agreed that adolescents with scoliosis who have disturbed perceptions of body image also experience greater problems in their psychological and social development. Quality of life is affected by the presence of and treatment for adolescent idiopathic scoliosis.[11,13] Braces especially, being a physical hindrance, create additional personal insecurity, which further complicates the teenager's identity development.[10,44]

Future research should focus on large, high-quality randomized controlled studies. We believe that it is possible and necessary to conduct a randomized trial evaluating braces and exercises, including an untreated control group with a follow-up until adulthood. We believe that, in future research, outcome measures should include psychological and social effects of different conservative treatments for adolescent idiopathic scoliosis.

Conclusion

The power and methodological quality of the studies were low, and studies were clinically heterogeneous. Therefore, it was impossible to draw firm conclusions regarding the effectiveness of conservative treatments for adolescents with idiopathic scoliosis. We conclude that the effectiveness of bracing and exercises is promising, but not yet established.

References

1 Scoliosis Research Society Web site. Available at: http://www.SRS.org/htm/glossary/medterms.htm. Accessed December 2003.

2 Reamy BV, Slakey JB. Adolescent idiopathic scoliosis: review and current concepts. *Am Fam Physician.* 2001;64:111–116.

3 Haasbeek JF. Adolescent idiopathic scoliosis: recognizing patients who need treatment. *Postgrad Med.* 1997;101:207–209, 215–216.

4 Skaggs DL, Bassett GS. Adolescent idiopathic scoliosis: an update. *Am Fam Physician.* 1996;53:2327–2335.

5 Pehrsson K, Larsson S, Oden A, et al. Long-term follow-up of patients with untreated scoliosis. *Spine.* 1992;17:1091–1096.

6 Burns YR, MacDonald J. *Physiotherapy and the Growing Child.* London, United Kingdom: Saunders; 1996:332–335.

7 Noonan KJ, Weinstein SL, Jacobson WC, Dolan LA. Use of Milwaukee brace for progressive idiopathic scoliosis. *J Bone Joint Surg Am.* 1996;78:557–567.

8 Dickson RA, Weinstein SL. Bracing (and screening): yes or no? *J Bone Joint Surg Br.* 1999;81:193–198.

9 Goldberg CJ, Moore DP, Fogarty EE, Dowling FE. Adolescent idiopathic scoliosis: the effect of brace treatment on the incidence of surgery. *Spine.* 2001;26:42–47.

10 Fällström K, Cochran T, Nachemson A. Long-term effects on personality development in patients with adolescent idiopathic scoliosis: influence of type of treatment. *Spine.* 1986;11:756–758.

11 Climent JM, Sánchez J; Group for the Study of Quality of Life in Spine Deformities. Impact of the type of brace on the quality of life of adolescents with spine deformities. *Spine.* 1999;24:1903–1908.

12 Sapountzi-Krepia DS, Valavanis J, Panteleakis GP, et al. Perceptions of body image, happiness, and satisfaction in adolescents wearing a Boston brace for scoliosis treatment. *J Adv Nurs.* 2001;35:683–690.

13 Payne BK, Ogilvie JW, Resnick MD, et al. Does scoliosis have a psychological impact and does gender make a difference? *Spine.* 1997;22:1380–1384.

14 Rowe DE, Bernstein SM, Riddick MF, et al. A meta-analysis of the efficacy of non-operative treatments for idiopathic scoliosis. *J Bone Joint Surg Am.* 1997;79:664–674.

15 The Cochrane Library. Available at: http://www.update-software.com/Cochrane. Accessed in December 2003.

16 PubMed. Available at: http://www.ncbi.nih.gov/entrez/query.fcgi. Accessed December 2003.

17 CINAHL Database. Available at: http://www.library.ucsf.edu/db/cinahl.html. Accessed December 2003.

18 Physiotherapy Evidence Database. Available at: http://www.pedro.fhs.usyd.edu.au/index.html. Accessed December 2003.

19 Robinson KA, Dickersin K. Development of a highly sensitive search strategy for the retrieval of reports of controlled trials using PubMed. *Int J Epidemiol.* 2002;31:150–153.

20 Verhagen AP, de Vet HCW, de Bie RA, et al. The Delphi list: a criteria list for assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. *J Clin Epidemiol.* 1998;51:1235–1241.

21 Verhagen AP, de Vet HCW, de Bie RA, et al. The art of quality assessment of RCTs included in systematic reviews. *J Clin Epidemiol.* 2001;54:651–654.

22 Jadad AR, Moher D, Klassen TP. Guides for reading and interpreting systematic reviews, part II: how did the authors find the studies and assess their quality? *Arch Pediatr Adolesc Med.* 1998;152:812–817.

23 Moher D, Jadad AR, Tugwell P. Assessing the quality of randomized controlled trials: current issues and future directions. *Int J Technol Assess Health Care.* 1996;12:196–208.

24 Van Tulder MW, Furlan A, Bombarbier C, Bouter LM; Editorial Board of the Cochrane Collabaration Back Review Group. Updated method guidelines for systematic reviews in the Cochrane Collaboration Back Review Group. *Spine.* 2003;28:1290–1299.

25 Smidt N, Assendelft WJ, van der Windt DA, et al. Corticosteroid injections for lateral epicondylitis: a systematic review. *Pain.* 2002;96:23–40.

26 Ferraro C, Masiero S, Venturin A, et al. Effect of exercise therapy on mild idiopathic scoliosis. *Europa Medico Physica.* 1998;34:25–31.

27 Athanasopoulos S, Paxinos T, Tsafantakis E, et al. The effect of aerobic training in girls with idiopathic scoliosis. *Scand J Med Sci Sports.* 1999;9:36–40.

28 Birbaumer N, Flor H, Cevey B, et al. Behavioral treatment of scoliosis and kyphosis. *J Psychosom Res.* 1994;38:623–628.

29 den Boer WA, Anderson PG, van Limbeek J, et al. Treatment of idiopathic scoliosis with side-shift therapy: an initial comparison with a brace treatment historical cohort. *Eur Spine J.* 1999;8:406–410.

30 Carman D, Roach JW, Speck G, et al. Role of exercises in the Milwaukee brace treatment of scoliosis. *J Pediatr Orthop.* 1985;5:65–68.

31 von Deimling U, Wagner UA, Schmitt O. Long-term effect of brace treatment on spinal decompensation in idiopathic scoliosis: a comparison of Milwaukee brace-Cheneau corset [in German]. *Z Orthop Ihre Grenzgeb.* 1995;133:270–273.

32 Dickson RA, Leatherman KD. Cotrel traction, exercises, casting in the treatment of idiopathic scoliosis. *Acta Orthop Scand.* 1978;49:46–48.

33 el-Sayyad M, Conine TA. Effect of exercise, bracing, and electrical surface stimulation on idiopathic scoliosis: a preliminary study. *Int J Rehabil Res.* 1994;17:70–74.

34 Fiore N, Onimus M, Ferre B, et al. Treatment of lumbar and dorso-lumbar scoliosis using the Boston orthosis and the 3-valve orthosis: comparative study of the results in the frontal and horizontal planes [in French]. *Rev Chir Orthop Reparatrice Appar Mot.* 1988;74:569–575.

35 Gepstein R, Leitner Y, Zohar E, et al. Effectiveness of the Charleston Bending Brace in the treatment of a single curve idiopathic scoliosis. *J Pediatr Orthop.* 2002;22:84–87.

36 Minami S. Results of brace treatment in idiopathic scoliosis; evaluation of the patients treated for over two years or those who completed the treatment [in Japanese]. *Nippon Seikeigeka Gakkai Zasshi.* 1982;56:471–485.

37 Mulcahy T, Galante J, DeWald R, et al. A follow-up study of forces acting on the Milwaukee brace on patients undergoing treatment for idiopathic scoliosis. *Clin Orthop.* 1973;93:53–68.

38 Nachemson AL, Peterson LE. Effectiveness of treatment with a brace in girls who have adolescent idiopathic scoliosis: a prospective, controlled study based on data from the Brace Study of the Scoliosis Research Society. *J Bone Joint Surg Am.* 1995;77:815–822.

39 Schlenzka D, Ylikoski M, Poussa M. Experiences with lateral electric surface stimulation in the treatment of idiopathic scoliosis [in German]. *Beitr Orthop Traumatol.* 1990;37:373–378.

40 Chalmers TC, Smith H, Blackburn B, et al. A method for assessing the quality of a randomised control trial. *Control Clin Trials.* 1981;2:31–49.

41 Vandal S, Rivard CH, Bradet R. Measuring the compliance behavior of adolescents wearing orthopedic braces. *Issues Compr Pediatr Nurs.* 1999;22(2–3):59–73.

42 Fernandez-Feliberti R, Flunn J, Ramirez N, et al. Effectiveness of TLSO bracing in the conservative treatment of idiopathic scoliosis. *J Pediatr Orthop.* 1995;15:176–181.

43 Weiss HR, Weiss G, Petermann F. Incidence of curvature progression in idiopathic scoliosis patients treated with scoliosis in-patient rehabilitation (SIR): an age and sex-matched controlled study. *Pediatr Rehabil.* 2003;6:23–30.

44 Ólafsson Y, Saraste H, Ahlgren R. Does bracing affect self-image? A prospective study on 54 patients with adolescent idiopathic scoliosis. *Eur Spine J.* 1999;8:402–405.