

1 **A comparison of patient-reported outcome measures following different treatment**
2 **approaches for adolescents with severe idiopathic scoliosis: A systematic review.**

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22 **Abstract:**

23 **Background:** Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional deformity of the spine
24 which is usually not symptomatic and which can progress during growth and cause a surface
25 deformity. In adulthood, if the final spinal curvature surpasses a certain critical threshold, the risk
26 of health problems and curve progression is increased. Although surgery is usually recommended
27 for curvatures exceeding 40 to 50° to stop curvature progression, recent reviews have shed some
28 light on the long-term complications of such surgery and to the lack of evidence for such
29 complicated procedures within the scientific literature. Furthermore a number of patients are
30 very fearful of having surgery and refuse this option or live in countries where specialist scoliosis
31 surgery is not available. Other patients may be unable to afford the cost of specialist scoliosis
32 surgery. For these patients the only choice is an alternative non-surgical treatment option.

33 **Objectives:** To examine the impact of different management options in patients with severe AIS,
34 with a focus on trunk balance, progression of scoliosis, cosmetic issues, quality of life, disability,
35 psychological issues, back pain, and adverse effects, at both the short-term (a few months) and the
36 long-term (over 20 years).

37 **Search methods:** We searched CENTRAL, MEDLINE, EMBASE, CINHAL and two other databases
38 up to January 2016 with no language limitations. We also checked the reference lists of relevant
39 articles and conducted an extensive hand search of the grey literature.

40 **Selection criteria:** We searched for randomised controlled trials (RCTs) as well as prospective
41 and retrospective controlled trials comparing spinal fusion surgery with no treatment or
42 conservative treatment in AIS patients with a Cobb angle greater than 40 degrees.

43 **Main results:** We did not identify any evidence of superiority of effectiveness of operative
44 compared to non-operative interventions for patients with severe adolescent idiopathic scoliosis.

45 **Authors' Conclusions:** Within the present literature there is no clear evidence to suggest that a
46 specific type of treatment is superior to other types of treatment.

47

48 **Keywords:** Adolescent idiopathic scoliosis, treatment, surgery, braces, scoliosis-specific exercises

49

50 **1. Introduction**

51 ***1.1 Description of the Condition***

52 Scoliosis is a complex three-dimensional deformity of the spine that comprises a lateral curvature
53 in the frontal plane (this is a vertical plane that divides the body into front and back halves),
54 thoracic lordosis in the sagittal plane (this is a vertical plane that divides the body into right and
55 left halves) and transverse vertebral rotation, which is produced by rotation of the vertebrae in
56 the transverse plane (horizontal plane); this results in the posterior elevation of the rib cage on
57 the convex side of the curve and a depression on the concave side [1]. These underlying skeletal
58 changes are usually reflected by a change in back shape, the unsightly shape of which is generally
59 more of a concern to the patient than is the underlying skeletal deformity [2]. The condition if left
60 untreated results in altered spinal mechanics and degenerative changes that lead to pain, loss of
61 spinal mobility and possible loss of function or disability. Cardiac and respiratory dysfunction may
62 also accompany these symptoms, depending on the time of onset of the deformity [2]. These
63 physical changes are accompanied by the psychological consequences resulting from the unsightly
64 and deformed shape of the back: a restricted social life, a lower marriage rate, a higher divorce
65 rate, fewer children per marriage and increased psychiatric consultations, including eating
66 disorders and increased suicide rate, have all been reported [3].

67 Whilst scoliosis can also occur secondary to certain diseases and conditions that affect the nervous
68 and muscular systems of the body. The deformity can be caused by defects in spine formation at
69 the embryo stage, or it can be part of certain syndromes. Very rarely, scoliosis can occur secondary
70 to tumours. However, most cases of scoliosis (80% to 90%) are called 'Idiopathic' because the
71 underlying cause cannot be ascertained. Adolescent idiopathic scoliosis (AIS), which is the most
72 common diagnosis, usually develops during adolescence- a period of rapid growth [4-5].

73 According to the Scoliosis Research Society and the International Society on Scoliosis Orthopaedic
74 Rehabilitation and Treatment [6], the prevalence of AIS is 2% to 3% in the general population.
75 Almost 10% of patients with AIS will require some form of treatment, and up to 0.1% will
76 eventually require surgery [7]. AIS is more commonly found in females (female/male ratio is
77 around 7:1) and, except for extreme cases, AIS does not typically cause any health problems during
78 growth; however, the resulting surface deformity frequently has a negative impact on adolescents
79 that can give rise to quality of life issues and, in the worst cases, psychological disturbances [8].

80 The aetiology or causation of idiopathic scoliosis remains unclear [9-12]. Many theories on the
81 causes of scoliosis have been proposed, such as the neuromuscular, growth and genetic theories
82 [2]. This sums up all the hypotheses related to the cause of scoliosis as follows: "The normal spine
83 in a growing person has a precise, precarious, delicate mechanical balance. Asymmetrical changes
84 in primary structures, support structures, growth centres, the position of the spine and related
85 neural or muscular components can all result in the development of scoliosis."

86 The potential for curve progression has been shown to be related to several factors, including the
87 patient's gender, age, curve magnitude, bone maturity, rate of growth and growth potential at
88 presentation. Dickson [13] demonstrated that when curves of 10 degrees Cobb and above were
89 considered, the female-to-male ratio was 1.6:1. The Cobb angle is a method of measuring the angle
90 of the spine that was devised by a surgeon named Cobb [7]. This value increased to 12:1 when
91 curves greater than 20 degrees Cobb were considered. Female-to-male ratios for treatment were
92 reported at 7:1 [14]. Moreover, when combining curves of all magnitudes, **Lonstein and Carlson**
93 **[15]** found a negative correlation of age with the percentage incidence of progression. This means
94 that the younger the child at presentation, the greater is the likelihood of progression. The same
95 negative correlation is shown with the Risser sign. This measures how much mature bone has
96 developed (ossification) in the upper rim of the pelvis (iliac crest). The greater the maturity of the
97 child, the greater is the Risser sign. A low Risser sign indicates that greater potential for growth is
98 left, and consequently the potential for curve progression is greater [16] and [7]. Curve magnitude,
99 however, was found to have a positive correlation with the percentage incidence of progression.
100 Thus the greater the magnitude of the curve at presentation, the greater is the potential for
101 progression.

102 Other factors taken into consideration when growth potential is determined are the changes in
103 secondary sexual characteristics that take place during the growth spurt. Different results have
104 been reported on the progression of various curve patterns. For example, **Clarisse [17] and Fustier**
105 **[18]** reported that double curves progressed most in their studies, with an incidence of 67% and
106 75%, respectively. Conversely, Bunnell **[19] and Lonstein and Carlson [15]** reported that thoracic
107 curves were most progressive. All authors, however, demonstrated that lumbar curves progressed
108 least. Other parameters of prognostic value include apical vertebral rotation [20-21] and the rib
109 vertebral angle [22]. When potential for curve progression is assessed, no single factor is taken in

110 isolation, but all factors are taken into account in attempts to predict the likelihood for progression
111 and make a treatment decision. Depending on the age of the individual at diagnosis, scoliosis
112 evolves and may deteriorate rapidly during periods of fast growth spurt [23-25]. Whilst children
113 grow until they have fully matured, growth is more rapid (growth spurt) during certain periods of
114 childhood and adolescence [26].

115 Early diagnosis is difficult, especially in countries where scoliosis school screening is not
116 implemented, as this condition is most often painless. External change to the body shape is
117 minimal in the early stages and most changes in back shape occur predominantly on the back of
118 the trunk, which makes it difficult for patients to see, and it can be concealed by their clothing
119 [27]. Treatment of idiopathic scoliosis is determined by the deformity itself. As most patients with
120 adolescent idiopathic scoliosis progress during growth, the main aims of all interventions are to
121 limit or stop the curvature progression, restore trunk balance [23-24] and prevent the long-term
122 consequences of the deformity.

123

124 ***1.2 Description of the Interventions***

125 Interventions for the prevention of AIS progression include scoliosis-specific exercises, bracing
126 and surgery [28-31], and other interventions have been reported in the literature. The goals of all
127 interventions are to correct the deformity and prevent further deterioration of the curve (i.e.
128 prevent progression) and to restore trunk asymmetry and balance, while minimising morbidity
129 and pain, allowing return to full function [7, 16].

130 Treatment approaches adopted by various orthopaedic surgeons and physicians specialising in
131 the field of scoliosis around the world are divided, indicating lack of clinical equipoise across
132 different professions and countries. In general, these approaches can be split grossly into two
133 opposing groups. The first group consists of those who regard scoliosis-specific exercises as
134 inefficient; members of the second group use these exercises and advocate their efficacy [30]; [32].
135 Similarly, bracing has been abandoned by some [33], but others support its use on the basis of
136 existing weak evidence about efficacy [34]; fusion is generally considered to be necessary when
137 AIS exceeds a certain degree (approximately 45 to 50 degrees), when previous treatments have

138 failed or when AIS causes symptoms, but indications vary widely according to the preference of
139 the treating physician/surgeon [33].

140 These two conflicting approaches to conservative management (non-surgical vs surgical
141 approaches) seem to prevail in different regions of the world. In the United States, the United
142 Kingdom and Australia, the wait-and-see strategy prevails, but in various parts of continental
143 Europe and Eastern and Southern Europe, conservative treatment (scoliosis-specific exercises and
144 bracing) is considered beneficial for the patient and is used routinely by a large majority of
145 scoliosis physicians and surgeons [29-31]. Scoliosis-specific exercises consist of individually
146 adapted exercises that are taught to patients in a centre that is dedicated to scoliosis treatment.
147 Patients learn an exercise protocol that is personalized according to their own medical and
148 physiotherapeutic evaluation. On the other hand, usual generalised physiotherapy is more generic,
149 consisting of low-impact stretching and strengthening activities like yoga, pilates or tai chi (taiji),
150 but it can include many different exercise protocols. Whilst scoliosis-specific exercises are usually
151 used for treating mild curves of less than 25 to 30 degrees, they are also used frequently with
152 braces for curves over this threshold. No side-effects of exercise are known, except for muscle
153 soreness that can be felt if the intensity of exercise is too great [31].

154 Bracing is defined as the application of external supports to the trunk; these are usually rigid and
155 are applied with the aim of achieving maximum correction of the pathological curve [35].
156 Treatment commences when the curve is diagnosed as progressive, or when it exceeds a threshold
157 of 30 degrees Cobb angle [30]; [7]; [31]. Braces generally need to be worn for a considerable
158 period of time per day (at least 20 hours), the treatment extending over several years until the end
159 of bone growth, which usually occurs at 16 years of age for girls and 18 years of age for boys [36].
160 This causes a significant negative impact on the lives of children and adolescents [37-39]. Other
161 conservative management strategies can be found in the literature: shoe insoles, electrotherapy
162 and chiropractic treatment have all been reported. However, to date, there is a dearth of evidence
163 for the effectiveness of these forms of therapy.

164 With regard to surgical interventions, a large multitude and variety are described in the literature
165 [40]. These include different operative approaches (anterior, posterior or combined) and many
166 types of metal implants. The sophistication of spinal implants has grown rapidly in the past 10 to

167 15 years. Modern operative techniques follow principles of segmental spinal instrumentation (this
168 means that each vertebra of the spine is attached to a metal rod, wires or screws), and both
169 anterior and posterior implants (operative rods, wires or screws) are now available. Segmental
170 instrumentation (with hooks or screws) can control sagittal and frontal plane correction in both
171 lumbar and thoracic curves. In contrast to Harrington instrumentation, introduced in the 1960s
172 [41], segmental instrumentation allows early mobilisation of patients, thereby eliminating the
173 need for postoperative casts and braces which were used in the past [1]. This type of surgery also
174 reduces the risk of potential neurological complications due to distraction forces (these are forces
175 applied to a body part to separate bony fragments or joint surfaces) that were applied with the
176 Harrington instrumentation [41].

177 Countless studies have been published in the literature comparing different approaches to the
178 spine (anterior, posterior or combined) and using various types of implants. A single threaded rod
179 inserted through an anterior approach (from the front of the spine) was initially developed by
180 Zielke, but this technique had a reported incidence of rod breakage as high as 31% [42]. Further
181 development of instrumentation resulted in the use of a double rod technique, such as Kaneda or
182 Cotrel-Dubousset-Hopf, which prevented rod breakage but had the disadvantage of increasing the
183 construct rigidity and favouring screw breakouts [43]. A further advantage was represented by a
184 lower reoperation rate in double rod fixation (0%) reported by Muschik et al [44] as compared
185 with single rod fixation (10%; [42]. The anterior approach is desirable because it can reliably
186 correct curvature yet save the vertebral levels instrumented in lumbar or thoracolumbar curves
187 [45-46]. However, if appropriate consideration is not given to planning and fusing the correct
188 segments (i.e., to neutral and stable vertebrae), this can lead to curve progression and disc
189 degeneration postoperatively [47]. Unfortunately, with the anterior approach to surgery, there is
190 a risk of potential trauma to the diaphragm and major abdominal organs. This type of surgery can
191 also affect pulmonary function. If a patient has multiple curves, posterior fusion can achieve good
192 correction and obviate the risks of anterior surgery [16]. The anterior approach also predisposes
193 to a negative effect on pulmonary function for up to five years postoperatively [48]; therefore,
194 some surgeons prefer a video-assisted thoracoscopy followed by posterior instrumentation,
195 which allows them adequate spinal access but reduces the adverse effects on pulmonary function
196 [49].

197 Luhmann and Lenke [50] suggested that instrumentation through a posterior approach
198 (approaching surgery from the back of the spine) was as efficient as a combined anterior and
199 posterior approach, but the former (posterior approach) eliminated the negative effect on
200 pulmonary function. In other words, approaching the operative procedure from the back rather
201 than from the front reduces the risks associated with deflating the lungs during the operative
202 procedure [51]. A significant variety of implants and approaches to operative treatment of the
203 spine are available, but double rod posterior instrumentation seems to have become the preferred
204 operative intervention in cases where progression of scoliosis cannot be stopped by conservative
205 treatment. All types of spinal fusion surgery are associated with significant risk both in the short
206 term and in the long term. The short-term risk for spinal fusion surgery is estimated to
207 be approximately 5%, while long-term risks over a lifetime are estimated to exceed 50% [52], with
208 reoperation rates ranging from 6% to 20% [24]. However, reoperation rates may be very high (up
209 to 50%) with the use of more recent instrumentation such as Cotrel-Debusset instrumentation
210 [53].

211 ***1.3 How the interventions might work***

212 Scoliosis-specific exercises can be used in three main clinical scenarios: (1) the sole use of exercise as
213 the primary treatment of AIS for mild curves, (2) in conjunction with braces for moderate curves and
214 (3) during adulthood if the scoliosis curves exceed certain thresholds [54]. In the treatment of mild
215 scoliosis, scoliosis-specific exercises can be used on curves greater than 10 to 15 degrees but less than
216 25 or 30 degrees Cobb. These intense three-dimensional spine and rib cage specific exercises are used
217 to try to limit the progression of the curve and thereby avoid the use of a brace. This critical Cobb
218 angle is generally regarded as the threshold for brace prescription [7]; [55]. In mild scoliosis cases for
219 which exercise is prescribed, exercise is used predominantly according to the recommendations
220 made by the **Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT)** [6]. The key
221 objectives of physical exercise in mild cases of AIS include stabilisation of the spine combined with
222 three-dimensional auto-correction of the pelvis, rib cage and shoulders in combination with isometric
223 muscle contractions [54-55].

224 Whilst scoliosis-specific exercises use internal corrective forces (i.e. muscles), braces use external
225 corrective forces to correct the trunk; this is usually achieved with the use of rigid supports.
226 However, some braces (called *soft braces*) are made of material similar to elastic bands and
227 comparable with materials used in physical therapy treatments [56]; [35]. The mechanical forces
228 of the brace are used to straighten the spine and derotate the pelvis and shoulders to bring the
229 whole body into normal alignment. Negrini et al [57] state that the external and proprioceptive
230 inputs due to bracing change the unnatural loading on the spine and rib cage, decrease
231 asymmetrical movements and improve neuromuscular control; this facilitates proper spinal
232 growth, neuromotor reorganization and changes in motor behaviours [58-66]. Although it has
233 been reported in the literature that some braces can be uncomfortable to wear, especially for long
234 periods, uncomfortable braces generally are a result of poor workmanship. Carefully crafted
235 braces are however generally easily tolerated. Further, if bracing is NOT combined with scoliosis-
236 specific exercises, weakening of the back muscles may occur.

237 With regard to operative treatment of the scoliotic spine, the two main approaches discussed
238 previously (anterior and posterior) aim to correct the spinal curvature (reduction of the Cobb
239 angle) and fuse the spine with the help of bone grafts that allow the spine to heal to a solid and
240 stable bone fusion mass (spinal fusion), supported by the instrumentation [67]. Posterior spinal
241 fusion with instrumentation and bone grafting is performed through the patient's back while the
242 patient lies on his or her stomach.

243 During scoliosis surgery, the surgeon attaches a metal rod onto the spinal curvature (one or both
244 sides – this varies according on the type of instrumentation and procedure used) by using hooks
245 or screws attached to the vertebral bodies [68]. Bony fusion of the spine is achieved by using bone
246 graft usually taken from the patient (autograft) and/or artificial bone substitutes. This promotes
247 bony ingrowth between the vertebrae and causes the spine to fuse and behave as a solid rod. The
248 metal rods attached to the spine ensure that curve correction is maintained while bony spinal
249 fusion occurs.

250 **1.4 Why it is important to do this review**

251 A literature search identified only three systematic reviews on this topic. The two reviews by
252 Weiss et al did not include full methodological appraisals of the quality of included studies [91-92]
253 and the third Cochrane review entitled `Surgical versus non-surgical interventions in people with
254 adolescent idiopathic scoliosis published in 2015 included only prospective studies with a control
255 group and did not include any retrospective studies. A systematic review including all types of
256 evidence with the inclusion of retrospective studies with a control group is urgently needed. From
257 a patient and parent's perspective any spinal surgical intervention is often considered as a last
258 option due to the fear and anxiety of having surgery. Additionally numerous patients may have no
259 choice but to either have no treatment or to have some form of non-surgical intervention. This
260 occurs primarily in patients living in developed countries who may not be able to afford the costs
261 as well as for patients in developing countries where specialist scoliosis surgery is not available.
262 It is very important for all patients and their parents who are considering surgery for severe
263 curves in adolescent idiopathic scoliosis, to know the short and long term outcomes of all
264 treatment options (both surgical and non-surgical). Being fully informed of all the short and long
265 term outcomes as well as the complications and side effects for all current treatments approaches
266 would significantly help service users and carers make fully informed decisions that are most
267 suited to their child`s specific scoliosis curve and quality of life.

268 **Objectives:** The objective of this review was to evaluate and compare changes in trunk balance,
269 progression of scoliosis, cosmetic issues, quality of life, disability, psychological issues and back
270 pain, as well as adverse effects for severe curves (>40 degrees) with both operative and non-
271 operative interventions provided in the short term (a few months) as well as in the long term (over
272 20 years).

273

274 **2. Methods**

275 ***2.1. Criteria for Considering Studies for this Review***

276 **2.1.1 Types of studies**

277 For the primary analysis we planned to combine the results of randomised control trials (RCTs)
278 and quasi-randomised control trials (QRCTs). We also planned to include both prospective and
279 retrospective non-randomised studies (NRSs) with a control group because it was anticipated that
280 very few RCTs would be found. We planned to include primary studies that compared operative
281 interventions with non-operative interventions or no interventions (i.e. observation). We planned
282 to exclude studies comparing non-operative methods alone (e.g. bracing vs scoliosis-specific
283 exercises) as two other Cochrane reviews cover these questions [57], [54].

284 **2.1.2. Types of Participants**

285 We planned to include patients with AIS who were diagnosed and managed between 10 and 18 years
286 of age, with a Cobb angle greater than 40 degrees (Scoliosis Research Society Guidance; accessed April
287 2015). We excluded any studies on participants with early-onset scoliosis (infant or juvenile) and
288 scoliosis secondary to other conditions.

289 **2.1.3. Types of interventions**

290 We included all types of instrumented operative interventions with fusion aimed to provide curve
291 correction and spine stabilisation. We excluded studies describing non-instrumented spinal
292 correction and fusion because it has been shown that they do not provide any better outcome than
293 is seen with untreated scoliosis [1]. We planned to compare instrumented operative interventions
294 with different types of non-operative treatments, such as scoliosis-specific exercises, bracing,
295 physiotherapy, chiropractic treatment, electrical stimulation and other non-operative
296 interventions, as well as no treatment controls (i.e. observation).

297 **2.1.4. Types of outcome measures**

298 We examined outcomes (primary and secondary) measured in the immediate term (perioperative
299 to six weeks postoperative), the short term (results at the end of bone growth), within two years,
300 and over the long term (results in adulthood and in old age).

301 **2.1.5 Primary Outcomes**

302 **Change in trunk balance, measured in centimetres:**

- 303 * Frontal (coronal) balance (refers to the plane that divides the body into front and back
304 halves);
- 305 * Lateral trunk shift; and
- 306 * Apical vertebral translation

307 **Progression of scoliosis, measured by:**

- 308 * Cobb angle in degrees (absolute values);
- 309 * Angle of trunk rotation (ATR) in degrees (absolute values); and
- 310 * Number of participants who progressed by more than 5 degrees Cobb (5 degrees Cobb is
311 the standard clinical measure reported within various research papers and commonly used
312 in clinical practice)

313 **Cosmetic issues, as measured by:**

- 314 * Validated scales or questionnaires: Walter Reed Visual Assessment Scale (WRVAS) [70],
315 Spinal Appearance Questionnaire (SAQ) [71], Trunk Appearance Perception Scale (TAPS)
316 [72]; and
- 317 * Topographic measurements: the integrated shape imaging system (ISIS) or ISIS2 [73],
318 Quantec [74], Formetric [75], measured in angles and millimetres

319 **Quality of life**

- 320 * Generic questionnaires: Short Form-36 (SF-36); and Scoliosis-specific questionnaires: SRS-
321 22 [76], Bad Sobernheim Stress Questionnaire [55], Brace Questionnaire [77].

322 **Psychological issues:**

323 *Specific psychological questionnaires evaluating psychological concepts such as self-
324 esteem, self-image etc., using specific questionnaires and subscales of SRS-22, BrQ, SF-36.

325 **Back pain and disability:**

326 •Validated scales measuring pain intensity and pain duration, such as the visual analogue
327 scale, McGill Pain Questionnaire and other validated specific questionnaires, as well as use
328 of medication.

329 **2.1.6. Secondary outcomes**

330 Secondary outcomes comprised any adverse effects or complications reported in any included
331 studies. These included blood loss, pseudarthrosis (a false joint where the bone has not healed
332 adequately),deep wound infection, neurological complications, delayed Infections, pedicle screw
333 misplacement, delayed paraparesis (weakness or partial paralysis in the lower limbs), loss of
334 normal spinal function and decompensation (spinal imbalance) and increased spinal deformity,
335 as well as death. We reported any adverse events in our review, even if they were not listed above.

336 **2.2. Search methods for identification of studies**

337 **2.2.1. Electronic searches**

338 We searched the following electronic databases since 1980. We did not search for papers before
339 this date because a number of papers reporting the research on older instrumentation might not
340 have been relevant. Although clear advances in materials and design of spinal instrumentation
341 have been made since 1980, the operative approach and training might still be the same even
342 though materials have changed.

- 343 • CENTRAL (*The Cochrane Library*, Jan 2016).
- 344 • MEDLINE (1980 to January 2016).
- 345 • EMBASE (1980 to January 2016).
- 346 • CINAHL (1980 to January 2016).

- 347 • PsycINFO (1980 to January 2016).
348 • PEDro (1980 to January 2016).

349 The search strategy combined the study design filter for observational studies adapted from the
350 Scottish Intercollegiate Guidelines Network with the usual Cochrane RCT filter, so that all study
351 designs were captured by the search. The study design terms were combined with blocks of search
352 terms for the disorder and the interventions. The strategy included subject headings (e.g. MeSH)
353 and was adapted for the other databases (see Appendix 1 and Appendix 2).

354 **2.2.2. Searching other resources**

355 The following strategies were also used.

- 356 • Screening the reference lists of all relevant papers.
357 • Searching the main electronic sources of ongoing trials (Cochrane Back Review Group
358 Trials Register, National Research Register, meta-Register of Controlled Trials; Clinical
359 Trials, World Health Organisation (WHO) International Clinical Trials Controlled Registry
360 Platform).
361 • Searching the grey literature, including conference proceedings and PhD theses completed
362 since 1980. For the latter, we searched the database, `Dissertation Abstracts which lists
363 American dissertations. This database also includes citations for dissertations from 50
364 British universities. To identify any further relevant British theses, we searched the
365 Electronic Theses Online Service database (EThOS) provided by the British Library, which
366 is an 'open access single point digital repository of UK research theses'.
367 • Contacting investigators and authors in this field for information on unpublished or
368 incomplete trials.

369 All searches included non-English language literature.

370 ***2.3 Process of selection of research papers:***

371 We first developed a study selection form on the basis of the inclusion criteria. This was piloted
372 and tested for both intra-observer and inter-observer reliability by two review authors, who then

373 independently screened the search results by reading the titles and abstracts. Potentially relevant
374 studies were obtained in full text, and once again they were independently assessed for inclusion
375 by two review authors, who resolved any disagreement through discussion. A third review author
376 was contacted if disagreements persisted. If a review author was also the author of a paper,
377 another review author who had not authored any of the papers undertook the selection.

378 We did not select any papers before 1980 because research done on older instrumentation may
379 not be relevant. Although clear advances in the materials and the design of spinal instrumentation
380 have been made since 1980, the surgical approach and training may still be the same.

381 We did not find any relevant prospective RCTs, QRCTs or NRSs with a control group. We found 10
382 retrospective studies, 9 of them could not be included because the patients in the comparative
383 brace group had curves of less than 40 degrees at the beginning of treatment. Only one very recent
384 study (abstract) by Ward et al [83] met the full inclusion criteria. However as the full manuscript
385 has not as yet been published we were unable to evaluate the methodological quality of the paper.
386 As such, we were unable to carry out most of the pre-stated methodology.

387 ***2.4 Assessment of risk of bias in included studies***

388 It was planned that the risk of bias for both randomised studies and NRSs would be assessed using
389 the criteria recommended by the Cochrane Back Review Group [78-79], together with items from
390 the Downs and Black [80] checklist, as outlined in 3. These criteria fall into five bias categories:
391 selection bias, performance bias, attrition bias, detection bias and selective outcome reporting.
392 The 'assessment of risk of bias' form was piloted and tested for intra-observer and inter-observer
393 reliability. It was planned that two review authors would independently assess the internal
394 validity of the included studies. Any disagreement between the review authors was resolved by
395 discussion; a third independent review author was consulted if disagreements persisted. We had
396 also planned to blind the risk of bias assessment to trial authors, institution and journal and to
397 score the risk of bias criteria as high, low or unclear and reported these ratings in the 'risk of bias'
398 table. We then rated the overall extent of risk of bias within each bias category (e.g. performance
399 bias) as "Bias" or "No bias".

400 Whilst it was difficult to provide an exhaustive list of all possible confounding variables at the start
401 of the review, the review authors have experience in this field and were aware of most of the
402 potential confounding variables that could occur when different treatment groups are compared.
403 These may have included, for instance, demographic variables such as age, Risser sign (bone
404 maturity), curve location and curve magnitude.

405 In regard to grading the quality of the evidence, we had planned to downgrade evidence from
406 studies judged "no bias" for all five categories. Evidence would have been downgraded (-1 point)
407 when 3 or fewer categories for each study were judged to have bias. Evidence would have been
408 downgraded by -2 points when four or more categories for each study were judged to have bias.

409 ***2.5 Data extraction and management***

410 We performed the review following the recommendations of the Cochrane Handbook for
411 Systematic Reviews of Interventions [79]. We had planned to do the following; to prepare a
412 standardized data extraction form on the basis of all the inclusion criteria, which two authors
413 would have piloted and tested for intra- and inter-observer reliability, and then used the form
414 independently to extract data from the included papers; extracted raw data, including information
415 about the study design (RCT, QRCT, prospective and retrospective controlled cohort study), study
416 characteristics (country, recruitment modality, study funding, risk of bias) and participant
417 characteristics (number of participants, age, sex, severity of scoliosis at baseline) as well as a
418 description of experimental and comparison interventions, co-interventions, adverse effects,
419 duration of follow-up, outcomes assessed and results, as well as any adverse effects. If a review
420 author had been the author of a paper, another review author would have undertaken the data
421 extraction process. Any disagreements were discussed with a third review author.

422 ***2.6 Data synthesis***

423 The plan for the data synthesis was as follows; the results from clinically comparable trials would
424 have been described qualitatively in the text. Regardless of whether sufficient data was available
425 for the use of quantitative analyses to summarise the data, we would have assessed the overall
426 quality of the evidence for each outcome. To accomplish this, we would have used the GRADE
427 approach, as recommended in the Cochrane Handbook for Systematic Reviews of Interventions

428 [79] and adapted in the updated Cochrane Back Review Group method guidelines [78]. Factors
429 that would have decreased the quality of the evidence included the study design and risk of bias
430 (all were retrospective studies and therefore all has a high risk of bias), inconsistency of results,
431 indirectness (not generalisable), imprecision (sparse data) and other factors (e.g. reporting bias).
432 The quality of the evidence for a specific outcome would have been reduced by a level, according
433 to the performance of the studies against these five factors.

- 434 • **High-quality evidence:** Consistent findings noted among at least 75% of RCTs with low risk
435 of bias; consistent, direct and precise data and no known or suspected publication biases.
436 Further research is unlikely to change the estimate or our confidence in the results.
- 437 • **Moderate-quality evidence:** One of the domains not being met. Further research is likely to
438 have an important impact on our confidence in the estimate of effect and may change the
439 estimate.
- 440 • **Low-quality evidence:** Two of the domains not being met. Further research is very likely to
441 have an important impact on our confidence in the estimate of effect and is likely to change the
442 estimate.
- 443 • **Very low-quality evidence:** Three of the domains not met. We are very uncertain about the
444 results. No evidence: No studies were identified that addressed this outcome.

445 **3. Results**

446 ***3.1 Description of included studies:***

447 Our search of databases identified 4798 records. After screening the records, we only found one
448 paper by Ward et al (2015) that fully met our inclusion criteria [83] (See study flow diagram,
449 [Figure 1](#)). We also found 9 articles that very closely met our criteria [84] (refer table 1). In these
450 papers the initial Cobb angles in the surgically (over 40 degrees Cobb) and non-surgically (less
451 than 40 degrees Cobb) treated groups at the initial hospital visit differed and the non-surgically
452 treated group did not meet the criteria of having a scoliosis curve of 40 degrees or over at initial
453 visit. In addition six of these papers were conducted on the same patient cohort with different
454 outcomes reported within six different papers. All were retrospective cohort studies with a control

455 group or retrospective case studies with a control group. There were no prospective studies with
456 a control group.

Table : 1 The 10 retrospective studies with a comparison group that we found were authored by [83- 90]

[83]Ward TW, Roach,J,W, Friel,N, Kenkre,TS,, Brooks MM. 22r Scores in Non-Operated AIS Patients with Curves over 40°. SRS 50th Anniversary Abstract booklet, Annual meeting and course, abstract 5, pp 180-181, 2015

[84] Simony A, Hansen EJ, Carreon LY, Christensen SB and Osterheden M. Andersen Health-related quality-of-life in adolescent idiopathic scoliosis patients 25 years after treatment. Scoliosis 2016

[85] Anderson M O, Christenesen S B, Thomsen K. Outcome at 10 Years After Treatment for Adolescent Idiopathic Scoliosis. SPINE 2006; 31: 350 - 354.

[86] Danielsson A J, Nachemson A L. Radiologic Findings and Curve Progression 22 Years After Treatment for Adolescent Idiopathic Scoliosis. SPINE 2001; 26: 516 - 525.

[87] Danielsson A J, Nachemson A L. Childbearing, Curve progression, and Sexual Function in Women 22 Years After Treatment for Adolescent Idiopathic Scoliosis. SPINE 2001; 26: 1449 - 1456.

[88] Danielsson A J, Wiklund I, Pehrsson K, Nachemson A L. Health-related quality of life in patients with adolescent idiopathic scoliosis: a matched follow-up at least 20 years after treatment with brace or surgery. Eur Spine J 2001; 10: 278 - 288.

[89] Danielsson A J, Nachemson A L. Back Pain and Function 22 Years After Brace Treatment for Adolescent Idiopathic Scoliosis: A Case-Control Study - Part 1. SPINE 2003; 28: 2078 - 2086.

[90] Danielsson A J, Romberg K, Nachemson A L. Spinal Range of Motion, Muscle Endurance, and back Pain and Function at Least 20 Years After Fusion or Brace Treatment for Adolescent Idiopathic Scoliosis. SPINE 2006; 31: 275 - 283.

[91] Pehrsson K, Danielson A, Nachemson A. Pulmonary function in adolescent idiopathic scoliosis: a 25 year follow up after surgery or start of brace treatment. Thorax 2001; 56: 388 - 393.

[92] Bunge E M, Juttman R E, De Kleuver M, Van Biezen F C, De Koning H J. Health-related quality of life in patients with adolescent idiopathic scoliosis after treatment: short-term effects after brace or operative treatment. Eur Spine J 2007; 16: 83 - 89.

**Please note that papers 86-91 were conducted on the same population group but with different outcome measures reported in different papers.*

457

458 **3.2 Risk of bias**

459 All ten studies we found were retrospective studies with a control/comparison group and
460 consequently this research design has a high risk of bias.

461 **3.3 Effects of interventions**

462 We only identified one retrospective study [83] with a comparison group that fully met our inclusion
463 criteria but still for this study we couldn't appraise the full paper as we only had the abstract. Ward
464 et al stated in his paper that "the similarity in SRS 22r scores between non-operated and operated
465 groups implies a limited benefit of surgery" for patients with adolescent idiopathic scoliosis who had
466 severe curves (>40 degrees). Surgery is often recommended when curves exceed 40°. Since 2000,
467 Ward et al states that "surgical candidates have been counselled in a manner that did not bias them
468 toward surgery". In this study the non-operative group of 141 AIS patient (with curves >40°) was
469 compared with patients (n=197) who had surgical intervention. X-rays and SRS 22r scores were
470 compared between the groups. Results: For the non-operative group the average age at follow up was
471 23.9 ± 5.2 years (range 18-39 yrs.), time since curve was 8.1 ± 4.6 years (range 0.5-19 yrs.), and
472 Cobb angle $50^\circ \pm 7^\circ$ (range 40°-72°). For 183 cases operated at an age < 18 years the average pre-
473 operative Cobb angle was $60^\circ \pm 11^\circ$ versus $64^\circ \pm 14^\circ$ for 14 cases operated after age 18. The non-
474 operative group showed no statistical differences from the operative groups for Pain, Function, and
475 Mental Health domains. Statistically significant improvement ($p < 0.05$) was found for total average
476 SRS 22r score and Self-Image in the < 18 year old operated group and for satisfaction in both operated
477 groups. However when published minimal clinically important difference (MCID) values for selected
478 SRS 22r domains are considered no comparison showed a conclusive clinical difference. So the

479 improvements in SRS 22r scores for AIS patients following surgery are small and probably clinically
480 insignificant. Alternative non-surgical approaches for AIS was recommended.

481 **4. Discussion**

482 ***4.1 Summary of main results***

483 As stated above we only identified one retrospective study (abstract) with a comparison group
484 that fully met our inclusion criteria. This study was presented by Ward et al [83] at the latest SRS
485 meeting in September 2015. Ward states in his paper that “the similarity in SRS 22r scores
486 between non-operated and operated groups implies a limited benefit of surgery” for patients with
487 adolescent idiopathic scoliosis who had severe curves (>40 degrees). We also identified nine
488 retrospective studies with a comparison/control group that nearly met all our stated criteria with
489 the exception that the braced group in these studies at initial treatment had a Cobb angle less than
490 40 degrees (see comment above).

491 ***4.2. Overall completeness and applicability of evidence***

492 There is currently only one study non-randomised trial-based evidence from a retrospective study
493 with a control group. As discussed above this review also found an additional 9 retrospective
494 studies with a control group that nearly met the proposed inclusion criteria. Whilst we
495 acknowledge that the nine retrospective studies found are considerably biased and the
496 intervention groups within these studies had different initial Cobb angles, we believe that this
497 review provides important information for patients and their families who are afraid of, refuse or
498 cannot afford surgery when their curve reaches 40 degrees or above. We also believe that this
499 review provides important information regarding research gaps in this field. The participants
500 were patients with adolescent idiopathic scoliosis (AIS) who were diagnosed and managed
501 between the ages of 10 and 18 years of age with severe curves of over 40 degrees. Studies on
502 participants with early-onset scoliosis (infant or juvenile) or scoliosis secondary to other
503 conditions were excluded.

504 Our literature search yielded no prospective randomised or non-randomised controlled studies
505 comparing operative interventions to non-operative ones, which is consistent with previously

506 published reviews on this topic [93-94]. The nine retrospective studies with a control group [87-
507 95] showed some differences between operative and non-operative groups in the short term, yet
508 no significant differences were found in the long to very long term (20-25 years).

509 Retrospective studies are considered to have a much weaker research design leading to a much
510 poorer quality research study. These studies are less expensive and are usually of much shorter
511 duration (than prospective cohorts). They also require large sample sizes. Rare outcomes are
512 difficult to study and there is much less control over subject selection and measurements. Crucially
513 the risk for confounding variables and therefore error is also very high in this type of research
514 design.

515 ***4.3 Patient outcomes in the short-term (up to 1 year)***

516 **Health Related Quality of Life outcomes**

517 Bunge et al [92] reported that short-term differences over approximately 10 months between Health
518 Related Quality of Life outcomes (HRQoL) outcomes in surgically and non-surgically treated AIS
519 patients were negligible and could not support preference of one treatment above the other. This
520 study was a cross-sectional analysis of the HRQoL of 109 patients with adolescent idiopathic scoliosis
521 who, after completing treatment, filled out the Dutch SRS-22 Patient Questionnaire. All patients had
522 been treated either with a brace or surgery, or with a brace followed by surgery. Further scrutiny of
523 the paper however revealed that surgically treated patients had a better score in the 'satisfaction with
524 treatment' domain than brace- treated patients; however, with modern braces this result may now
525 be different. The recent developments of asymmetric high correction braces have a higher rate of
526 success than the Boston brace [96, 97, 98]. Furthermore, it is important to consider that short-term
527 results do not provide results for post-operative complications and side-effects, which may be
528 revealed in the longer term. No other consistent differences in HRQoL were found between patients
529 treated with a brace and patients treated surgically. Gender, curve type and curve size had no relevant
530 effect on HRQoL.

531 **4.4 Patient outcomes in the mid-term (approximately less than 10 years after surgery or end**
532 **of bracing)**

533

534 **Activities of daily living and back pain**

535 In a study of patient outcomes measured approximately 10 years after treatment for AIS,
536 Anderson et al [85] reported a generally high level of activities of daily living and found no
537 significant differences between brace treated (BT) and surgically treated (ST) patients. A total of
538 215 consecutive patients treated either by bracing or surgery received a questionnaire. The main
539 topics of the questionnaire included patient demographics, back pain, activities of daily living. A
540 total of 181 patients replied. The mean age at follow-up was 26.0 years. The level of back or leg
541 pain was relatively low, though the BT patients had more pain than their ST peers. Compared with
542 age-matched healthy controls, the SF-36 scores were lower in the AIS patients. Brace related
543 questions revealed a significant impact of the disease and the treatment on the patients' lives. The
544 patients also had moderately reduced perceived health status and activities of daily living, and
545 increased pain with the ST patients generally at a better level than the BT.

546 In a very recent study Ward et al (2015) as described above, evaluated the SRS 22r Health related
547 quality of life scores in Non-Operated AIS Patients with Curves of over 40° and compared them to
548 those of patients who had been operated. The authors found that the similarity in SRS 22r scores
549 between non-operated and operated groups" implies a limited benefit of surgery". Ward states
550 that the natural history of scoliosis is relatively benign. However, surgery is often recommended
551 when curves exceed 40°. Since 2000, his surgical patients were counselled in a manner that did
552 not bias them toward surgery. The non-operative group showed no statistical differences from the
553 operative groups for Pain, Function, and Mental Health domains. Ward et al concluded that
554 improvements in SRS 22r scores for AIS patients following surgery are small and probably
555 clinically insignificant. The authors also suggested that alternative non-surgical approaches for
556 AIS should be considered.

557 **4.5. Patient outcomes in the longer term (approximately 20 years after surgery or end of**
558 **bracing)**

559 The following 6 studies [84-90] reported on a number of different patient outcomes from what
560 appear to be the same cohort of patients. These patients were treated between 1968 and 1977 and
561 before the age of 21, either with distraction and fusion using Harrington rods or with a brace and
562 who were followed for at least 20 years after completion of their treatment.

563 **Health related quality of life 20 years after treatment**

564 Recently in 2015, Ane Simony et al [84] evaluated the long-term health related outcomes, in a
565 cohort of AIS patients, treated 25 years ago. Method: 219 consecutive patients treated with Boston
566 brace (Brace) or posterior spinal fusion (PSF) using Harrington- DDT instrumentation between
567 1983 and 1990 at Rigshospitalet Copenhagen, where patients were invited to participate in a long-
568 term evaluation study. A validated Danish version of the Scoliosis Research Society 22R (SRS22R)
569 and Short Form-36 (SF36v1) were administrated to the patients two weeks before the clinical and
570 radiological examination. Results: 159 (72,6 %) patients participated in the clinical follow up and
571 questionnaires, 11 patients participated only in the questionnaires, 8 emigrated, 4 were excluded
572 due to progressive neurological disease and 2 were deceased. The total follow up was 170 patients
573 (83 %), and the average follow up was 24.5 years (22–30 years). SRS22R domain scores were
574 within the range described as normal for the general population with no statistical difference
575 between the groups except in the Satisfaction domain, where the PSF group had better scores than
576 the braced group. The SF36 PCS and MCS scores in both AIS cohorts were similar to the scores for
577 the general population. The authors concluded that HRQOLs, as measured by the SRS22R and SF-
578 36, of adult AIS patients treated with Boston brace or PSF during adolescence were similar to the
579 general population. No clinical progression of the deformity has been detected during the 25-year
580 follow up period. The PSF group had a small but statistically significant higher score in the
581 Satisfaction domain compared to the braced group.

582 Danielsson [88] also reported in 2001 on the health-related quality of life in patients with AIS at
583 least 20 years after treatment with brace or surgery. Ninety-four percent of the ST patients and
584 91% of BT patients filled in a questionnaire comprising four different validated patient reported

585 outcome measures (the SF- 36, Psychological General Well-Being Index (PGWB), Oswestry
586 Disability Back Pain Questionnaire, parts of SRS/MODEM'S questionnaire) as well as study-
587 specific questions concerning the treatment, as part of an unbiased personal follow-up
588 examination including radiography and clinical examination. An age and sex-matched control
589 group of 100 participants without scoliosis was randomly selected and subjected to the same
590 examinations. The results showed no differences in terms of socio-demographic data between the
591 groups. Both ST and BT patients had slightly reduced physical function compared to the non-
592 scoliosis controls. Neither of the mental health questionnaires showed any significant differences
593 between the groups. A significantly greater number of the surgically treated group (49% percent
594 of ST, 34% of BT and 15% of controls) admitted limitation of social activities due to their back
595 mostly due to difficulties with physical participation in activities or self-consciousness about
596 appearance. Pain was a minor reason for limitation. No correlation was found between the
597 outcome scores and curve size after treatment, curve type, total treatment time or age at
598 completed treatment. Patients treated for adolescent idiopathic scoliosis were found to have
599 approximately the same HRQL as the general population. A minority of the patients (4%) had
600 severely decreased psychological well-being, and a few (1.5%) were severely physically disabled
601 due to the back.

602 **Radiological findings and curve progression 20 years or more after treatment**

603 Danielsson [86] also reported on *the* radiological findings and curve progression 22 years after
604 treatment, in which 252 patients attended a clinical and radiological follow-up assessment by an
605 unbiased observer (91% of the surgically treated and 87% of the brace- treated patients). This
606 evaluation included chart reviews, validated questionnaires, clinical examination, and full- length
607 standing frontal and lateral x-rays. The occurrence of any degenerative changes or other
608 complications was noted. The deterioration of the curves was 3.5° for all the surgically treated
609 curves and 7.9° for all the brace-treated curves. Although the results were statistically significant,
610 it should be highlighted that a difference of only 4 degrees in Cobb angle is reported between the
611 two groups. This difference is well within the margin of error for Cobb angle measurement (the
612 measurement error is reported to be 5 degrees). Having said this, the overall complication rate
613 after surgery was low: Pseudarthrosis occurred in three patients, and flat back syndrome
614 developed in four patients. Eight of the patients treated with fusion (5.1%) had undergone some

615 additional curve-related operative procedure. The lumbar lordosis was less in the surgically
616 treated than in the brace-treated patients or the control group (mean, 33°vs 45° and 44°,
617 respectively). A decreased lumbar lordosis compared to normal lordosis can be indicative of back
618 pain in future. Both surgically treated and brace-treated patients had more degenerative disc
619 changes than the non -scoliosis control participants but no significant differences were found
620 between the scoliosis groups.

621 **Marital status, child bearing, number of children and low back pain over 20 years after**
622 **treatment**

623 Further Danielsson reported [89] that patients who had borne children and were sexually active
624 appeared to function well with regard to marital status, number of children and low back pain. No
625 statistically significant differences were found between the brace-treated vs surgically treated
626 subjects. The limitations were largely because of the difficulties in participating in physical
627 activities or self- consciousness about appearance. Pain was a minor reason for limitation. There
628 was no correlation between progression of the major or lumbar curve and number of pregnancies,
629 or between curve progression and age at first pregnancy. The scoliosis curve did not seem to
630 increase as a result of childbearing and only minor problems occurred during pregnancy and
631 delivery. Some patients, however, experienced a slight negative effect in their sexual life. The mean
632 age for all the groups was 40 years. Of the surgically treated and brace-treated women, 85% were
633 or had been married, as compared with 82% of the non-scoliosis control women. In the total
634 cohort, 628 pregnancies had occurred. No significant mean difference existed between the groups
635 in the number of children born (1.8 for the surgically treated, 1.9 for the brace-treated, and 2 for
636 the control women. The age for the surgically treated women (26.6 years) did not differ
637 significantly from that for the brace-treated women. There were no significant differences
638 between the groups in rates for low back pain (35% for the surgically treated, 43% for the brace-
639 treated, and 28% for the control group) or for caesarean section (19% for the surgically treated,
640 14% for the brace-treated, and 18% for the normal control group) during the first pregnancy. The
641 rate of vacuum extractions was higher in the surgically treated group (16%) than in the control
642 group (5%) or the brace-treated group (8%). Limitation of sexual function from the back was
643 admitted by 33% of the surgically treated, 28% of the brace-treated, and 15% of the control
644 women.

645 **Function and pain 20 years after treatment**

646 Danielsson [89] also reported minimal pain and no dysfunction compared with normal controls
647 22 years after brace or operative treatment for adolescent idiopathic scoliosis. Compared with
648 surgically treated patients, no significant differences were found except that BT patients
649 experienced more affective components of their pain. Lumbar and thoracic back pain, although
650 mild was significantly more frequent among the patients than the normal controls. Only 24% of
651 the patients admitted daily pain and painkillers were sparsely used. The patients had a slightly,
652 but significantly, worse back function as measured by the Oswestry Disability Index and general
653 function score but general health-related quality of life was not affected. No differences could be
654 seen in socio-demographic variables between the groups, except for having 'ever been on sick
655 leave because of the back'. Furthermore, no differences could be found between patients with
656 different curve types. No correlation could be found between pain and its localisation and curve
657 size, an increase of at least 10 degrees since end of treatment, curve type, degenerative changes
658 on any of the two lowest lumbar disc levels, body mass index, or smoking.

659 **Spinal mobility and muscle endurance 20 years after treatment**

660 For both brace treated and surgically treated AIS patients, spinal mobility and muscle endurance
661 were reduced more than 20 years after completed treatment [90]. Physical function was not
662 severely restricted. For both ST and BT groups, lumbar spinal motion as well as muscle endurance
663 was significantly decreased compared with healthy controls. For ST patients, better lumbar
664 extensor and flexor muscle endurance or lumbar spinal mobility correlated with a better physical
665 function. The length of fusion into the lumbar spine correlated inversely with lumbar range of
666 motion, but the finger tip to floor distance was not affected (this is most probably because the
667 patients may have overcompensated by increased flexion occurring at the hips rather than at the
668 lumbar spine). BT patients with reduced lumbar spinal mobility experienced lumbar back pain
669 more often than healthy controls.

670 **Pulmonary function 20 years or more after treatment**

671 Finally patients treated by posterior fusion or a brace gradually increased their pulmonary
672 function up to 25 years after treatment [91]. Smoking and curve size were not found to be risk

673 factors for reduced pulmonary function and vital capacity (VC) increased from 67% immediately
674 before surgery to 73% after surgery and to 84% at the long term follow up. In brace treated
675 patients VC increased from 77% before treatment to 89%, 25 years after start of the treatment.
676 The mean Cobb angles at the follow up study were 40° in both surgically and brace treated
677 patients. The authors stated that these results of lung volumes did not correlate with pre-
678 treatment or post-treatment Cobb angles or smoking habits.

679 ***5.6. Evidence from other AIS studies in the literature***

680 As stated previously, complications can include any adverse effects such as blood loss, pseud-
681 arthrosis (a false joint where the bone has not healed adequately), deep wound infection,
682 neurological complications, delayed Infections, pedicle screw misplacement, delayed paraparesis
683 (weakness or partial paralysis in the lower limbs), loss of normal spinal function and
684 decompensation (spinal imbalance) and increased spinal deformity.

685 The recent study on the long-term effects of Cotrel Dubousset (CD) dorsal double rod
686 instrumentation [53] where long-term risks over a lifetime were very high and thought to exceed
687 50% (Weiss 2008a) must be viewed with caution. Furthermore many issues (e.g. metallosis) may
688 not as yet have been investigated, and later in life and into old age various problems could occur,
689 which may not necessarily be attributed to spinal fusion surgery [69]. In a recent article, the
690 problem of 'metallosis' has been described. This is described as the deposition and build-up of
691 metal debris in the soft tissues of the body. The consequences of the findings of 'metallosis' are not
692 yet clear [95]. It is for these reasons that a dialogue is essential and must be in keeping with the
693 goal that treatments should always incur the least potential harm and maximum potential benefit
694 in both the short and long term [99] Indeed the findings of a relatively recent study published in
695 2011 put forward by Westrick and Ward [97] support our findings and also reported that 'no long-
696 term, prospective controlled studies exist to support the hypothesis that operative intervention
697 for AIS is superior to non-operative interventions or natural history'. Whilst surgery does reliably
698 arrest the progression of deformity, achieves permanent correction in the frontal plane Cobb
699 angle, and improves appearance, there is no medical organic necessity for surgery based on the
700 current body of literature.

701 Furthermore research from Weinstein's [101] seminal work in 2003, in what is perhaps the field's
702 best known study on the natural history of untreated adults with scoliosis, found that patients
703 with *'late onset adolescent idiopathic scoliosis (LIS) are still productive and functional to a high level*
704 *at a 50-year follow-up'*. Indeed Weinstein states in his paper that *'untreated LIS causes little*
705 *physical impairment other than back pain and cosmetic concerns'*. With regards to the current
706 effectiveness of non-operative interventions, two recent Cochrane reviews, one on the
707 effectiveness of Braces [57] on AIS and the other on the effectiveness of Scoliosis-specific exercises
708 (SSE) [54] on AIS have both reported low to very low quality evidence for their effectiveness.
709 Further two very recent RCT's reported by Weinstein [102] and Monticone [103] have shown that
710 both Braces and Physiotherapy based scoliosis-specific exercises were significantly effective in
711 treating AIS patients with mild and moderate curves.

712 Weinstein [102] found that bracing significantly decreased the progression of high-risk curves to
713 the threshold for surgery in patients with adolescent idiopathic scoliosis and that the benefit
714 increased with longer hours of brace wear. Monticone [103] and many others [104-108] reported
715 that an RCT of scoliosis-specific exercises including active self-correction and task-oriented
716 exercises reduce spinal deformity and improve quality of life in subjects with mild adolescent
717 idiopathic scoliosis. The programme of active self-correction and task-oriented exercises was
718 superior to traditional non scoliosis-specific exercises in reducing spinal deformities and
719 enhancing the HRQL in patients with mild AIS. The effects lasted for at least 1 year after the
720 intervention ended.

721
722 In the field of AIS most physicians, surgeons, physical therapists and other allied health
723 professionals would agree that there are still many unknowns. Few 'ideal' treatment protocols
724 exist for the patients suffering from scoliosis, especially from the perspective of the adolescent
725 patient and his/her parents. Moramarco[99] suggests that full disclosure about the potential
726 unknowns of surgery in the short and long term should be mandatory so families may weigh the
727 myriad of unknowns against the perceived benefits of surgery and enable them to make fully
728 informed decisions based on current evidence together with the Health care professional, that is
729 best for their daughter or son.

730 As stated previously all types of spinal fusion surgery are associated with significant risk both in
731 the short term and in the long term. The short-term risk for spinal fusion surgery is estimated to
732 be approximately 5%, while long-term risks over a lifetime are estimated to exceed 50% (Weiss
733 2008a), with re-operation rates ranging from 6% to 20% [76]. However, re-operation rates may
734 be very high (up to 50%) with the use of more recent instrumentation such as Cotrel-Debusset
735 instrumentation [53].

736 Considering the above, it would be reasonable to argue that, non-operative interventions and/or
737 other exercise intervention protocols should be considered first when the curve is still small and
738 surgery should only be considered when non-operative interventions have been shown not to
739 work. In addition, clinicians should also provide full disclosure of the lack of long term scientific
740 evidence for surgery and the possible long-term consequences and complications that may arise,
741 to the patients and their relatives. This also raises an awareness of lack of scientific developments
742 in patient-specific interventions within the clinical management of scoliosis. There is a clear need
743 for inter-professional working between surgeons, orthotists, physical therapists and other health
744 care professionals to develop new and effective clinical management procedures that benefits the
745 patient and improves the socio-economic impact.

746 In summary we can conclude that there is only 1 retrospective controlled abstract was available
747 for comparing operative to non-operative interventions where their results concludes that there
748 is no difference between surgical and non-surgical management of AIS patients.. Also
749 consideration should be given to the fact that current and recent evidence by Mueller [53] suggests
750 that the re-operation rate for some types of instrumentation currently used in clinical practice is
751 low in the very short term but may be as high as 50% in the long-term and over a life-time.

752

753 **5. Implications for practice**

754 ***5.1 Adolescents with idiopathic scoliosis and their parents/care-givers and relatives***

755 There is a clear lack of evidence for both the short and long term effectiveness of operative over
756 non-operative management. Considering the fact that surgery is a huge decision both for young

757 teenagers as well as their parents, the lack of both short and long term outcomes in this area
758 prevents service users from making decisions on treatment based on high quality evidence. Those
759 interested may wish to promote high quality studies in this area.

760 ***5.2. Clinicians***

761 Despite thousands of studies currently available in the area of the operative effectiveness on AIS
762 nothing is as yet available comparing the two main methods of treatment. It would appear that
763 clinicians have no choice but to continue with their current practices using clinical judgement
764 because of the lack of both randomised as well as prospective controlled evidence to help guide
765 their choice of intervention. Clinicians have the responsibility to promote as well as help support
766 and conduct high quality research in this area.

767 ***5.3. Policy makers***

768 Policy makers today have randomised evidence for bracing and scoliosis-specific exercises only,
769 upon which to base guidelines for the management of adolescents with idiopathic scoliosis. They
770 are likely to continue to rely on opinion and clinical experience when making their
771 recommendations.

772 ***5.4. Commissioners of services***

773 Until such time that high quality evidence is made available both for the short term as well as the
774 long term effectiveness of operative versus non-operative treatment it is important that
775 commissioners also consider commissioning alternative non-operative interventions such as
776 bracing and physiotherapy based scoliosis-specific exercises for smaller curves [6].
777 Commissioners should also consider re-introducing school screening for adolescents with
778 scoliosis as currently in many countries due to the abolition of scoliosis school screening
779 programs, most patients with small curves for whom non-operative management is most
780 appropriate are being missed. Frequently the curve is diagnosed only when the child's curve has
781 progressed significantly and is over 45 or 50 degrees at which point the only treatment option is
782 surgery.

783 **5.5 Implications for research**

784 Clinically meaningful comparative studies or prospective studies with a control group are urgently
785 needed to help guide clinicians in their management of adolescents with IS. Available
786 retrospective publications suggest that such studies might be able to be conducted prospectively
787 on a patient preference basis. However it might be very difficult to obtain ethical approval for such
788 a study. The authors of this review are aware that due to the long term nature of these studies
789 significant funding may be required. Funders of studies may wish to make this important group of
790 people a priority for future research. This review has also highlighted the urgent need for
791 *prospective studies with a control group* to be conducted. A patient-preference prospective
792 comparative study of operative intervention vs. high quality conservative treatment as available
793 today in specialist conservative centre is urgently needed for curves over 40 degrees. This
794 prospective study could be based on the patients' decision for either treatment approach; after a
795 full disclosure based on the evidence in the literature, of not only the potential gains that could be
796 achieved with operative treatment but also to include a full disclosure of the high rate of long-term
797 complications. Researchers should also explore the full use of biomechanical computer
798 simulations and patient specific modelling to inform and assess any clinical management
799 procedures. This could be made possible with the advances in technology and computer
800 applications.

801

802 **Conclusions**

803 In conclusion further primary studies are urgently needed to evaluate the effectiveness as well as
804 the short and long term impact of operative versus non-operative interventions on patient-
805 centred outcomes. Their quality of life and disability, psychological issues such as back pain and
806 disability change in trunk balance and progression of scoliosis, cosmetic issues in the mid to long
807 term (old age) as well as the adverse effects of both types of interventions both in the short term
808 to the mid-term (adulthood) as well in as in the long term to old age (70-80 years old). We are well
809 aware that the design of such a prospective study with a comparative non-operative intervention
810 would need significant planning and funding. Nevertheless we believe that a well conducted multi-

811 centre study that might include the use of a world-wide registry (many of which are already on-
812 going) might make this possible.

813

814 **Acknowledgement**

815 This extended comprehensive review is based on a Cochrane protocol published 2013 [109] and
816 a Cochrane review published 2015 [110]. In this protocol [109] the authors have provided the
817 following background information which is still valid today and was updated according to actual
818 literature. The Cochrane review published finally [110] included prospective and randomized
819 studies, only. Purpose of this review was (1) to update the literature search and (2) to also include
820 retrospective controlled papers so as to allow to draw a more comprehensive figure of the
821 literature there currently is on that topic.

822 All authors have read and approved the final manuscript.

823

824 **Conflict of interest / Competing interest disclosure**

825 HRW is receiving financial support for attending symposia and receives royalties from Koob GmbH & Co
826 KG. The company is held by the spouse of HRW.

827 None of the other authors report any competing interest or potential conflict of interest.

828

829

830

831 **References**

- 832 [1] Bradford D, Lonstein J, Moe J, Ogilvie J, Winter R. Moe's Textbook of Scoliosis and Other Spinal
833 Deformities. Philadelphia: Saunders 1987.
- 834 [2] White A, Panjabi M. In: Clinical Biomechanics of the Spine Chapter 7, Ed 2. Functional analysis and
835 clinical applications. Baltimore: Lippincott. 1990.
- 836 [3] Freidel K, Petermann F, Reichel D, Steiner A. Quality of life in women with idiopathic scoliosis.
837 Spine 2002; 27(4): E87-91.
- 838 [4] Kanayama M, Tadano S, Kaneda K, Ukai T, Abumi K A. Mathematical expression of three
839 dimensional configuration of the scoliotic spine. ASME J Biomech Eng 1996; 2(118): 247-252.
- 840 [5] Stokes I, Spence H, Aronsson D, Kilmer N. Mechanical modulation of vertebral body growth:
841 implications for scoliosis progression. Spine 1996;21(10):1162-7.
- 842 [6] Negrini S, Aulisa A, Aulisa L, *et al.* SOSORT guidelines: orthopaedic and rehabilitation treatment of
843 idiopathic scoliosis during growth. Scoliosis SOSORT Guidelines 2012; 7(1): 3.
- 844 [7] Lonstein J. Scoliosis: operative versus non-operative treatment. Clin Orthop 2006; 443: 284-59.
- 845 [8] Reichel D, Schanz J. Developmental psychological aspects of scoliosis treatment. Pediatr Reh 2003;
846 6(34): 221-5.
- 847 [9] Sevastik B, Xiong B, Sevastik J, Lindgren U, Willers U. Rib-vertebral angle asymmetry in idiopathic,
848 neuromuscular and experimentally induced scoliosis. Eur Spine J 1997; 6: 84-8.
- 849 [10] Stokes I. Analysis of symmetry of vertebral body loading consequent of lateral spinal curvature.
850 Spine 1997; 22: 2495-503.
- 851 [11] Machida M. Cause of idiopathic scoliosis. Spine 1999; 24(24): 2576-83.
- 852 [12] Burwell R, Dangerfield P. Adolescent idiopathic scoliosis: hypothesis of causation. State of the
853 art reviews. Spine 2000; 14(2): 319-32.
- 854 [13] Dickson R, Lawton J, Archer I, Butt W. The pathogenesis of idiopathic scoliosis: biplanar spinal
855 asymmetry. J Bone Joint Surg BR 1984; 66(1): 8-15.
- 856 [14] Rogala E, Drummond D, Gurr J. Scoliosis: incidence and natural history. A prospective
857 epidemiological study. J Bone Joint Surg AM 1978; 60(2): 173-6.
- 858 [15] Lonstein J, Carlson J. The prediction of curve progression in untreated idiopathic scoliosis during
859 growth. J Bone Joint Surg AM 1984; 66(7): 1061-71.
- 860 [16] Bridwell K. Surgical treatment of idiopathic adolescent scoliosis. Spine (Focus Issue) 1999;
861 24(24): 2607-16.

862 [17] Clarisse P. Prognostic evolution of minor scoliosis curves of 10 degree to 29 degrees during the
863 growth spurt [Prognostic evolutif des scolioses idiopathiques mineures de 10 degrees to 29 degrees
864 en periode de croissance]. Doctoral Thesis. Lyon: Claude Bernard University 1974.

865 [18] Fustier J. Spontaneous evolution of idiopathic scoliosis under 45 degrees during growth:
866 retrospective study from the Lyon centre of rehabilitation [Evolution radiologique spontanee des
867 scolioses idiopathiques de moins de 45 degrees en periode de croissance: etude graphique
868 retrospective de cent dossier due Centre d'adaptation fonctionnelle de massues]. Thesis. Lyon:
869 Claude Bernard University 1980.

870 [19] Bunnell W. The natural history of idiopathic scoliosis before skeletal maturity. Spine 1986;
871 11(8): 773-6.

872 [20] Weinstein S, Ponseti I. Curve progression in idiopathic scoliosis. J Bone Joint Surg AM 1983;
873 65(4): 447-55.

874 [21] Perdriolle R, Vidal J. Thoracic idiopathic scoliosis: curve evolution and prognosis. Spine 1985;
875 10(9): 785-91.

876 [22] Mehta M. The rib-vertebra angle in the early diagnosis between resolving and progressive
877 infantile scoliosis. J Bone Joint Surg BR 1972; 54(2): 230-43.

878 [23] Goldberg C, Moore D, Fogerty E, Dowling F. The natural history of early onset scoliosis. Stud Hea
879 Tech Info 2002; 91: 68-70.

880 [24] Asher M, Burton D. Adolescent idiopathic scoliosis: natural history and long term treatment
881 effects. Scoliosis 2006; 1:2. [DOI: 10.1186/1748-7161-1-2]

882 [25] Hawes M, O'Brien J. The transformation of spinal curvature into spinal deformity: pathological
883 processes and implications for treatment. Scoliosis 2006; 1(3): 1-9.

884 [26] Weiss H. Physical therapy intervention studies on idiopathic scoliosis: review with the focus on
885 inclusion criteria. Scoliosis 2012; 7(4): 1-11.

886 [27] Roaf R. Spinal Deformities. 2nd ed. Tunbridge Wells: Pitman Medical 1980.

887 [28] Rowe D, Bernstein S, Riddick M, *et al.* A meta-analysis of the efficacy of non-operative treatments
888 for idiopathic scoliosis. J Bone Joint Surg AM 1997; 79(5): 664-74.

889 [29] Lenssinck M, Frijlink A, Berger Y, *et al.* Effect of bracing and other conservative interventions in
890 the treatment of idiopathic scoliosis in adolescents: a systematic review of clinical trials. Phys Ther
891 2005; 85(12): 1329-39.

- 892 [30] Negrini S, Aulisa L, Ferraro C, *et al.* Italian guidelines on rehabilitation treatment of adolescents
893 with scoliosis or other spinal deformities. *Europa Med phys* 2005; 41(2): 183-201.
- 894 [31] Weiss H, Negrini S, Hawes M, *et al.* Physical exercises in the treatment of idiopathic scoliosis at
895 risk of brace treatment. *SOSORT Consensus Paper Scoliosis* 2006; 1:6.
- 896 [32] Weiss H, Negrini S, Rigo M, *et al.* Indications for conservative management of scoliosis
897 (guidelines). *Scoliosis* 2006; 1: 5
- 898 [33] Dolan L, Weinstein S. Operativerates after observation and bracing for adolescent idiopathic
899 scoliosis: an evidence-based review. *Spine* 2007; 32(19): S91-100.
- 900 [34] Negrini S, Marchini G. Efficacy of the symmetric, patient-oriented, rigid, three-dimensional, active
901 (SPoRT) concept of bracing for scoliosis: a prospective study of the Sforzesco versus Lyon brace. *Eur*
902 *Med phys* 2007; 43(2): 171-81.
- 903 [35] Rigo M, Negrini S, Weiss H, *et al.* SOSORT consensus paper on brace action: TLSO biomechanics
904 of correction (investigating the rationale for force vector selection). *Scoliosis* 2006; 1:11.
- 905 [36] Katz D, Durrani A. Factors that influence outcome in bracing large curves in patients with
906 adolescent idiopathic scoliosis. *Spine* 2001; 26(21): 2354-61.
- 907 [37] Fallstrom K, Cochran T, Nachemson A. Long-term effects on personality development in patients
908 with adolescent idiopathic scoliosis: influence of type of treatment. *Spine* 1986; 11(7): 756-8.
- 909 [38] Noonan K, Dolan L, Jacobson W, Weinstein S. Long-term psychosocial characteristics of patients
910 treated for idiopathic scoliosis. *J Pediatr Orthop* 1997; 17(6): 712-7.
- 911 [39] Climent J, Sanchez J. Impact of the type of brace on the quality of life of adolescents with spine
912 deformities. *Spine* 1999; 24(18): 1903-8.
- 913 [40] Maruyama T, Takeshita K. Operativetreatment of scoliosis: a review of techniques currently
914 applied. *Scoliosis* 2008; 3(6): 1-6.
- 915 [41] Harrington P. Treatment of scoliosis: correction and internal fixation by instrumentation. *J Bone*
916 *Joint Surg AM* 1962; 44A: 591-610.
- 917 [42] Betz R, Harms J, Clements D III, Lenke L, Lowe T, Shufflebarger H. Comparison of anterior and
918 posterior instrumentation for correction of adolescent thoracic idiopathic scoliosis. *Spine* 1999; 24:
919 225-39.
- 920 [43] Betz R, Lenke L, Lowe G. Proximal screw pull-out during anterior instrumentation for thoracic
921 scoliosis: preventive techniques. In: 35th Annual Meeting Scoliosis Research Society. Cairns,
922 2000:156.

923 [44] Muschik M, Kimmich H, Demmel T. Comparison of anterior and posterior double-rod
924 instrumentation for thoracic idiopathic scoliosis: results of 141 patients. *Eur Spine J* 2006; 15: 1128-
925 38.

926 [45] Arlet V. Anterior thoracoscopic spine release in deformity surgery: a meta-analysis and review.
927 *Eur Spine J* 2000; 9(Suppl 1): S17-23.

928 [46] Kaneda K, Kiyoshi M, Shono Y, *et al.* New anterior instrumentation for the management of
929 thoracolumbar and lumbar scoliosis: application of the Kaneda two-rod system. *Spine* 1996; 21(10):
930 1250-61.

931 [47] Bridwell K. Operativetreatment of adolescent idiopathic scoliosis: the basics and the
932 controversies (Spine update). *Spine* 1994; 19(9): 1095-100.

933 [48] Kim Y, Lenke L, Bridwell K, Kim K, Steger-May K. Pulmonary function in adolescent idiopathic
934 scoliosis relative to the operative procedure. *J Bone Joint Surg AM* 2005; 87: 1534-41.

935 [49] Newton P, Marks M, Faro F, *et al.* Use of video-assisted thoracoscopic surgery to reduce
936 perioperative morbidity in scoliosis surgery. *Spine* 2003; 28: S249-54.

937 [50] Luhmann S, Lenke L, Kim Y, Bridwell K, Schootman M. Thoracic adolescent idiopathic scoliosis
938 curves between 70 degrees and 100 degrees. Is anterior release necessary? *Spine* 2005; 30: 2061-67.

939 [51] Di Silvestre M, Bakaloudis G, Lolli F, *et al.* Posterior fusion only for thoracic adolescent idiopathic
940 scoliosis of more than 80 degrees: pedicle screws versus hybrid instrumentation. *Eur Spine J* 2008;
941 17: 1336-49.

942 [52] Weiss H, Goodall D. Rate of complications in scoliosis surgery: a systematic review of the PubMed
943 literature. *Scoliosis* 2008; 3: 1-18. [DOI: 10.1186/1748-7161-3-9]

944 [53] Mueller F, Gluch H. Cotrel-Dubousset instrumentation for the correction of adolescent idiopathic
945 scoliosis: long-term results with an unexpected high revision rate. *Scoliosis* 2012; 7(1): 13.

946 [54] Romano M, Minozzi S, Bettany-Saltikov J, *et al.* Exercises for adolescent idiopathic scoliosis.
947 *Cochrane Database of Systematic Reviews* 2012, Issue 8. Art. No.: CD007837. DOI:
948 10.1002/14651858.CD007837.pub2.

949 [55] Weiss H, Reichel D, Schanz J, Zimmermann-Gudd S. Deformity related stress in adolescents with
950 AIS. *Stud HeaTech Info* 2006; 123: 347-51.

951 [56] Coillard C, Leroux M, Zabjek K, Rivard C. SpineCor—A nonrigid brace for the treatment of
952 idiopathic scoliosis: post-treatment results. *Eur Spine J* 2003; 12(2): 141-8.

953 [57] Negrini S, Minozzi S, Romano M, *et al.* Braces for idiopathic scoliosis in adolescents. Cochrane
954 Database of Systematic Reviews 2010, Issue Issue 1. Art. No.: CD006850. DOI:
955 10.1002/14651858.CD006850.pub2.

956 [58] Coillard C, Leroux M, Badeaux J, Rivard C. SPINECOR: a new therapeutic approach for idiopathic
957 scoliosis. *Stud Hea Tech Info* 2002; 88: 215-7.

958 [59] Lupparelli S, Pola E, Pitta L, *et al.* Biomechanical factors affecting progression of structural
959 scoliotic curves of the spine. *Studies in Health Technology and Informatics* 2002; 91: 81-5.

960 [60] Castro F Jr. Adolescent idiopathic scoliosis, bracing and the Hueter-Volkman principle. *Spine*
961 2003; 3(3): 180-5.

962 [61] Odermatt D, Mathieu P, Beausejour M, Labelle H, Aubin C. Electromyography of scoliotic patients
963 treated with a brace. *J Orthop Res* 2003; 21(5): 931-6.

964 [62] Weiss H, Hawes M. Adolescent idiopathic scoliosis, bracing and the Hueter-Volkman principle.
965 *Spine J* 2004; 4(4): 485-6.

966 [63] Negrini S, Marchini G. Efficacy of the symmetric, patient-oriented, rigid, three-dimensional,
967 active (SPoRT) concept of bracing for scoliosis: a prospective study of the Sforzesco versus Lyon
968 brace. *Eur Med phys* 2006; 43(2): 171-81.

969 [64] Stokes I, Burwell R, Dangerfield P. Biomechanical spinal growth modulation and progressive
970 adolescent scoliosis — a test of the 'vicious cycle' pathogenetic hypothesis: summary of an electronic
971 focus group debate of the IBSE. *Scoliosis* 2006; 1:16.

972 [65] Grivas T, Vasiliadis E, Olga D, Triantafyllopoulos S, Triantafyllopoulos G. What a school screening
973 program could contribute in clinical research of idiopathic scoliosis aetiology. *Disabil Rehabil* 2008;
974 30(10): 752-62.

975 [66] Smania N, Picelli A, Romano M, Negrini S. Neurophysiological basis of rehabilitation of adolescent
976 idiopathic scoliosis. *Disabil Rehabil* 2008; 30(10): 763-71.

977 [67] Haheer T, Merola A. *Atlas of Spine Operative Techniques*. New York: Thieme 2003.

978 [68] Cailliet R. *Scoliosis: Diagnosis and Management*. Philadelphia: FA Davis 1975.

979 [69] Hawes M. Impact of spine surgery on signs and symptoms of spinal deformity. *Pediatr Reh* 2006;
980 9(4): 318-39.

981 [70] Pineda S, Bago J, Gilperez C, Climent J. Validity of the Walter Reed Visual Assessment Scale to
982 measure subjective perception of spine deformity in patients with idiopathic scoliosis. *Scoliosis* 2006;
983 1:18.

984 [71] Sanders J, Harrast J, Kuklo T, *et al.* The Spinal Appearance Questionnaire: results of reliability,
985 validity, and responsiveness testing in patients with idiopathic scoliosis. *Spine* 2007; 32(24): 2719-
986 22.

987 [72] Bago J, Sanchez-Raya J, Sanchez Perez-Grueso F, Climent J. The Trunk Appearance Perception
988 Scale (TAPS): a new tool to evaluate subjective impression of trunk deformity in patients with
989 idiopathic scoliosis. *Scoliosis* 2010; 5: 6.

990 [73] Berryman F, Pynsent P, Fairbank J, Disney S. A new system for measuring three-dimensional
991 back shape in scoliosis. *Eur Spine J* 2008; 7: 663-72.

992 [74] Oxborrow N. Methodology. Current topic: assessing the child with scoliosis: the role of surface
993 topography. *Arch Dis Child* 2000; 83: 453-5 .

994 [75] Knott P, Mardjetko S, Rollet M, *et al.* Evaluation of the reproducibility of the formetric 4D
995 measurements for scoliosis. *Scoliosis* 2010; 5 :(Suppl 1): O10.

996 [76] Asher M, Min Lai S, Burton D, Manna B. The reliability and concurrent validity of the Scoliosis
997 Research Society – 22 patient questionnaire for idiopathic scoliosis. *Spine* 2003; 28(1): 63-9.

998 [77] Vasiliadis E, Grivas T, Gkoltsiou K.. Development and preliminary validation of Brace
999 Questionnaire (BrQ): a new instrument for measuring quality of life of brace treated scoliotics.
1000 *Scoliosis* 2006; 1(7): 1-8.

1001 [78] Furlan A, Pennick V, Bombardier C, Van Tulder M. Editorial BCBRG. Updated method guidelines
1002 for systematic reviews in the Cochrane Back Review Group. *Spine* 2009; 34(18): 1929-41.

1003 [79] Higgins JPT, Green S, Eds. *Cochrane Handbook for Systematic Reviews of Interventions* Version
1004 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. www.cochrane-handbook.org.

1005 [80] Downs S, Black N. The feasibility of creating a checklist for the assessment of the methodological
1006 quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol*
1007 *Community Health* 1998; 52: 377-84.

1008 [81] Shekelle P, Andersson G, Bombardier C, *et al.* A brief introduction to the critical reading of the
1009 clinical literature. *Spine* 1994; 19(19): 2028S-31S.

1010 [82] Van Tulder M, Furlan A, Bombardier C, *et al.* Editorial Board Cochrane Back Review Group.
1011 Updated method guidelines for systemic reviews in the Cochrane Collaboration Back Review Group.
1012 *Spine* 2003; 28(12): 1290-9.

1013 [83] Ward TW, Roach,J,W, Friel,N, Kenkre,TS,, Brooks MM. 22r Scores in Non-Operated AIS Patients
1014 with Curves over 40°. SRS 50th Anniversary Abstract booklet, Annual meeting and course, abstract 5,
1015 pp 180-181, 2015

1016 [84] Simony A, Hansen EJ, Carreon LY, Christensen SB and Osterheden M. Andersen Health-related
1017 quality-of-life in adolescent idiopathic scoliosis patients 25 years after treatment. Scoliosis 2015

1018 [85] Anderson M O, Christenesen S B, Thomsen K. Outcome at 10 Years After Treatment for
1019 Adolescent Idiopathic Scoliosis. SPINE 2006; 31: 350 - 354.

1020 [86] Danielsson A J, Nachemson A L. Radiologic Findings and Curve Progression 22 Years After
1021 Treatment for Adolescent Idiopathic Scoliosis. SPINE 2001; 26: 516 - 525.

1022 [87] Danielsson A J, Nachemson A L. Childbearing, Curve progression, and Sexual Function in Women
1023 22 Years After Treatment for Adolescent Idiopathic Scoliosis. SPINE 2001; 26: 1449 - 1456.

1024 [88] Danielsson A J, Wiklund I, Pehrsson K, Nachemson A L. Health-related quality of life in patients
1025 with adolescent idiopathic scoliosis: a matched follow-up at least 20 years after treatment with brace
1026 or surgery. Eur Spine J 2001; 10: 278 - 288.

1027 [89] Danielsson A J, Nachemson A L. Back Pain and Function 22 Years After Brace Treatment for
1028 Adolescent Idiopathic Scoliosis: A Case-Control Study - Part 1. SPINE 2003; 28: 2078 - 2086.

1029 [90] Danielsson A J, Romberg K, Nachemson A L. Spinal Range of Motion, Muscle Endurance, and back
1030 Pain and Function at Least 20 Years After Fusion or Brace Treatment for Adolescent Idiopathic
1031 Scoliosis. SPINE 2006; 31: 275 - 283.

1032 [91] Pehrsson K, Danielson A, Nachemson A. Pulmonary function in adolescent idiopathic scoliosis: a
1033 25 year follow up after surgery or start of brace treatment. Thorax 2001; 56: 388 - 393.

1034 [92] Bunge E M, Juttman R E, De Kleuver M, Van Biezen F C, De Koning H J. Health-related quality of
1035 life in patients with adolescent idiopathic scoliosis after treatment: short-term effects after brace or
1036 operative treatment. Eur Spine J 2007; 16: 83 - 89.

1037 [93] Weiss H, Goodall D. The treatment of adolescent idiopathic scoliosis (AIS) according to present
1038 evidence. A systematic review. Eur J Phy Reh Med 2008; 44(2): 177 - 193.

1039 [94] Weiss H, Moramarco M, Moramarco K. Risks and long-term complications of adolescent
1040 idiopathic scoliosis surgery vs. non-operativeand natural history outcomes. Hard Tissue 2013; 2(3):
1041 27.

1042 [95] Cundy T, Antoniou G, Sutherland L, Freeman B, Cundy P. Serum titanium, niobium and
1043 aluminium levels following instrumented spinal arthrodesis in children. Spine 2013; 38(7): 564-70.

1044 [96] Landauer F, Wimmer C, Behensky H. Estimating the final outcome of brace treatment for
1045 idiopathic thoracic scoliosis at 6-month follow-up. *Pediatr Rehabil.* 2003;**6**(3-4):201-7. [DOI]
1046 [PubMed]

1047 [97] Weiss HR, Werkmann M. Rate of surgery in a sample of patients fulfilling the SRS inclusion
1048 criteria treated with a Cheneau brace of actual standard. *Stud Health Technol Inform.* 2012;**176**:407-
1049 10. [PubMed]

1050 [98] De Giorgi S, Piazzolla A, Tafuri S, Borracci C, Martucci A, De Giorgi G. Chêneau brace for adolescent
1051 idiopathic scoliosis: long-term results. Can it prevent surgery? *Eur Spine J.* 2013;**22**(6):815-22.

1052 [99] Moramarco K. For adolescent idiopathic scoliosis patients, treatment should incur the least
1053 potential harm. *Hard Tissue* 2013; 2(5): 44.

1054 [100] Westrick E, Ward W. Adolescent idiopathic scoliosis: 5-year to 20-year evidence-based
1055 operative results. *J Pediatr Ortho* 2011; 31(1 suppl): S61-68.

1056 [101] Weinstein S, Dolan L, Spratt K, Peterson K, Spoonamore M, Ponseti I. Health and Function of
1057 Patients With Untreated Idiopathic Scoliosis. *JAMA* 2003; 289(5): 559 - 567.

1058 [102] Weinstein S, Dolan L, Wright J, Dobbs M. Effects of Bracing in Adolescents with Idiopathic
1059 Scoliosis. *N Eng J Med* 2013; 369: 1512 - 1521.

1060 [103] Monticone M, Ambrosini E, Cazzaniga D, Rocca B, ferrante S. Active self-correction and task-
1061 orientated exercises reduce spinal deformity and improve quality of life in subjects with mild
1062 adolescent idiopathic scoliosis. Results of a randomised controlled trial. *Eur Spine J* 2014.

1063 [104] Wan, L.; Wang, G. X.; Bian, R. Exercise therapy in treatment of essential S-shaped scoliosis:
1064 Evaluation of Cobb angle in breast and lumbar segment through a follow-up of half a year

1065 [105] Toledo, Pollyana Coelho Vieira; de Mello, Danielli Braga; Araújo, Maria Erivania; Daoud,
1066 Rejane; Dantas, Estélio Henrique Martin Global posture reeducation effects in students with
1067 scoliosis *Fisioterapia e Pesquisa* 2011;18(4):329-334 6p

1068 [106] Schreiber, S.: Schroth Exercises for Adolescent Idiopathic Scoliosis – Reliability, A
1069 Randomized Controlled Trial and Clinical Significance 2015;PhD():170

1070 [107] Schreiber, S.; Parent, E. C.; Moez, E. K.; Hedden, D. M.; Hill, D.; Moreau, M. J.; Lou, E.; Watkins, E.
1071 M.; Southon, S. C. The effect of Schroth exercises added to the standard of care on the quality of life
1072 and muscle endurance in adolescents with idiopathic scoliosis-an assessor and statistician blinded
1073 randomized controlled trial: "SOSORT 2015 Award Winner" *Scoliosis* 2015;10():24

1074 **[108]** Kuru, T.; Yeldan, I.; Dereli, E. E.; Ozdincler, A. R.; Dikici, F.; Colak, I. The efficacy of three-
1075 dimensional Schroth exercises in adolescent idiopathic scoliosis: a randomised controlled clinical
1076 trial Clinical Rehabilitation 2016 Feb;30(2):181-90. doi: 10.1177/0269215515575745.

1077

1078 **[109]** J Bettany-Saltikov, H R Weiss, N Chockalingam, R Taranu, S Srinivas, J Hogg, V Whittaker, R V
1079 Kalyan. Surgical versus non-surgical interventions in patients with adolescent idiopathic
1080 scoliosis Editorial Group: Protocol of the Cochrane Back Group Published Online, 2013, DOI:
1081 10.1002/14651858.CD010663 July.

1082 **[110]** J Bettany-Saltikov, H R Weiss, N Chockalingam, R Taranu, S Srinivas, J Hogg, V Whittaker, R V
1083 Kalyan, Arnell T. Surgical versus non-surgical interventions in people with adolescent idiopathic
1084 scoliosis. The Cochrane database of systematic reviews 4: 2015,
1085 DOI: 10.1002/14651858.CD010663.pub2 April.

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1088 **Figure 1. Study Flow Diagram**

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1090

1091 **Appendices**

1092

1093 **Appendix 1**

1094

1095 **CBRG Trials Register, CENTRAL, MEDLINE, EMBASE and CINAHL search strategies**

1096

1097 **CBRG Trials Register**

1098 Last searched 11 August, 2014

1099 #1 scoliosis

1100

1101 **CENTRAL**

1102 Last searched 8 August, 2014

1103 #1 MeSH descriptor: [Scoliosis] explode all trees

1104 #2 scoliosis:ti,ab,kw (Word variations have been searched)

1105 #3 #1 or #2
1106 #4 MeSH descriptor: [Orthopedic Procedures] explode all trees
1107 #5 MeSH descriptor: [Orthopedic Fixation Devices] explode all trees
1108 #6 "spine fusion" or "spinal fusion" or "spinal instrumentation" or spondylodesis:ti,ab,kw (Word
1109 variations have been searched)
1110 #7 surg* or operat* or realign* or screw* or hybrid or wire* or hook* or sublaminar:ti,ab,kw (Word
1111 variations have been searched)
1112 #8 #4 or #5 or #6 or #7
1113 #9 MeSH descriptor: [Orthotic Devices] explode all trees
1114 #10 braces:ti,ab,kw (Word variations have been searched)
1115 #11 bracing:ti,ab,kw (Word variations have been searched)
1116 #12 MeSH descriptor: [Exercise] explode all trees
1117 #13 MeSH descriptor: [Physical Therapy Modalities] explode all trees
1118 #14 MeSH descriptor: [Rehabilitation] explode all trees
1119 #15 MeSH descriptor: [Drug Therapy] explode all trees
1120 #16 non-surg* or nonsurg* or non-operat* or nonoperat* or conserv* or taping or tape* or
1121 immobilis* or immobiliz* or therap* or electrotherap*:ti,ab,kw (Word variations have been
1122 searched)
1123 #17 #9 or #10 or #11 or #12 or #13 or #14 or #15 or #16
1124 #18 #3 and #8 and #17 Publication Year from 2013 to 2014, in Trials
1125
1126 **MEDLINE and MEDLINE In-Process & Other Non-Indexed Citations**
1127 Last searched 8 August 2014
1128 1. exp Spinal Diseases/
1129 2. Scoliosis/
1130 3. scoliosis.mp.
1131 4. or/1-3
1132 5. Orthopedics/
1133 6. exp Surgical Procedures, Operative/
1134 7. surgery.fs.
1135 8. surg\$.tw.

- 1136 9. operat\$.tw.
- 1137 10. realign\$.tw.
- 1138 11. spondylodesis.tw.
- 1139 12. spine fusion.tw.
- 1140 13. spinal fusion.tw.
- 1141 14. spinal instrumentation.tw.
- 1142 15. Bone Screws/
- 1143 16. screw\$.tw.
- 1144 17. hybrid.tw.
- 1145 18. Bone Wires/
- 1146 19. sublaminar.tw.
- 1147 20. wire\$.tw.
- 1148 21. hook\$.tw.
- 1149 22. or/5-21
- 1150 23. exp Rehabilitation/
- 1151 24. rehabilit\$.tw.
- 1152 25. rehabilitation.fs.
- 1153 26. exp Physical Therapy Modalities/
- 1154 27. Physical Therapy Speciality.mp.
- 1155 28. physiotherapy.tw.
- 1156 29. physical therapy.tw.
- 1157 30. exp Exercise/
- 1158 31. exercise\$.tw.
- 1159 32. Exercise Movement Techniques/
- 1160 33. exp Exercise Therapy/ (30988)
- 1161 34. exp Musculoskeletal Manipulations/
- 1162 35. Immobilization/
- 1163 36. Braces/
- 1164 37. brace\$.mp.
- 1165 38. bracing.mp.
- 1166 39. exp Orthotic Devices/

1167 40. Orthopedic Equipment/
1168 41. limit 40 to yr="1902 - 1975"
1169 42. (non-surg\$ or nonsurg\$ or non-operat\$ or nonoperat\$ or conserv\$).tw.
1170 43. (immobilis\$ or immobiliz\$ or therap\$ or taping or tape\$ or electrotherapy\$).tw.
1171 44. or/23-43
1172 45. 4 and 22 and 44
1173 46. limit 45 to adolescent <13 to 18 years>
1174 47. Adolescent/
1175 48. adolescen\$.mp.
1176 49. 47 or 48
1177 50. 45 and 49
1178 51. 46 or 50
1179 52. Comparative Study/
1180 53. exp Evaluation Studies/
1181 54. exp Follow-Up Studies/
1182 55. exp Prospective Studies/
1183 56. exp Cross-Over Studies/
1184 57. exp Epidemiologic Studies/
1185 58. exp Case-Control Studies/
1186 59. exp Cohort Studies/
1187 60. exp Cross-Sectional Studies/
1188 61. (cohort adj (study or studies)).mp.
1189 62. cohort analy\$.mp.
1190 63. (follow up adj (study or studies)).mp.
1191 64. (observational adj (study or studies)).mp.
1192 65. longitudinal.mp.
1193 66. retrospective.mp.
1194 67. cross sectional.mp.
1195 68. control\$.mp.
1196 69. prospective\$.mp.
1197 70. volunteer.mp.

1198 71. or/52-70
1199 72. randomized controlled trial.pt.
1200 73. controlled clinical trial.pt.
1201 74. randomi#ed.ti,ab.
1202 75. placebo.ti,ab.
1203 76. drug therapy.fs.
1204 77. randomly.ti,ab.
1205 78. trial.ti,ab.
1206 79. groups.ti,ab.
1207 80. or/72-79
1208 81. (Animals not (Humans and Animals)).sh.
1209 82. 80 not 81
1210 83. 71 not 81
1211 84. 82 or 83
1212 85. 51 and 84
1213 86. limit 85 to yr=2013-2014
1214 87. limit 85 to ed=20130705-20140808
1215 88. 86 or 87

1216

1217 **EMBASE**

1218 Last searched 8 August 2014

- 1219 1. exp spine/
1220 2. exp spine disease/
1221 3. exp scoliosis/
1222 4. exp idiopathic scoliosis/
1223 5. scoliosis.mp.
1224 6. or/1-5
1225 7. orthopedics/
1226 8. exp surgery/
1227 9. su.fs.
1228 10. surg\$.ti,ab.

1229 11. operat\$.ti,ab.
1230 12. realign\$.ti,ab.
1231 13. spondylodesis.ti,ab.
1232 14. spine fusion.ti,ab.
1233 15. spinal fusion.ti,ab.
1234 16. spinal instrumentation.ti,ab.
1235 17. bone screw/
1236 18. screw\$.ti,ab.
1237 19. hybrid.ti,ab.
1238 20. Kirschner wire/
1239 21. sublaminar.ti,ab.
1240 22. wire\$.ti,ab.
1241 23. hook\$.ti,ab.
1242 24. or/7-23
1243 25. exp rehabilitation/
1244 26. rehabilitat\$.ti,ab.
1245 27. rh.fs.
1246 28. exp physiotherapy/
1247 29. physiotherapist/
1248 30. physiotherapy.ti,ab.
1249 31. physical therapy.ti,ab.
1250 32. exp exercise/
1251 33. exercise\$.ti,ab.
1252 34. kinesiotherapy/
1253 35. exp manipulative medicine/
1254 36. immobilization/
1255 37. brace/
1256 38. brace\$.mp.
1257 39. bracing.mp.
1258 40. exp orthotics/
1259 41. exp orthopedic equipment/

1260 42. (non-surg\$ or nonsurg\$ or non-operat\$ or nonoperat\$ or conserv\$).ti,ab.
1261 43. (immobilis\$ or immobiliz\$ or therap\$ or taping or tape\$ or electrotherap\$).ti,ab.
1262 44. or/25-43
1263 45. 6 and 24 and 44
1264 46. limit 45 to adolescent <13 to 17 years>
1265 47. adolescent/
1266 48. adolescen\$.mp.
1267 49. or/47-48
1268 50. 45 and 49
1269 51. 46 or 50
1270 52. exp Clinical Study/
1271 53. exp Case Control Study/
1272 54. exp Family Study/
1273 55. exp Longitudinal Study/
1274 56. exp Retrospective Study/
1275 57. exp Prospective Study/
1276 58. exp Cohort Analysis/
1277 59. (cohort adj (study or studies)).mp.
1278 60. (case control adj (study or studies)).mp.
1279 61. (follow up adj (study or studies)).mp.
1280 62. (observational adj (study or studies)).mp.
1281 63. (epidemiologic\$ adj (study or studies)).mp.
1282 64. (cross sectional adj (study or studies)).mp.
1283 65. exp Comparative Study/
1284 66. evaluation study.mp.
1285 67. follow-up study.mp. or exp Follow Up/
1286 68. Crossover Procedure/
1287 69. prospective\$.mp.
1288 70. exp VOLUNTEER/
1289 71. or/52-70
1290 72. Clinical Article/

1291 73. exp Clinical Study/
1292 74. Clinical Trial/
1293 75. Controlled Study/
1294 76. Randomized Controlled Trial/
1295 77. Major Clinical Study/
1296 78. Double Blind Procedure/
1297 79. Multicenter Study/
1298 80. Single Blind Procedure/
1299 81. Phase 3 Clinical Trial/
1300 82. Phase 4 Clinical Trial/
1301 83. crossover procedure/
1302 84. placebo/
1303 85. or/72-84
1304 86. allocat\$.mp.
1305 87. assign\$.mp.
1306 88. blind\$.mp.
1307 89. (clinic\$ adj25 (study or trial)).mp.
1308 90. compar\$.mp.
1309 91. control\$.mp.
1310 92. cross?over.mp.
1311 93. factorial\$.mp.
1312 94. follow?up.mp.
1313 95. placebo\$.mp.
1314 96. prospectiv\$.mp.
1315 97. random\$.mp.
1316 98. ((singl\$ or doubl\$ or trebl\$ or tripl\$) adj25 (blind\$ or mask\$)).mp.
1317 99. trial.mp.
1318 100. (versus or vs).mp.
1319 101. or/86-100
1320 102. 85 or 101

1321 103. exp animals/ or exp invertebrate/ or animal experiment/ or animal model/ or animal
1322 tissue/ or animal cell/ or nonhuman/
1323 104. human/ or normal human/ or human cell/
1324 105. 103 and 104
1325 106. 103 not 105
1326 107. 102 not 106
1327 108. 71 not 106
1328 109. 107 or 108
1329 110. 51 and 109
1330 111. limit 110 to yr=2013-2014
1331 112. limit 110 to em=201326-201431
1332 113. 111 or 112
1333
1334 **CINAHL**
1335 Last searched 8 August 2014
1336 v S85 S83 or S84
1337 S84 S82 and EM 20130705-20140808
1338 S83 S82 Limiters - Published Date: 20130701-20140831
1339 S82 S77 OR S81
1340 S81 S76 AND S80
1341 S80 S78 OR S79
1342 S79 adolescen*
1343 S78 MH Adolescence+
1344 S77 S34 AND S39 AND S75 Limiters - Age Groups: Adolescent: 13-18 years
1345 S76 S34 AND S39 AND S75
1346 S75 S56 OR S74
1347 S74 S57 or S58 or S59 or S60 or S61 or S62 or S63 or S64 or S65 or S66 or S67 or S68 or S69 or
1348 S70 or S71 or S72 or S73
1349 S73 TI (immobilis* or immobiliz* or therap* or taping or tape* or electrotherap*) or AB
1350 (immobilis* or immobiliz* or therap* or taping or tape* or electrotherap*)

1351 S72 TI (non-surg* or nonsurg* or non-operat* or nonoperat* or conserv*) or AB (non-surg* or
1352 nonsurg* or non-operat* or nonoperat* or conserv*)
1353 S71 MH "Orthopedic Equipment and Supplies+ "
1354 S70 orthotic*
1355 S69 (MH "Orthoses+") OR "orthoses"
1356 S68 bracing
1357 S67 brace*
1358 S66 MH Immobilization
1359 S65 MH Manipulation, Orthopedic
1360 S64 MH Therapeutic Exercise+
1361 S63 TI exercise* or AB exercise*
1362 S62 MH Exercise+
1363 S61 TI "physical therapy" or AB "physical therapy"
1364 S60 TI physiotherapy or AB physiotherapy
1365 S59 MH Physical Therapists
1366 S58 MH Physical Therapy+
1367 S57 MH Rehabilitation+
1368 S56 (TI hook* or AB hook*) AND (S40 OR S41 OR S42 OR S43 OR S44 OR S45 OR S46 OR S47 OR
1369 S48 OR S49 OR S50 OR S51 OR S52 OR S53 OR S54 OR S55)
1370 S55 TI hook* or AB hook*
1371 S54 TI wire* or AB wire*
1372 S53 TI sublaminar or AB sublaminar
1373 S52 TI hybrid or AB hybrid
1374 S51 TI screw* or AB screw*
1375 S50 MH Orthopedic Fixation Devices
1376 S49 TI "spinal instrumentation" or AB "spinal instrumentation"
1377 S48 TI "spinal fusion" or AB "spinal fusion"
1378 S47 TI "spine fusion" or AB "spine fusion"
1379 S46 TI spondylodesis or AB spondylodesis
1380 S45 TI realign* or AB realign*
1381 S44 TI operat* or AB operat*

1382 S43 TI surg* or AB surg*
 1383 S42 MW Surgery
 1384 S41 MH Surgery, Operative+
 1385 S40 MH Orthopedics
 1386 S39 S35 OR S36 OR S37 OR S38
 1387 S38 scoliosis
 1388 S37 MH Scoliosis+
 1389 S36 MH Spinal Diseases+
 1390 S35 MH Spine+
 1391 S34 S32 or S33
 1392 S33 S30 not S31
 1393 S32 S14 not S31
 1394 S31 MH Animals
 1395 S30 S15 OR S16 OR S17 OR S18 OR S19 OR S20 OR S21 OR S22 OR S23 OR S24 OR S25 OR S26 OR
 1396 S27 OR S28 OR S29
 1397 S29 volunteer*
 1398 S28 prospective*
 1399 S27 control*
 1400 S26 retrospective
 1401 S25 longitudinal
 1402 S24 "observational studies" or "observational study"
 1403 S23 "follow-up stud*" or "followup stud*"
 1404 S22 "cohort analys*"
 1405 S21 "cohort studies" or "cohort study"
 1406 S20 MH Epidemiological Research+
 1407 S19 MH Prospective Studies+
 1408 S18 MH Evaluation Research+
 1409 S17 MH Comparative Studies
 1410 S16 latin square
 1411 S15 MH Study Design+
 1412 S14 S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13

1413 S13 MH Random Sample
1414 S12 random*
1415 S11 MW Drug Therapy
1416 S10 placebo*
1417 S9 MH Placebos
1418 S8 MH Placebo Effect
1419 S7 TI groups or AB groups
1420 S6 triple-blind
1421 S5 single-blind
1422 S4 double-blind
1423 S3 clinical W3 trial
1424 S2 "randomi?ed controlled trial*"
1425 S1 (MH "Clinical Trials+")

1426
1427

1428 **APPENDIX 2**

1429

1430 **OTHER SEARCH STRATEGIES**

1431

1432 **PsycINFO**Last searched 8 August 2014

1433 1 scoliosis.mp.

1434 2 (surg* or operat* or realign* or spondylodesis or fusion or instrumentation or screw* or hook*
1435 or hybrid or wire* or sublaminar).mp. [mp=title, abstract, heading word, table of contents, key
1436 concepts, original title, tests & measures]

1437 3 (rehabilit* or therap* or physiotherapy or exercise* or braces or bracing or orthotic* or non-
1438 surg* or nonsurg* or non-operat* or nonoperat* or conserv* or immobilis* or immobiliz* or taping
1439 or tape* or electrotherapy).mp. [mp=title, abstract, heading word, table of contents, key concepts,
1440 original title, tests & measures]

1441 4 1 and 2 and 3

1442 5 limit 4 to yr=2013-2014

1443

1444 **PEDro**

1445

1446 Last searched 8 August 2014

1447 Abstract & Title: scoliosis

1448 AND

1449 Method: clinical trial

1450 New records added since 05/07/2013

1451

1452 **PubMed**

1453

1454 Searched 11 August 2014. This search was designed to

1455 capture citations not indexed in MEDLINE.

1456 (surg* or fus* or orthopedic* or instrument* or screw* or wire* or hook*[Title/Abstract]) OR

1457 (nonsurg* or non-surg or nonop* or non-op* or immobiliz* or immobilis* or exercise* or therap*

1458 or braces or bracing or taping or tape* or electrotherap* or rehab* or conserv*[Title/Abstract]

1459 AND (adolescen* AND scoliosis[Title/Abstract] AND ("2013/07/05"[Date - Publication] :

1460 "3000"[Date - Publication] NOT MEDLINE[sb]

1461

1462 **UKCTG**

1463

1464 Last searched August 2014

1465 scoliosis

1466

1467 **ClinicalTrials.gov**

1468

1469 Last searched 8 August 2014

1470 Condition: scoliosis

1471

1472 **WHO ICTRP**

1473

1474 Last searched 8 August 2014

1475 Condition: scoliosis

1476

1477 **EThOS**

1478

1479 Last searched August 2014

1480 Scoliosis

1481

1482

1483

1484

1485 **Appendix 3.**

1486

1487 **Criteria for assessing risk of bias for internal validity for randomised and non- randomised**
1488 **studies (Downs and Black 1998; Furlan 2009)**

1489

1490 Risk of bias is low if compliance with the interventions was acceptable on the basis of reported
1491 intensity/dosage, duration, number, and frequency for both index and control intervention(s). For
1492 single-session interventions (for example surgery), this item is irrelevant.

1493

1494 **Co-interventions**

1495

1496 Risk of bias is low if no co-interventions were provided, or if they were similar between index and
1497 control groups.

1498

1499 Attrition bias

1500

1501 **Incomplete outcome data**

1502

1503 Risk of attrition bias is low if no outcome data were missing; reasons for missing outcome data were
1504 unlikely to be related to the true outcome (for survival data, censoring unlikely to be introducing
1505 bias); missing outcome data were balanced in numbers, with similar reasons for missing data across

1506 groups; for dichotomous outcome data, the proportion of missing outcomes compared with the
1507 observed event risk was not enough to have a clinically relevant impact on the intervention effect
1508 estimate; for continuous outcome data, the plausible effect size (difference in means or standardised
1509 difference in means) among missing outcomes was not enough to have a clinically relevant impact on
1510 observed effect size, or missing data were imputed using appropriate methods (if dropouts were very
1511 large, imputation using even 'acceptable' methods may still suggest a high risk of bias). The
1512 percentage of withdrawals and dropouts should not exceed 20% for short-term follow-up and 30%
1513 for long-term follow-up and should not lead to substantial bias (these percentages are commonly
1514 used but are arbitrary and are not supported by the literature).

1515

1516 **Intention-to-treat analysis**

1517

1518 Risk of bias is low if all randomly assigned participants were reported/analysed in the group to which
1519 they were allocated by randomisation.

1520

1521

1522 **Measurement/detection**

1523

1524 **Blinding of outcome assessment**

1525

1526 Risk of detection bias is low if blinding of the outcome assessment was ensured and it was unlikely
1527 that the blinding could have been broken; or if no blinding or incomplete blinding was performed, but
1528 the review authors judge that the outcome was not likely to be influenced by lack of blinding, or for
1529 participant-reported outcomes in which the participant was the outcome assessor (e.g. pain,
1530 disability): Risk of bias for outcome assessors is low if risk of bias for participant blinding is low;for
1531 outcome criteria that are clinical or therapeutic events that will be determined by the interaction
1532 between participants and care providers (e.g. co-interventions, length of hospitalisation, treatment
1533 failure), in which the care provider is the outcome assessor: Risk of bias for outcome assessors is low
1534 if risk of bias for care providers is low; andfor outcome criteria that are assessed from data from
1535 medical forms: Risk of bias is low if the treatment or adverse effects of the treatment could not be
1536 noticed in the extracted data.

1537

1538 **Timing of outcome assessments**

1539

1540 Risk of bias is low if all important outcome assessments for all intervention groups were measured at
1541 the same time, or if analyses adjust for different lengths of follow-up.

1542

1543

1544

1545 **Selective reporting**

1546

1547 **Data dredging**

1548

1549 Risk of bias is low if all analyses were planned at the outset of the study.

1550

1551 Risk of bias is high if analyses were conducted retrospectively (for example retrospective unplanned
1552 subgroup analyses).

1553

1554 **Outcome measures**

1555

1556 Risk of reporting bias is low if the study protocol is available and all of the study's pre specified
1557 (primary and secondary) outcomes that are of interest in the review have been reported in the pre-
1558 specified way, or if the study protocol is not available, but it is clear that the published reports include
1559 all expected outcomes, including those that were pre-specified (convincing text of this nature may be
1560 uncommon).

1561

1562 Risk of reporting bias is high if not all of the study's pre-specified primary outcomes have been
1563 reported; one or more primary outcomes were reported using measurements, analysis methods, or
1564 subsets of the data (for example sub-scales) that were not prespecified; one or more reported primary
1565 outcomes were not pre-specified (unless clear justification for their reporting was provided, such as
1566 an unexpected adverse effect); one or more outcomes of interest in the review were reported

1567 incompletely, so that they cannot be entered into a meta-analysis; the study report failed to include
1568 results for a key outcome that would be expected to have been reported for such a study.

1569

1570 *Items are relevant only to non-randomised studies.

1571

1572 **Questions for assessing clinical relevance**

1573

1574 1. Are the participants described in detail so that you can decide whether they are comparable with
1575 those that you see in your practice?Yes/No/Unsure2. Are the interventions and treatment settings
1576 described well enough so that you can provide the same for your patients?Yes/No/Unsure3. Were all
1577 clinically relevant outcomes measured and reported?Yes/No/Unsure4. Is the size of the effect
1578 clinically important?Yes/No/Unsure5. Are the likely treatment benefits worth the potential
1579 harms?Yes/No/Unsure