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Incidence of curvature progression in idiopathic scoliosis patients treated with scoliosis in-patient rehabilitation (SIR): an age- and sex-matched controlled study

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Summary

The goal of this study is to test the hypothesis that physiotherapy-based intervention can reduce incidence of progression in children with IS. Two independent patient groups matched by age and sex at diagnosis were analysed using the outcome parameter, incidence of progression ($\geq 5°$). One group was untreated and the other received scoliosis in-patient rehabilitation (SIR). Incidence of progression in groups of untreated patients ranged from 1.5-fold (71.2% vs 46.7%) to 2.9-fold (55.8% vs 19.2%) higher than in groups of patients treated with SIR, even when SIR-treated groups included patients with more severe curvatures. Statistically, the differences were highly significant. Efforts to test the hypothesis that physical therapies addressing postural imbalance can be used effectively in the treatment of IS have been limited. The results of this study are consistent with the possibility that a supervized programme of exercise-based therapies can reduce incidence of progression in children with IS.

Introduction

Scoliosis is a partly fixed lateral deviation of the spine accompanied by distortion of individual parts of the spinal sections against each other [1–3]. The diagnosis of scoliosis is made based on a Cobb angle of $\geq 10°$ [3, 4]. Up to 90% of all cases are of unknown cause or 'idiopathic' scoliosis (IS).

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Once the diagnosis of IS has been made, the risk that the degree of spinal curvature will increase is of paramount clinical interest. Progression is generally defined as an increase of $\geq 5°$ in the Cobb angle [5]. Most information available on curve progression derives from studies of girls, particularly those with thoracic curves. In the immature patient, the risk of progression is related primarily to growth potential, with the highest risk for progression occurring during the pubertal growth spurt [4]. In girls, significantly higher risk of curvature progression exists when curves are detected before the onset of menarche. Males with comparable curves have $\sim$10% the risk of progression of females. Two curve-specific factors are also important in prognostication: (1) Double curve patterns have a greater tendency to progress than single curve patterns, and (2) the larger the curve at detection, the greater the risk of progression [4].

Evaluation of the risk of curvature progression is essential to the appropriate design of IS treatment. School screening programmes have allowed large-scale referral of children to orthopaedic surgeons for evaluation while spinal deformity is at early stages of development and curvatures are $< 15°$, as defined by Cobb [5]. Until curvatures progresses to 25° or more, however, physicians prescribe 'observation only', a regime in which children are subjected to radiological exams at intervals, but are not treated. At 25°, bracing has been used in efforts to stabilize progression, and its efficacy continues to be examined [6]. Spinal fusion surgery is recommended for skeletally immature patients when curves progress to 40–45° and for mature patients with curvatures $> 50°$ [3].

In the US, virtually no effort has been made to employ proactive, physiotherapy-based methods to treat IS in early stages when curvatures are mild,

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because natural history surveys have shown that many small curvatures remain stable or spontaneously improve without treatment [4, 7–10]. However, most ‘natural history’ studies which underlie the existing knowledge base have included patients who received physiotherapy whose possible impact was ignored [11, 12]. Thus, there is no way to rule out the possibility that curvatures which stabilized or improved did so in response to conservative therapy.

Basic research by Harrington [13] established that postural imbalance alone can induce severe scoliosis which can be resolved when the imbalance is removed before growth is complete [14]. Two clinical studies considered the impact of exercises on scoliosis [15, 16]. Shands *et al.* [15] surveyed US clinics and found that of 185 patients (curvature range 0–40°) treated with ‘exercises of all types’, the deformity was stable in 35%, increased in 61% and improved in 4%. Detailed protocols, approaches, supervision and comparisons were not available. Stone *et al.* [16] prescribed a short daily home programme to 41 children with curves from 5–20° and compared the outcome with a matched, untreated control group. Unfortunately, more than 90% of the ‘treated’ children failed to perform the exercises as prescribed, so the authors were unable to draw conclusions about the impact of exercise.

In Europe, a conservative treatment approach is pursued actively from the time of diagnosis based on the rationale that postural imbalance is an integral component of scoliosis irrespective of its cause [13]; and, therefore, postural balancing treatment is a logical approach to ameliorate clinical aspects of spinal deformity [2, 17–20]. In Germany, this approach includes outpatient physiotherapy beginning at 15°. Scoliosis in-patient rehabilitation (SIR) is recommended for curvatures of 20–30°, with or without bracing, depending on prognosis [22–27]. For adult IS, outpatient physiotherapy is offered for curvatures of 30–40° with moderate pain. Physiotherapists in different regions are trained so that patients have the option of outpatient treatment close to their residence. For adult patients with curves over 40° in association with cardiorespiratory functional impairment and pain, SIR is recommended. In-patient treatment offers structure for a daily 6-hour intensive rehabilitation treatment. Following the criteria of Bloch [28], results from cohort studies and case follow-up studies are consistent with the conclusion that physiotherapy is effective in treating signs and symptoms of scoliosis [21–27].

The purpose of the current study was to compare incidence of curvature progression in two populations of patients, with and without an intensive in-patient physiotherapy regime.

Materials and methods

STUDY DESIGN

Follow-up (of groups matched by sex, age and degree of curvature) of the outcome of two different prospective studies using the outcome parameter ‘incidence of progression’ in patients with idiopathic scoliosis, with and without SIR treatment.

SUBJECTS

The goal of the current study was to analyse statistically the incidence of progression in the SIR-treated group with the incidence of progression in a control group. The data for this study are from a prospective follow-up of patients, who had SIR, without bracing (Study A, intervention group) and from a prospective follow-up [29] of untreated patients from the same geographical region of Germany (Study B, control group). Patients with prior treatment by lateral electrical surface stimulation [9] or surgery were excluded.

Study A (intervention group)

In a prospective follow-up study of 181 patients with idiopathic scoliosis, the incidence of progression in patients with SIR treatment was evaluated (table 1). Of the 181 patients, 156 were female, 25 were male. The average Cobb angle was 27° before the study, the average Risser stage (appearence of the iliac crest apophysis on a standing radiograph, ranging from 0 = before the onset of the pubertal growth spurt, to 5 = fully mature) was 1.4 with an average follow-up period of 33 months. Curvature patterns included thoracic (35%), thoracic lumbar (7%), lumbar (28%) and double major (27%).

Study B (control group)

The prospective natural history study by Hopf *et al.* [29], which was done within the same geographical area of Germany (Rhineland-Palatinate), served as the control group (table 1). In this study, 135 patients (111 girls and 24 boys) with an average age of 10 years and a follow-up period of 52.4 months were included [29]. In 59% of the patients, Risser sign was 0; 13.2% had Risser 1; 12.3% had Risser 2; 6.6% had Risser 3; and

Table 1 Description of treated and control patient groups

Source	*Total*	*#F*	*#M*	*Age*	*Cobb*	*Follow-up (months)*
(a) Weiss*	181	156	25	9–15	6–68	33
(b) Hopf**	135	111	24	4–15	5–30	52.4

* Inclusion criteria for prospective follow-up: (1) diagnosis of IS; (2) age between 9–15; (3) Risser <4; (4) No brace, LESS or surgical treatment; (5) Two or more SIR; (6) first follow-up after 1–3 years (during repeat SIR); (7) Evaluable pre-treatment X-rays of the whole body in standing position taken no longer than 6 months before the first SIR treatment. Mean initial Cobb angle was 27°.
** Inclusion criteria for prospective follow-up: (1) Diagnosis of IS; (2) age 4–15; (3) initial curvature 5–30°; (4) No LESS or surgical treatment; (5) Follow-up ≥ 1 year.

8.5% had Risser 4. The curvature was less than 10° in 18.5% of the population.

Building of comparable groups out of Study A and B

As there was no essential progression in the group of the 15-year-old patients, only younger patients were included. Matching groups were formed from Study A and Study B based on age and sex, as described by Lonstein and Carlson [30] and Hopf *et al.* [29] and included Group I (up to 12 years of age) and Group II (12–14 years of age). Male patients were excluded.

Group I. From Study A, 30 SIR-treated female patients met criteria for inclusion in Group I (table 2). Their average age was 9.9666 ± 0.85 years and mean curvature angle was $21 \pm 10.7°$, with a range from 6–52°. The average follow-up was 35 months. The average Risser sign was 0.3°.

Group I from the untreated control Study B included 64 patients whose curvatures ranged from 5–30°.

Group II. Study A, Group II included 59 female patients with an average age of 13.4 ± 0.71 years and an average curvature angle of $29.5 \pm 14.3°$, with a range from 8–68°. The average follow-up was 34.3 months (table 2). The average Risser sign was 2.3°. Group IIa was a sub-set of Group II including those patients with more severe curvatures, ranging from 30–68°; Risser 2.8, average age 13.5 years. The mean follow-up period was 36 months in this sub-group (table 2).

Study B, Group II included 43 patients with curvatures ranging from 5–30°.

SCOLIOSIS IN-PATIENT REHABILITATION

SIR employs an individualized exercise programme combining corrective behavioural patterns with physiotherapeutic methods, following principles described by Lehnert-Schroth [2]. The three-dimensional scoliosis treatment is based on sensomotor and kinesthetic principles and its goals are (1) to facilitate correction of the asymmetric posture and (2) to teach the patient to maintain the corrected posture in daily activities (figures 1–3).

Referrals are from spine centres, general orthopaedic surgeons, paediatric physicians and general practitioners. A 4-week minimum stay is required for the first treatment, which may be up to 6 weeks, depending on prognosis; return treatments are 3–6 weeks in length, depending on symptoms and prognosis. Patients are admitted in groups, with the first day of the programme devoted to diagnosis and evaluation of the three dimensional deformity, supervized by nine staff physicians (two orthopaedic surgeons and seven general practitioners or specialists for Physical Medicine and Rehabilition) who also provide oversight for each

Table 2 Progression in matching sub-set of treated and control groups. In the intervention groups (Weiss), only female patients with Cobb angles of more than 30° were included. In the control groups, Cobb angles where limited to 30°

Source	*Total*	*Age*	*Curve*	*Follow-up*	*Progression*
(a) Weiss					
I	30	10 ± 0.85	21 ± 10.7	35 ± 23	14/30 (46.7%)
II	59	13 ± 0.71	29.5 ± 14.3	34 ± 37	18/59 (30.5%)
IIa	26	13.6 ± 0.5	42.3 ± 10.9	36 ± 34.1	5/29 (19.2%)
(b) Hopf					
I	64	<12	5–30	52.4	45/64 (71.2%)
II	43	12–14	5–30	52.4	24/43 (55.8%)

Inclusion criteria for I: Females only; age <12, Inclusion criteria for II: Females only; age 12–14, Inclusion criteria for IIa: Females only; age 12–14, Cobb angle >30.

Figure 1 After being introduced into the programme during the first week, the patients are assigned to exercise groups with similar curve patterns. They learn how to improve their postural feeling and how to manage themselves during daily activities.

Figure 2 During the training sessions, mirror monitoring and tactile stimulation by the therapist are most important to improve postural feeling for the exercises to be done at home regularly by themselves.

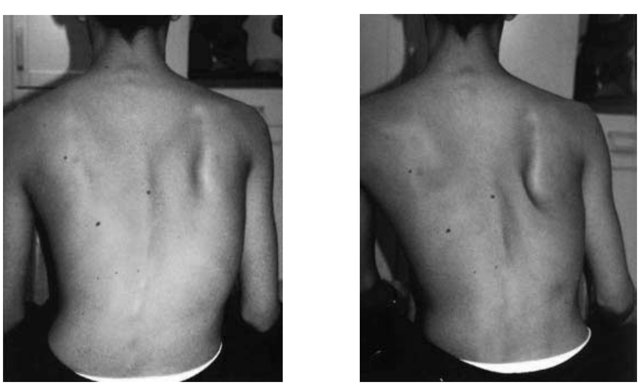

Figure 3 Sitting school for scoliosis patients during SIR. Left, sitting as usual; right, sitting in a relaxed but straightened position to prevent compression in the concave side of the curve.

patient's programme. On the second day, instruction in basic human anatomy, spinal deformity and principles of postural balancing therapy is provided to the group. Each patient receives a detailed summary of his/her own condition and those with matching diagnoses (based on age, degree and pattern of curvature) work together in groups. Evening and weekend social activities provide a sense of community and foster development of psychological support systems that can be maintained after treatment is complete.

The treatment programme consists of correction of the scoliotic posture with the help of proprioceptive and exteroceptive stimulation and begins on the third day after admission. Each weekday, after a 20-minute group warm-up session, the patients exercise in matched groups for 2 hours in the morning and 2 hours in the afternoon and receive shorter more individual training sessions in between. Central to the individual and group exercise programmes is therapist assistance, by a staff of 20 physical therapists and sports therapists who supervize all exercises and provide exteroceptive stimulation needed to obtain desired correction. Depending on individual curve patterns, the patients are assigned to special exercise groups for an additional 2 hours daily. Development and maintenance of the corrected posture is facilitated using asymmetric standing exercises designed to employ targeted traction to restore torso balance and mobility. Rice-bag bolsters provide localized sustained pressure during floor exercises for mobilization of rib prominences or other torso and lumbar asymmetries. Bracing (since 1992) and passive transverse forces (PTF) are applied as needed (depending on curvature pattern, flexibility and magnitude) using a vertical frame with adjustable belts.

The correction is supported by 'rotational breathing' exercises, an integral part of the regime: By selective contraction of convex areas of the trunk, the inspired air is directed to the concave areas of the chest and the ribs to lengthen and mobilize soft tissues in these regions. Female patients wear bikini tops during all sessions and ceiling and wall mirrors enable the patients to self-monitor progress at all times during standing and floor exercises; this practice facilitates optimum correction during exercises and fosters patient proprioception of a balanced posture. Four full-time massage therapists provide bi-weekly mobilization therapy for each patient, using myofascial release, manual traction, ischemic pressure and pressure point therapy. Three full time respiratory therapists meet weekly with each patient to monitor vital capacity and to provide training in corrected breathing patterns. Psychological counselling is provided by two staff psychologists to help patients cope with feelings about the diagnosis of deformity as well as the impact of treatment, as needed; patients can request individual psychotherapy in response to anxiety, depression or other psychological distress. Optional evening group sessions devoted to relaxation therapies, including meditation and visualization approaches, also are available. Osteopathic manipulation and acupuncture by staff therapists are available to treat pain as needed, upon request by the patient.

At the end of in-patient treatment, the primary goal is for patients to be able to assume their personal corrected postural stereotype, independent of the therapist and without mirror control, and to maintain this position in their daily activities. Recommended at-home follow-up treatment includes three-to-four exercises for 30 minutes daily in order to maintain the improved postural balance. Therapists throughout Germany receive training in the Schroth Clinic approaches so that local outpatient resources are available to patients after discharge. In case of pain, curvature progression or pulmonary symptom development, repeat SIR treatment is available by referral from primary care physicians.

DATA ACQUISITION AND ANALYSIS

The monitoring process was measuring the Cobb angle on standing radiographs before the intervention (SIR) and after a second intervention or at out-patient presentation with an observation time of at least 12 months in the intervention group.

In the controls, radiographs were taken at least at the beginning and at the end of the observation period. The test parameter used to measure progression was Cobb angle; all measurements in the intervention group were carried out blind, without reference to previous patient records, by a reader who is independent of this study [5, 31]. An increase of $\geq 5^\circ$ in angle of the most severe curvature was used to define ‘progression’. An one-sided statistical test to compare two independent proportions was used to test the hypothesis that the proportion of patients with progression differed between the two study groups [32].

Results

GROUP I (< 12 YEARS OF AGE)

Within the untreated control Group I, curvatures of 71.2% of patients whose initial Cobb angles ranged from 5–30° progressed by $\geq 5^\circ$ (table 2). Even though more severe curvatures (range 6–52°) were included in the SIR Group I, the incidence of progression in the SIR test group was only 46.66% (table 2) and was statistically distinct at the 0.011 level of probability (table 2).

Within a SIR test sub-group, whose range of curvatures was closely matched with that of the control group, only 40.0% of the cases progressed. The difference was statistically significant at the 0.0029 level of probability.

GROUP II (AGES 12–14)

Within the untreated control Group II, curvatures of 55.8% of patients whose initial Cobb angles ranged from 5–30° progressed by $\geq 5^\circ$ (table 2).

Within the SIR test Group II, in contrast, curvatures of only 18 of 59 patients (30.5%) progressed by $\geq 5^\circ$, even though more severe curvatures (range 8–68°) were included. These differences were statistically distinct at the $p < 0.0045$ level of probability.

In Group IIa, which included the most severe initial curvatures (30–68°), incidence of progression was only 19.2%. This value was distinct from that of control Group II at the 0.0004 level of probability (table 2).

Discussion

The possibility that physical methods can be used to treat scoliosis was controversial by the time of Hippocrates and remains so to this day [6, 8, 33]. Since no other vertebrate species suffers from a comparable spinal deformity, the use of experimental animals to translate principles into clinical approaches that reliably allow patients to avoid surgery have not been successful [34]. Testing treatment effectiveness in a controlled manner in humans is complicated by ethical issues. Because no human patient can be denied treatment that might be effective in the interest of proving that it is effective, establishing control samples to compare outcome is difficult for any disease or deformity. The fact that any given population of patients with IS includes cases with divergent and unknown aetiologies makes evaluation of treatment protocols especially problematical. The role of a specific treatment in improvement in an individual child is always questionable because curvatures can stabilize or improve spontaneously prior to skeletal maturity [11].

This centre has used an exercise-based approach to treat IS for decades and a systematic analysis of its efficacy is ongoing. Research to date has examined predictions of the hypothesis that physiotherapy can alleviate the signs and symptoms of IS in a multi-layered experimental approach that has included case report series, clinical studies and population-based comparisons [22–27]. The results are consistent with the hypothesis that physiotherapy can significantly alleviate the primary symptoms of spinal deformity: pulmonary deficiency, pain and psychosocial issues. Results of a preliminary study of 181 patients treated with SIR were consistent with the possibility that physiotherapy is associated with a reduced incidence of progression, compared with natural history [22]. In the current paper, a sub-set of this study group was compared with a matched group of patients in a separate study who did not receive treatment. If the hypothesis that physiotherapy is an effective treatment for IS is correct, a prediction is that the incidence of progression will be higher in a population of untreated patients than in a comparable population of patients who received SIR. The results revealed that incidence of progression in untreated patients was higher than in patients treated with SIR, even when the prognosis of the SIR-treated group was substantially less benign than that of the control group. Factors other that SIR treatment which could account for the observed differences include (1) error in documenting or interpreting incidence of progression and (2) inadequate matching of test and comparison populations. These concerns are discussed below.

1. *Measuring incidence of progression*. In past studies to evaluate treatment influence on curvature progression, an apparently positive result was undermined by choice of a population with a very low probability of progression [6]. What appeared to be reduced progression actually was natural history of that test group, which included children with curves unlikely to progress. In this study, significant differences were seen even though children were included whose degree of curvature, age and sex all placed them at a high probability of progression [4, 30]. Indeed, Group II, which comprised patients with the worst prognosis for progression (including curvatures with more than 30), exhibited an incidence of progression that was lower than that of the control group. In addition to selecting patients with a high probability of progression, an outcome parameter at the accepted limit of experimental error ($\geq 5°$), based on the standard Cobb angle assay, was selected to increase the odds that all cases of progression would be detected. Most researchers report intra- and inter-observer reliability of ± 2–$3°$ in Cobb angle measurement and mean experimental error of no more than $5°$ [35–41]. Intra-observer and inter-observer reliability in Cobb angle measurement at the clinic is 1.5–2.3° [31], so a difference of $\geq 5°$ is a reliable indicator of curvature increase, yet a small enough increment to detect all incidents of progression.
2. *Matching of populations*. Of most concern in comparing two outcomes in IS progression, once the study is controlled for sex, is how well matched the populations are with respect to skeletal maturity [4]. Because growth potential is the variable most closely correlated with curvature progression, even small differences in skeletal age can obviate the results of outcome comparisons. Risser sign is a more reliable parameter for prognostication than age [42], especially when populations are derived from distinct geographical locations where genetic and cultural influences may substantially alter age at maturity. Studies carried out during different time periods may also be affected by cultural changes. In the current report, absence of Risser sign documentation in the sub-sets of the comparison study made it necessary to rely on age alone to define skeletal maturity in the study groups. This would be especially problematical in a study in which only small differences in outcome occurred, but is less troublesome given the highly significant differences obtained in the current study.

The concern that unidentified differences in skeletal age, rather than SIR treatment, are responsible for the reduced progression in the treated group is offset by several factors. First, the two study groups were derived not just from the same country but from the same geographical area within Germany, reducing the chances that large differences in skeletal age existed in the same-age groups. In addition, the studies were conducted during the same time period in the late 1980s and early 1990s. Both studies were completed during the period of early adolescence when prognosis for progression is highest and were finalized at the age of 15 when expectation of significant further progression is low [4, 30, 43]. Most important, a substantial bias toward *higher* progression existed in the SIR-treated populations, with respect to degree of curvature. The fact that some of the control patients in Group I (initial age < 12 years) could have been younger at the time of final follow-up than those in the SIR treated Group I could offset the curvature bias. However, in Group II there was no such age divergence, but the difference in incidence of progression remained. Although the 20% difference (38.4 vs 55.8%) between the most closely matched groups of 12–14 year old patients (Weiss Group II vs Hopf Group II) was not statistically distinct within the limits of the sample size and the analytical test used, incidence of progression in untreated controls was nearly three-fold higher than in SIR-treated patients with the worst prognosis for progression (Group IIb), and the difference was highly significant.

Of course a longer-term follow-up study is crucial for the long-term evaluation of the intensive physiotherapy programme concerned in sub-group I. A follow-up period of, on average, more than 30 months after intervention in sub-group II (age 12–14 years), however, can be regarded as the end result for a significant progression is not expected in girls at the age of 15 at least in those cases with less than 30° [29].

The results suggest that a supervized programme of exercise-based therapy can significantly reduce the incidence of curvature progression in IS and are consistent with a previous report of reduced progression in children treated with posture-balancing exercise [44]. In addition, improved curvature flexibility was achieved in response to a 10-day exercise programme [45] and a recent case report documents dramatically improved chest wall mobility and function in moderately severe IS in response to physical methods in a previously untreated middle aged adult [46]. Taken together, the results are consistent with the hypothesis that the signs and symptoms of IS can be positively influenced by physical therapies and highlight the need for research to develop proactive methods to intervene in spinal deformity at early stages of development.

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