Hans-Rudolf Weiss, Christa Lehnert-Schroth, Marc Moramarco and Kathryn Moramarco

Schroth Therapy

Advancements in Conservative Scoliosis Treatment (3rd edition)

The Schroth Best Practice Program by Dr. Weiss

Special Schroth Best Practice Academy Edition

B P International

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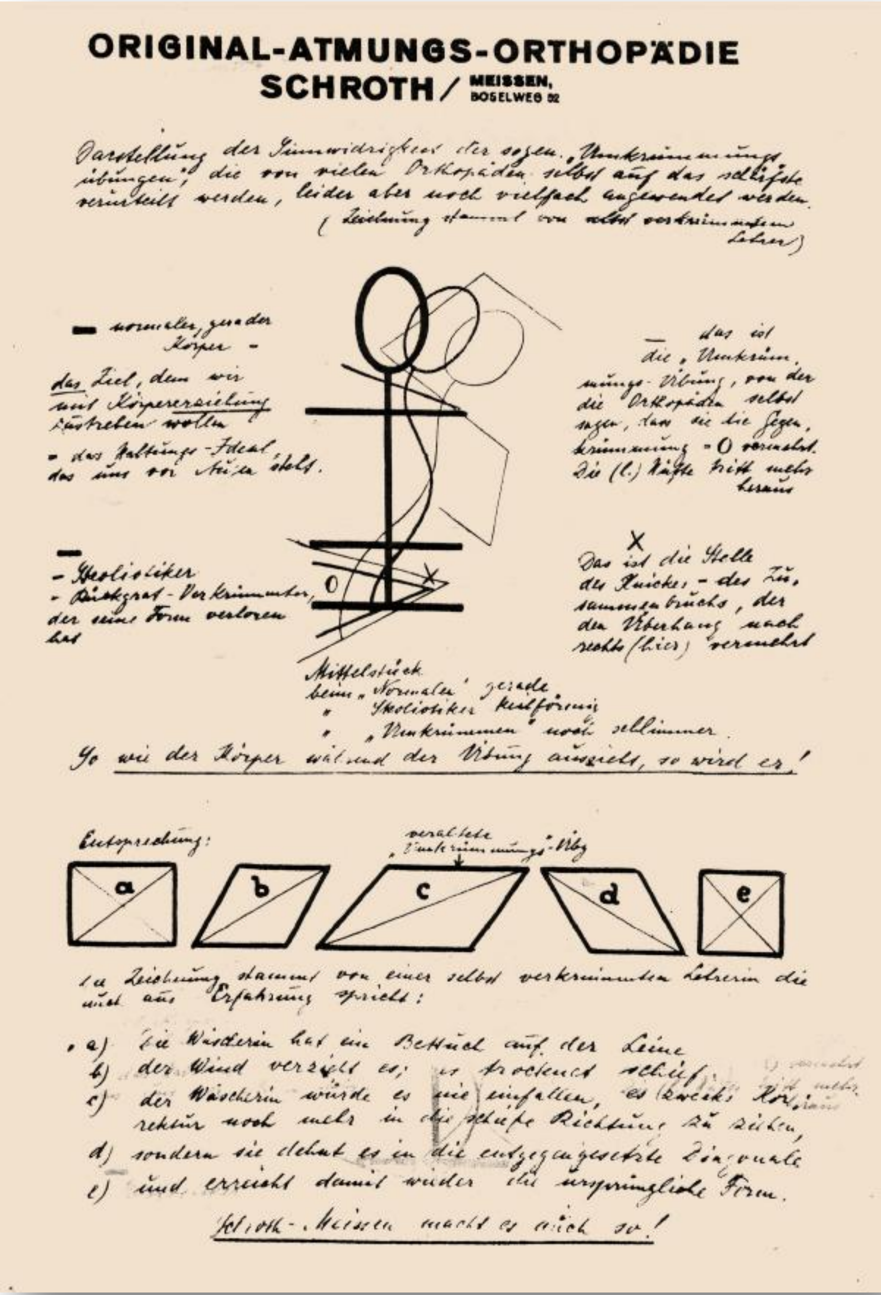

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PREFACE

The first English edition of this book was published in March 20th, 2015. Sadly, my mother and coauthor Christa Lehnert-Schroth did not witness the publication of the first edition of this book. On the 20th March, the day of publication, she suffered a fall and passed away two days later at the age of 90. In gratitude, my coauthors and I would like to dedicate this book to my mother who further developed the three-dimensional scoliosis treatment according to Katharina Schroth and made it accessible to an international audience of specialists.

After just two years, the release of the second edition has become necessary to capture the current state of scientific knowledge and to present the most recent developments in the area of non-surgical scoliosis treatment.

It has been almost 4 years since the 2nd edition of this book was published.

In the meantime, the carousel of science has continued to turn, also in the field of treatment of patients with spinal deformities.

The current indication guidelines have since been evaluated and adapted to the latest findings. Accordingly, the previous version of the guidelines has also been replaced in this book.

Chapter 6 (Physiotherapeutic findings) has also been completely revised and adapted to the current state of knowledge. All other chapters have been completely revised as well.

A new feature is the introduction of QR codes, which lead to videos and to current original papers. This makes this book a multi-media documentation of the subject. It simplifies access to the current basic literature and expands the illustration possibilities beyond simple pictorial representation. We therefore hope that this book will also facilitate entry into the Schroth Best Practice Academy training program.

The demand for the Schroth Best Practice® program has increased significantly worldwide in the last three years, even if the spread of this program in courses has stagnated somewhat in the last two years due to the Covid pandemic. However, our friends in China have meanwhile held a large number of courses in China again, while in the rest of the world further dissemination is now gaining momentum again in 2022.

At the same time, numerous centers have been established globally that offer the Schroth Best Practice® compatible Gensingen Brace® (GBW). This success is not just a source of joy, but also drives further development with the goal of discovering even more effective and less burdensome treatment approaches.

My sincere gratitude extends to the experienced specialists who have established these centers around the world for treating scoliosis patients with the Schroth Best Practice® Program and for supplying the Gensingen Brace®. They have done so with great commitment, personal initiative, and dedication.

In particular, I thank my remaining coauthors Marc and Kathryn Moramarco for their commitment to this book and for their constant support. I also thank my many patients for the trust they have shown me, as well as for the opportunities to learn from them and with them and to thereby develop the methods presented here.

Neu-Bamberg, Spring 2022
Dr. med. Hans-Rudolf Weiss

QR-link to the Schroth Best Practice Academy.

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Schroth Therapy Advancements in Conservative Scoliosis Treatment (3rd Edition)

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ABSTRACT

This book presents comprehensive and practice-oriented physiotherapy and brace treatment for scoliosis patients. The treatment examples are based on the differentiated
findings of the curvature patterns. Their approach follows - albeit in an expanded form - the basic ideas of the scoliosis therapy of Katharina Schroth, the pioneer in this field.
The third edition of the book has been thoroughly revised, taking into account the latest literature and the updated and now scientifically evaluated indication guidelines. The basic modules "physio-logic", "Activities of daily living, ADL", "3D made easy" and "Schroth" merge into an evidence-based overall concept, which can be used in a differentiated manner depending on the individual indication.
The specific exercises have been simplified without sacrificing effectiveness. In fact, when all the tips and tricks described here are taken into account, clinical overcorrections are even possible in the exercise, which were not even attempted in the past. The "Schroth Best Practice" program (SBP) allows effective rehabilitation including patient training within a few days. Thus, this book is also addressed to all those who attend the course program provided by the Schroth Best Practice Academy and want to start effective treatment of their scoliosis patients after just one week of the course.

Keywords: Scoliosis; kyphosis; physiotherapy; rehabilitation; brace treatment.

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1. INTRODUCTION

In the past, scoliosis was defined as a partially structural lateral distortion of the spine, meaning that the spine could no longer be straightened out completely (Heine and Meister 1972; Meister 1980; Asher and Burton 2006; Weiss and Moramarco 2013). In contrast to the types of scoliosis with a known etiology (hereditary scoliosis, neurogenic scoliosis, myogenic scoliosis, scoliosis due to metabolic diseases or systemic diseases), idiopathic scoliosis (Fig. 1.1) appears without visible cause before the attainment of skeletal maturity (Heine 1980; Perdriolle and Vidal 1985; Weiss and Moramarco 2013).

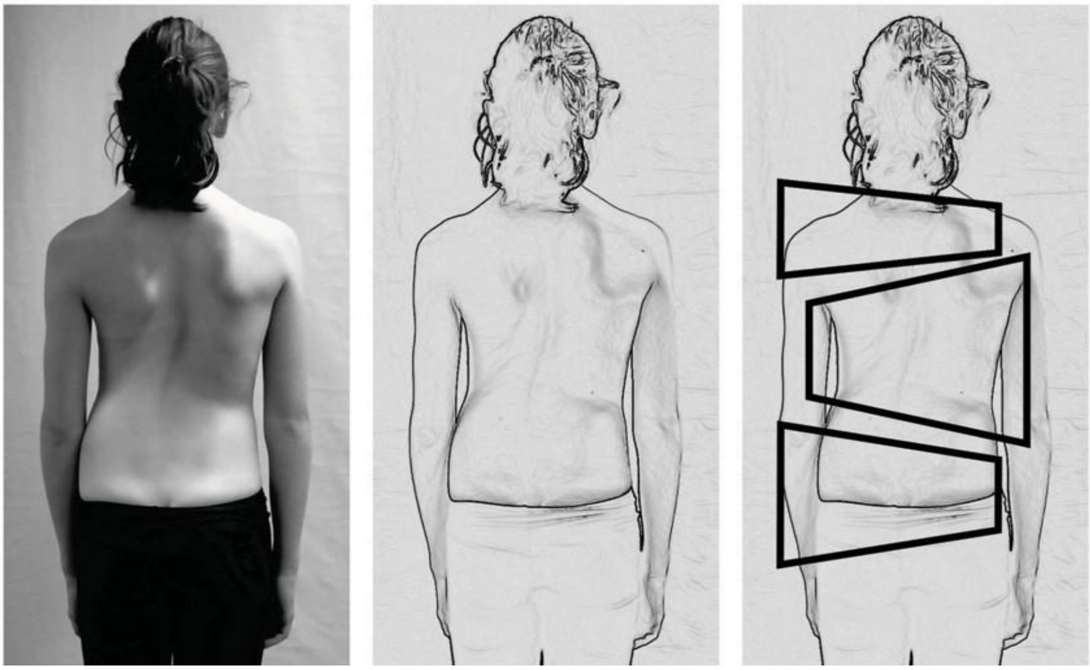

Fig. 1.1. *Clearly visible scoliosis in a 13-year-old patient. All scoliosis traits are clearly identifiable: (1) deviation from the vertical, (2) costal hump as an expression of the twisting of the trunk sections against each other, and (3) flat-back with clear reduction of the kyphosis in the thoracic spinal section. In the middle image, the lateral deviation of the spine is clearly visible, and on the right, one can see how the trunk sections have pushed against each other.*

Idiopathic scoliosis accounts for 80-90% of all cases. An asymmetrical silhouette of the trunk, when standing, can be taken as evidence of a scoliosis. It is in the forward-bending test where the structural component of the scoliosis can be seen most clearly. This is due to the costal hump or lumbar bulge that appears in this position. In addition, a “ventral costal hump” evolves due to the ribs on the thoracic concave side being twisted in a ventral direction.

The diagnosis of scoliosis is verified by an x-ray of the entire spine in a standing position (Figs. 1.2 & 1.3).

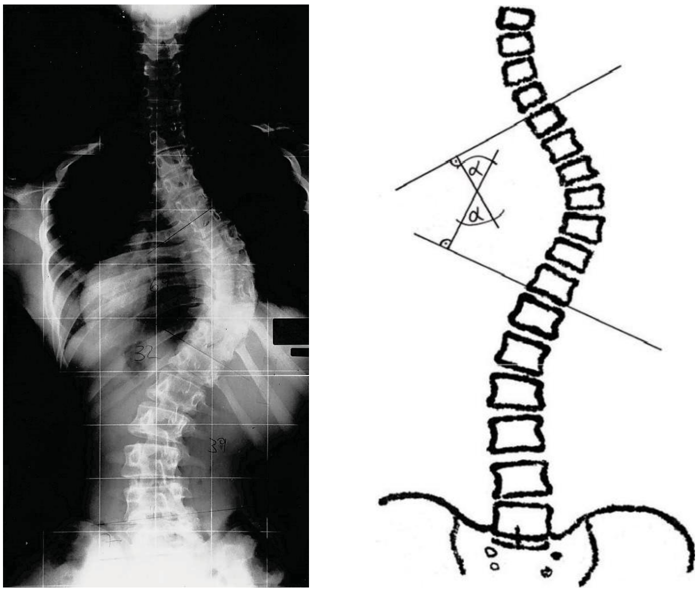

Fig. 1.2. *Full-spine image in a standing position. In digital x-ray, through direct radiography (DR), the necessary region (Region of Interest/ROI) for children and adolescents can now almost always fit onto a usual detector plate using optimal settings. On the right: Schematic representation of the curvature angle formation. The plate covering the upper end vertebra, which generally is tilted the most, has been marked with a tangent line, as has the end plate of the lower end vertebra. Vertical lines (on the left side of the image here) are aligned with these tangents, crossing to form the curvature angle according to Cobb (labeled here with the angle symbol).*

In the age of digital x-ray, one can optimize the settings in the processing in such a way that a small image is sufficient, thus reducing the exposed area of the body and the exposure time (one-plate technique; Weiss and Seibel 2013; Fig. 1.3). For patients with a height greater than 170 cm, however, it is usually necessary to make two partial images and join them together.

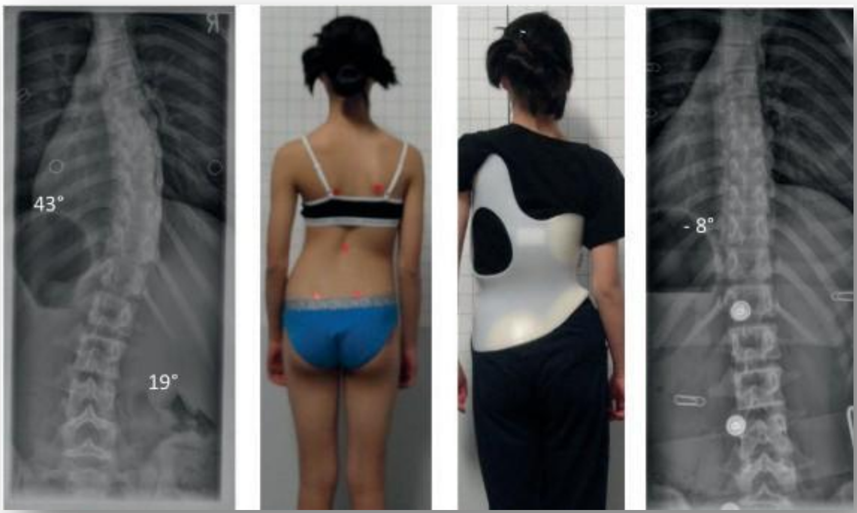

Fig. 1.3. *In digital x-ray, through direct radiography (DR), the necessary region (Region of Interest/ROI) for children and adolescents can now almost always fit onto a DR plate using optimal settings. In doing so, exposure to radiation outside the ROI is eliminated. Left, patient without brace clinically and radiographically with a 43° curve; right, patient in the brace with full correction of the curvature. Reduction of the diagnostic field did not reduce the necessary information on either x-ray.*

The assessment of the x-ray images consists of measuring the degree of curvature using Cobb's method (1948, Fig. 1.2), measuring the rotation of the apical vertebra, and examining the osseous signs of maturity (Fig. 1.4). Curvatures of less than 10° are not defined as scoliosis by Cobb (1948).
Females are roughly four times more likely to be affected by idiopathic scoliosis. The frequency of curvatures of less than 10° is the same for males as for females; however, the more marked the curvature is, the greater the proportion of sufferers that are females (Weinstein 1985; 1986; Asher and Burton 2006).

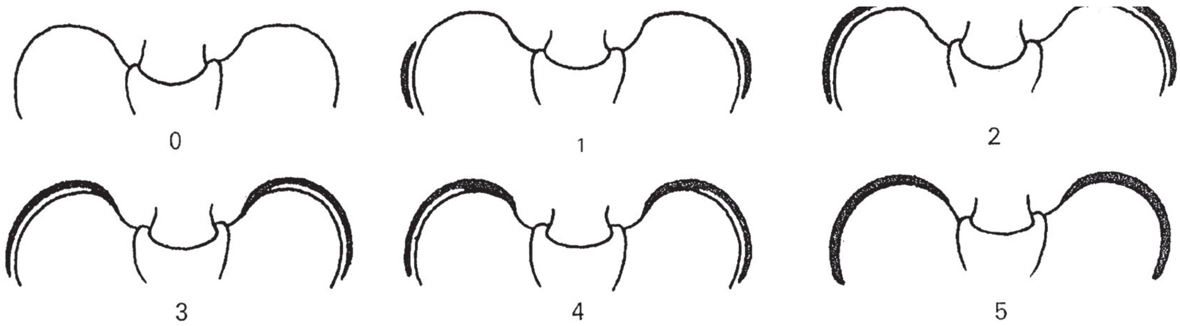

Fig. 1.4. *Representation of bone maturity according to Risser in the style of Henke (1982). The Risser sign refers to the amount of calcification of the iliac crest of the human pelvis as a measure of maturity. With a Risser 0, the pubertal growth spurt is yet to happen or just happening (when the first signs of maturation are visible); from a Risser value of 3, the pubertal growth spurt is nearly complete. A fully completed growth spurt is shown by a Risser value of 5, although in some cases, a Risser value of 4 will remain into adulthood.*

We do not yet have reliable information regarding the natural course of untreated idiopathic scoliosis. In recent literature, there have been varied observations regarding progression, particularly since the conditions in the individual studies differed by sample. The concept 'progression' has also been defined in different ways. However, it is possible that minor spinal distortions may resolve (Brooks et al 1975; Rogala et al 1978; Asher and Burton 2006). In contrast, Sahlstrand and Lidstrom (1980) and Lonstein and Carlson (1984) agree that curvatures of greater dimensions, in statistical terms, lead to progression far more often. With a comparable curvature, females are four to ten times more likely to experience progression than males, depending on the Cobb angle (Weinstein 1985; Asher and Burton 2006). As skeletal maturity increases, the risk of progression decreases, although with more severe curvatures a significant tendency towards deterioration can exist despite skeletal maturity.
Upon reaching skeletal maturity, the tendency towards increased curvature is markedly lower. Duriez (1967), Collis and Ponseti (1969), and Weinstein (1986) discovered that a curvature can, in principle, increase over a lifetime. However, this typically only affects curvatures of 30° or more, with the most seriously affected cases being between 50° and 75° at the point of skeletal maturity. These curvatures will continue to increase by 0.5-1° per year (Weinstein, 1986). Caillens et al. (1991) report that in the case of major single lumbar scoliosis, for people between the ages of 50 and 70, an annual progression of more than 2° can occur. Within this study, an increase of curvature of more than 5° per year in patients between the ages of 65 and 80 was possible. However, it is not yet clear whether these increases in curvature are of medical significance.
The main aim of rehabilitative efforts is, therefore, preventing increases in curvature (stabilization), as well as the preservation or improvement of functionality. Secondary goals include the prevention of subsequent functional disruptions, which can manifest themselves either in terms of the musculoskeletal system or cardiopulmonary system.
The study carried out by Collis and Ponseti (1969) showed that people suffering from scoliosis were not significantly more affected by back pain than a control group not suffering from scoliosis. In later studies (Weiss 1993a; Weiss et al. 1999; Asher and Burton 2006), no connection between the degree of curvature and back pain could be correlated. It is interesting to note that inasmuch as pain is present, patients with scoliosis experience a higher susceptibility to pain in the area of the curvature's apex (Weiss 1993a). Even though there is no correlation between the degree of curvature and pain in patients suffering from scoliosis, pain can be reduced effectively with intensive physiotherapy and brace treatment (Weiss 1993a; Weiss et al. 1999; Weiss, Moramarco and Moramarco 2016).

Generally, patients with scoliosis are concerned with constrictions in the cardiopulmonary region. However, in most cases, these fears are unfounded. According to Pehrsson et al. (1992), after completion of growth, curvatures of less than 100° do not lead to cardiopulmonary constrictions that would reduce life expectancy. Patients with curvatures of less than 100° after completion of growth are, therefore, not threatened by cor pulmonale. On the other hand, there is no indication that those afflicted with curvatures of significantly more than 100° cannot live to the age of eighty, nor will they necessarily suffer from a lower quality of life. What is known, however, is that impairments of the breathing apparatus, and performance in general, can exist even in cases of very slight curvatures (DiRocco and Vaccaro 1988; Weber et al. 1975). For this reason, the rehabilitation of breathing plays a role in physiotherapy for thoracic scoliosis, not only to correct the scoliotic breathing pattern, but also for improving breathing function and, thereby, the general performance of those affected.

The physiotherapeutic and gymnastic treatment of scoliosis has a long tradition in Europe and particularly in Germany. In Europe, there are a multitude of specialized centers that concern themselves with physiotherapy for patients with scoliosis. For twenty years, there was a European society for the physiotherapeutic treatment of scoliosis (Groupe Européen Kinésithérapie Travail sur la Scoliose, GEKTS) whose members exchanged information and ideas on an annual basis at academic congresses for the advancement of physiotherapeutic approaches. This group later was part of the organization SIRER (Société Internationale de Recherches et d'Etudes sur le Rachis), although the treatment of scoliosis has remained a strong focus. Due to language barriers, there has been a limited amount of contact between this originally French-speaking society and German- or English-speaking specialists. Today, there is the international society SOSORT (Society of Scoliosis Orthopaedic and Rehabilitation Treatment), of which Weiss and Moramarco are founding members. SOSORT was established to improve the standards of conservative treatment on an international level, but surgeons are playing a greater role with each passing year and the focus seems to have shifted somewhat.

Over the years, in Germany, there have been a variety of physiotherapeutic approaches used for treatment. Those that ultimately established themselves were the techniques based on developmental-kinesiologic foundations (Vojta and E-technique [E-Technik]) for early treatment of scoliosis, and Katharina Schroth's three-dimensional scoliosis treatment.

The PEP technique (peripherally evoked posture reaction) described in this book may also be used for early treatment, predominantly with children under the age of ten.

New findings concerning the potential of scoliosis to be corrected (Weiss 2004; 2005; Weiss et al. 2006; van Loon et al. 2008) determined that the lateral distortion of the spine and the spinal rotation can be minimized with a simple corrective movement. Simply by increasing the lumbar lordosis at the height of the first lumbar vertebra in association with an increase of the kyphosis in the lower ribcage area, a decline in the lateral distortion is possible. Consequently, recently more exercises concerning the correction of the sagittal profile are being integrated into the Schroth concept. These physio-logic® exercises have visibly improved the results of treatment, when incorporated into in-patient rehabilitation (Weiss and Klein 2006).

A new method of physiotherapy has been developed in order to address the functional tethered cord (Weiss et al. 2013; Deng et al. 2015) evident in patients with severe idiopathic scoliosis, but also in other scoliosis etiologies. These exercises are described within this book as well.

The long-term prognosis for adolescent idiopathic scoliosis (AIS) is, on the whole, favorable (Weinstein et al. 2003; Weiss et al. 2016). However, the signs and symptoms of idiopathic scoliosis are of importance, even when present to a minor degree (Hawes and O'Brien 2006). These cases must have target parameters of conservative scoliosis treatment due to their economic significance such as increased susceptibility or the inability to work.

In the long-term, scoliosis sufferers who have had brace treatment or have been operated upon can expect increased deterioration and, according to contemporary studies, a slightly higher level of pain, versus a control group without scoliosis (Danielson and Nachemson 2001; Danielsson et al. 2001). Also, in the long-term, impairments due to scoliosis are the same for patients regardless if they have had surgery or not. Therefore, impairments (loss of function, reduction in general health, increase in pain, and impairment in lung function) cannot be precluded by undergoing surgery. Recent Cochrane Reviews from Romano et al. (2012) and Negrini et al. (2010) have shown that both physiotherapy for scoliosis and brace application count as evidence-based methods of treatment. In this context, it is interesting to mention the randomized, controlled study from China according to which non-specific exercises apparently had a positive effect on scoliosis in mature adolescents (Wan et al. 2005).

Recently, some RCTs on conservative treatment have been published on corrective exercises (Monticone et al. 2014; Schreiber et al. 2015; Kuru et al. 2015) and on bracing (Weinstein et al. 2013). Therefore, conservative treatment is now supported by evidence on Level I.

In several systematic reviews of the entire treatment spectrum, including surgery, bracing is seen as effective, scoliosis-specific exercise is gaining momentum, and although surgery is the most popular and widely prescribed treatment remedy, recently questions have been raised regarding its necessity based on long-term results and complications (Weiss and Goodall 2008; Westrick and Ward 2011; Weiss et al. 2013; Bettany-Saltikov et al. 2015; Bettany-Salti kov et al. 2016; Weiss et al. 2021). With this in mind, it is with firm resolve that we commit ourselves to the conservative treatment of scoliosis, especially since no significant side effects or risks have been noted for conservative, active physical rehabilitation techniques specific to scoliotic curve patterns.

Idiopathic scoliosis is classified as infantile, juvenile or adolescent and is determined by the age of initial diagnosis (Winter 1995; Kruzel und Moramarco 2020). The non-idiopathic forms of scoliosis that occur less frequently are, according:

- Neuromuscular (neuropathic, myopathic)
- Congenital
- Neurofibromatosis
- Mesenchymal changes (Marfan, Ehlers-Danlos, and others)
- Osteochondrodystrophy
- Other rare forms of symptomatic scoliosis (Winter 1995; Chik 2020)

Genetic defects (e.g. Prader-Willi syndrome, Fig. 1.5) also play a role (Weiss and Goodall 2009).

Fig. 1.5. *Patients with Prader-Willi syndrome, involving various expressions of a genetic defect. Generally, obesity is present and often an insatiable appetite. Even though the patient tends to be of short stature, patients with Prader-Willi syndrome often have severe scoliosis (Weiss and Goodall 2009).*

By definition, idiopathic scoliosis involves curvatures of the spine in otherwise healthy children and adolescents. In contrast, we refer to non-idiopathic scoliosis as symptomatic or even syndromic, since its occurrence can directly be attributed to an underlying disease.

For instance, neuromuscular scoliosis is linked to a disturbance in the nervous system (neuropathic), such as cerebral palsy or meningomyelocele (Fig. 1.7). An example of a subform of myopathic scoliosis is associated with muscular dystrophy or arthrogryposis multiplex congenital (AMC).

Scoliosis with neurofibromatosis is characterized by a rapidly progressive course of the disorder and exhibits characteristic café au lait spots (Fig. 1.7). Because of the potential for rapid progression, the prognosis for symptomatic scoliosis is rather different among the various forms of scoliosis and difficult to predict. Follow-up examinations every three months are advisable during times of growth, as with idiopathic scoliosis. Surgery should not be considered as the first option when there are conservative treatment options, particularly since evidence for surgery is lacking (Cheuk et al. 2012; Weiss et al. 2021) and there are reports of high complication rates (Weiss and Goodall 2008).

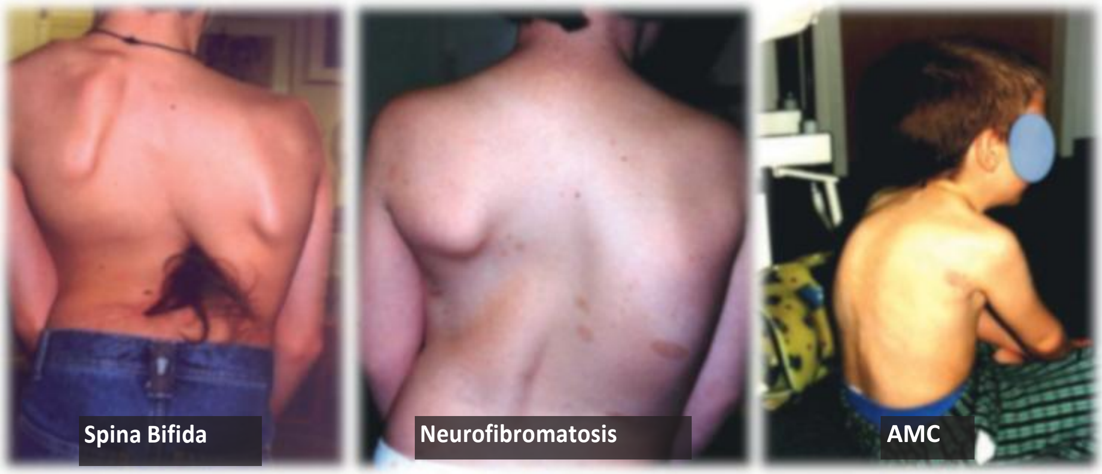

Fig. 1.6. *Various forms of scoliosis. Left: ambulatory patient with meningomyelocele without a skin defect, but with considerable hair growth in the area over the defect. Center: right convex thoracic scoliosis in a boy with neurofibromatosis. The café au lait spots on the skin are typical. Right: boy with arthogryposis multiplex congenital (AMC) with typical kyphoscoliosis.*

Fig. 1.7. *Left: x-ray images of development without progression in a girl with congenital scoliosis without any treatment between age 10 and 14. Right: the clinical image once growth was complete (Kaspiris et al. 2011).*

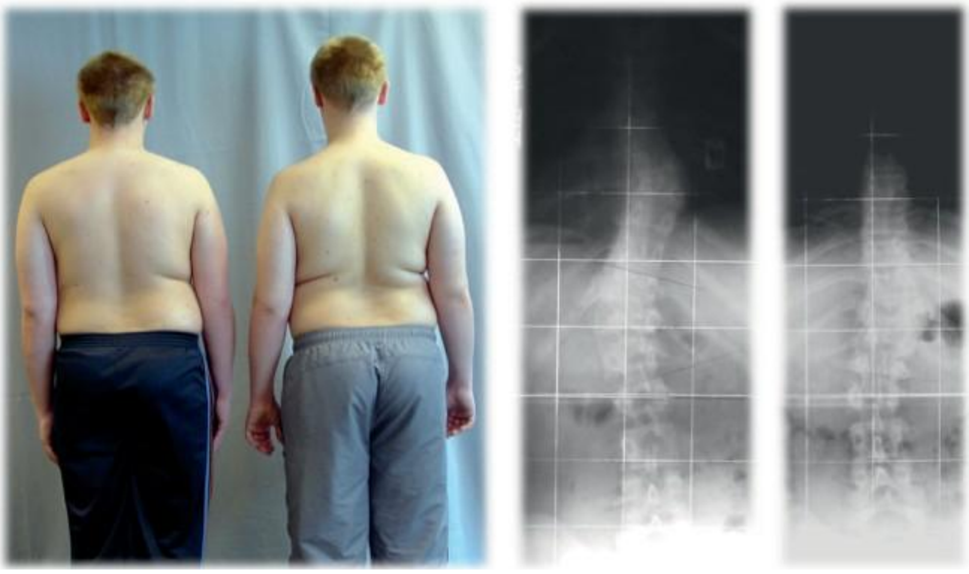

Fig. 1.8. *Monozygotic twins with different forms and severity of congenital scoliosis in the x-ray image, but clinically without considerable deformity and therefore not requiring treatment due to having reached physical maturity (Kaspiris et al. 2008).*

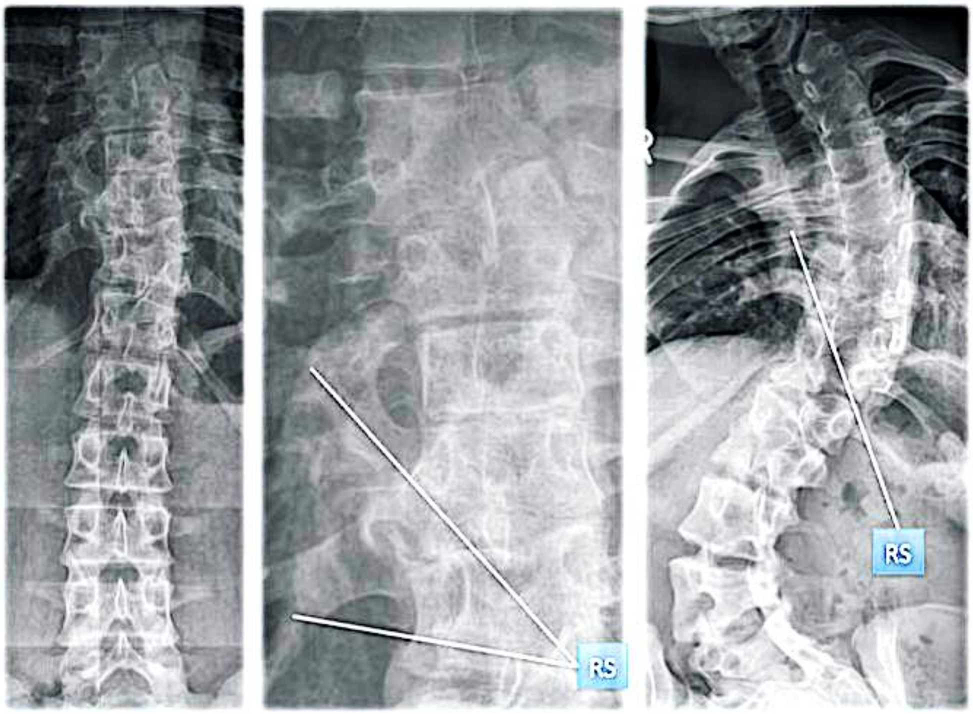

Fig. 1.9. *Two patients with congenital scoliosis and rib synostosis (RS). Nearly at the end of bone maturation, the spinal column of the patient on the left side is practically straight despite proven rib synostosis. Center image is an enlarged view of part of the left image. Right: rib synostosis with severe deformity involving multiple segments.*

With congenital scoliosis, formation defects (wedge-shaped vertebrae, hemivertebrae) need to be differentiated from segmentation defects (onesided bar formation, rib synostosis). Frequently, formation defects occur hand-in-hand with segmentation defects. Many cases of congenital scoliosis are benign, often requiring no treatment

(Fig. 1.7 and Fig. 1.8). Segmentation defects are not necessarily progressive, even if an unfavorable prognosis is assumed when synostosis involves multiple segments (Fig. 1.9).

As far as the clinical appearance is concerned, congenital scoliosis is sometimes inconspicuous (Fig. 1.8 and Fig. 1.9) but can lead to considerable deformities, especially in conjunction with segmentation defects (Fig.1.10).

Fig. 1.10. *Left: a young man with a thoracolumbar formation defect. The thoracolumbar kyphosis in the affected section of the spinal column stands out, while the lateral deviation is not terribly conspicuous. Right: adolescent with rib synostosis (see also Fig. 1.9 right) and severe deformity. The first author indicated an operation for this patient. The operation was declined due to considerable neurological risk after an MRT examination was performed by the spinal surgeon.*

The often recommended early operative treatment of congenital scoliosis is usually unnecessary for balanced deformities and not necessarily successful for more severe deformities (Fig. 1.11). The high complication rate after surgery (Weiss and Goodall 2008) and the lack of evidence of long-term post-operative development through the end of adolescence (Kaspiris et al. 2011) makes the case against surgery as a first resort for patients with congenital scoliosis. (Weiss and Moramarco 2016).

Consequently, the primary treatment indication for symptomatic and syndromic scoliosis is the conservative option. A brace is the primary treatment approach during phases of intense growth and specific physical rehabilitation during all phases when growth is expected (Weiss and Goodall 2009; Weiss 2012; Kaspiris et al. 2011).

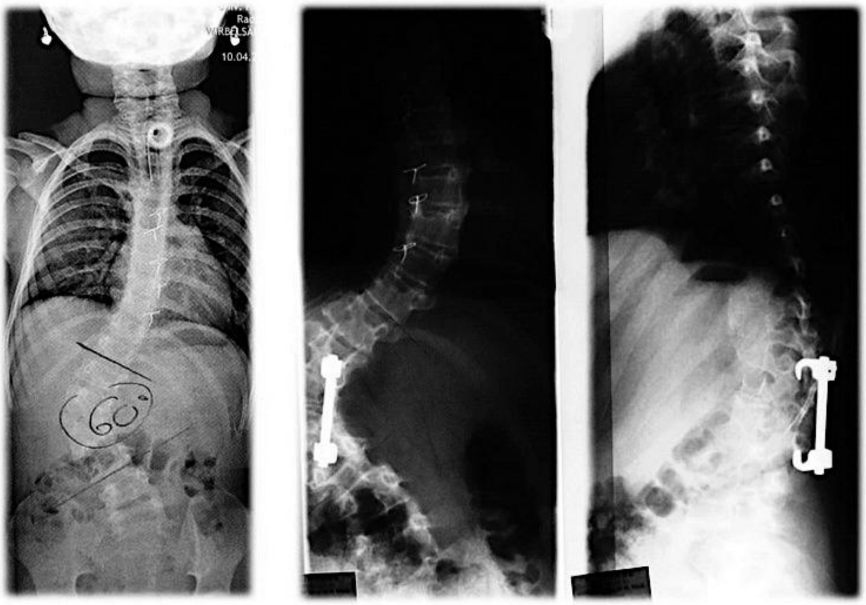

Fig. 1.11. *Congenital scoliosis in a small child with a Cobb angle of 60° initially. After surgery, he progressed to 85° along with an increase in the lumbar kyphosis as shown on the right picture.*

Scar scoliosis has also been described in the literature (Chik 2020). In rare cases, these can also occur as a complication after early childhood heart surgery. These curvatures are often quite pronounced and stiff even before the pubertal growth spurt and, if left untreated, have an extremely unfavorable prognosis (Weiss et al. 2021b; Fig. 1.12 & Fig. 1.13).

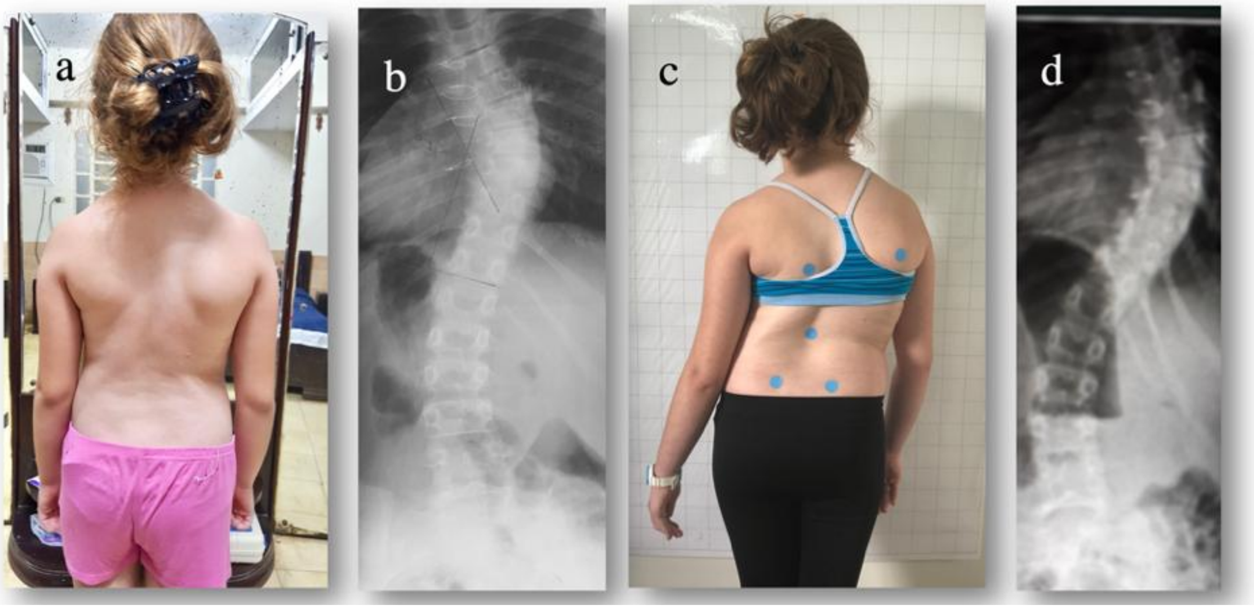

Fig. 1.12. *Significant progression of the curve within 18 months from 45° (a & b) to appr. 65° Cobb (c & d). While the trunk of the patient was compensated at the age of eight (a), at the start of treatment at 9.9 years the patient showed signs of a collapsing spine with a drastic decompensation of the trunk to the right side (Weiss et al. 2021b).*

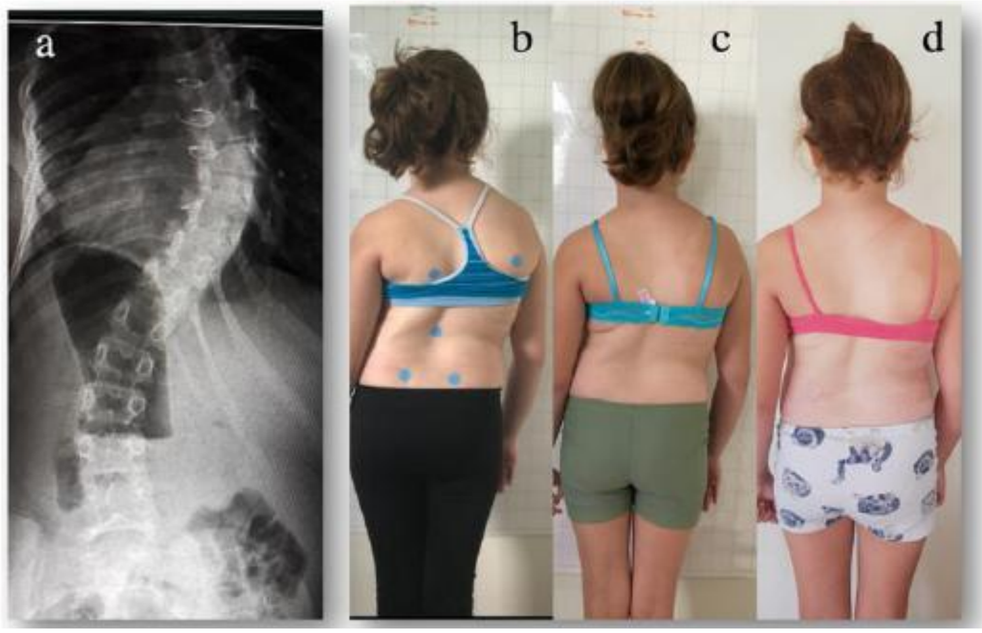

Fig. 1.13. *The patient with two operations for CHD with a collapsing spine at the age of 9.9 years at the start of treatment. (a) x-ray taken November 2019 with a Cobb angle of approx. 65° Cobb, (b) picture from the same time showing the patient from the rear with a collapsing spine. (c) after the application of the Schroth Best Practice Program while waiting for the brace and (d) after a few nights spent in the brace (Weiss et al. 2021b).*

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2. HISTORY

Scoliosis was recognized as early as the 5th century BC when Hippocrates (460-375 BC) described scoliosis and its treatment (Fig. 2.1). His belief was that one of the causes of the deformation of the vertebrae was the luxation of the spine. He tried to counteract this luxation using mechanical devices. In the process, he made use of the Hippocratic luxation table (Vasiliades et al. 2009). The Romans also recognized the Hippocratic luxation table. Galenos (130-201 AD) described spinal deformations in the following way: kyphosis (curvature to the rear), lordosis (curvature to the front), and scoliosis (lateral curvature).

In the 16th century, the Hippocratic braces were described and would go on to be promoted by Paré (Paré 1840). It was only at the beginning of the 19th century and particularly at the beginning of the 20th century when a systematic orthopedic physiotherapeutic method was introduced. This physiotherapeutic treatment was supported by the founding of various orthopedic institutions. These institutions which made time-intensive treatment possible were a prerequisite for successful education concerning posture. In these special institutions, brace-fitting occurred under the supervision of a doctor, often for hours on end.
At the same time, however, the first supportive exercises were carried out, frequently with the help of mechanical correction devices that were specially constructed for the treatment of scoliosis (Fig. 2.2-2.3). Residency in these establishments was very expensive and few people could afford such treatment.

In the 19th century, Zander (1893) tried to overcome the problem of large staff costs with the construction of diverse equipment. Instead of manual resistance from the therapist, he employed suitable devices with resistance for the patient to overcome which could be increased or decreased as one desired, with the extent of the resistance being set using weights.

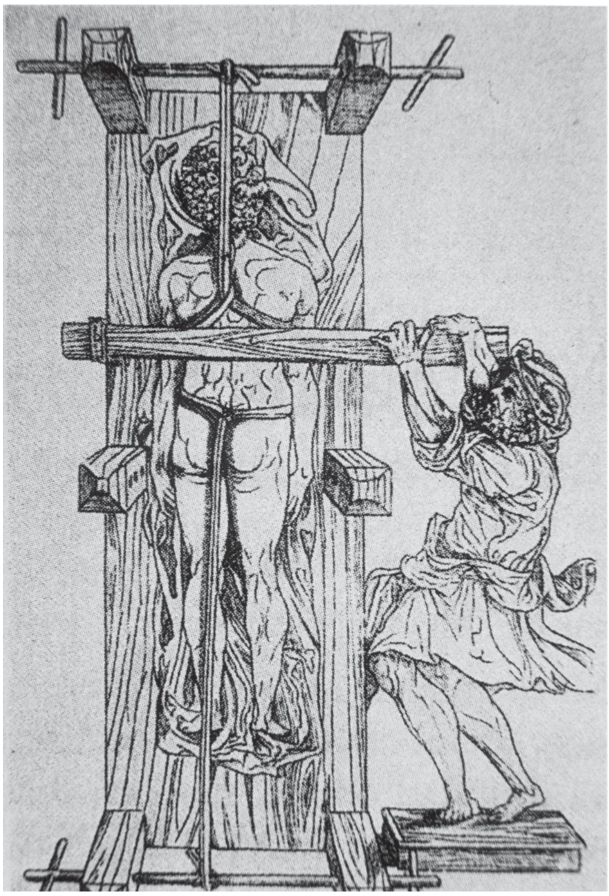

Fig. 2.1. *The "luxation table" by Hippocrates (see also Vasiliades et al. 2009).*

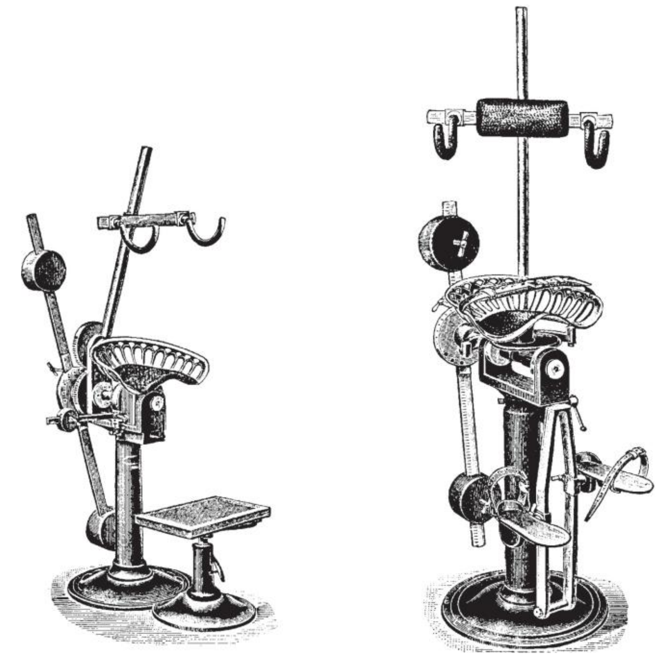

Fig. 2.2. *Representation of two correction (redressment) devices for spinal gymnastics. The trunk moved against the seat area, which was why these devices were described by Schanz (1904) as "trunk pendulums."*

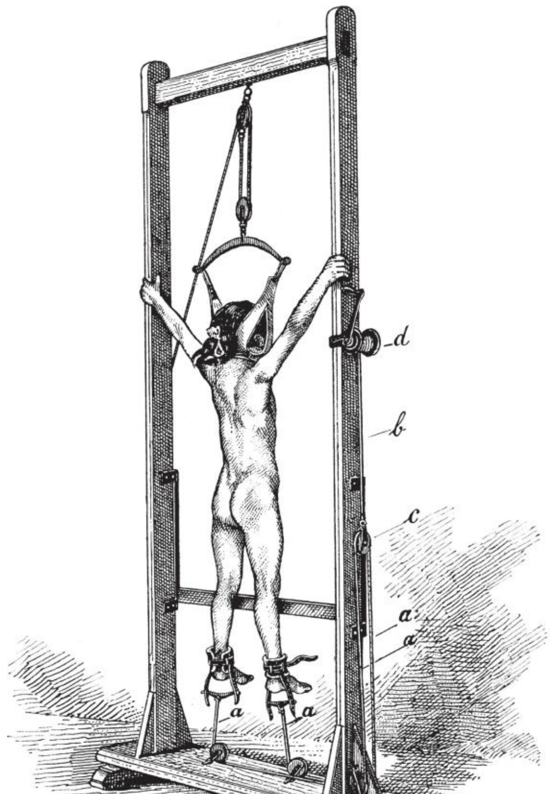

Fig. 2.3. *Correction devices for suspension and correction in preparation for the plaster bandage treatment (Schanz, 1904).*

Lorenz (1886) and Hoffa (1905) developed treatment in the passive upright position. In this treatment, one attempts to achieve a correction of the spine by way of passive reshaping. Lorenz introduced reshaping exercises, which were executed with the assistance of specialized equipment (Fig. 2.4). Hoffa (1905) introduced active exercises in the upright position for the treatment of scoliosis. Parallel to the manual upright attempts, therapy was also developed which utilized machines, as used by Wullstein (1902). Patients were initially stretched using various instruments, and, in order to stabilize the spine, patients were immobilized in plaster or wore braces for many years.

Klapp developed his own method before 1905. This method was expanded into a physiotherapeutic system by the development of specific exercises that were tailored to the various forms of scoliosis. He raised awareness that muscles, bones, and ligaments can only be strengthened through functional use. Thus, his system was a forerunner of functional physiotherapy. The Klapp technique consisted of actively mobilizing the spine and simultaneously strengthening the musculature to help retain flexibility. Klapp observed that good results could only be achieved if these exercises were carried out for at least two hours a day. His method had many enthusiastic supporters, but soon had its critics too, some of whom pointed to possible deterioration of the countercurve due to his method (Lange 1913), while others generally criticized the mobilization of the spine (Haglund 1916).

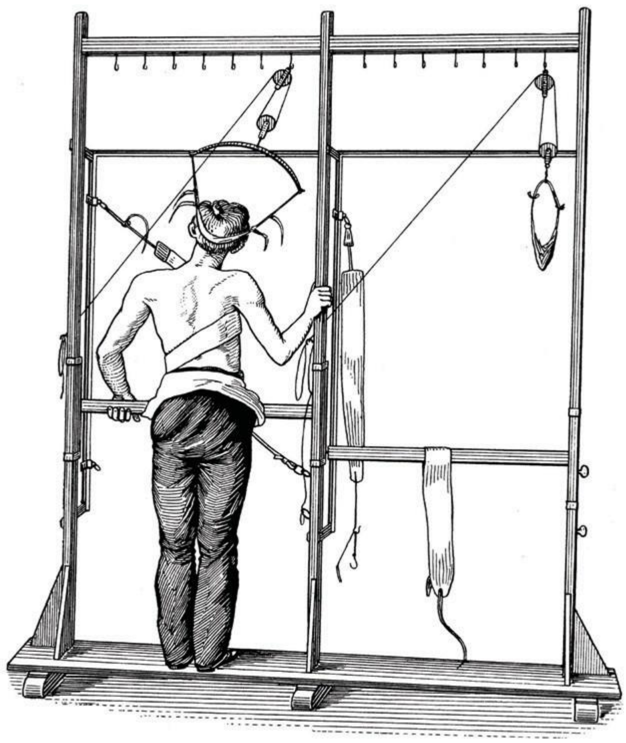

Fig. 2.4. *Modification of the Lorenz spiral cables, from Schanz (1904). This was a passive correction device used several times a day to achieve a corrective effect for treatment taking place over the course of many months.*

In Schanz's book (1904) concerning the load-bearing deformities of the spine, he provides a good overview of the possible treatments that were available at the time. He doesn't neglect questions concerning everyday activities, and, in particular, he provides information concerning the furniture in schools. He also presents the benefits of massage and remedial gymnastics (Fig. 2.5), which, in his opinion, can be summarized as follows: massage and remedial gymnastics can contribute to the minimizing of the static demands on the spine. They do this by reducing the period of time in which the spine is in a position of fatigue and therefore subject to relatively high static demands. Massage and gymnastics can also contribute to an increase of the static performance of the spine. By improving the general condition of the body and strengthening the spinal musculature, they help to bring about an increase in the rigidity of the osseous tissue in the spine.

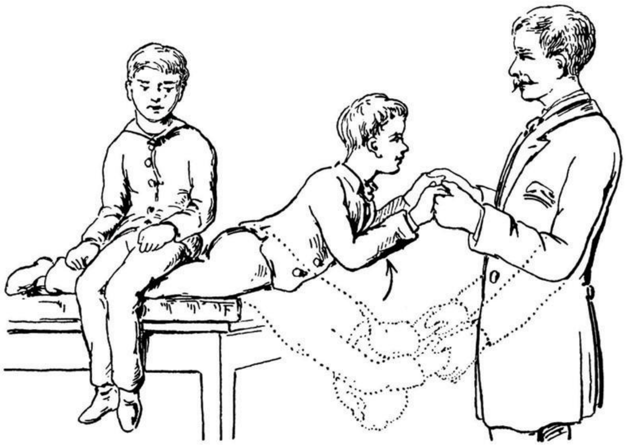

Fig. 2.5. *Staff-intensive upright exercises to strengthen the trunk muscles (Schanz 1904).*

Schanz valued the advantages of massage and remedial gymnastics all the more since there were apparently no significant disadvantages to the techniques.

Brace treatment was introduced, as well as redressment (correction) devices that were intended to support the "plaster bandage treatment." After correction therapy in the plaster mold, very good results were achieved.

Interestingly, the brace treatment available at that time differs from contemporary treatment only slightly. The "portative correction device" also shares similarities to the dynamic correction brace (DCB) used today.

Swedish remedial gymnastics according to Ling's method (1924) grew in popularity at the beginning of the 20th century. Ling used resistance exercises in sitting, standing, and hanging positions, as well as lying on the front and the back. Oldevig (1913), who was instrumental in the introduction of Swedish remedial gymnastics in Germany, had recognized the disadvantage of these resistance exercises which always needed to be carried out under the guidance of at least one doctor or physiotherapist (Fig.2.5-2.6).

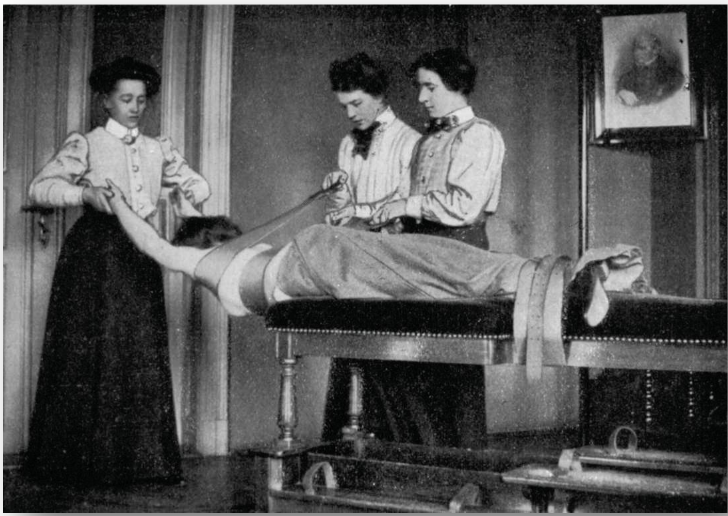

Fig. 2.6. *Staff-intensive physiotherapy for spinal deformities - the strap is pulled (Oldevig 1913).*

With his belt exercises (Fig.2.7-2.8), Oldevig tried to isolate individual curvatures and work on them in that way. The aim of the belt exercises was to trigger muscle activity. Oldevig believed that muscle activity could be achieved more conveniently, more precisely, and more effectively through belt exercises than through any other method. He saw the "gymnast" as a modeler who reshapes the living body. He therefore demanded from this gymnast a high level of independent reflection, much feeling, and visual judgment. The exercises he developed are based on anatomical principles and it was of absolute importance to him that compensatory curvatures not be increased during the excercises.

Fig. 2.7. *Therapy involving pulling a strap in a standing position, with extra staff assisting (Oldevig 1913).*

Fig. 2.8. *Lordosis exercises for kyphosis according to the Oldevig method (Oldevig 1913).*

For Lange (1907), scoliosis was a disruption of the muscular balance. He constructed various resistance devices with which he wanted to achieve an overcorrection of the spine. The patient had to re-bend the spine on the concave side against the resistance of the device in order to achieve the desired overcorrection.

Fig. 2.9. *Typical setting of the correction exercises, according to Oldevig, at the wooden bars and on the exercise bench (Oldevig 1913).*

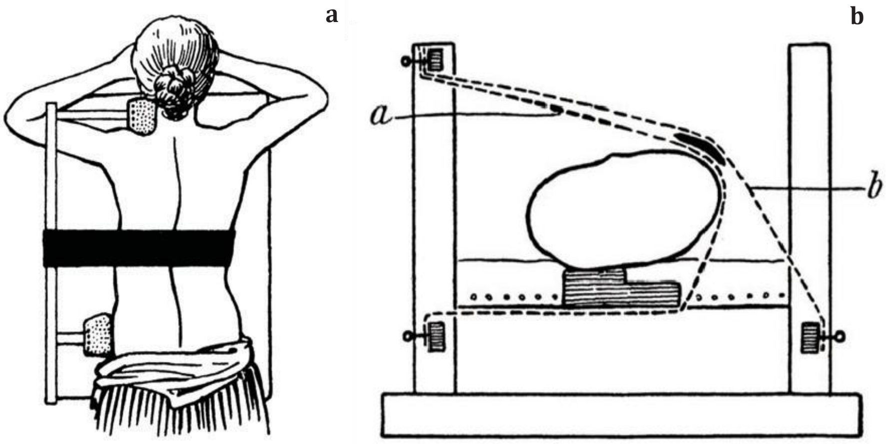

Fig. 2.10. *(a) A schematic representation of the three-point principle for correction in a belt device and (b) schematic representation of correction straps that looped the costal hump dorsolaterally (Lange 1907).*

Everyday activities played an important role. Lange visualized the scoliosis curvature using his "diopter" and could thus monitor the success of the treatment. The goal of his treatment was to correct the insufficiency in the erector spinae muscles. He was of the opinion that there were two conditions that had to be satisfied in order to tackle scoliosis effectively:

- The scoliosis-affected spine needed to be re-bent forcefully, both actively and passively (Fig. 2.9, 2.10);
- The devices used for the active and passive overcorrection needed to be as simple as possible (Fig. 2.11).

Lange also observed the counter-curve and stated that an overcorrection must be strictly limited to the section of the spine that was distorted. It was for this reason that he was not able to sympathize with "the original idea of the highly esteemed Bonn-based surgeon Klapp," who wanted to heal scoliosis using crawling.

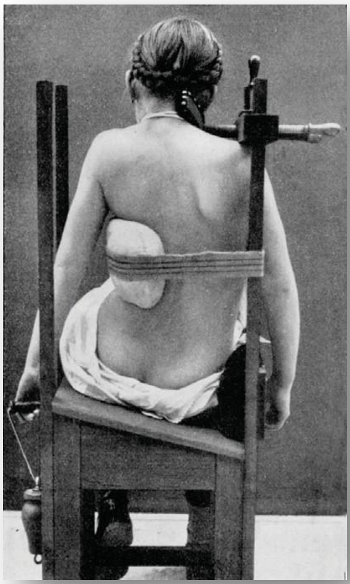

Fig. 2.11. *A patient sitting in a three-point correction device (Lange 1907).*

Blencke (1913) was an advocate of the more specific treatment approach for scoliosis. He distinguished between remedial gymnastics for general treatment and a form of correction gymnastics for a direct influence on the pathological form of spinal deformities (Fig. 2.12-2.13). He rejected the idea that just anyone or even just any gymnastics teacher could provide treatment for scoliosis. For serious cases of scoliosis, he believed that asymmetric exercises were indispensable (Fig. 2.14a, b). Just as Schultheß did, he viewed special orthopedic gymnastics for the treatment of scoliosis as work to be tailored to the individual case. Treatment involved an overcoming of resistances in specially chosen positions, with certain parts of the skeleton being held in a fixed position with the elimination of certain secondary movements and undesired side effects. Blencke (1913) also viewed the Klapp crawling exercises in a negative light, since, in his opinion, gymnastic scoliosis treatment needed to be tailored to the individual.

Around the end of the second decade of the 20th century, Katharina Schroth developed her three-dimensional scoliosis treatment. Her own body had been deformed by scoliosis and it was by looking at the way that it reacted that she developed specific corrective mechanisms and a corrective breathing technique that she named “rotational breathing” (Fig. 2.15a-b). Along with the rotational breathing technique, Schroth’s holistic principle was new to the treatment of scoliosis. Katharina Schroth wanted to influence scoliosis via a change in the entire feeling of the body.

Fig. 2.12. *The torsion pattern of a thoracic vertebra with scoliosis. The vertebral body tends to the right whilst the zygapophyseal joint lies more to the left and the spinous process points to the right. Furthermore, there is a wedge-shaped formation that is not shown on this image (Blencke 1913).*

Fig. 2.13. *Torsion of the ribcage with thoracic scoliosis. (Blencke 1913).*

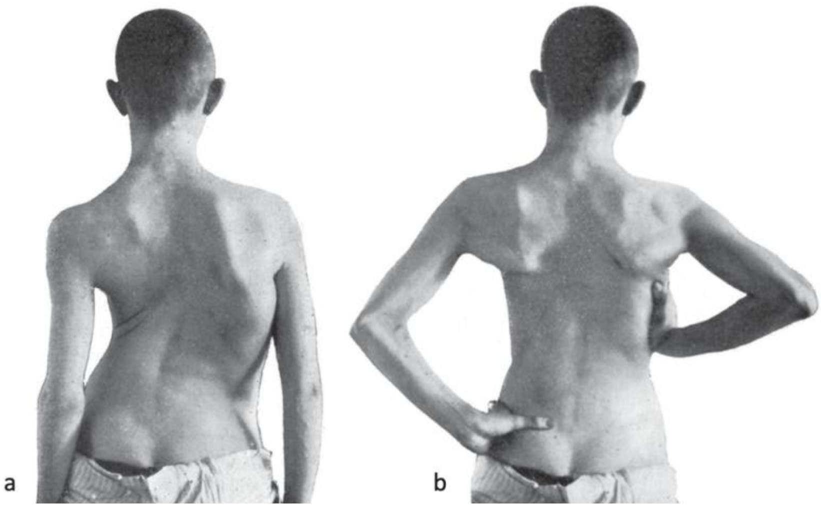

Fig. 2.14. *(a) A patient with right thoracic scoliosis and left lumbar counterswing before the exercise. (b) The patient in the auto-correction, which was to be carried out several times a day (Blencke 1913).*

With the opening of the first institute in Meißen in 1921, Schroth's three-dimensional treatment for scoliosis enjoyed increased popularity. For the first-time scoliosis wasn't simply seen in a mechanical light, although the mechanics by no means played an inferior role. Katharina Schroth introduced for the first-time sensorimotor kinesthetic principles to the treatment options of scoliosis. These principles use the most active erection possible to provide a sense of awareness in order to avoid curvature-inducing behavior in one's daily routine (Fig. 2.16 and 2.17). Breathing was also integrated as a crucial factor in the correction of scoliosis not only of the ribcage, but also of the lumbar spinal region (Schroth 1924; 1929; 1931; 1935). After introducing these principles, treatments lasting three to six months would be carried out with the most serious cases of scoliosis.

The successful treatment of curvatures, some of which were very significant and rigid, can be seen in the first publications from the institute that Katharina Schroth founded (Fig. 2.15 - 2.17). However, in a report whose contents only became known after the Second World War, Prof. Schede from Leipzig criticized the treatment as early as the 20s, describing the treatment as "charlatanism that people must be warned against."
This criticism was so influential that it led to the removal of Franz Schroth - Katharina's husband - from his official post position. His wife's work was supposedly scandalous and unworthy of an official. However, there were also many positive voices from the medical profession that ultimately led to Franz's reinstatement after a disciplinary inquiry.

In 1924, Katharina Schroth published the small volume 'Die Atmungskur.'

The Essen-based Dr. Grewers wrote the following in the foreword:

"Personally, I can already judge that which I have seen and I will never fail to recommend this technique to patients in certain cases, since I know that it will be of help to them where everything else has failed them. I do not believe I am saying too much when I claim that this remedial system has a full medical grounding and that a medical practitioner free of prejudice can use it side-by-side with the existing remedial system."

The volume was not intended necessarily for those suffering from scoliosis, but rather contains information for exercises for all patients suffering from collapsed posture. However, Katharina Schroth makes it clear that she addresses the treatment of scoliosis with particular focus. This is clear in the following description of treatment:

"I then brought out the left side slowly but surely using one-sided breathing and many types of gymnastic exercises. Since there was a double curvature, I of course had to be careful that none of the exercises helped one part but damaged the other. It is often the case that canceling-out exercises must be carried out. Meticulous observation and many years of experience also allow one to avoid these pitfalls."

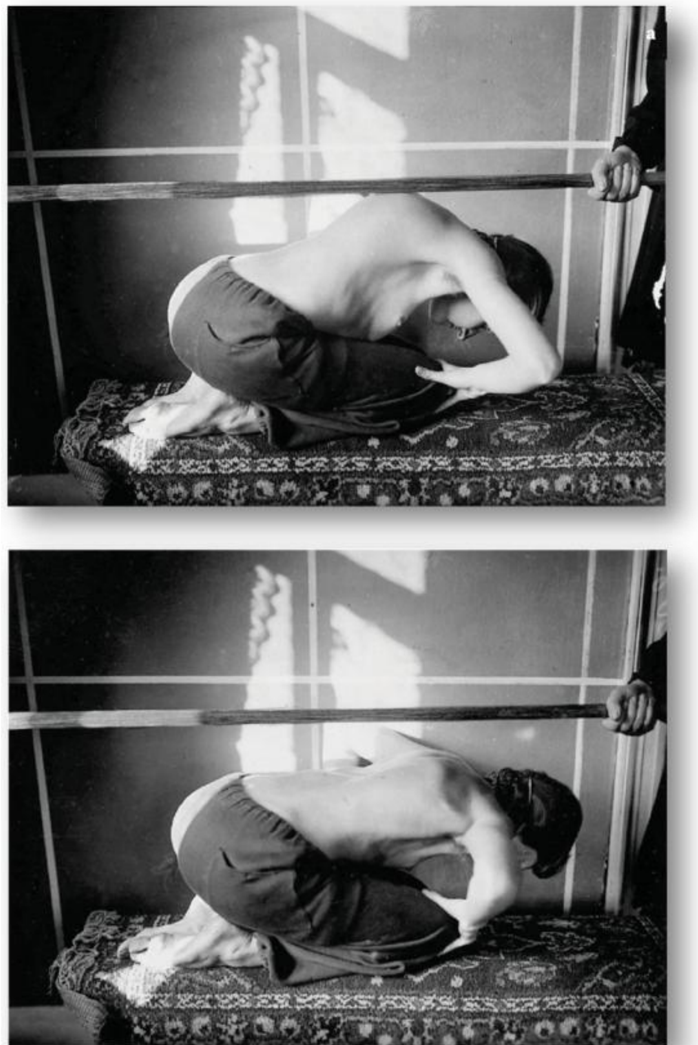

Fig. 2.15. *Execution of the rotational breathing technique with a severe thoracic distortion (a) before the exercise and (b) during the exercise. Positive results were observed after many months of treatment.*

Fig. 2.16. *Strengthening the feeling of posture via the use of so-called "redressment (corrective) grasps" and "breath grasps" to improve the corrective movement during exercising.*

Fig. 2.17. *Use of mirror control in order to facilitate auto-correction with the assistance of breathing.*

In 1929, Katharina Schroth presented her increasingly holistic approach in a second illustrated brochure:

> *"Why is it so often the case that gymnastic efforts to straighten out the spine of a child suffering in this way so often result in failure? Because one approaches the child in a far too mechanical way, far too exercise-oriented, without first investigating the difficulties the child experiences in life, the unendurable problems they have - problems that might well seem insignificant to an adult. Getting the external person to stand up straight and erect their spine will only be possible if you first allow the inner person to 'stand up straight,' to give them hope, to allow them to 'breathe out.' Here, language shows itself to be much smarter than the current materialistically minded generation of, let us say, practitioners who view the human as a machine."*

In Naturmedizin (Natural Doctor), a publication from 1931, Katharina Schroth wrote the following about the rotational breathing technique:

> *"It is challenged on many sides that one can control one's breathing so precisely that it will go where we want it to go. To achieve it, the teacher must help the pupil to develop a sense of control for the right load and the wrong load, for the proper orientation of the rib joints at the right location."*

The principle of "helping the patient to help themselves" is also present in the same article:

> *"If one considers how terrible the lot of those who suffer from spinal deformations is, how ostracized they must feel simply due to their appearance, how limited they are in their professional life, how reduced their joy in life is, then one must accept that in order to achieve an improvement to this situation - something that is perfectly possible - a brief education with expert instruction must first create a foundation that can then be built upon at home in self-treatment."*

On the subject of "body feeling," we find the following statement from Katharina Schroth in a special edition of a journal from the upper Ore Mountains region in 1935:

> *"It is self-evident that the patient must be activated in each and every sense: bodily, mentally, and emotionally; that they themselves must take on the struggle against their suffering - for the character, this educational influence brings with it intense repercussions. With precise and specific work one can unlock the potential to develop the patient's body feeling and to generate a sense of the body on a higher level, so that even work involving layers of muscle buried deep under other layers is under command and can be carried out precisely. This is a scenario whose possibility of fulfillment leaves even highly educated professional gymnasts lost for words."*

There is very little written information about the treatment system developed by Gocht and Gessner. Gocht (1909) had concerned himself initially with the equipment-based treatment of scoliosis; however, the exercises based on Gocht and Gessner's work were developed after 1925 at the Charité Hospital in Berlin. Mater (1957) wrote the following on the subject:

> *"The scoliosis exercises that Gocht and Debrunner described in their book Orthopedic Therapy from 1925 are not the same as those that are carried out today. In this book, above all it is corrections of the spine that are described with the patient in a passive role. Treatment is through hand pressure against the costal hump and thus a movement of the trunk against the pelvis, or in the case of lumbar scoliosis, a pelvic inclination on the concave side via re-location and relief of the affected leg. Gocht describes these as an active static recurving. The exercises that Ms. Gessner arranged at the Berlin Charité Hospital in later years, which are in principle still broadly in use today, are actually exercises taken from Swedish remedial gymnastics."*

For Hug (1921), the degenerated muscle fibers have a central role in scoliosis. We find him saying, for example, "the earlier the onset of scoliosis, the more drastic the bodily deformation." His principle for treatment is the "temporary overcorrection on the other side." At least from a mechanical perspective, he is in agreement with Lange and Schroth here.

For Port (1922), the musculature is also of key importance. He was of the opinion that the development of rachitic scoliosis was dependent upon the condition of the musculature. For him, this meant that the practitioner's entire attention must be turned towards the musculature and that measures of redressment and supportive braces only be worn for the sake of the musculature.

Farkas (1925) noted that with thoracic scoliosis a lordosis can be observed. On the other hand, he noted that kyphosis had the opposite effect. He describes the paradoxical phenomenon that, in actual fact, the costal hump is increased by lordosis, reduced through kyphosis and therefore, in terms of the apparent degree of costal hump, lordosis and kyphosis behave inversely. He was of the opinion that the development of "habitual" scoliosis took place in the same way and was caused and promoted by the same factors as physiological scoliosis, namely from the mechanics of walking. There is a quotation from him that the admonishers amongst those involved in therapy should bear in mind:

> *"A child that continues to sit improperly, despite "reminders," does not get scoliosis, but rather already suffers from it. The reclining position of a child suffering from scoliosis is indeed a scoliotic position, because it demands the least possible work and because all other reclining positions are associated with effort by the child and are therefore no longer actual comfortable reclining positions."*

This opinion is just as relevant today as it was then and should also be taken into consideration in the conceptual development of treatment for scoliosis.
On the subject of therapeutic setting of goals, Farkas said the following: "The principle of functional therapy for scoliosis is based on the restriction of damaged functions." Farkas believed that the contraction of the spine could be corrected, in terms of inclination. He went on to explain that one could only influence the portion of the costal hump that arose from the rotation of the trunk.
Heuer (1927) summarizes the work concerning the etiology of scoliosis and develops a self-sufficient model of scoliosis.
Despite Katharina Schroth's scoliosis treatment being received warmly in many circles, Lempert and Brodermann (1931) still favored the Klapp exercises. However, the authors were not critical of the exercises and expressed no position with respect to the possible deterioration of countercurves as a result of this treatment method - the reason this method came under fire from critics two decades earlier.

At the beginning of the 20th century, Egon von Niederhöffer also concerned himself with the biomechanics of the back musculature in cases of scoliosis. In her publications from 1929 and 1936, Luise von Niederhöffer does not yet exhibit a physiotherapeutic concept. It was only in 1942 that the Niederhöffer treatment principle was presented along with a sequence of exercises (Fig. 2.18) - this would later be refined by Becker.

Fig. 2.18. *Description of von Niederhöffer's treatment principle. Above the surface musculature a correction movement was carried out on the spine with the help of the thoracic concave side arm. This is contrary to the three-dimensional scoliosis treatment developed by Schroth where the ribcage is first corrected and the thoracic convex side arm is pulled against the ribcage correction over to the thoracic convex side, in order to correct the cranial section (modified from Weber and Hirsch 1986).*

After the Second World War, Katharina Schroth and her daughter Christa relocated to the west and founded a new institute in what was then known as Sobernheim, following the wards in Bad Steben and Bad Kreuznach. This institute was initially exclusively private, but was then run as a sanatorium from the beginning of the 70s. Here, Katharina Schroth's three-dimensional scoliosis treatment was developed further and quickly became more and more well known. Before the end of the 70s, the effect of intensive in-patient rehabilitation of the breathing function was studied with a comparison group. Götze (1976) was able to show that this kind of intensive program not only increased cardio-pulmonary performance, but also the vital capacity; the vital capacity showed no significant change after a four-week aerobic fitness program.

Despite being led by medical professionals, the establishment - which had been named the Katharina Schroth Clinic in the 80s - became the target of multiple accusations from critics of the method. Using a supposedly academically led "method fight," they tried to annul this concept, which was becoming more and more successful. After this conflict had been overcome, the method received general recognition from everyone in the orthopedic world and from German insurance companies.

In the 50s, Vaclav Vojta began developing a treatment for children with cerebal palsy based on kinesiologic methods. In the 60s and 70s (Vojta, 1965), his treatment began gaining the interest of German therapists. By the end of the 70s, Vojta's treatment was widespread and scoliosis was also being treated using his approach. With this method, the belief was that, with the assistance of facilitation of the reflex movements, the muscular imbalance that exists in patients suffering from scoliosis can be compensated through central mechanisms. Many mistakenly believed that the correction could be predominantly traced back to the increase in activity of the segmental dorsal musculature, which is partially degenerated in the case of scoliosis (Fig. 2.19).

Today, apart from Katharina Schroth's three-dimensional scoliosis treatment, the old treatments no longer play a significant role in Germany because they have not been continually developed over time. This is also the case with Scharll's scoliosis treatment, which experienced a renaissance in the 80s (Weber and Hirsch 1986).

Fig. 2.19. *Exercise for the facilitation of reflex turning, developed by Vojta. At the beginning of the 80s, Hanke introduced the E-technique (E-Technik), based upon Vojta's principles. In a horizontal position, he tried to straighten out the costal hump via tension exercises and, at the same time, stabilize the posture, which had been altered by the central reactions.*

In the out-patient setting, Schroth's three-dimensional scoliosis treatment is spreading. The physiotherapeutic treatment methods based on developmental kinesiology (Vojta and Hanke) are still employed in Germany to some degree as well. Beyond these, numerous approaches were used in the past to expand the range of treatment methods for scoliosis (Ozarcuk 1994), but over time these have been abandoned due to imprecision and inefficiency. Therefore, in the out-patient field, we can in good faith limit our selection of suitable physical rehabilitation methods to those introduced above and the subsequent developments they experienced.

Undoubtably, in other countries and other continents there are and have been effective developments for the conservative treatment of scoliosis, perhaps many hundreds or thousands of years old.

However, perhaps the readers will forgive the first author for limiting his sketches to the developments within the German-speaking world. At the time of publication, no comprehensive international multilingual sources were available.

Recently, several developments on the international level have been marketed aggressively, such as Yoga, SEAS, or Dobomed (Fusco et al. 2011), although these approaches apparently make do without using a systematic system of correction. If, however, we bear in mind that with brace treatment we are absolutely concerned with the correction effect (Landauer et al. 2003), then we should focus on methods that are inherently corrective, such as Side-Shift, Monticone, Schroth, and the Schroth Best Practice program® (Borysov and Borysov 2012; Pugacheva 2012; Monticone et al. 2014; Lee 2014) when choosing which rehabilitative method to pursue.

In all probability, the future will be governed by treatment approaches that are simpler and easier, but without compromising effectiveness. New pedagogical approaches must take into account that today's adolescent patient is unlike the youth of times past who regularly underwent six-week in-patient intensive rehabilitation. Experiential learning should be incorporated and treatment approaches which align methodology to the constantly changing traits of the patients are essential for a positive outcome.

It is safe to assume that Katharina Schroth's three-dimensional scoliosis treatment and its subsequent development, the Schroth Best Practice® program, are the most widely used forms of treatment across the globe. Books on the subject have already been translated into many languages. The upcoming sub-chapter will focus on the history of Katharina Schroth's three-dimensional scoliosis treatment drawn in part from a publication from Weiss (2011).

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2.1 Katharina Schroth's Scoliosis Treatment Method

Katharina Schroth was born February 22, 1894, in Dresden, Germany. She suffered from moderate scoliosis and underwent treatment with a steel brace at the age of sixteen before she decided to develop a more functional treatment approach.
Inspired by a balloon, she tried to breathe away the deformities of her own trunk by inflating the concavities of her body selectively in front of a mirror. She also tried to "mirror" the deformity by overcorrecting with the help of certain pattern specific corrective movements. She recognized that postural control can only be achieved by changing postural perception.
This new treatment concept consisting of specific postural correction, correction of breathing patterns, and correction of postural perception was introduced at a small institute she had established in Meissen, Germany, with rehabilitation taking place over the course of three months. Beginning in the late 30s and early 40s, she was assisted by her daughter, Christa Schroth, a collaboration that spanned decades.
It wasn't until the late 1980s that the first studies of Schroth methodology were carried out. The patient series for the first prospective controlled trial was derived from the patient samples of 1989-1991.
Over time, the content has evolved and rehabilitation times have changed. Bracing has been introduced and refined for Schroth compatibility to offer patients improved treatment outcomes.
In the last few years, the first author modified the older techniques thereby modernizing the program and reducing training times by adding new forms of postural education such as sagittal correction, activities of daily living (ADL) correction and experiential learning.
While the program is still based on the original approaches of the three-dimensional treatment according to Katharina Schroth - specific postural correction, correction of breathing patterns, and correction of postural perception - the patient is now instructed in a way where these concepts can more easily be applied during daily routines.

The Schroth Method and Its Evolution

The history of conservative treatment of scoliosis is rather long and leads us back to the original methods of Hippocrates, 460-370 BC (Vasiliades et al. 2009). Although more than 2000 years have passed since the days of Hippocrates, the main approach of conservative scoliosis treatment in the early 20th century was still based on mechanical viewpoints or concepts related to approaches still used today. Correction exercises were used widely throughout Europe during the last two centuries. Some of them requiring three therapists for one patient (Fig. 2.6) during scoliosis correction (Oldevig 1913).

The history of the Schroth method involves the professional work of three generations. The initiation of the program was the result of Katharina Schroth's self-study, in part as a result of analyzing her own body, her own spinal function, and the corrective movement patterns. Mirror monitoring took on an important role in the original Schroth program, as it does in current protocols, and allows the patient to synchronize the corrective movement and postural perception with visual feedback (Fig. 2.18). Since breathing and its functional correction play such a key role, her first writings focused on breathing in general (Schroth 1924). Later, she also described the importance of postural perception by the patient and its improvement via specific correction exercises (Schroth 1931; 1935).
The Schroth family history as it relates to scoliosis all began in East Germany early in the last century. Katharina Schroth began her professional life as a teacher at a business and language school. However, she decided to change careers to undergo training at a gymnastics school (predecessors to what we know as a physical therapy education). She immediately recognized that the techniques learned were not specific to scoliosis, however, this allowed her to begin to treat patients like herself.
When she began her scoliosis program in Meissen, 1921, (Figs. 2.21 and 2.22) most patients she treated had curvatures exceeding 70º with large rib humps and stiff deformities as a result of scoliosis of varying origins.

Fig. 2.21. *Katharina Schroth (center in the background) seen with her patients in the 30s. [Historical picture from the picture database of Christa Lehnert-Schroth.*

Fig. 2.22. *A group of patients with large curvatures exercising in the garden of the institute run by Katharina Schroth in the 30s in Meissen. [Historical picture from the picture database of Christa Lehnert-Schroth].*

In the 40s, Christa Schroth (Fig. 2.23) assisted, and helping those with large curves became their main focus (Figs. 2.24 and 2.25).

Besides individual exercises with passive manual correction by a therapist, a group setting was established allowing treatment of patients with similar curve patterns in one group (Fig. 2.26).

Fig. 2.23. *Individual training of a patient by Christa Schroth, daughter of Katharina Schroth, in the 40s. [Historical picture from the picture database of Christa Lehnert- Schroth].*

The Meissen institute had a large garden and a small building which housed helpful tools for individual and group treatment. When possible, most of the treatment was carried out in the garden. The fresh air and sun's rays contributed to the patients' general health and well-being at a time when people were not used to exposing their skin to the sun or to other people.

For Katharina Schroth, mirror monitoring was of utmost importance as is demonstrated in Fig. 2.17 showing a patient treated by Christa Schroth in the 1940s. Husband and father, Franz Schroth also helped patients in the Meissen institute with individual corrections and special arise and as early as the late 1920s a battle of methods emerged. Professor Scheede from Leipzig, where Hoffa exercises were performed, objected to Katharina Schroth's center mostly because she was neither a professional trainer nor a physician, but had started her program as a school teacher and attended a school of gymnastics after she had started her institute.

After World War II, Katharina Schroth was forced to leave her Meissen institute. She accepted a position of employment to provide her services, together with her daughter, now a physical therapist at a state-run medical center in Gottleuba during the early 50s.

Fig. 2.24. *A typical patient with a large curvature as treated in Katharina Schroth's strengthening exercises first institute in the 30s in Meissen. [Historical picture from the picture database of Christa Lehnert-Schroth].*

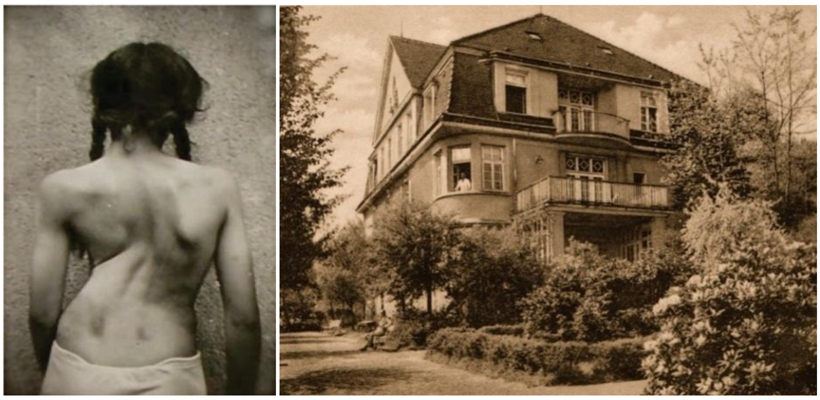

Fig. 2.25. *Another typical patient with a large curvature as treated in the second Schroth institute. [Historical picture from the picture database of Christa Lehnert-Schroth. Gottleuba 1950, second Schroth institute, East Germany as on the right].*

Fig. 2.26. *A group of patients with major thoracic curvatures exercising the muscle cylinder. [Historical picture from the picture database of Christa Lehnert-Schroth, Meissen in the 30s].*

From Gottleuba, Katharina and daughter relocated to Bad Kreuznach, West Germany where they opened a private practice. Christa Schroth married Ernst Weiss, gave birth to a son, Hans-Rudolf Weiss, and divorced. In 1961, mother and daughter established an institute in Sobernheim. This institute attracted many patients, often 150 at a time, with typical stays of six weeks' duration (Fig. 2.27 and Fig. 2.28). Christa married Adalbert Lehnert in 1962 who contributed to the growth of this center and was involved in patient treatment.
By the 1970s, Christa Lehnert-Schroth had advanced Katharina Schroth's method and introduced a simple classification system which is still used today by practitioners (Fig. 2.29).
In addition, she discovered the importance of the lumbosacral (counter-) curve (4th curve) for pattern-specific postural correction and described this in her book, Three-Dimensional Treatment for Scoliosis, first published in 1973, now available in the 7th English edition (Lehnert-Schroth 2007). This historically important book is available in several languages, including English, Spanish, Mandarin, and Korean.

It was also in the 1970s that a series of investigations were carried out with respect to vital capacity and cardiopulmonary function improvements at the clinic. The findings from these studies resulted in the acknowledgement of the method at some universities (Götze 1976; Götze et al. 1977).

It was at that same time that the impact of the lumbosacral curve on the correction of certain curve patterns was discovered (Lehnert-Schroth 1981; 1982).

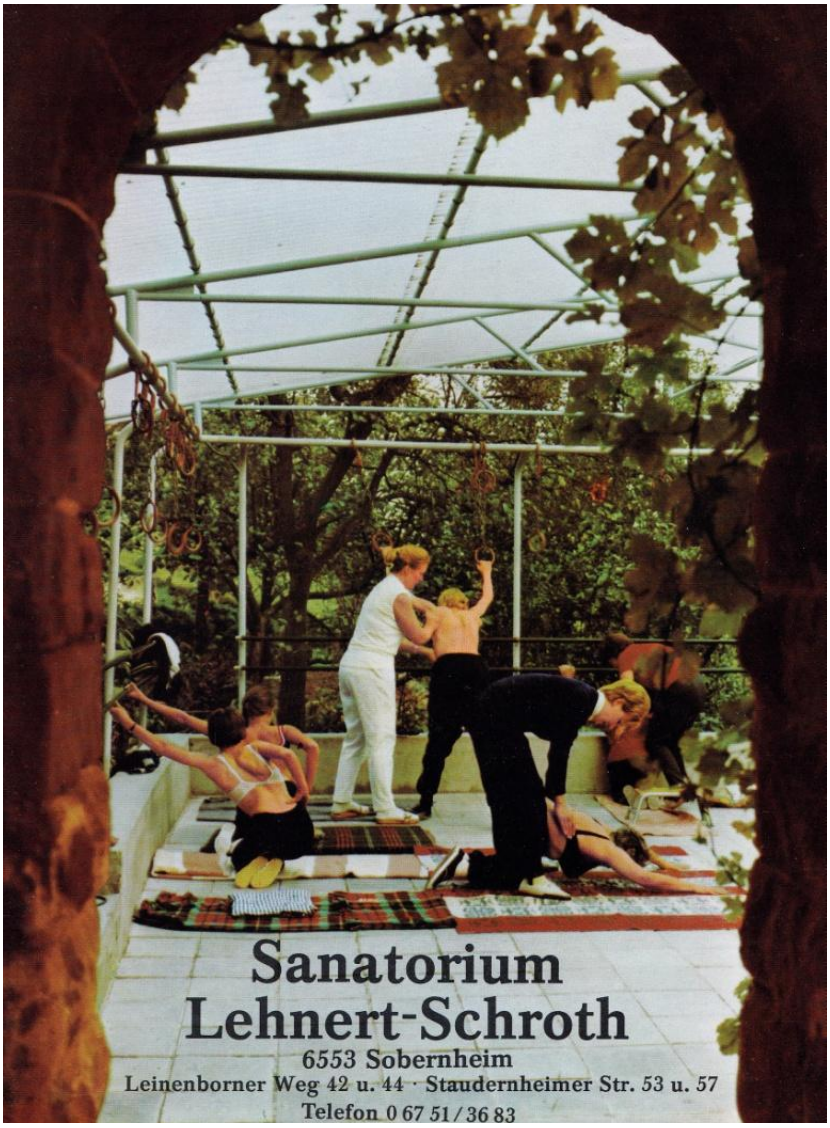

Fig. 2.27. *Christa Lehnert-Schroth, Katharina Schroth's daughter, amidst a group of patients at her new institute in Sobernheim. (Folder of the Sanatorium Lehnert-Schroth in the 70s). [Historical picture from the picture database of Christa Lehnert-Schroth].*

Christa Lehnert-Schroth also recognized the spontaneous correction of a functional leg length discrepancy just by straightening the lumbar curve (Lehnert-Schroth 1981).

It is worth noting that until the end of the 70s, Schroth in-patient practices included passive (cervical) traction, especially for those with large curvatures. This type of treatment was eventually abandoned because of adverse effects. This topic will be discussed further in Chapter 3.

In the early 80s, the Sanatorium Lehnert-Schroth Institute was renamed the Katharina Schroth Clinic, but by this time Katharina Schroth was not as active. Nevertheless, she continued to lobby for her method of treatment having numerous disagreements with professors from various German universities until her death on February 19, 1985.

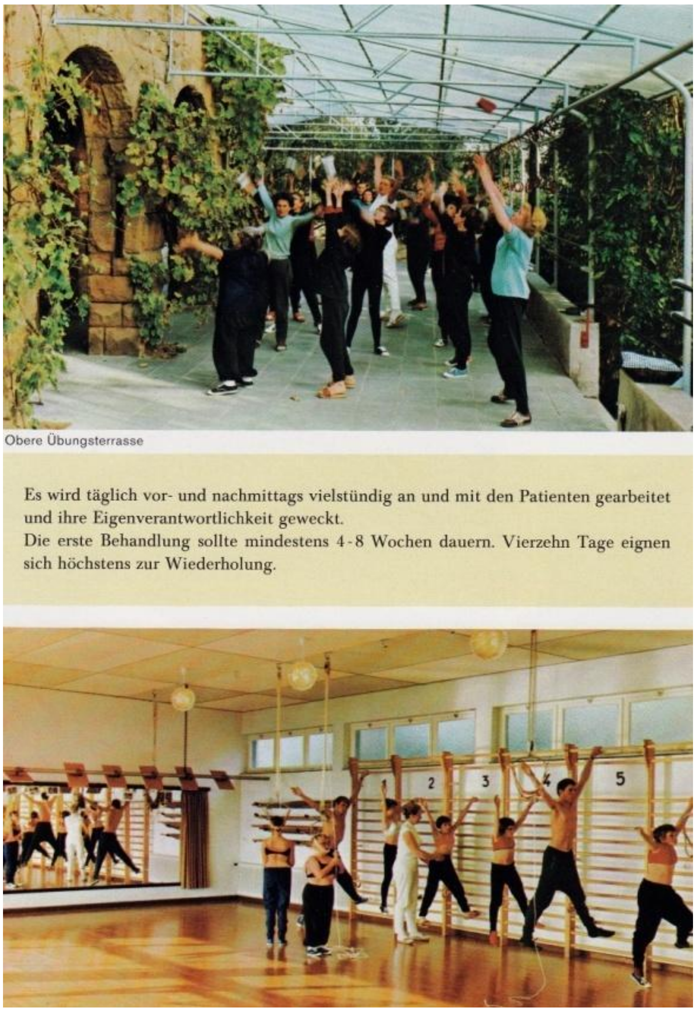

Fig. 2.28. *Exercise setting at the Sobernheim institute. (Folder of the Sanatorium Lehnert-Schroth in the 70s). [Historical picture from the picture database of Christa Lehnert-Schroth].*

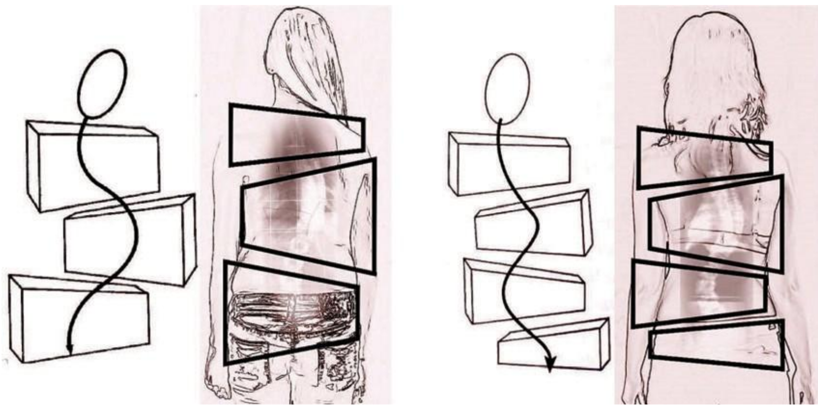

Fig. 2.29. *The original classification according to Lehnert-Schroth (2007). On the left, the three-curve pattern with the shoulder, thoracic, and lumbopelvic block deviated from each other in the frontal plane and also rotated against each other. On the right, the four-curve pattern with a separation of the lumbopelvic block into a lumbar and a pelvic block deviated from each other in the frontal plane and also rotated against each other. Per definition: the pelvic block symbolizes the lumbosacral counter-curve and this curve is defined as the 4th curve.*

First Investigations - First Scientific Evidence

As previously stated, the patient series for the first prospective controlled trial was derived from the patients seen at the clinic from 1989-1991. A sample of results was published in 1995 as a prospective study in German (Weiss 1995). It was published in English for the first time in 1997 (Weiss et al. 1997), and later included age- and sex-matched controls from another regional study on untreated patients as a prospective controlled study (Weiss, Weiss and Petermann 2003). Studies on the improvement of cardiopulmonary capacity, vital capacity improvement, electromyography, and the influence of the treatment of pain were also conducted (Weiss 1991; Weiss 1993a and b; Weiss 1995; Weiss and Bickert 1996; Weiss et al. 1999).
Most of the studies were cohort studies in a pre- / post-intervention design and there were no mid- or long-term follow-ups. Nevertheless, large numbers of patients were studied. Patients (n=794) investigated with ECG showing signs of manifesting right cardiac strain were significantly reduced after an in-patient rehabilitation of six weeks using the Schroth program (Weiss and Bickert 1996). More than 800 people were included in a study on vital capacity and rib mobility which was published in Spine (Weiss 1991). Another study on muscle activity reductions after intensive rehabilitation consisted of more than 300 patients (Weiss 1993a).
The only mid-term study with a follow-up of more than thirty months was the cohort treated between 1989 and 1991. This study was the basis for a prospective controlled trial published in 2003 (Weiss, Weiss and Petermann 2003).
During the 90s there was development with respect to the correction of thoracolumbar curves including the de-rotational effect of the psoas muscle. More and more exercises were instructed and performed in horizontal positions with numerous corrective tools which were not always easily available for the patient for practice at home (Fig. 2.30 and 2.31).

Fig. 2.30. *Typical exercise setting in the Katharina Schroth Klinik in Bad Sobernheim. The elevation of both arms leads to an increase of the flat-back deformity [Weiss 2011].*

***Fig. 2.31.** Treatment according to intermediate Schroth instruction methods requires multiple props, not always easily available at home. In this example, because the patient is lying on the floor, they are not able to take advantage of the automated postural correction by using the corrective postural reflex [Weiss 2011].*

Previously, the lead author performed an analysis of the different aspects of the original Schroth method (Weiss 1988). One of the most important factors of the original Schroth method is the automated pre-correction of the deformity with the help of postural reflex activity in certain asymmetric upright starting positions. The exercise begins pre-corrected with the help of postural reflex activity in upright asymmetric starting positions and the exercise itself increases this pre-correction.

In horizontal starting positions, these pre-corrections, due to postural reflex activity, cannot be achieved. Therefore, the postural corrections cannot be regarded as effective when starting exercise in an asymmetric horizontal position.

In the 1980s, Dr. Weiss and his wife initiated a training course for professionals. Dr. Manuel Rigo, a medical physician from Spain, was trained as an instructor after a stay in the in-patient Schroth clinic where he learned the basic treatment methods. He then began treating at the clinic bearing the name of his mother-in-law, the Elena Salva Institute in Barcelona. Dr. Rigo then began treating in smaller groups finding success in Spain.

As time passed, however, emphasis was increasingly placed on the correction of pelvic asymmetries in order to address the lumbosacral curve. Unfortunately, the result was that the powerful corrections which initially defined the treatments of Katharina Schroth were being minimized. Corrections were only performed to the midline in order to achieve symmetry, as opposed to overcorrections.

Treatment methodology became more and more complicated, focusing on minute deviations while losing sight of the main curvature correction.

After the Asklepios group took over, the program seemed to become more complex for patients to learn. Unfortunately, it was becoming apparent to the first author, then clinic director, that a clear direction of development was no longer foreseeable and a re-examination of the existing approaches seemed necessary to shift to and focus on more efficient corrective movements.

At that time, the groups of sometimes fifteen to sixteen patients to one therapist were too big for significant patient improvement. The exercise program at the Katharina Schroth Clinic appeared to be stagnant. While the original technique of Katharina Schroth continued to be effective, it seemed to require undue efforts on the part of patients. On the other hand, brace treatment was evolving and improving.

Increasingly, patients with curvature angles of less than 40° and typical flatback deformities were being treated, but there was no real development towards a systematic correction of the sagittal profile.

In marked contrast to that, the original Schroth program was designed for thoracic curves exceeding 80° and trunk rotations and rib humps leading to a more kyphotic inclination of the trunk. Moderate curvatures were addressed quite well in the coronal and transverse planes, but the sagittal profile was not being adequately considered. The only correction of a thoracic flatback was through rotational breathing, while the starting positions of the exercises were still with both arms in elevation, increasing the flatback deformity (Fig. 2.30 and Fig. 2.31).

Schroth/Best Practice Goes Global

In 2001, coauthor Moramarco contacted Dr. Weiss for advice and treatment of his daughter's scoliosis. Dr. Weiss welcomed the American family to Germany in early 2002 when he was director of the Katharina Schroth Clinic. The authors established an enduring professional relationship. Moramarco continued to pursue study of the original Schroth techniques, including a 2004 course with Dr. Rigo and informal training with Christa Lehnert-Schroth, PT.

In 2006, Weiss published his latest developments of newer, more innovative Schroth educational approaches, taking into account the correction of the sagittal profile. (Weiss et al. 2006; Weiss and Klein 2006).

Also, in 2006, Best Practice in Conservative Scoliosis Care was published. Weiss introduced the principle concepts at the 2007 SOSORT conference in Boston and while there, he invited Dr. Moramarco to Germany for the first international course for Schroth certification where he became the first U.S. Schroth Method practitioner certified at the Asklepios Katharina Schroth Clinic. He returned to establish the first Schroth-based out-patient program using Weiss's cutting edge Schroth Best Practice treatment protocols, offering patients complete out-patient programs in less than a week.

It is only in the last decade that Schroth methodology has reached beyond the borders of Europe. In the U.S., Moramarco's work with patients incorporates the most innovative evolution of Schroth principles - as do others in the Ukraine, Russia, South Korea, China, Hong Kong, Japan, Indonesia, Singapore, Australia and some European centers as well. Dr. Weiss continues to train physicians and therapists internationally as well as focus on continuing improvement of his newest Schroth-compatible brace, the Gensingen brace® (GBW), now offered in North America, Europe and Asia.

Because patients seek methods to halt progression, improve postural appearance, relieve pain and yearn for alternatives to surgery, the benefits of Schroth-based concepts and bracing are spreading rapidly and are now known and recognized all over the world.

Recent Developments

With far more than 50,000 evaluations of in-brace x-rays over the past thirty years, the first author has continuously improved not only in-brace corrections, but also the effectiveness of the corrective movements (Weiss and Moramarco 2013). Since the 2006 add-ons, training times have been shortened, but the concepts are still based on the original three-dimensional treatment approach according to Katharina Schroth.

In 2010, the Schroth Best Practice program was officially established and it is the focus of the remainder of this book. Patients can achieve results within a week, or less, which rivals the previous four to six weeks of in-patient rehabilitation (Weiss and Seibel 2010). Meanwhile, Scoliosis Short-Term Rehabilitation (SSTR) has been tested and the results, as achieved in the pilot investigation, have been shown to be repeatable worldwide (Borysov and Borysov 2012; Pugacheva 2012; Lee 2014).

Physical rehabilitation which focuses on ADLs to avoid loss of postural control during everyday activities is advisable. Add-ons derived from the original Schroth approach aim at unloading the curve and are essential elements for postural control. It is important to note that thirty minutes of scoliosis exercise daily is less effective without knowledge of curve-pattern specific ADLs since without them the curve(s) are loaded during the rest of the day.

It should also be noted that it is important to incorporate physical rehabilitation during brace wear whenever possible, with more intensive work as the patient is weaned from the brace.

The Schroth Best Practice program® has been improved with respect to correction of the sagittal plane. Today, we strive to foster optimal postural correction and here the circle closes again when we consider the remarkable corrections formerly achieved in exceptionally large curvatures.

The newest developments, also referred to as 'New Power Schroth,' as part of the Best Practice program is designed for small, moderate and somewhat severe curvatures. Once a thoracic curve exceeds 70°, the original Schroth program should be incorporated as well to offer the patient the greatest advantage.

Therefore, the newest evolution of Schroth-based therapy (Schroth Best Practice® program) is preferred in curves less than 70° because it is simpler for the patient, addresses the sagittal plane, makes the patient aware of the importance of unloading the spine, and emphasizes the maintenance of postural corrections whenever possible throughout the course of the day.

The development of three-dimensional scoliosis treatment according to Schroth has taken place in three steps since its origin 100 years ago.

1. The program originally developed by Katharina Schroth - the original - was in principle a program focused on a single curvature pattern for thoracic major curvatures with individual modifications. The sagittal correction principles were lumbar delordotic and thoracic anticyphotic. After all, this is the only way to correct the protruding rib hump in such large thoracic scolioses.

2. The further development of Christa Lehnert-Schroth took into account the fact that Katharina Schroth's original program was not applicable to lumbar curvatures. She therefore developed her own series of exercises for patients with lumbar and thoracolumbar curves and a small but meaningful classification (functional 3-curve / functional 4-curve). Retrospectively, we now call this program, which is geared to two different curvature patterns, the intermediate Schroth program, which continues today largely unchanged in the Bad Sobernheim School and the Barcelona School. Only the terminology has changed from by the time.

3. The Schroth Best Practice Program, or SBP for short, is characterized by a system of treatment modules which, in a logical sequence, take into account all aspects of specific scoliosis treatment known today. These are described in more detail in this book.

The following figure shows an overview of the development of Schroth scoliosis treatment.

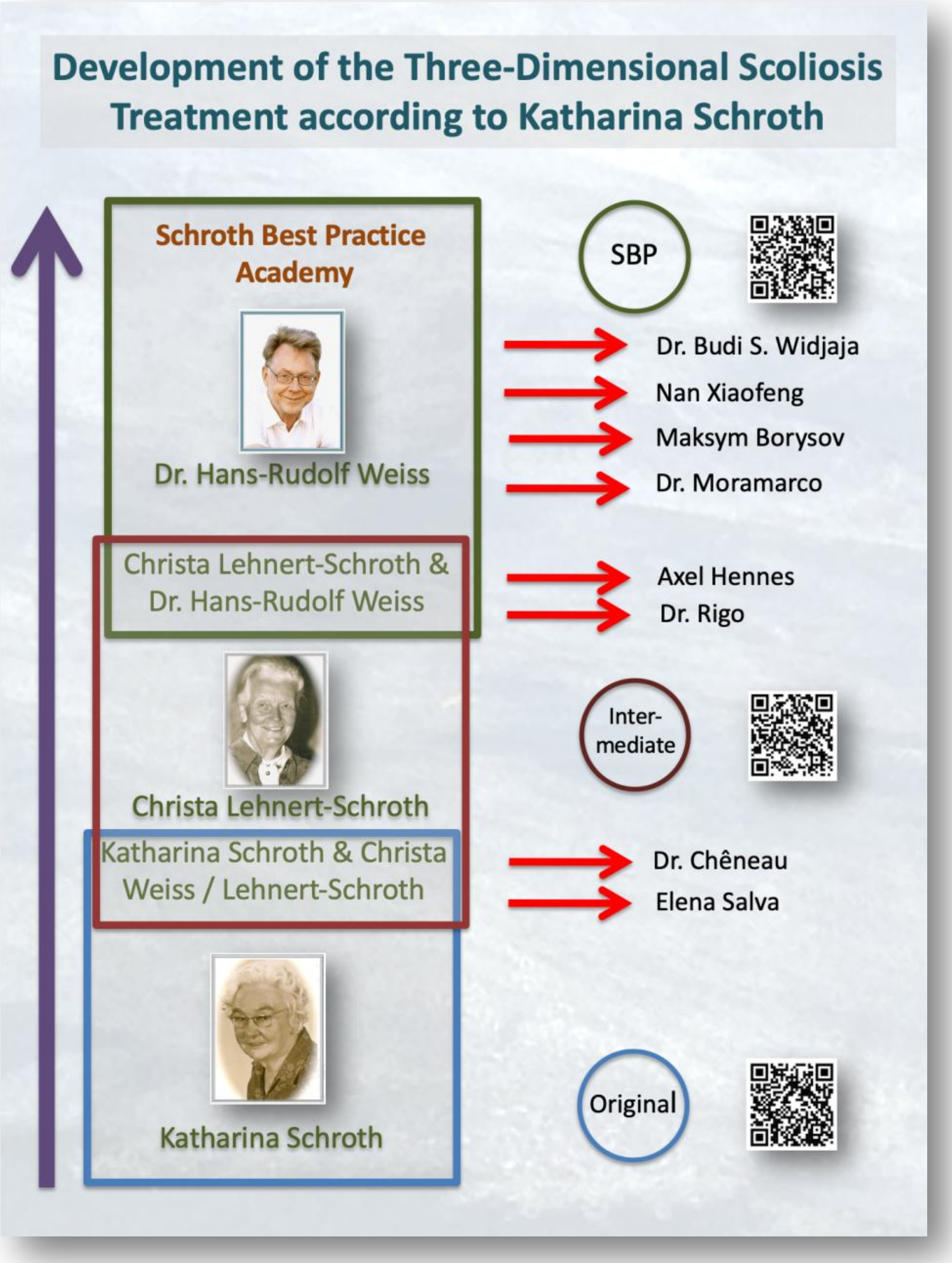

Fig. 2.32. *The development of the three-dimensional scoliosis treatment according to Katharina Schroth as a synopsis based on a poster of the Schroth exhibition, on display in the Miriquidi Rehabilitation Clinic, Thermalbad Wiesenbad, Germany.*

QR codes to historical videos by Christa Lehnert-Schroth

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3. PHYSICAL REHABILITATION SPECIFIC TO SCOLIOSIS - A REVIEW OF THE LITERATURE

Scoliosis is a three-dimensional deformity of the spine and trunk which may deteriorate quickly during periods of rapid growth (Goldberg et al. 2002; Asher and Burton 2006; Hawes and O'Brien 2006; Weiss and Moramarco 2013). Although scoliosis may be the expression or symptom of certain diseases (e.g., neuromuscular, congenital, or due to certain syndromes or tumors), the majority of patients with scoliosis (80-90%) are idiopathic because the underlying cause has not been determined. Treatment of symptomatic scoliosis may be influenced by the underlying cause. As scoliosis progresses mostly during growth, and in adulthood, the primary goal of intervention is to stop curvature progression (Goldberg et al. 2002; Asher and Burton 2006; Hawes and O'Brien 2006; Weiss and Moramarco 2013).

To understand and interpret the studies on children and adolescents, basic knowledge about growth dynamics may be helpful (Weiss 2012). During childhood and adolescence there are certain times of rapid growth when curvature progression is more probable. During times of slower growth, progression is less likely (Goldberg et al. 2002; Asher and Burton 2006; Hawes and O'Brien 2006) (Fig. 3.1). For example, the "baby spurt" ends at the age of five and a half to six years, followed by a "flat phase" which lasts until the first signs of maturation. Upon the first signs of breast development or pubic hair, the pubertal growth spurt begins (P1) and in its ascending phase (P2-P3), progression may occur (Goldberg et al. 2002). Shortly after the growth peak (P3) - menarche in girls / voice change in boys - the onset of the descending phase of growth occurs until cessation of growth (P5) resulting in skeletal maturity (Weiss 2012).

In patients with adolescent idiopathic scoliosis (AIS), the risk for progression of Cobb angle (Cobb 1948) can be calculated using a generally accepted progression factor formula (Lonstein and Carlson 1984). Treatment indications for growing adolescents with scoliosis are determined based on this formula (Fig. 3.2). Guidelines derived from this knowledge have first been established by SOSORT (Society of Scoliosis Orthopaedic and Rehabilitation Treatment, Weiss et al. 2006), later by the Schroth Best Practice Academy (Dereli et al. 2021) in order to avoid over- and under-treatment.

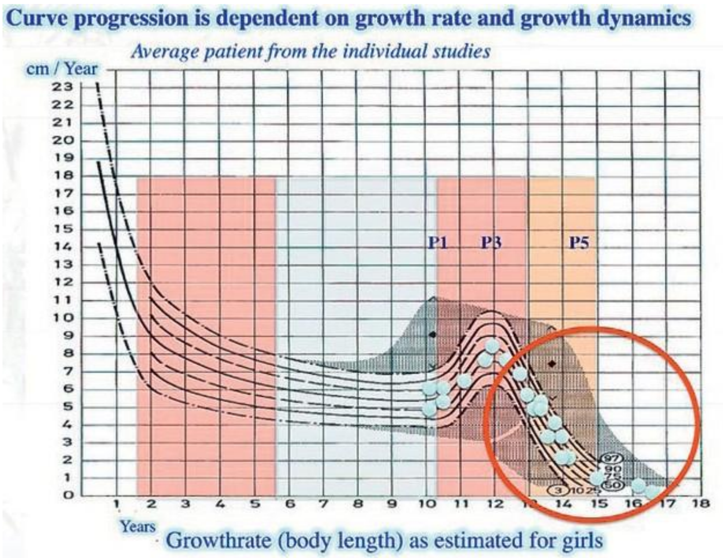

Fig. 3.1. *Growth rate (body length) as estimated for girls. This figure shows that immature individuals experience two phases of growth with higher velocity. One may be called the 'baby spurt' with a descended characteristic (0 to approx. 6 years of age). The other is the pubertal growth spurt (approx. 10 to 13 years). Between these two phases of higher growth velocity, a flat phase of growth with little risk for progression occurs (Figure modified from Weiss and Weiss 2005). The distribution of the average patients from the studies on physiotherapy in scoliosis patients (Weiss 2012) is demonstrated (spots). With kind permission of Pflaum, Munich (Weiss HR: "Best Practice" in Conservative Scoliosis Care, 4th edition, 2012).*

<u>*The formula: Cobb angle - (3 x Risser stage) / chronological age*</u>

The product of this formula, the progression factor, may be identified on a correlating chart and can help identify percentage risk of progression (Fig. 3.2). The corresponding estimate can be used as criteria for treatment indications during growth as demonstrated in the international guidelines, included in Chapter 5 (Weiss et al. 2006; Dereli et al. 2021).

To determine risk of progression, the Risser sign, or epiphyseal growth over the iliac crest (Risser 1958), must be considered. Risser is scaled from 0-5. Premenarcheal girls, on average, are a Risser 0. The Risser sign advances after the onset of menarche for girls and voice change for boys, through skeletal maturity (Risser 5). Risser varies by individual, but clinical experience indicates, generally speaking, that a fourteen-year-old girl usually presents as a Risser 3, sometimes 4, while a fifteen-year-old girl usually presents as a Risser 4, sometimes 5.

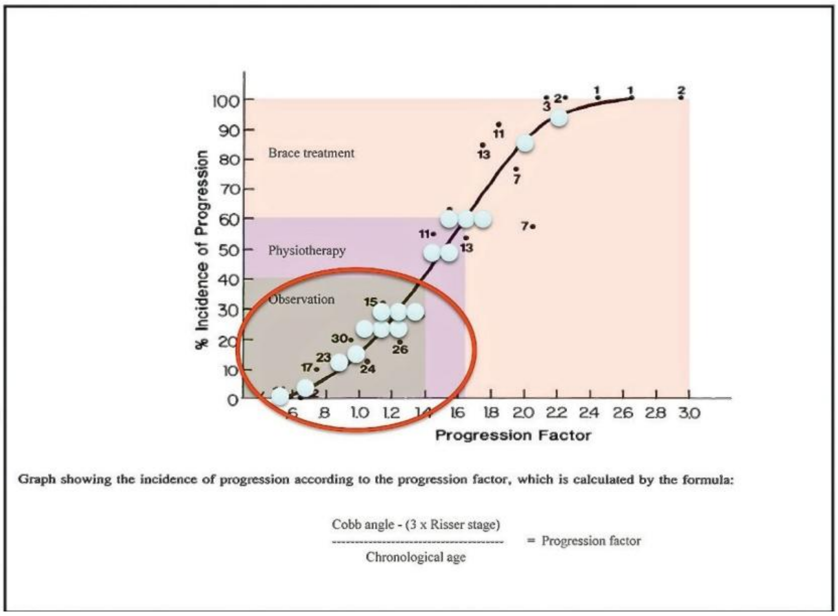

Fig. 3.2. *Incidence (risk) of progression can be calculated according to the formula by Lonstein and Carlson (1984). According to the indication guidelines (Weiss et al. 2008) we have to distinguish between an Indication for observation only (Incidence (risk) of progression 40%). Indication for physiotherapy (Incidence (risk) of progression 40-60%). Indication for bracing (Incidence (risk) of progression 60% and more). The average patient from the majority of papers on physical therapy found have no indication for treatment, but only for observation (see spots; Weiss 2012).*

Progression factor calculation examples are as follows: a ten-year-old girl with a 20° Cobb angle and a Risser sign of 0 would have a progression factor of 2. The correlating chart indicates a 90% risk of progression. A fifteen-year-old girl with a 20° Cobb angle might typically be 2.6 years postmenarcheal and a Risser 4. When the latter is the case, the progression factor is 0.53 which indicates little risk for progression (Fig. 3.2).

It is important for the specialized practitioner to understand the relationship between potential for growth and risk of progression when considering treatment options, particularly for the patient at high risk. The therapist must know their limitations when considering whether to proceed with physiotherapy alone and its relationship to natural history, considering the lack of existing evidence at this juncture.

A critical review on physiotherapy (Weiss 2012) notes that outcome papers (start of treatment in immature samples/end results after the end of growth; controlled studies in adults with scoliosis with a follow-up of more than five years) were absent in a search of the literature. Some papers investigated mid-term effects of exercises, but most were retrospective. Few were prospective, and many included patient samples with questionable treatment indications.

Moreover, an RCT with measured Cobb angles, comprising a cohort in the progressive phase, with subjects having an indication for physiotherapy (see Chapter 5) and followed from the premenarcheal status until skeletal maturity does not exist. As a matter of fact, many samples noted in the review were mature with little chance of being progressive (Fig. 3.1) with most samples lacking indication for treatment (Fig. 3.2).

It is not known why scoliosis occurs or why some curves progress and others do not. Roaf (1960) has suggested that spinal imbalance (lateral curvature) leads to asymmetric loading of the vertebral growth plates through gravity and continuous muscle action which then leads to asymmetric growth of the vertebra in accordance with the Hueter-Volkmann principle (Weiss and Hawes 2004).

The mechanism of scoliosis progression during growth has been described by the “vicious cycle” model whereby a scoliosis deformity produces asymmetric loading of the spine. This leads to asymmetric growth, disc and vertebral wedging, and greater deformity (Stokes et al. 2006).

Physical rehabilitation, corrective bracing, and spinal fusion surgery are the treatment modules currently applied in the treatment of scoliosis (Hawes 2003). Physical rehabilitation for scoliosis is by far the under studied, questioned and controversial of the three (Mordecai and Dabke 2012; Romano et al. 2012; Weiss 2012). Historically, surgeons, the gatekeepers of scoliosis treatment, have mostly been opposed to any form of exercise for scoliosis as a form of treatment at any level of risk. Certainly, from the outside looking in, it appears as a group there is little interest in studying how exercise may benefit the scoliosis patient, even if only in terms of creating spinal flexibility for an improved quality of life. Published studies from the U.S. on exercise as it relates to scoliosis until recently were almost nonexistent. In Scoliosis and the Human Spine, Hawes notes a long-standing bias against physical rehabilitation for scoliosis in English speaking countries where "watch and wait" was the recommended treatment for mild curves where the resulting lack of early intervention could be perceived as the appearance of a conflict of interest (Hawes 2003).

As mentioned, the scientific literature about physical rehabilitation and scoliosis is scant, especially in comparison to the magnitude of studies regarding surgical techniques or bracing. Recent findings on the current literature supporting physiotherapy conclude that evidence of a higher caliber is needed (Mordecai and Dabke 2012; Weiss 2012). To date, there have been only limited retrospective controlled studies (Level III), a few prospective controlled studies (Level II), and few randomized controlled studies (RCT) (Level I) (Monticone et al. 2014; Schreiber et al. 2015 and Kuru et al. 2015). As previously noted, some studies on exercise efficacy for idiopathic scoliosis have multiple shortcomings (Mordecai and Dabke 2012; Weiss 2012).

One obstacle to such a study would be the limited research or lack of funding for rehabilitative treatment methods by well-funded organizations. The RCT, the gold-standard in research, requires funding and support. The individual practitioner or small organization working to advance specific nonsurgical approaches for those with idiopathic scoliosis would have a difficult time conducting an RCT, or any study requiring a control group for higher level evidence with a large enough sample size. In regard to SRS members, “running a research program and managing a clinical practice essentially are two different professions,” (Hawes 2003) and this holds true for the conservative care practitioner as well. Funding from corporations affiliated with surgery for scoliosis, such as the suppliers of > $1000 pedicle screws for fusions or the newest hardware for double rod instrumentations, is not a realistic expectation. Corporations whose revenue is based on a function of increasing the number of spinal surgeries, with lengthy fusions, is a reason these entities fund surgeons via consultancies, compensate for advisory positions, and fund research.

For proponents of conservative rehabilitative interventions, perhaps this lack of an RCT better serves the interests of that small subset of adolescent patients who would potentially be randomly assigned to ‘watch and wait’. This is based on the premise that education and curve-pattern training are inarguably superior to doing nothing when a scoliosis above 15º exists in an immature patient sample. Beyond that, in accordance with international guidelines (Weiss et al. 2006) the pool for such an RCT would be quite limited since any eligible sample would theoretically be restricted to patients having curves between 15º and 19º since indications recommend observation for patients under 15º (Weiss et al. 2006), and bracing for the 'at risk' population, over 20º. In consideration of the recent RCT on bracing (Weinstein et al. 2013), one could claim it is unethical to neglect to brace a progressive curve considering a scoliosis could deteriorate without bracing intervention. Moreover, when larger curves are involved, longer bracing times are required (Weiss 2013) potentially having an enduring impact.

Systematic reviews on the limited published literature, mostly taking place outside the U.S. on exercise rehabilitation are mixed (Fusco et al. 2010; Weiss 2012; Mordecai and Dabke 2012). Of the existing literature, studies have variable designs, many lack controls, follow-up periods are short, assessment methods vary, compliance is questionable, exercise methods are combined with bracing, and adequate statistical analysis is often lacking (Mordecai and Dabke 2012; Weiss 2012). Furthermore, most of the studies considered used patient samples which failed to align with the indications for treatment guidelines. Some studies investigated immature patient samples including curvatures of less than 15°, while the RCT from China included nearly mature patients.

In that RCT (Wan et al. 2005), physical exercise for the treatment of AIS consisted of a patient sample of eighty, with an average age of fifteen ±4 years, with Cobb angles at 24º ±12º. This study could be criticized from a scientific standpoint in that much of the cohort had little risk of progression.

Additionally, the follow-up period was only six months on average. Since, at fifteen years of age, there is usually little significant residual growth remaining, the conclusions of this study could be challenged. Although this RCT reported Cobb angle improvement for the treated group, that conclusion is overshadowed considering results could be skewed by spines less at risk for progression due to the mature cohort. One positive is that it did show that physical exercise for scoliosis can be beneficial even at later stages of growth, just prior to bone maturity.

The various international methodologies included in the systematic reviews (Fusco et al. 2010; Mordecai and Dabke 2012; Weiss 2012) critique studies on the various exercise approaches. Most of consequences are referenced at the end of this chapter for the interested reader.

Maruyama et al. (2003) showed that treatment of curves in the 20º-40º range respond more favorably in comparison to curves on the threshold of surgery. This point strengthens the case for earlier intervention via exercise instruction. An important point remains; no studies, of any nature, of any size, exist for AIS comparing a treated to an untreated control group with subjects having curvatures of moderate magnitude or greater.

Glassman evaluates conservative treatment of adult scoliosis patients (Glassman et al. 2010). Two others studied operative versus nonoperative treatment (Bridwell et al. 2009; Li et al. 2009). It is important to distinguish the difference. Nonoperative does not imply, indicate or necessarily include curve pattern-specific scoliosis exercise rehabilitation.

In the study on adults undergoing 'conservative' treatments, the modalities included were defined as medication, unspecified exercise therapy, general physical therapy modalities (e.g., electrical muscle stimulation), injections/blocks, chiropractic, bracing, and bedrest. This study questioned the value of nonsurgical treatment for adults with scoliosis, concluding that documented costs are "substantial" with no improvement in health status observed for two years (Glassman et al. 2010). These conclusions were based on a study combining several methods, and deem nonsurgical treatment, as a whole, ineffective and costly without including any specific exercise-based approach. Limitations were acknowledged, but conclusions were drawn in spite of the admitted shortcomings, "An important caveat of this study was that the treatment was not randomized and therefore the treatment group might have deteriorated if not for the treatment they received."

At this juncture, it is probably clear that research into conservative therapeutic methods for scoliosis is not comparable, lacks substantive follow-up and drawing conclusions from a scientific standpoint about exercise approaches for scoliosis is challenging, at best, from the mixed body of evidence (Fusco et al. 2010; Weiss 2012; Mordecai and Dabke 2012).

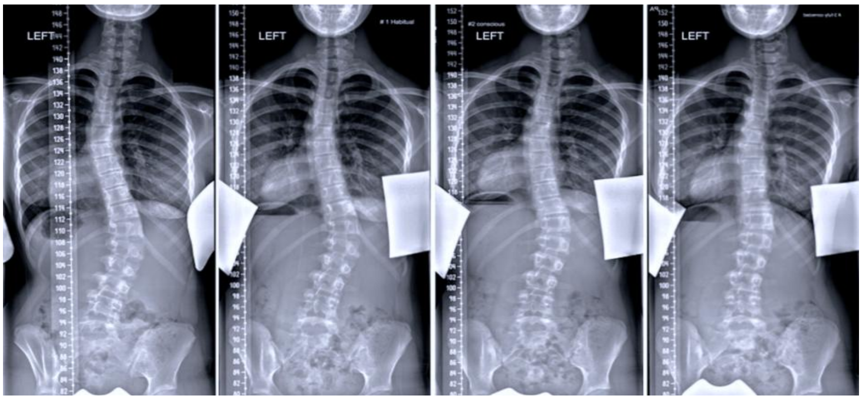

Fig. 3.3. *This fourteen-year-old patient, never braced, participated in the first Schroth Best Practice Program in the U.S. in July, 2008. Initial Cobb angles: (Left) 6/2008 at 26° left thoracic (T5-T10) and right thoracolumbar at 41° (T10-L3). Left Center (LC), Right Center (RC) and Right (R) x-ray images taken on 1/2009. (LC) 22°/37°, (RC) elongation at 21°/30°, and (R) with side-shift (translation) and elongation 18°/22°. 7/2008 ATR°: 7° thoracic/13° thoracolumbar. Five years later, 2/2014 ATR°: 4° thoracic/9° thoracolumbar. (X-ray with permission from Dr. Marc Moramarco, Scoliosis 3DC™, Woburn, MA).*

However, practitioners committed to advancing exercise rehabilitation continue to persevere and improve treatment standards for patients and families that feel quite alone at times in terms of their best interests or options for treatment (Fig. 3.3). For this reason, the body of evidence will continue to grow. Three RCT's are promising and add to the limited body of evidence. These new level I studies focus on self- correction (autocorrection) and task-oriented movements to reduce curvature (Monticone et al. 2014; Schreiber et al. 2015; Kuru et al. 2015).

THE SCHROTH METHOD AND SCHROTH BEST PRACTICE®

The authors' experience collectively comprises more than a century dedicated to delivering the most highly evolved scoliosis-specific rehabilitative technique in existence. The Schroth method scoliosis-specific treatment has helped improve the lives of scoliotics, now internationally, and provides the compliant patient the opportunity to affect curvature. Results often include halted progression in adults and/or Cobb angle improvement in adolescents (Weiss, Weiss and Petermann 2003; Otman et al. 2005; Lehnert-Schroth 2007; Fig. 3.3), improved postural appearance (Lehnert-Schroth 2007), improved muscular imbalance (Weiss 1993a), reduction or elimination of pain (Weiss 1993b), and improved vital capacity and chest expansion (Weiss 1991; Moramarco et al. 2016).

Research in support of Schroth-based therapies based on three-dimensional correction include Schroth method in-patient investigations dating back to 1991. A study published in Spine, (Weiss 1991) determined that the Schroth method improved vital capacity and rib mobility in a cohort from the Katharina Schroth Clinic in-patient program. Other documented benefits have been that the Schroth in-patient program improves quality of life and the self-concept of scoliosis patients (Weiss and Cherdron 1992; 1994), there is a beneficial effect on muscular imbalance (Weiss 1993a) and pain (Weiss 1993b), and another study showed a Schroth program may enable the reduction of right cardiac strain after intensive scoliosis-specific exercise (Weiss and Bickert 1996).

A Saudi Medical Journal published an independent Schroth study from Turkey providing additional evidential reinforcement that curve-pattern specific exercise can have a beneficial influence on the clinical signs and symptoms of scoliosis. The study concluded that Schroth breathing and exercise can positively influence Cobb angle, vital capacity, muscle strength and postural defects in adolescents participating in an out-patient program (Otman et al. 2005). Most notably, after six weeks Cobb angles decreased over time, with Cobb angle improvements exceeding the 5º margin of error (Morrissy et al. 1990), the accepted benchmark to document change. Vital capacities increased, providing long-term validation of Schroth method improvement of lung function (Weiss 1991). The Otman et al. study (2005) reported Cobb angle improvement in all but one subject who experienced stabilization. None worsened, and after one year each patient experienced improvement to some degree.

Added evidence from a prospective controlled study comparing Schroth-treated patients versus untreated control groups during growth show a percentage were stabilized. In addition, when comparing the untreated control group to an in-patient treated group consisting of the most severe curves, there was a significant difference in terms of reduction of incidence of curve progression in the treated group (Weiss, Weiss and Petermann 2003).

As a result of these recent findings, Schroth Best Practice® is the newest evolution of the Schroth method. During Best Practice® instruction, the patient is taught to achieve optimal postural control during daily activities by incorporating 3-D corrective movements into every-day life. These newest concepts allow efficiency (Weiss and Klein 2006) combining more modern, effective and simpler techniques with Schroth methodology in the out-patient setting. This helps the patient achieve heightened postural awareness via active self-correction techniques. These newest methods are essential to stimulate stabilization and encourage balance in the scoliotic spine (Monticone et al. 2014).

The Schroth Best Practice program combines several components for the treatment of scoliosis, including self-correction. According to SOSORT, autocorrection is considered the key technique when physical exercise is utilized for scoliosis rehabilitative techniques (Fusco et al. 2010). The recent RCTs validate the effectiveness of self-correction (Monticone et al. 2014; Schreiber et al. 2015; Kuru et al. 2015). Since the Best Practice methodology combines autocorrection with Schroth principles, it offers patients a new, more viable rehabilitative approach via exercise because postural correction plays a major role in exercise rehabilitation (Ng et al. 2017), as it does in bracing (Landauer et al. 2003).

Self-correction maneuvers are important for the scoliotic and essential for constructing that corrected sense of posture. It is only via asymmetric trunk muscle tension that the corrected posture can be easily perceived. This is best achieved in the upright position to trigger postural reflex activity (activation of the segmental spinal muscles). 3-D self-correction is an essential preliminary for effective Schroth exercise since the pelvis is recompensated, any thoracic or lumbar rib humps are addressed and the sagittal profile is restored.

The recent Schroth Best Practice developments (Weiss, Hollaender and Klein 2006; Weiss and Klein 2006) also incorporate side-shift as part of the protocol. When performing self-correction, side-shift (translation) plays a role. Side-shift maneuvers help to accomplish the needed translation and are exercise maneuvers which potentially result in a reduction of curvature of up to 10º in some patients (Maruyama et al. 2002). Additional findings have shown that progression may be slowed in the skeletally mature scoliotic when side-shift and hitch exercises are incorporated daily (Maruyama et al. 2002).

Translation movements are favorable for scoliotic curves under 50º (White and Panjabi 1976) and support the asymmetric autocorrections performed in the frontal plane and are superior to elongation (traction) for postural correction. Elongation in a biomechanical model is superior to translation for curves greater than 50º (White and Panjabi 1976), but in practice, a combination of these particular maneuvers may be effective, regardless of the curvature degree.

Physio-logic® exercises address scoliosis in the sagittal profile and are also an important component of the Best Practice protocols. It is important to address the sagittal profile (Weiss and Klein 2006; van Loon et al. 2008; Monticone 2014). The physio-logic® exercises were studied in a pilot program (Weiss and Seibel 2010) incorporating the add-ons to scoliosis rehabiliation. The physio-logic® technique created reduced lateral deviation of the scoliotic trunk (Weiss and Klein 2006). The physio-logic® program has been approved in an independent study by Kuru et al. (2015) as well.

When progressive sagittal imbalance occurs, curve severity increases in a linear fashion (Glassman et al. 2005). Kyphosis is more favorable in the upper thoracic region, but poorly tolerated in the lumbar spine. Evidence shows that scoliosis correction in the sagittal plane leads to a 3-D correction of the curves in an experimental (Weiss 2005) and clinical study (Weiss and Klein 2006). During physical rehabilitation via exercises derived from the original Schroth program, and bracing techniques that align with Schroth principles, efforts of focus are on correcting the sagittal alignment to restore lumbar lordosis and thoracic kyphosis (Weiss 2011).

During a two-week program, this ADL approach combining side-shift, physio-logic®, and 3D-ADL exercises with Schroth-based exercises resulted in similar improvements of lateral deviation and trunk rotation when compared to the traditional four-week in-patient program of Schroth based exercise. These developments offer a time-efficiency of treatment for the scoliotic (Weiss, Hollaender and Klein 2006).

Another component, the signature of Schroth, is rotatory breathing, the technique responsible for the longevity and success of the original Schroth in-patient program. In combination with the newer modifications of the Schroth Best Practice® out-patient program, patients can now work to improve vital capacity and rib mobility with the added benefit of incorporating techniques into everyday living.

The new Schroth developments (Schroth Best Practice program®) have spread internationally into the U.S., Canada, Ukraine, Russia, China, Hong Kong, Taiwan, Indonesia, Singapore, Australia, New-Zealand, Japan and Korea. In the Ukraine, documented improvement of ATR via Bunnell's Scoliometer™ and improvement of vital capacity has been documented in a cohort of thirty-four (Borysov and Borysov 2012).

In Russia, surface topography was used to evaluate change in adolescent females with an average age of thirteen. The study demonstrated reduction of lateral asymmetry angle and surface rotation angle beyond the statistical margin of error. Additional positive findings included improvement of trunk tilt, an increase in lumbar lordosis, an improved reading of bioelectrical activity of paravertebral spinal muscles on the convex side of the spine as measured by EMG, and a positive shift in the coefficient of weight distribution (CWD) (Pugacheva 2012).

In Korea, Cobb angle was measured in sixty adolescent subjects from eleven to nineteen years with an average thoracic Cobb angle of 23.5° (6 - 56°), and lumbar of 21.2° (6 - 52°). Follow-up was short, only 2.9 months, but results showed a decrease in thoracic Cobb angle of 5.3º and lumbar of 5.5º. ATR (angle of trunk rotation) in the thoracic and lumbar spine decreased by 2.4º and 2.2º respectively (Lee 2014).

These findings are in accordance with results from subjects attending Dr. Moramarco's out-patient program incorporating Schroth Best Practice® techniques with Schroth exercises which were the subject of a 2011 DPT thesis (McKenna and Hicks 2011). Outcome measurements of Cobb angle, Scoliometer™, lung capacity and chest expansion were evaluated for a cohort of eight girls and two boys. Conclusions were, "There was a significant decrease in the thoracic Cobb angle, significant decreases in the thoracic Scoliometer™ angles, and significant increases in vital capacity and chest expansion after treatment. The mean [lumbar] Cobb angle and mean Scoliometer™ lumbar angle decreased, but not significantly." The statistical difference between the thoracic and lumbar is likely due to the fact that only five of the subjects, or half the cohort, had a lumbar curvature.

The Schroth Best Practice approach for the treatment of idiopathic scoliosis correlates with scientific knowledge regarding growth modulations (Aronsson and Stokes 2011). In the clinical setting, the patient is taught how to induce the maximum possible correction effects for their spinal curve pattern via rehabilitative techniques designed to stabilize or reduce curvature. Finally, the Schroth Best Practice approach now is supported by the RCT by Kuru et al. (2015), a physiotherapist from Istanbul, now instructor for the Schroth Best Practice program, trained by Dr. Weiss.
The newest multimodal form of the Schroth concept may easily be regarded as the most logical evidence-based method to incorporate when patient safety and potential for benefit are considered. For adolescents at risk of progression, the focus should be on effective bracing, with rehabilitation concepts secondary. However, a strategy combining both may provide improved chances for stabilization and opportunity for potential improvement.

The Schroth Best Practice Program® is thus the end product of all these evidence-based developments and is now used worldwide (www.schrothbestpractice.com).

QR code to the homepage of the Schroth Best Practice Academy.

Mobilization, Spinal Manipulation

Spinal mobilization and manipulation should be considered when rendering rehabilitation therapy to the scoliotic. The purpose of mobilization and manipulation is to address joint hypomobility (joint dysfunction). As a result of joint dysfunction, decreased range of motion and/or pain may be present.
The purpose of spinal manipulation is to restore joint mobility, thereby eliminating joint dysfunction. "The condition of joint dysfunction is the only pathological condition that will respond to the treatment of manipulation," (Mennell 1964). The goal with these modalities is to restore joint mobility in rotation, lateral bending, and flexion/extension, and to eliminate pain, if present.
A pilot study (Rowe et al. 2006) compared medical (observation and/or brace) to chiropractic for scoliosis treatment. A small cohort of only six patients was studied. The results revealed the three patients treated with observation or observation and brace, and one with chiropractic care, had essentially unchanged Cobb angles. The patient treated with sham manipulation was the only to progress greater than 5º and one patient treated with chiropractic care reduced 10º in the lumbar spine, but results were inconclusive and the cohort too small with mixed modalities.
Conclusions to date have been that there is a lack of scientific data supporting manual therapy or its role in influencing the natural history (progression) of the scoliosis (Romano and Negrini 2008). Another systematic review concluded weak Level IV evidence for the use of chiropractic manipulation in adults (Everett and Patel 2007). More recently, a pilot study demonstrated segmental mobilization using shockwaves may indeed have a positive effect on the deformity (Weiss, Seibel, Moramarco 2014).

Methods Lacking Evidence or with Possible Contraindications

Currently, no scientific evidence exists for the use of Yoga in the treatment of scoliosis. While Yoga may be of benefit for those having a symmetrical body, our clincal experience has shown, repeatedly, the contraindication of Yoga for scoliotics. This is due to the complex asymmetrical anatomy of those with scoliosis. Moreover, Yoga instruction is usually guided by those who lack specialized training in the conservative management of spinal deformities, lack radiological expertise, or are not likely to be familiar with scoliosis curve classifications. This results in an inability to understand the differences among the classifications and, thus, the implications of specific movements for individual curve patterns. Yoga, and Pilates as well, does not include targeted autocorrection, cited by Fusco et al. (2011) as an essential element of any exercise program for scoliosis.

Fig. 3.4. *Passive traction combined with the application of lateral forces in a correction apparatus as used more than 100 years ago. [Historical picture from the picture database of Christa Lehnert-Schroth].*

Another method used in the U.S. focuses on passive traction of the cervical spine. This approach also lacks high level evidence. There is no prospective controlled study which shows that methods utilizing traction can improve posture or the final outcome in at-risk patients. Furthermore, passive traction is only of minor value in curves within the general range for conservative management (White and Panjabi 1976). Traction was once used as an add-on to the original Schroth program, but abandoned more than thirty years ago after adverse effects were recorded (Fig. 3.4 and Fig. 3.5). These negative effects consisted of headaches, numbness, destabilization and hypermobility of the occipitocervical juncture. In addition, it was noted that the traction force applied had more impact on the cervical spine than on the rigidity of the thoracic spine or the deformity itself. Today, it is known that passive traction may indeed be a risky procedure (Zhang et al. 2010) and due to a lack of specific evidence, it should not be applied.

Current evidence demonstrates scoliosis-specific correction exercises that are dynamic and incorporated throughout the day are the most effective. The side-shift, included in today's Schroth Best Practice program®, is highly corrective in the frontal plane. To achieve maximum benefits, the corrective movements must be applied in 3-D, respecting the sagittal profile. When integrated with scoliosis-specific breathing mechanics beneficial effects for cardiopulmonary function are a reasonable expectation.

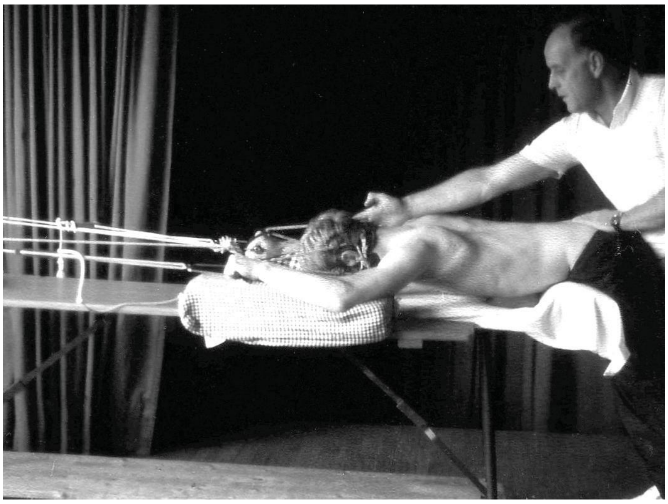

Fig. 3.5. *Passive traction combined with the application of guided active corrections in the 70s in combination with the Schroth program. [Historical picture from the picture database of Christa Lehnert-Schroth].*

These multiple mechanisms are integrated with the treatment concepts initiated by Katharina Schroth (Weiss 2011) and the result is the newest evolution of curve-pattern specific exercise for scoliosis - the Schroth Best Practice program. These recent developments are the safest and easiest way to successful curve management and are standardizable, making them easy to teach. No other application in use today shares the Schroth record of success, nor are they supported by a body of evidence with demonstrated improvements with respect to the many signs and symptoms of scoliosis (Weiss et al. 2016).

However, the much-cited randomized studies on Schroth therapy are not all very conclusive either. In one study, the health-related quality of life was investigated. Both patient groups (target group/control group) received some unspecified standard treatment and the target group additionally received Schroth (Schreiber et al. 2015). The authors concluded that Schroth improves the patients' quality of life.

It is well known that any kind of attention from the therapeutic side can improve the quality of life of patients (Freidel et al. 1999 & 2002). The conclusion would therefore only be justified if the control group had received the same amount of attention as the target group as an add-on to 'standard care.'

The authors additionally investigated the development of the Cobb angle in both patient groups and published it in another paper (Schreiber et al. 2016). Here, there was a slight but significantly better treatment effect in the Schroth group compared to the control group. However, this can already be explained by the fact that there were more combined (double major / triple major) in the control group than in the Schroth group. Combined curvatures are more difficult to correct than curvatures with radiologically single curvature patterns (Weiss et al. 2021). Thus, despite the elaborate study design, the validity of both studies is severely limited and does not justify the conclusions drawn.

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4. DIAGNOSTIC ASSESSMENT

Diagnostic assessment plays a decisive role in the specific treatment plan. First, the diagnosis of scoliosis must be verified by an x-ray to determine a prognosis so treatment can proceed in an appropriate manner. The x-ray helps the practitioner with goal setting for conservative treatment. It should be noted, that in the case of congenital scoliosis, the goals of treatment differ from those of idiopathic scoliosis (scoliosis with no known cause). Beyond prognosis, the x-ray can indicate Risser sign - an indication of a patient's skeletal maturity.
Generally speaking, a deformation of the spine will typically deteriorate most significantly during the growth period. Curvatures in excess of 50° may or may not remain stable for many years once the patient has reached adulthood (Weinstein 1985).

4.1 X-ray findings

The angle of curvature according to Cobb

In order to monitor spinal deformities, the Cobb angle (Cobb 1948) is the predominant method, although this only allows the three-dimensional spinal deformation to be measured in two dimensions (Fig. 4.1a-b). It is the standard measurement technique used to monitor scoliosis. The Cobb angle is the starting point for the treatment plan and is necessary for the creation of a prognosis, particularly with idiopathic scoliosis. The measurement of this angle is subject to error (Weiss 2000). During monitoring, differences in the position of the patient in front of the x-ray screen can contribute to inaccuracies in the measurements as well. Finally, the time of day when the x-ray is taken may play a role. According to a study from Canada (Beauchamps et al. 1993), the degree of curvature was 5° greater in the evening than in the morning, with differences reaching as high as 20° on the same day. These results demonstrate the relativity of measured values. For these reasons, changes in the angle of less than 5° from the previous x-ray are considered to be insignificant.
At the very least, x-ray examinations should be comparable in terms of the format and the film/focus. This was the reason for the decision to x-ray patients in a standing position, with standard settings (Figs. 4.1; 4.2), for monitoring patients with spinal deformities.
For diagnosis, a single x-ray of the entire spine from the side usually is also required. This x-ray involves a higher exposure to radiation than the images made from the front (AP), or from the rear (PA). However, with the side x-ray, the sagittal profile can be assessed and the degree of kyphosis can be determined precisely.

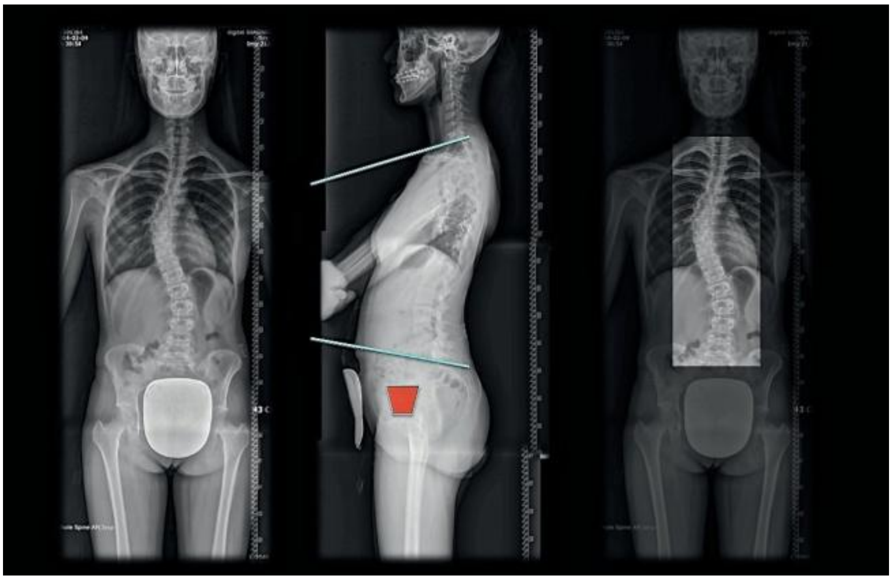


Fig. 4.1. *Image of the entire spinal column of a patient with idiopathic scoliosis. As can be seen the head and parts of the legs are on the x-ray which is not necessary at all. On the side view (middle picture) there is no shelter applied. On the right picture one can see the region of interest (ROI) allowing to diagnose the patient well and to measure the Cobb angle. Exposure to radiation drastically can be reduced by limiting the field to the ROI.*

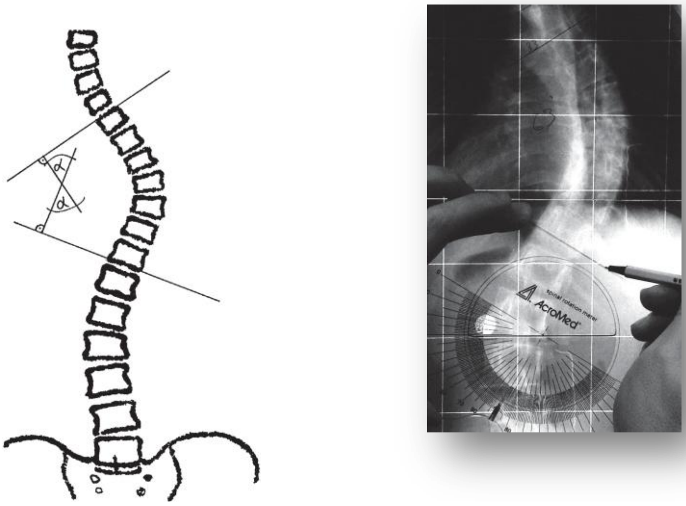


Fig. 4.2. *The Cobb angle can also be derived with the help of a device that allows the tilt of the neutral vertebrae to be determined.*

Since a decrease of the thoracic kyphosis is an indicator of an unfavorable prognosis (Perdriolle 1985; 1993), the sagittal profile is a significant criterion for the formation of a prognosis. There is, however, the consideration of whether the assessment and monitoring of a flat back could take place clinically via the use of surface measurement systems (Weiss and Verres 1998).

To minimize exposure to radiation, it is recommended x-rays are limited to necessary sections of the spine (ROI, Region of Interest; see Fig. 1.3), and only take side-view images if information that is crucial for the treatment can be attained (Weiss and Seibel 2013).

Some years ago, a new stereo x-ray system reached market maturity. The so-called EOS Imaging System enables a radiation-saving three-dimensional reconstruction of the spine and an automatic and thus objective measurement of the curvature angles. It not only enables semi-automatic evaluation and measurement of the X-ray images (Fig. 4.3), but also semi-automatic documentation of the findings (Fig. 4.4).

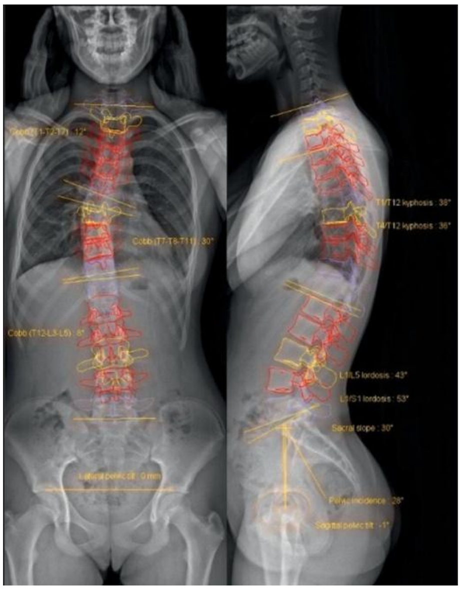
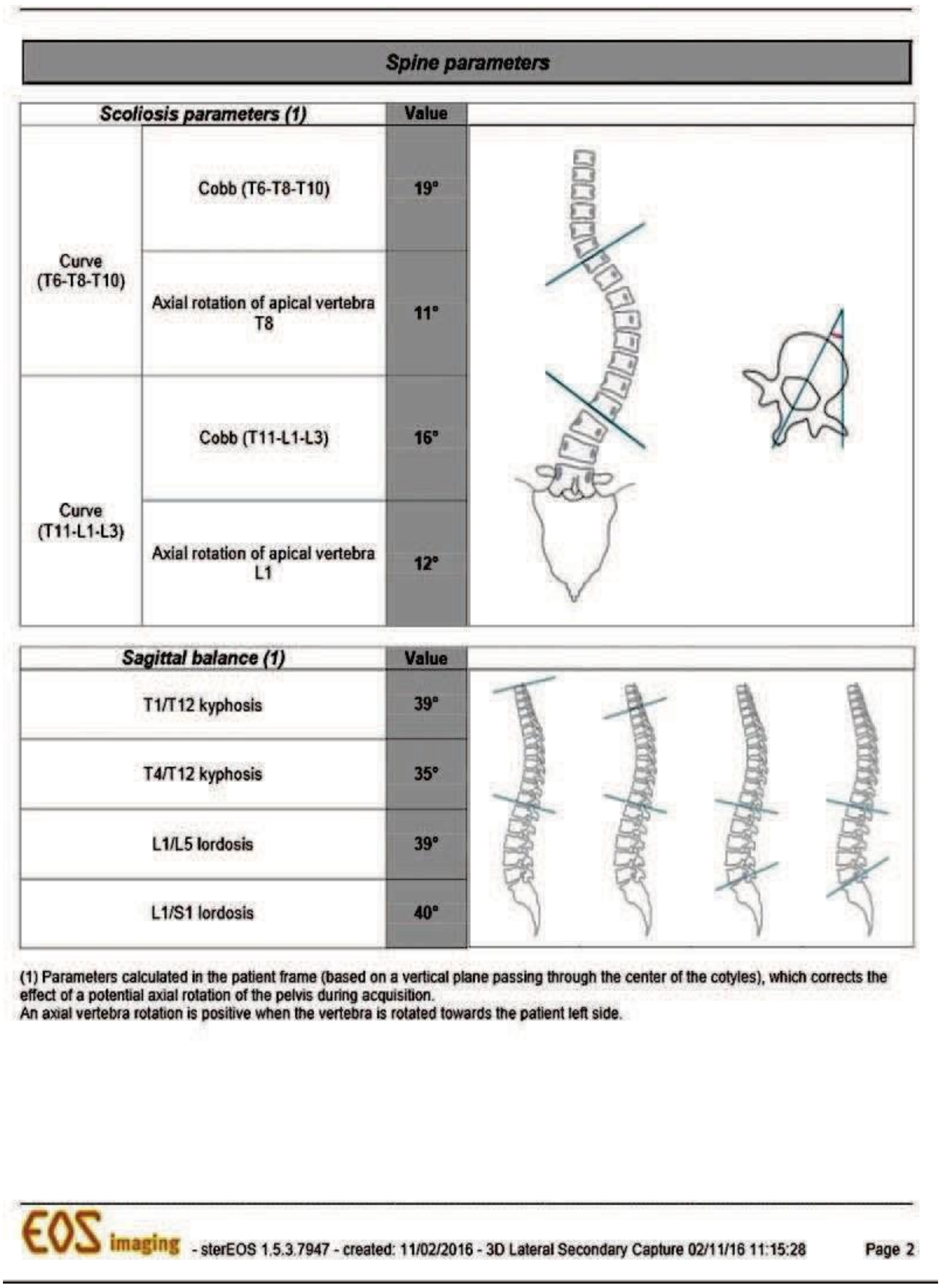


Fig. 4.3. *Images from an EOS system with automated calculations of the angles of curvature (with kind permission by Daniel Comerford, Melbourne).*

However, the high cost of this technology has so far prevented widespread use of the system. Radiation reduction leads to a 2-fold reduced risk of cancer as a result of radiation exposure. However, girls have a significantly higher risk of exposure than boys (Branchini et al. 2018; Law et al. 2018).



Spine parameters

Scoliosis parameters (1)		Value
Curve (T6-T8-T10)	Cobb (T6-T8-T10)	19°
	Axial rotation of apical vertebra T8	11°
Curve (T11-L1-L3)	Cobb (T11-L1-L3)	16°
	Axial rotation of apical vertebra L1	12°

Sagittal balance (1)	Value
T1/T12 kyphosis	39°
T4/T12 kyphosis	35°
L1/L5 lordosis	39°
L1/S1 lordosis	40°

(1) Parameters calculated in the patient frame (based on a vertical plane passing through the center of the cotyles), which corrects the effect of a potential axial rotation of the pelvis during acquisition.
An axial vertebra rotation is positive when the vertebra is rotated towards the patient left side.

EOS imaging - sterEOS 1.5.3.7947 - created: 11/02/2016 - 3D Lateral Secondary Capture 02/11/16 11:15:28 Page 2

Fig. 4.4. *Part of the EOS Imaging report (with kind permission by Daniel Comerford, Melbourne).*

Measuring the spinal rotation

The Cobb angle is not recommended as sole criterion for an assessment since it only measures the curvature in one arbitrary perspective and cannot completely capture and depict the three-dimensional character of the deformity.

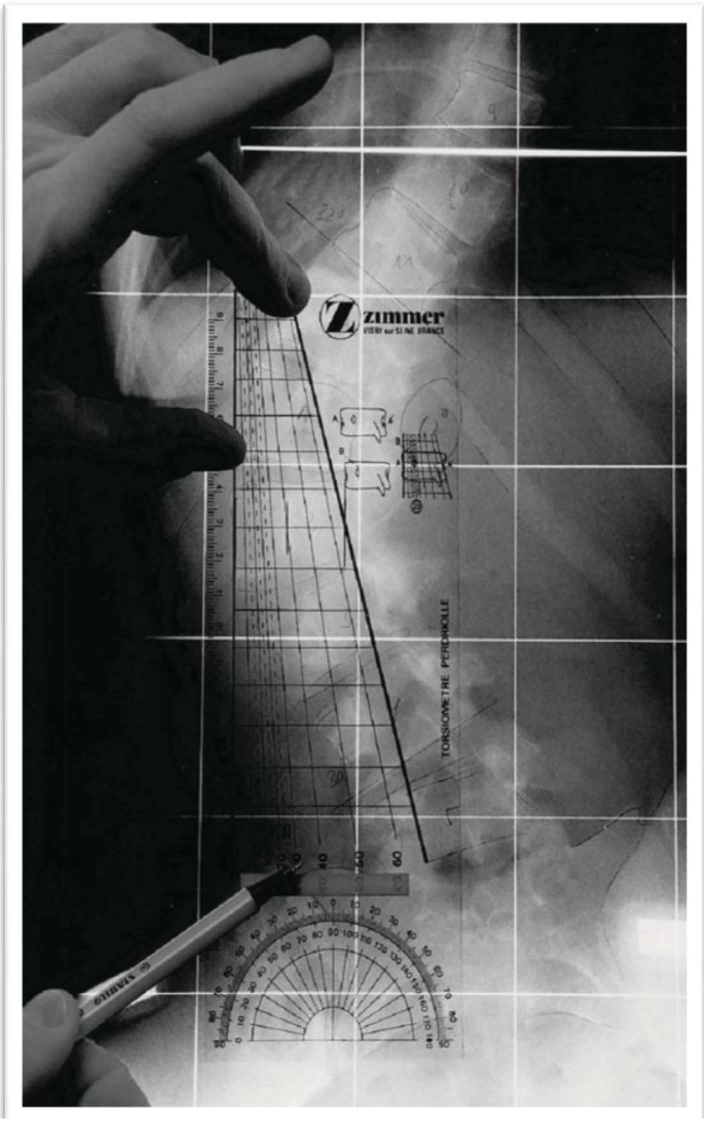


Fig. 4.5. *Investigation of the vertebral rotation using Perdriolle's measurement technique. The waists of the vertebrae marked with a vertical stripe are aligned with the thick black lateral limitation lines from the ruler; the pedicle marking in this image is relatively central which shows a rotation of 40° to be interpreted off the scale.*

For this reason, the rotation measurement according to Nash and Moe (1969) was initially adopted, although today we can investigate the spinal rotation more precisely using the methods of Perdriolle (1985) and Raimondi (Weiss 1995) (Figs. 4.5-4.6). With the latter two measurement techniques, the relevant templates are used to locate the apical vertebra between two vertical lines at the vertebral body waist and to halve the convex-side pedicle, lengthwise. Via the application of the measuring method Raimondi's measuring technique is based on the same measurement points as is the method of Perdriolle, although the process of interpreting the measurement proceeds somewhat differently. According to the template, the rotation can then be interpreted at the position of the pedicle marking using Perdriolle's measurement of the spine, the width of the vertebral body is set in the small window of the slide-rule of the measuring template using the Raimondi ruler. Above this reading, one looks for the displacement of the convex-sided vertebral body boundary/pedicle marking. Next to this, the rotation in degrees can be determined from the cover sheet of the measurement slide. Both techniques produce highly precise results (Weiss 1995).

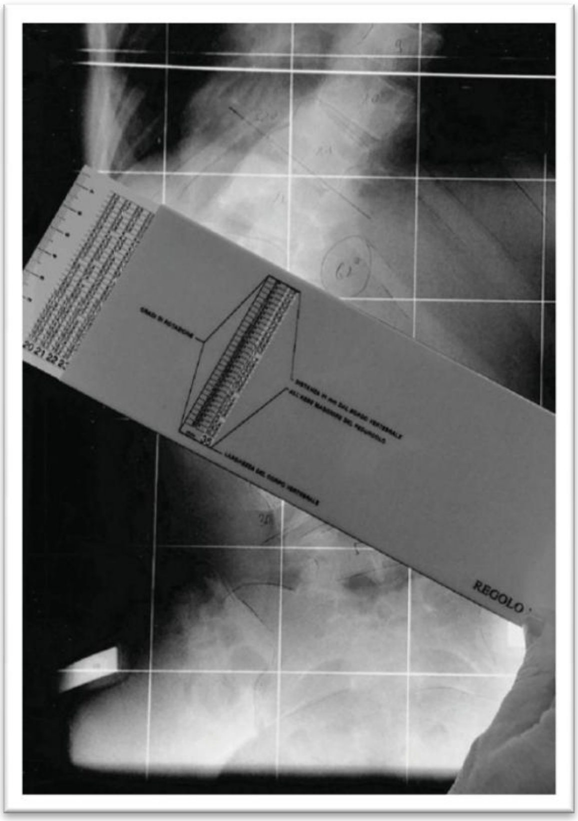


Fig. 4.6. *Investigation of the spinal rotation using Raimondi's measurement technique. The width of the vertebral body is set in the lower window of the ruler. Then, the degrees can be read from the cover plate of the slide-rule, next to the distance (in mm) between the pedicle halving and the convex- side vertebral body limitation.*

Assessment of osseous maturity

When monitoring a prognosis and planning for the treatment of scoliosis, the assessment of osseous maturity is essential. A spinal deformation of 25° in an eleven-year-old patient with only the first signs of maturity is to be taken very seriously. With the pubertal growth spurt imminent, a neglected curvature of this degree could rapidly increase within a few weeks or months to the threshold of recommended surgery. On the other hand, a curvature of the same degree in a sixteen-year-old female patient with little or no residual growth and whose sexual organs are fully mature is not as critical. For the second patient, without treatment, it is likely that little may change until menopause. Insight concerning body maturity or bone age, therefore, is of great significance with regard to the question of whether therapeutic measures are justified, and if so, which measures are to be suggested.

The bone age can be approximately determined using the "Risser (1958) value" (Fig. 1.5 and Fig. 4.7). Girls who have not yet begun menstruation and boys whose voices are not yet broken usually have a Risser of 0, meaning the apex of the main growth spurt of puberty is still to come.

With a Risser value of 3, the main phase of growth is complete and the prognosis becomes markedly more favorable. With a Risser value of 4, no more significant growth is expected; with a Risser value of 5, growth is complete. It is to be noted that even after an x-ray image shows the completion of the epiphyseal cartilage, a small amount of growth still takes place. However, for curvatures less than 30°, this is not usually of significance. With spinal deformations of more than 45°, one should prescribe a new brace when taking into consideration even a small amount of remaining growth. In this way, the further increase in the curvature that would be expected with such a severe curvature could be kept under control during the remaining period of growth.

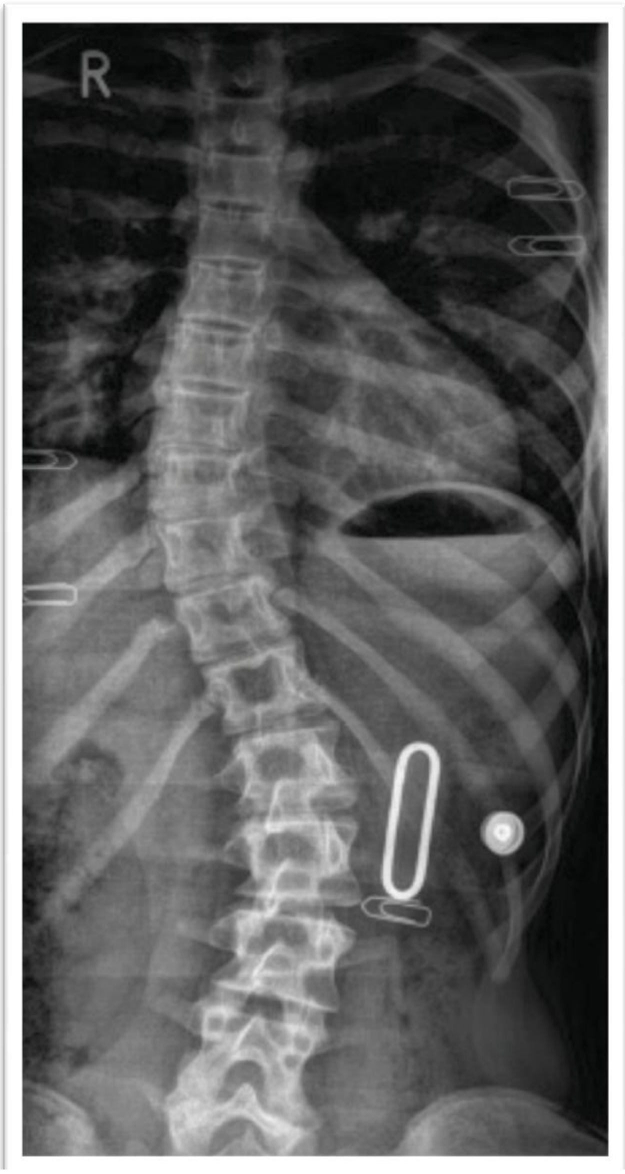


Fig. 4.7. *Full-spine x-ray image with brace, with metal markers to determine the position of the pressure pad of the brace. This image is made with a DR system with only one exposure and a reduced exposure time. On the right and left at the edge of the image, above the iliac crest, the cartilage of the iliac bone is not completely connected (Risser 3-4).*

Frequently, the Risser value is not clearly detectable on the iliac crest in the x-ray image of the spine. Usually this has to do with the quality of the image, but sometimes is due to collections of intestinal gas that may appear on the image as black spots which obscure the iliac crest. In such cases, the bone age and the remaining growth can be determined with the help of an x-ray of the left hand AP view (Fig. 4.8). This technique is the standard procedure for determining bone age and is also used by orthopedic jaw surgeons to determine maturity. With younger children, a bone age determination can be carried out when individual bone cores appear - particularly when the bone cores of the carpal bones appear. With youths, one typically uses the completion of the epiphyseal cartilage, which happens in a particular sequence thus allowing the bone age and remaining growth to be determined with the assistance of a specially created atlas (Greulich and Pyle 1959).

Fig 4.8. *X-ray image of the left hand, AP view for determination of bone age. In this instance, all growth cartilage in the fingers are still open, the sesamoid bone in the thumb's metacarpophalangeal joint is already relatively large. According to Greulich and Pyle (1959), a bone age of twelve years is estimated, which is in the middle of the major growth spurt. For scoliosis, there is a high risk of curvature increase*.

4.2 Clinical Measurement Procedures

Clinical measurement procedures are necessary for monitoring scoliosis and to minimize radiation.
During the growth spurt, monitoring should be at three-month intervals. This means that other measurement procedures must be employed to be able to confidently rule out the highly unlikely event of therapy-relevant deterioration and also to keep the diagnostic exposure to radiation at a minimum. One important aid in this instance is Bunnell's Scoliometer™ (1984), which is still employed in scoliosis screenings in the USA. This measurement procedure does, however, have European forerunners (Fig. 4.9).

Fig. 4.9. *Measurement of the back surface using the Schultheß leaning-forward test (Blencke 1913).*

Other manual clinical measurement procedures (Fig. 4.10a-b, Fig. 4.11) are no longer performed today due to known inaccuracies in the measurement procedures. Surface topography is a (semi-) automated clinical measurement which measures the surface of the trunk. It is relatively powerful and has held up to scientific scrutiny.

Fig. 4.10. *(left) Measurement of the sagittal breath at a defined position; (right) Measurement of the frontal breath on the anterior axillary line.*

The Scoliometer™

The Scoliometer™ is a spinal level whose design accommodates the form of the back in such a way that a cavity in the middle of the device leaves room for the spinous processes (Bunnell 1984). The measurements are carried out in a forward-bending test (Fig. 4.10) with the legs in a locked position. When measuring, the practitioner must take care that the patient's pelvis is in a horizontal position and that any possible oblique sacral position is to be canceled out before the measurement, using risers placed under the appropriate foot. This is the case particularly with individuals who are still growing. The length of the legs can be highly variable when monitoring is carried out with an interval of three months in a growing child or adolescent. Even when the measurement procedure itself appears relatively straight forward, a lack of experience can be expected to lead to inaccuracies that will lead to significant variations in the measurement results. In examinations, Murrell et al. (1993) indicate a variable measurement of between 1.2° and 1.6° with the same subject.

The Scoliometer™ value is directly proportional to the spinal rotation in the x-ray and with slim individuals, and with limits, can even allow a conclusion concerning the expected Cobb angle (Weiss and El Obeidi 1994).

In the hands of an experienced professional, the Scoliometer™ is a valuable aid that allows monitoring with minimal effort and without requiring new x-ray images every three months.

Today, measuring loops are used less frequently; the circumference values at certain positions can provide a good measurement of the rib mobility and breathing function in its totality (Weiss 1991). However, these results should be assessed critically and the margin of error for the measurements must be known before the changes in the values can be accorded valid significance.

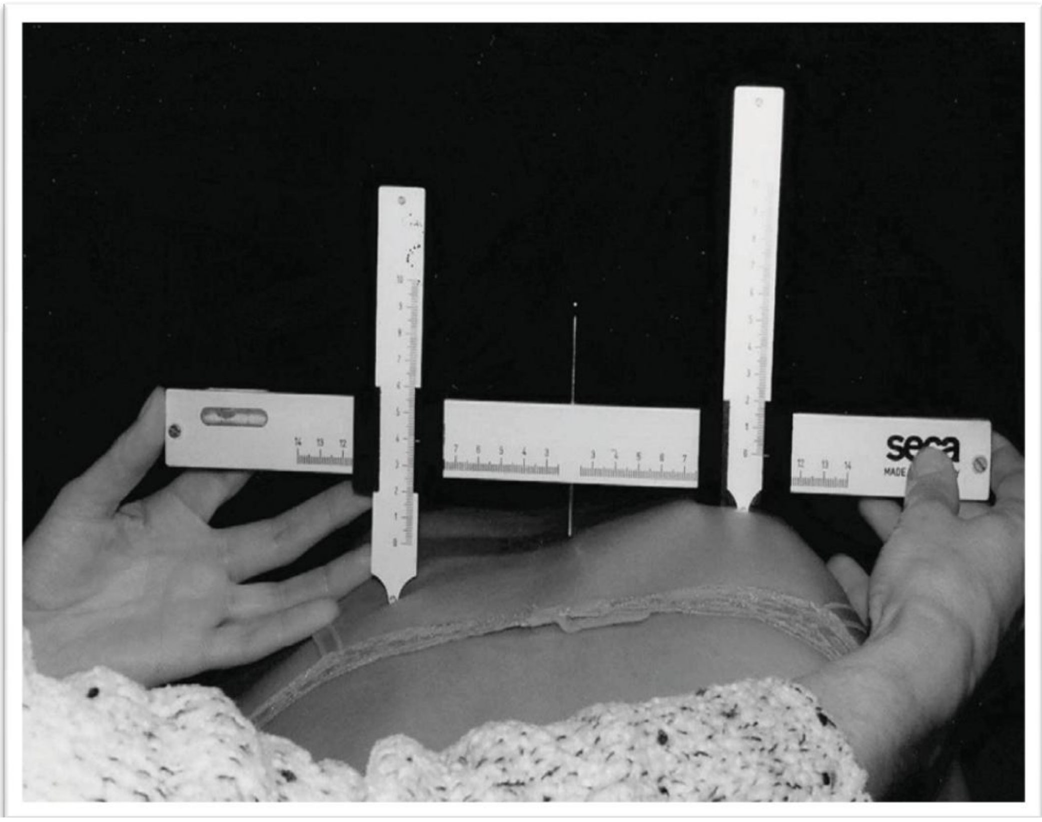


Fig. 4.11. *Measurement of the costal hump height. With this measurement, error due to repetition is also relatively high.*

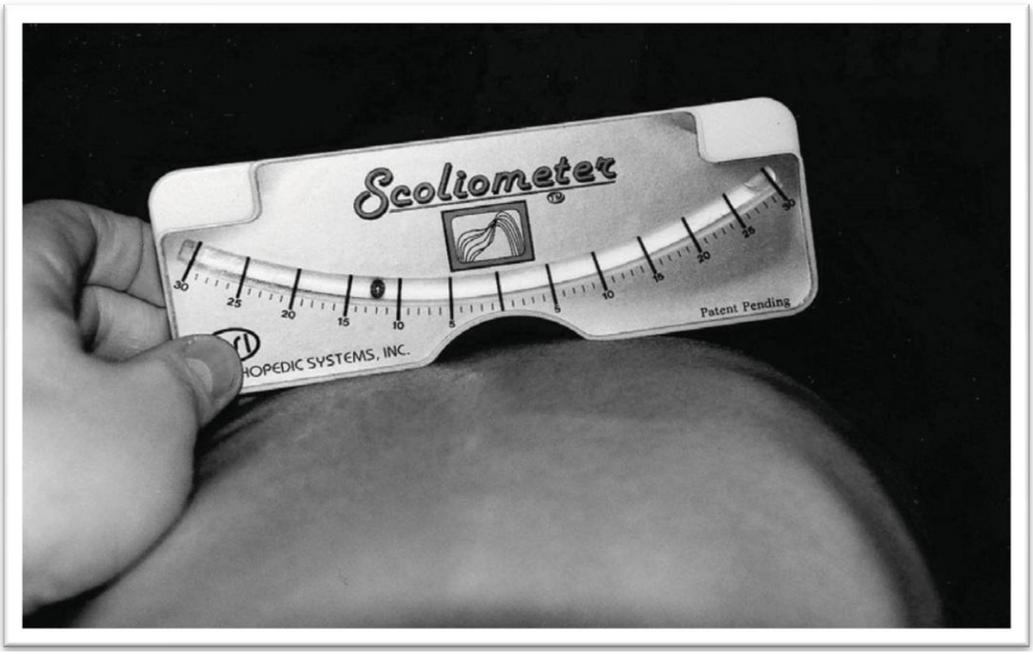


Fig. 4.12. *Scoliometer™ measurement with the forward-bending test. The technique is simple and, for those with experience, quick to execute. The repetition error is approximately 1.2-1.6°. In the case shown, a ribcage asymmetry of 12° is measured. Normally, the Scoliometer™ should be held in both hands to minimize the risk of error.*

QR code to a short video on measuring the Cobb angle and the Scoliometer angle.

Other clinical measurement procedures

In addition to the angle of trunk rotation (ATR) as measured with the Scoliometer™, other comparable anthropometric data, as well as measurement data for lung function, are useful for investigating the quality of the results of conservative scoliosis treatment. This data is produced and recorded before and after treatment. Recommended measures include bodyweight, height when standing in a resting position and subsequently corrected, body length when sitting in a comfortable position and subsequently corrected, arm span, as well as the deviation from the vertical (plumbline) and, as already mentioned, the ATR.

A spirometric minimum program features the vital capacity and forced expiratory volume (FEV) as the most important parameters of measurement. Additionally, the time taken to breathe out and the breath are investigated as functional parameters - the breath is seen as a direct measure of ribcage mobility (Weiss 1991; Weiss 2016). Alongside the volume of breath, there is also the possibility of recording the breath in frontal and sagittal planes with a measuring loop in the region of standardized measurement planes (Fig. 4.10).

It is recommended that the clinical appearance of patients also be recorded photographically in order to have images to use when explaining the goals of treatment and to illustrate possible changes as treatment progresses. In the case of positive cosmetic changes, these series of photos can also be an important source of motivation. The investigation of these success parameters requires effort on the part of the practitioner, but for the physical rehabilitation specialist these are essential to track progress. The scoliosis practitioner should obtain the diagnostic aids needed for measuring the required parameters.

Some specialized centers conduct a comprehensive diagnostic and initial assessment. At the very least, no specialist center for the treatment of spinal deformities should do without the Scoliometer™.

4.3 Objective form Analysis of the Trunk Via Surface Measurement

Sometimes, it is back pain which brings the scoliosis patient to the doctor, but, usually, it is the change in the shape of the back. In standardized conditions, x-ray images in a standing position are the traditional method of assessing a spinal distortion.

Patients who undergo treatment using a brace will sometimes be subject to more than twenty x-ray examinations over a period of three years (Rao and Gregg 1984; Doody et al. 2000; Don 2004; Ronckers et al. 2010; Yoshinaga 2012). Accordingly, the exposure to x-rays is so high, particularly for patients with spinal deformities, that for women who are affected, the chance of breast cancer has been shown to be above average (Nash et al. 1979), with the risk of leukemia also having been shown to be higher than average (Rao and Gregg 1984). In a further study on the same issue, the incidence of breast cancer was seen to be twice as high for patients with scoliosis as it was for the control group (Hoffmann et al. 1989).

Various surface measurement techniques have been developed, first to reduce the number of x-ray images needed and, second, to do more justice to the three-dimensional character of the spinal deformity. We can distinguish between two different concepts for these surface measurement techniques: the multiple line projection technique and the line scanning technique.

With the multiple line projection technique, the entire object is illuminated by a pattern of parallel lines and measured in a single instant, requiring a mere 40 milliseconds (Hierholzer 1993). Using the automatic surface measurement, the image taken by a CCD camera is saved on the computer, the various grid lines are identified, and an automatic 3D reconstruction of the back is created using form analysis, typically measuring with 25,000 surface points for every 0.5 mm (Fig. 4.13).

With the somewhat out-of-date line scanning method (ISIS: Turner-Smith 1988), the surface of the back is scanned with a single moving line of light; the automatized surface measurement is very easy, but is more susceptible to errors (Weiss 2000) (Fig. 4.14).

Today, for overall trunk assessment, the grid stereography and the Formetric® system are the most common techniques used. This is due to the fact that with this type of system one can automatically recognize the key topographical points necessary for calculating spinal changes with a greater degree of accuracy. This means that the measurements can be created without manual contact with the trunk of the patient and without the adhesion of any measurement markers. Other systems for surface measurement can no longer be recommended. The margins of error for the measurements are well known, the assessment algorithms for the system have been described (Drerup 1993; Hierholzer 1993), and the Formetric® system now boasts the widest use internationally.

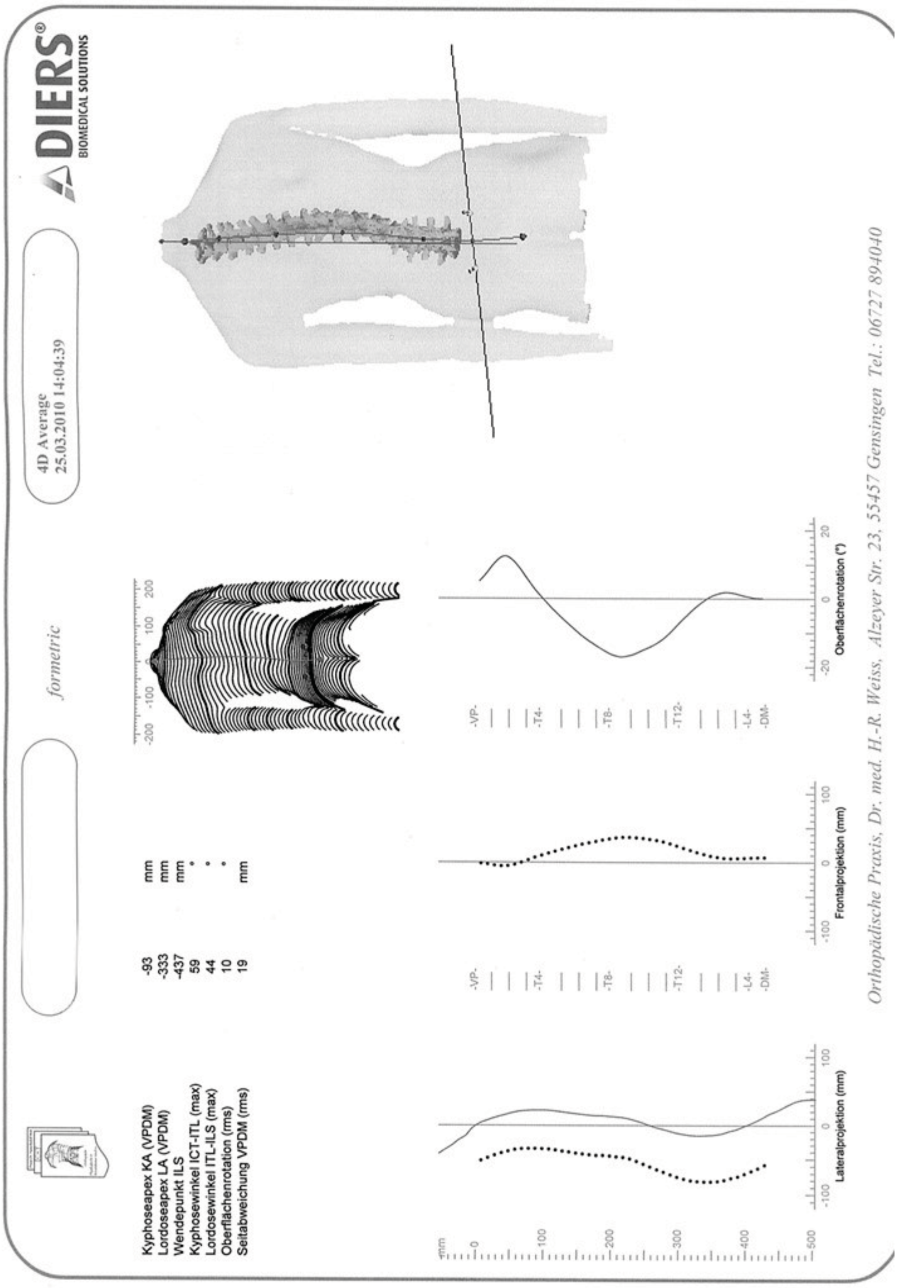


Fig. 4.13. *Formetric® printout of a patient with a thoracic right convex scoliosis. In the upper left corner, the measurement values are shown; at the bottom, the graphic assessment, with side profile, side deviation, and surface rotation.*

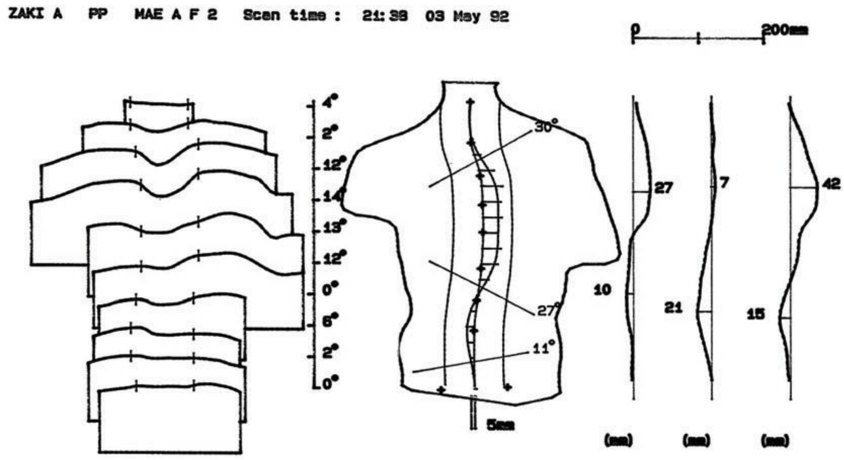


Fig. 4.14. *Computer printout of an ISIS scan that was created with the line-scanning method.*

Tests with 3D whole-body scanners, used for trunk measurement in preparation for a brace, are the newest developments (Rothstock et al. 2020). When using these scanners for suitable measured values, clinical progress monitoring can be conducted at the same time that the patient's measurements are obtained for providing a brace. In the future, such multifunction use may well enable specialist practices to offer surface topography for monitoring patients with spinal deformities.

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5. INDICATIONS FOR CONSERVATIVE TREATMENT- THE SCHROTH BEST PRACTICE GUIDELINES 2022

Spinal deformities can manifest as scoliotic, lordotic, and kyphotic deformities. While scoliosis is a three-dimensional deformity with deviations in all three planes, lordotic and kyphotic deformities are considered deformities in the sagittal plane without significant deviations in the frontal and/or horizontal planes. Exclusive hyperlordosis is relatively rare, whereas scoliosis and kyphosis are adequately described in the literature. There is also some evidence for conservative treatment of patients with spinal deformities including functional rehabilitation as well as brace application. Lordotic deformities, which are rare and due to specific causes, are not considered in the following indication guidelines.

The present guideline is a further development of the guideline "Indication for conservative treatment of scoliosis" (Weiss et al. 2006), adapted for the German Association of Scientific Medical Societies (AWMF) (Weiss 2012) and was developed by international specialists in the field of conservative scoliosis treatment during the SOSORT conference in Milan, Italy in 2005 and first published in 2006 (Weiss et al. 2006).

The subsequent review in the 2011 SOSORT guidelines resulted in more complexity and detail, but without significant changes in content (Negrini et al. 2012). The goal of our effort was to (1) produce guidelines that incorporate current knowledge, (2) expand the previous guideline on scoliosis to include kyphosis as well, and (3) present the results clearly to make it easy for professionals and laypersons to easily identify the appropriate approach for an individual patient.

Participants of the Assessment Procedure for the Evaluation of the Guideline Protocol (Stage I)

Medical specialists, physiotherapists, orthopedic therapists, occupational therapists, and Cochrane authors were invited to evaluate the proposed guideline reformulation in a 3-stage evaluation process. Participating specialists came from Europe, North America, and Asia (Denmark, Canada, China, Greece, Hong Kong, Indonesia, Japan, Korea, Russia, United Kingdom, United States, and Ukraine). The evaluation process was coordinated by Deborah Turnbull, an expert physiotherapist and author from England.

Methods: First, the guideline protocol was established. This protocol was the basis for the elaboration and final version with the aim of achieving a high-quality evidence-based final outcome (analogous to the German S3 guidelines).

According to the German AWMF system, guidelines are developed and categorized into three development levels from S1 to S3, with S3 representing the highest quality level of development methodology. All participants have agreed to this protocol.

Through a 3-stage review process, a consensus of international experts in the treatment of spinal deformities was reached for a 2019 guideline protocol regarding the indications for the treatment of patients with spinal deformities (Weiss & Turnbull 2020), based on the previously cited guidelines (Weiss et al. 2006, Weiss 2012).

Identification of the international expert panel: International experts from various professional societies in the field of conservative treatment of spinal deformities were identified. These included representation from the International Research Society of Spinal Deformities (IRSSD), Society on Scoliosis Orthopaedic Rehabilitation and Treatment (SOSORT), World Confederation for Physical Therapy (WCPT), Chartered Society of Physiotherapists UK, Maltese Association of Physiotherapists, College of Physiotherapists of Ontario, Danske Fysioterapeuter, The Japanese Academy for Health and Medical Treatment, The Japanese Association for the Study of Pain, The Japanese Society of Judo Therapy, The Japanese Society of Bone and Muscle Ultrasound, UAPT and the Hong Kong Chiropractic College Foundation.

Participants in the Delphi Process for the Evaluation of the Guideline Protocol (Stage II)

Dereli and Kuru (2021) developed a questionnaire with 46 questions based on the pre-evaluated guideline protocol (Weiss & Turnbull 2020), which was sent out to specialists worldwide.

The questionnaire contained (1) 21 general statements, (2) 15 statements regarding indications for scoliosis treatment, and (3) 10 statements regarding indications for kyphosis treatment.

Participants could decide whether to agree or disagree with each question. The strength of agreement or disagreement could be indicated with a measurement scale from 1 (little agreement/disagreement) to 7 (strongest agreement/disagreement). This questionnaire, including the results of the initial response, was presented at the international online conference celebrating the 100th anniversary of Schroth treatment in March 2021.
The study has now been completed and published in the South African Journal of Physiotherapy. The methodology of the Delphi study can be found in the 'Open Access' publication (Dereli et al. 2021). With a participant number of more than 100 international specialists, the results show high approval ratings after only two rounds of questioning.
Thus, the evidence-based and comprehensively studied guideline presented in the following can be considered validated.

Definition

Scoliosis: Scoliosis may be caused by alterations of the neuromuscular system (neuromuscular scoliosis), alterations of soft tissue (e.g., Marfan's syndrome and Ehlers-Danlos syndrome), alterations of the nervous system (neurofibromatosis), failure of formation/segmentation of vertebrae and ribs (congenital scoliosis), and other causes (Winter 1995; Chik 2020). The majority of patients with scoliosis are idiopathic scoliosis (Lonstein 1994; Winter 1995; Kruzel & Moramarco 2020).
Adolescent idiopathic scoliosis (AIS) is the most common form of scoliosis (80%-90% of the scoliosis population; Lonstein 1995; Kruzel & Moramarco 2020). AIS is also sometimes referred to as "late-onset scoliosis" when it occurs at the age of 10 or later in adolescence (Kruzel & Moramarco 2020). In contrast, early-onset idiopathic scoliosis (EOS) has a far lower prevalence (11%-15% of all idiopathic scoliosis cases; Kruzel & Moramarco 2020). EOS can be subdivided into two groups: infantile idiopathic scoliosis, which develops before the age of 3, and juvenile idiopathic scoliosis, which has its onset after the fourth year of life (Kruzel & Moramarco 2020).
While AIS may be regarded as being rather benign, EOS may progress to more than 100° after growth leading to severe health problems.
Idiopathic scoliosis will therefore be the focus of the guidelines, as in the very rare symptomatic or syndromatic scoliosis of other origin, treatment indications are mainly dependent on the underlying cause.

Kyphosis: Kyphosis is a more uniform condition than scoliosis. In contrary to poor posture kyphosis is a rigid deformity. The origin of kyphosis may be Scheuermanns disease, idiopathic (rigid kyphosis without any signs of M. Scheuermann), congenital, neurofibromatosis, arthrogryposis multiplex congenita and others (Winter 1995; Chik 2020). Kyphosis may appear in the thoracic, thoracolumbar and lumbar region, rarely in the cervical region of the spine (Winter 1995; Chik 2020). Scheuermann's disease is the most common form of kyphosis and initially was described as a rigid kyphosis associated with wedged vertebral bodies occurring in late childhood (Scheuermann 1920). It usually is defined as a kyphosis with two or more wedged vertebra (Bradford 1980; Halal & Gledhill 1978; Wenger & Frick 1999), or 'characteristic' radiographic findings (kyphosis, wedging of vertebral bodies, endplate irregularities, Schmorl's nodes). Unlike scoliosis, where any significant lateral deviation in the coronal plane is abnormal, the sagittal alignment of the spine has a normal range of thoracic kyphosis. The Scoliosis Research Society has defined this range from 20° to 40° in the growing adolescent (Wenger & Frick 1999). Little is written on the subject of the lumbar or thoracolumbar patterns of Scheuermann's disease. The Schmorl's nodes and endplate irregularity may be so severe that the lower lumbar Scheuermann's disease has been confused with infection, tumor, or other conditions (Wenger & Frick 1999).
The normal range of kyphosis in the thoracolumbar region until now is not defined well and the normal range of lumbar lordosis is not yet described. Therefore, we may assume any degree of a rigid kyphosis in the lumbar and thoracolumbar spine to be a pathogenic condition.
The guideline will therefore focus on Scheuermann's kyphosis, as in the other very rare symptomatic or syndromatic kyphosis of other origin (Winter 1995; Chik 2020), treatment indications are again mainly dependent on the underlying cause. Kyphoscoliosis is a combination of both, scoliosis and kyphosis. To include the rare case of kyphoscoliosis in these guidelines we would not have enough evidence-based information.

Etiology

Scoliosis: Idiopathic scoliosis is the most common of all the forms of lateral deviation of the spine. By definition; idiopathic scoliosis is a lateral curvature of the spine in an otherwise healthy child for which a recognizable cause has not been found (Lonstein 1995; Kruzel & Moramarco 2020). Recent investigations have focused on a functional tethering of the spinal cord (Deng et al. 2015) or neuro-osseus disturbance, which may result in a ventral overgrowth (Chu et al. 2006); however, loss of lumbar lordosis has not yet been clearly explained. Less common but more clearly defined etiologies of the disorder include scoliosis of neuromuscular origin, congenital scoliosis, scoliosis in neurofibromatosis, Prader Willi syndrome, and mesenchymal disorders such as Marfan's syndrome (Winter 1995; Chik 2020).

Kyphosis: Scheuermann's kyphosis is the most common form of all kyphosis conditions (Winter 1995; Chik 2020), however, the etiology of Scheuermann's kyphosis is still not clear. The etiology of lumbar Scheuermann's kyphosis is unknown, but strong associations with repetitive activities involving axial loading of the immature spine favor a mechanical cause (Wenger & Frick 1999). Although the radiographic appearance may be similar, lumbar Scheuermann's kyphosis is regarded as a different entity than thoracic Scheuermann's kyphosis (Wenger & Frick 1999).

Epidemiology

Scoliosis: The prevalence of adolescent idiopathic scoliosis (AIS), when defined as a curvature greater than 10° according to Cobb, is 2 to 3% of the population. The prevalence of curvatures greater than 20° are between 0.3 and 0.5%, while curvatures greater than 40° according to Cobb are found in less than 0.1% of the population. All etiologies of scoliosis other than AIS are encountered more rarely (Lonstein 1995; Kruzel & Moramarco 2020).

Kyphosis: According to Wenger and Frick (1999) the incidence of Scheuermann's disease has been estimated at 1 to 8% of the population (Wenger & Frick 1999; Scoles et al. 1991). The typical presentation is in the late juvenile age period from 8 to 12 years, with the more severe fixed form commonly appearing between age 12 and 16 years. Patients with thoracic roundback, who have classic type I Scheuermann's disease, may have pain in the thoracic spine area, but more frequently present because of patient and parental concerns related to trunk deformity (Wenger & Frick 1999; Weiss et al. 2009).

Classifications

Scoliosis: The anatomical level of the deformity has received attention from clinicians as a basis for scoliosis classification. The level of the apex vertebra (i.e. thoracic, thoracolumbar, lumbar, or double major) forms a simple basis for description. In 1988 King et al. classified different curvature patterns by the extent of spinal fusion needed; however, recent reports have suggested that these classifications lack reliability. Another approach developed by Lenke et al. (1998) calls for assessment of scoliosis and kyphosis with respect to sagittal profile and curvature components. Systems designed for conservative Schroth-based management include the classifications by Lehnert-Schroth (Weiss et al. 2015; Akçay et al. 2021) (functional three-curve and functional four-curve scoliosis), Rigo and Weiss (Weiss et al. 2015; Akçay et al. 2021).

Kyphosis: Kyphosis may appear in the thoracic, thoracolumbar and lumbar region, rarely in the cervical region of the spine. The level of the apex vertebra (i.e. thoracic, thoracolumbar, lumbar, or cervical) forms a simple basis for the description of kyphotic conditions (Wenger & Frick 1999; Weiss et al. 2009).

Objectives of Conservative Management

The primary goal of scoliosis and kyphosis management is to stop curvature progression. Improving pulmonary function (vital capacity) and treating pain are also of major importance, as is improving postural appearance (Weiss et al. 2006; Weiss 2012; Negrini et al. 2012).

Scoliosis: Conservative scoliosis management is based on rehabilitative treatment and bracing. Therapy methods include: Méthode Lyonaise, Side Shift, Schroth, Schroth Best Practice, and others (Weiss et al. 2015). Although discussed from contrasting viewpoints in the international literature, today there is evidence for the effectiveness of scoliosis treatment using physical rehabilitation alone (Weiss et al. 2003; Monticone et al. 2014; Schreiber et al. 2015; Kuru et al. 2016). It should be made clear that (1) therapy for scoliosis does not just consist of general exercises, but rather one of the cited methods specific to scoliosis designed to address the particular nuances of spinal deformity, and (2) the application of such methods requires that clinicians be specifically trained and certified in these targeted conservative intervention methods (Weiss et al. 2015).

For quite some time, in-patient rehabilitation produced short-term results which were effective regarding many of the signs and symptoms of scoliosis and its ability to impede curve progression. Today, however, advances in methodologies allow for out-patient rehabilitation which produces similar results quite effectively. In the past, a six-week intensive in-patient program was investigated with documented results, yet recently there has been no documentation of results for in-patient therapies, whereas out-patient practices are gaining momentum (Weiss et al. 2015).

The second mode of conservative management is brace treatment. Bracing has been found to be effective in preventing curvature progression (Weinstein et al. 2013) and thus in altering the natural history of idiopathic scoliosis (IS). It appears that brace treatment may reduce the prevalence of surgery, restore the sagittal profile, and influence vertebral rotation. There are also indications that the end result of brace treatment is predictable with patient compliance (Weiss et al. 2021a). This conclusion applies to rigid braces only since independent studies on soft bracing have shown inferiority to the TLSO (Weiss und Weiss 2005; Wong et al. 2008; Weiss et al. 2021a).

Kyphosis: Simple deflexion exercises can be performed in general to achieve a wider range of motion. Systematically physical rehabilitation of patients with thoracic kyphosis has been described by Lehnert-Schroth (2007). Exercises and activities of daily living (ADLs) for patients with lumbar and thoracolumbar kyphosis conditions have been described in a recent textbook (Turnbull & Weiss 2020; Weiss et al. 2020). Some of these exercises described for kyphosis treatment could be considered too simplified, considering this condition requires a specialized rehabilitation designed by a specialist in order to avoid hypermobility of the adjacent sections of the spine.

Bracing has been found to be effective in preventing curvature progression and thus in altering the natural history of kyphosis (Wenger & Frick 1999; Lehnert-Schroth 2007; Weiss et al. 2009). There are different braces available for the treatment of the specific location of kyphosis - thoracic, thoracolumbar and lumbar kyphosis (Weiss et al. 2009).

Evidence

Scoliosis: High quality evidence (Level I) has been achieved for conservative management of scoliosis (Weiss et al. 2003; Weinstein et al. 2013; Monticone et al. 2014; Schreiber et al. 2015; Kuru et al. 2016; Weiss et al. 2021a). There are Cochrane reviews supporting physical rehabilitation and brace treatment (Negrini et al. 2010; Romano et al. 2012). Randomized controlled trials also support physical rehabilitation and brace treatment (grade A recommendation; Weinstein et al. 2013; Monticone et al. 2014; Schreiber et al. 2015; Kuru et al. 2016).

No high-quality evidence exists for spinal fusion surgery (Weiss & Goodall 2008; Bettany et al. 2025; 2016; Weiss et al. 2021b).

Kyphosis: There is low quality evidence (Level III) for the conservative management of kyphotic deformities (Wenger & Frick 1999; Weiss et al. 2009). Conservative management is accepted as ‘good practice’ worldwide and - unlike spinal fusion surgery (Weiss & Goodall 2008; Mueller & Gluch 2012; Weiss et al. 2021b) - does not lead to severe side effects or long-term complications. Therefore, a clear indication for treatment can be derived from the body of literature (grade C recommendation; Bradford et al. 1974; Wenger & Frick 1999; Weiss et al. 2009).

Systematic Application of Conservative Treatment with Respect to Cobb Angle and Maturity

Scoliosis: The Guidelines for conservative intervention are based on current information regarding the risk for significant curvature progression within a given period.

Each patient with scoliosis has their own natural history and must be considered on an individual basis in the context of a thorough objective clinical evaluation and patient subjective and past medical history. The estimation of risk for progression is based on epidemiological surveys in which children diagnosed with scoliosis were radiographed periodically to quantify changes in curvature magnitude over time. Such surveys support the premise that, among populations of children with a diagnosis of idiopathic scoliosis, the risk of progression is highly correlated with potential for growth over the period of observation. In males the prognosis for progression is more favorable, with relatively fewer individuals having curves that progress to 40° (Weinstein 1989; Lonstein 1994; Lonstein 1995).

For these guidelines, prognostic risk estimation during the growth spurt (see II.) is based on the calculation of Lonstein and Carlson (1984). This calculation is based on curvature progression observed among 727 patients (575 females, 152 males) diagnosed between 1974 and 1979 in school screening programs in the Minnesota (United States) who were followed until they reached skeletal maturity.

Systematic application of conservative treatment with respect to Cobb angle and maturity in different age groups

I. Children (no signs of maturity, age 6 - 10 years)

a. Cobb angle up to 15°: Observation (6-12-month intervals).
b. Cobb angle 15-20°: Physical rehabilitation with treatment-free intervals (6-12 weeks without physical rehabilitation for those patients having low risk for curve progression at the time).
c. Cobb angle 20-25°: Physical rehabilitation.
d. Cobb angle >25°: Physical rehabilitation and brace wearing part-time (12-16 hours).

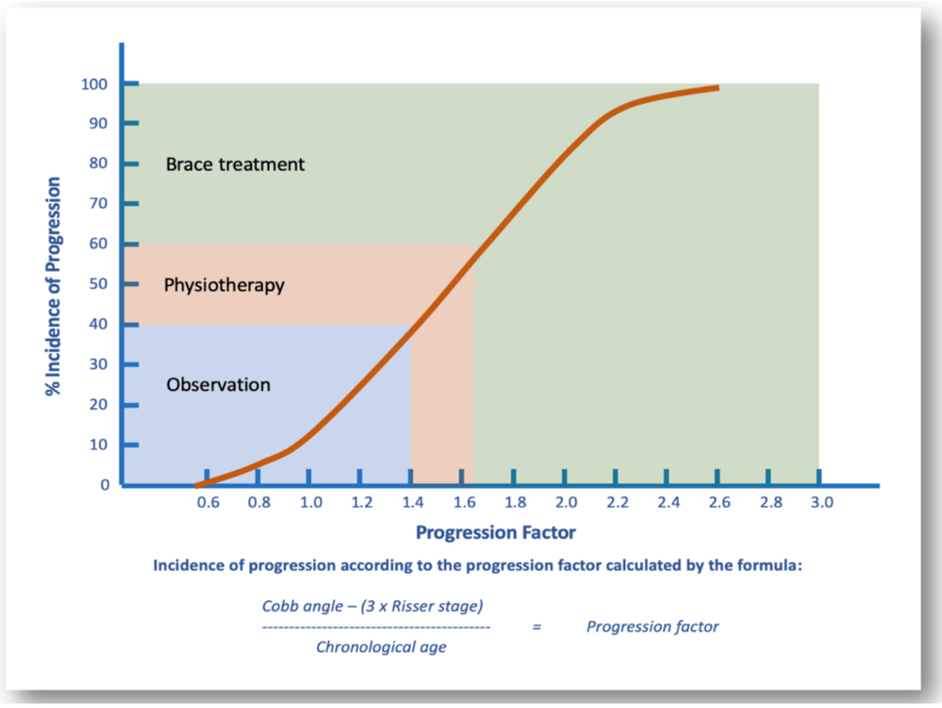

Fig. 5.1. *The estimation of the prognostic risk to be used during the pubertal growth spurt (modified from Lonstein and Carlson, 1984). Lonstein and Carlson's progression estimation formula originally was based on curves between 20 and 29 degrees. The progression factor is calculated using the formula outlined at the bottom. With the help of this factor the prognostic risk can be derived from the graph.*

II. Children and adolescents, Risser 0-3, first signs of maturation, less than 98% of mature height (bone age < 14 years in girls / < 16 years in boys)

The following section is based on progression risk rather than on Cobb angle measurement because of the changing risk profiles for deformity as the skeleton matures. For the purposes of this study, progression risk is calculated by the formula shown in Fig. 1.

a. Progression risk <40%: Observation (3-month intervals).
b. Progression risk 40-60%: Physical rehabilitation.
c. Progression risk 60-80%: Physical rehabilitation + part-time brace indication (16-23 hours [low risk]).
d. Progression risk >80%: Physical rehabilitation + full-time brace indication (23 hours [high risk]).

III. Children and adolescents presenting with Risser 4 (more than 98% of mature height)

a. Cobb angle up to 20°: Observation (6-12 monthly intervals).
b. Cobb angle 20-35°: Physical rehabilitation.
c. Cobb angle >35°: Physical rehabilitation + brace (part-time, about 16hours).
d. For brace weaning: Physical rehabilitation + brace with reduced wearing time.

IV. First presentation with Risser 4-5 (more than 99.5% of mature height before growth is completed)

a. Cobb angle 25-35°: Physical rehabilitation.
b. Cobb angle >35°: Physical rehabilitation + brace (part-time, about 16 hours are sufficient in cosmetic indication only, when surgery can be avoided).

V. Adults with Cobb angles >30°

Physical rehabilitation, in-patient rehabilitation.

VI. Adolescents and adults with scoliosis (of any degree) and chronic pain

Physical rehabilitation, scoliosis rehabilitation program (multimodal pain concept/behavioral + physical concept), brace treatment when a positive effect has been proven during specific testing.

For the highly rare infantile idiopathic scoliosis (first onset at 1.5 - 3 years of age), there are some data regarding prognosis (Lonstein, 1995; Kruzel & Moramarco 2020). A large proportion of these curvatures reduce by age 6 years without any treatment. However, if progression is observed, full-time (> 20 hrs/day) brace treatment should be started at 20° due to the strong growth dynamics at the age < 6 years.
The prognostic estimation and corresponding indications for treatment apply to the most prevalent condition - idiopathic scoliosis. For other types of scoliosis, a similar procedure can be applied. Exceptions include cases where the prognosis is clearly unfavorable, for example in neuromuscular scoliosis where a functional ability and mobility can be significantly affected (surgery for maintaining sitting capability may be required). Other reasons for considering alternative treatments include:

- Severe decompensation
- Severe sagittal deviations with structural lumbar kyphosis (flat-back)
- Lumbar, thoracolumbar, and caudal component of double curvatures with a disproportionate rotation compared to the Cobb angle and with a high risk of future instability at the caudal junctional zone
- Severe contractures and muscle shortening
- Reduced mobility of the spine, especially in the sagittal plane
- Others to be individually considered

Kyphosis: kyphosis occurs in the thoracic, thoracolumbar and lumbar regions of the spine, but rarely in the cervical region of the spine (Winter 1995; Wenger & Frick 1999; Weiss et al. 2009). During spinal bone growth any worsening in mobility, increase in stiffness, in these regions may benefit from physical out-patient rehabilitation, in order to prevent curvature progression.
Brace treatment, like in other spinal deformities, is indicated when the curvature exceeds a Cobb angle of 40° in the thoracic area and when lumbar or thoracolumbar lordosis has vanished and a kyphosis is visible in these areas. Taking into account that loss of lumbar lordosis is a clear predictor of low back pains in adulthood (Glassman et al. 2005; Djurasovic et al. 2007) the reason to treat seems clear. In the thoracic region cosmetic issues and prevention of deformity related dyspnea are the main reasons, besides occasional pains (Wenger & Frick 1999; Weiss et al. 2009).

Although there is no high-level evidence for any kind of kyphosis treatment, at least conservative treatment worldwide is fully accepted and recommended on grade C (Level III evidence).
With the exception of congenital kyphosis, neurofibromatosis, arthrogryposis multiplex congenita (AMC) and other very rare conditions kyphosis onset is mainly during the adolescence (Bradford 1980; Wenger & Frick 1999). Therefore, these rare cases are not included within this guideline as the underlying cause of the deformity determines the treatment indications. The indications for kyphosis treatment is according to the maturity of the patient and where they are within pubertal growth.

I. Children and adolescents, Risser 0-3, first signs of maturation, less than 98% of mature height

a. Any inhibition of extension thoracic, thoracolumbar or lumbar: Physical rehabilitation.
b. Cobb angle >40° thoracic, any kind of thoracolumbar or lumbar kyphosis: Physical rehabilitation + brace (part-time, about 16 hours are sufficient).
c. For brace weaning: Physical rehabilitation + brace with reduced wearing time.

II. Children and adolescents presenting with Risser 4 (more than 98% of mature height)

a. Cobb angle 40-50° thoracic, any kind of thoracolumbar or lumbar kyphosis: Physical rehabilitation.
b. Cobb angle >50° thoracic, > 10° of kyphosis thoracolumbar or lumbar: Physical rehabilitation + brace (part-time, about 16 hours).

III. First presentation with Risser 4-5 (more than 99.5% of mature height before growth is completed)

Cobb angle >50° thoracic, > 10° of kyphosis thoracolumbar or lumbar: Physical rehabilitation.

IV. Adults with Cobb angles thoracic >50°, > 10° of kyphosis thoraco-lumbar or lumbar

Physical rehabilitation, in-patient rehabilitation.

V. Adolescents and adults with kyphosis (of any degree) and chronic pain

Physical rehabilitation, scoliosis rehabilitation program (multimodal pain concept/behavioral + physical concept), brace treatment when a positive effect has been proven during specific testing.

PREDICTED TREATMENT OUTCOMES

The indication of physical rehabilitation during the main growth spurt depends upon the individual, and certain variables such as Cobb angle, apical location, Risser sign and patient compliance. These are factors, which play a role in conservative treatment outcomes. In the case of patients with AIS who have not received treatment during the main growth spurt, approximately 30% remain unchanged, 50% stabilized (or improved) after Schroth-based in-patient treatments (results from the 1980s), 70% stabilized using the symmetric Boston brace without physical rehabilitation, and 80% stabilized with a previous version of the asymmetric Chêneau brace. Today with the recent standardized computer aided designed developments of the Chêneau brace around 90% of the patients stabilize or improve (Weiss et al. 2015; 2016; 2017; 2021a). This illustrates that brace treatment is indicated and paramount to conservative management during growth and following the main growth spurt, physical rehabilitation can be effective independently of brace treatment.
In kyphosis treatment the Milwaukee brace was once popular and was proven effective (Level III) in the US (Bradford et al. 1974), while in Europe other braces with 3-point pressure systems are used (Weiss et al. 2009).

There are psychological benefits for intensive rehabilitation during the main growth spurt (Weiss et al. 2015). In-patient rehabilitation measures are the preferred method for patients with pain or severe lung function impairment. But for those with a more favorable prognosis, finite out-patient sessions as determined by the clinician or one short out-patient rehabilitation of several days are often all that is necessary for acquiring the skills needed for the home exercise program. Outcomes will depend on curve severity and ability to incorporate the concepts learned. The exercise treatments are evolving along with their relative effectiveness.
For the very latest concepts that utilize the daily routine known as ADL's (Activities of Daily Living; Weiss et al. 2015), it is more a matter of changing the postural habits in everyday life than prolonged intensive

rehabilitation. If this is successful after a short rehabilitation period and if the newly corrected postural patterns can become automatic, adapting the natural posture, then it's feasible that no further intensive physical rehabilitation should be necessary in the long-term. These conservative measures are designed for the least interference in a patient's quality of life.

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6. PHYSIOTHERAPEUTIC FINDINGS

Scoliosis is a three-dimensional deformity of the spine and trunk which may progress quickly during phases of rapid growth. Scoliosis may be caused by osseus malformations, certain diseases or syndromes (eg. congenital scoliosis, neuromuscular scoliosis, scoliosis in mesenchymal disorders and many others). The majority of scoliotic curves are called idiopathic as a certain underlying cause has not been determined as of yet (Chik 2020; Kruzel & Moramarco 2020).

Treatment of scoliosis historically consists of pattern specific exercises (eg. Schroth / side shift / Monticone; see: Kuru et al. 2016; Romano et al. 2012), brace treatment (Boston brace / Chêneau brace) and spinal fusion surgery. Today there is high quality evidence supporting pattern specific exercises (PSE) and brace treatment (Weiss, Moramarco & Borysov 2020; Weiss & Moramarco 2020) Spinal fusion surgery still today is not supported by high quality evidence (Weiss et al. 2021a).

In recent literature it has been shown that the results of the standardized asymmetric Chêneau style braces may be superior to the results as achieved with the Boston brace or other more symmetric brace types. However, the overall results of Chêneau braces in literature vary to a high extent. Therefore, with respect to patient's safety in scoliosis treatment only original, well developed and evidence based Chêneau derivates should be used which we call pattern specific braces (PSB) (Weiss et al. 2021b).

Scoliosis is not a uniform condition (Chik 2020). While in symptomatic or syndromic scoliosis the curve may appear very individual, sometimes bizarre, in idiopathic scoliosis there are certain curve patterns which regularly occur. Therefore, the curve patterns in idiopathic scoliosis but also in most of the symptomatic / syndromic scoliosis can be classified within certain limits.

In PSE (Schroth) as well as for PSB (standardized CAD Chêneau derivates) the corrective routine differs according to the different curve patterns. Therefore, these patterns of curve correction need to rely on a classification.

Pattern classifications assist in creating a plan of correction not just in physiotherapy, but also with pattern specific (asymmetric) brace applications and for surgical treatment. One of the oldest classifications, created in the 70s, can be traced back to Lehnert-Schroth (1981; 2007) and was later used by Jacques Chêneau for the planning of the brace bearing his name. In 2020, the Lehnert-Schroth (LS) classification was validated for the first time (Borysov et al. 2020).

The King classification (1988) was introduced in the 80s for planning surgeries, although it proved to be imprecise and was reworked many times in the 90s. It was ultimately replaced with the Lenke classification (Lenke et al. 1998, Lenke 2005). The Lenke classification contains a consideration of the sagittal configuration, as well as a classification of the curvatures in the frontal plane.

Rigo (2004) derived his first classification from the Lenke classification, which can also be found in the previous edition of a textbook. In 2010, Rigo (et al.) reworked the classification and introduced new terminology that was somewhat unclear and seemed more complicated.

Therefore, an expansion of the Lehnert-Schroth classification has been developed in the hope that it will be a valuable practice-based aid for practitioners and orthopedic technicians (Weiss 2010). The extended, or augmented Lehnert-Schroth (ALS) classification was validated by a research group from Turkey in 2021 (Akcay et al. 2021).

In order to determine the appropriate treatment plan for a scoliosis-specific conservative treatment approach, the practitioner must identify the pattern of curvature. Although not every form of curvature can be reduced to a certain basic pattern, for more than 90% of scoliosis patients, special patterns can be identified. For each pattern, specific exercises have been developed. These can be taught in the clinical setting and then carried out independently at home. In out-patient therapy, patients can either receive individual education and instruction or be separated into groups, based upon their scoliosis pattern. For the treatment of scoliosis, identification of the curvature pattern allows for the correct choice and combination of rehabilitation exercises.

According to contemporary academic knowledge, the creation or replacement of a physiological sagittal profile can lead to a real three-dimensional correction of the back surface (Weiss and Moramarco 2013). Furthermore, it has been shown that by simply correcting a sagittal profile that has been inverted by the idiopathic scoliosis, a correction of the scoliosis in the frontal plane (Cobb angle) can be affected (Weiss 2004; 2005; Weiss et al. 2006; van Loon et al. 2008). Following Dickson et al. (1984) and Tomaschewski (1987), the flattening or inverting of the sagittal profile must be seen as the starting point of idiopathic scoliosis (Fig. 6.1).

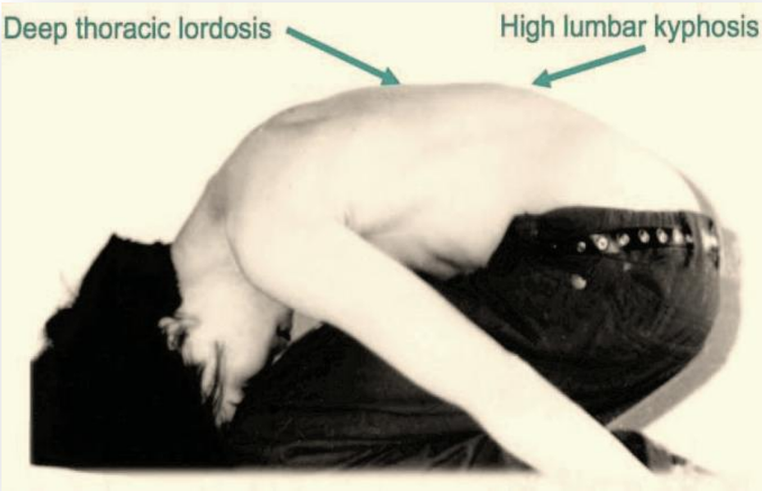


Fig. 6.1. *Patient with initial idiopathic scoliosis in Tomaschewski's "package sitting position." The deep thoracic flattening and the compensatory high lumbar kyphosis can be seen and are expressions of a structural inversion of the physiological sagittal profile.*

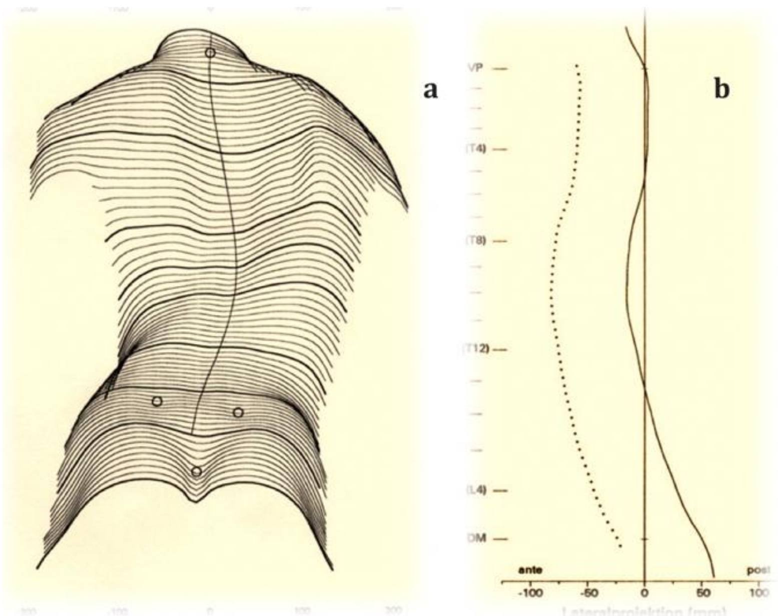


Fig 6.2. *(a) High-degree right thoracic idiopathic scoliosis with exaggerated ribhump as seen on a Formetric® scan. (b) A lordosis of the thoracic major curvature area can be seen in the lateral view.*

In the case of patients with idiopathic scoliosis and a thoracic pattern of curvature, a flattening of the thoracic sagittal profile into a thoracic lordosis is observed (Fig. 6.2); in the case of a lumbar curvature, a flattening of the lumbar lordosis in to a lumbar kyphosis is seen. In the case of double major curvature patterns, an inversion of the sagittal profile is recognizable (Fig. 6.3 - Fig. 6.4). As Fig. 6.4 shows, the alignment of the zygapophyseal joints in the thoracic region differs from that of the lumbar spine. The normal sagittal profile is considered rotationally and laterally stable, while any resulting change in the center of axial rotation leads to instability.

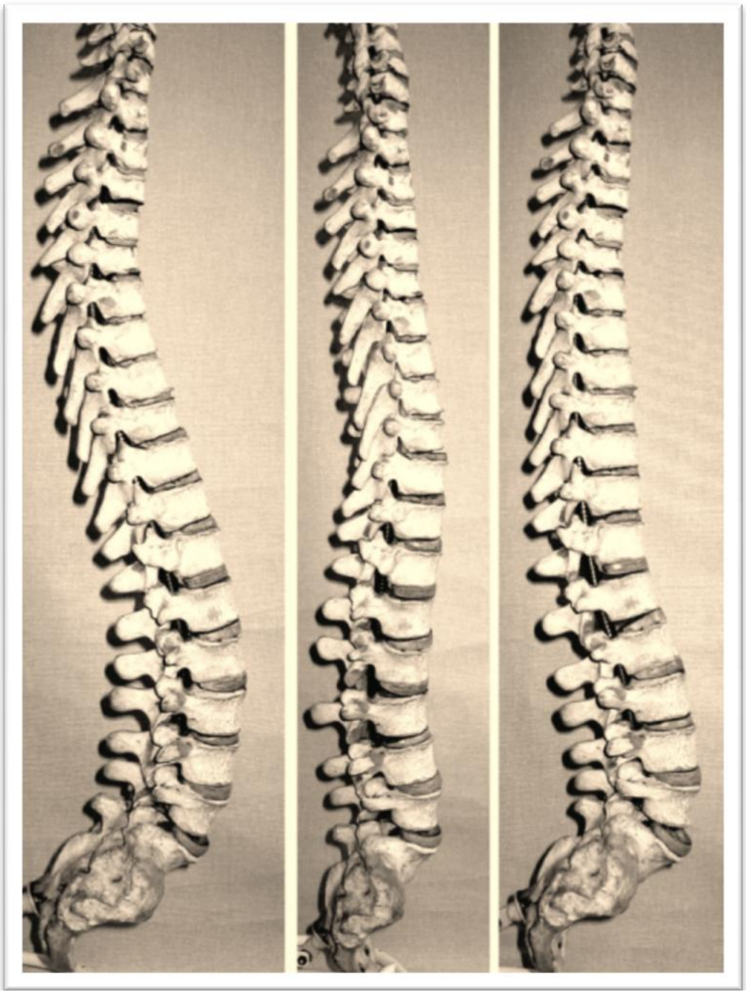


Fig. 6.3. *Left - Physiological sagittal profile of the spine with kyphosis in the thoracic region and a lordosis which encompasses the entire lumbar spinal section. In the middle, the structurally inverted sagittal profile of a double major scoliosis can be seen, with a lordosis in the thoracic region and a kyphosis in the lumbar region. On the right, an image of "sitting kyphosis" which is the case when exercises are performed in a seated position. However, this situation is often found with thoracolumbar and lumbar scoliosis as well. Typically, the lumbar lordosis is reduced and an acute sacrum position can be recognized. This leads to increased stress on the zygapophysial joint and on the vertebral curve region of L5/S1. The overall lordosis appears to be limited to this segment, with the cranial segment not sharing in the lordosis.*

In the thoracic region, the facet joints are more frontally positioned, allowing a rotation around the center of axial rotation which in the thoracic spine is in the vertebral body. In a scoliotic flatback (thoracic lordosis), the center of axial loading (rotation) is at the base of the spinous process. Therefore, movements become hypomobile, and this creates spinal rigidity.

If we view the inversion of the sagittal profile as the initial deformity in the development of idiopathic scoliosis (Fig. 6.1), then the thoracic apical vertebra moves initially in a ventral direction during development of the scoliosis, before the rotation and lateral distortion appear. Accordingly, in the lumbar region of the spine, the apical vertebra moves dorsally in the direction of a kyphosis, before rotation occurs, leading to the development of a lumbar bulge. It is then the lateral deviation becomes visible. This model is shown in Fig. 6.5.

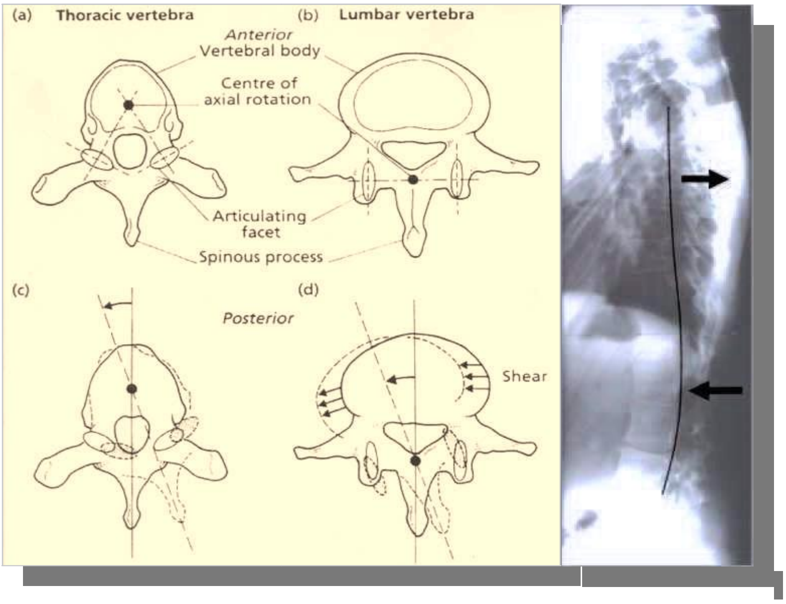


Fig. 6.4. *Left - The orientation of the zygapophyseal joints in the thoracic region differs significantly from that in the lumbar region. Under physiological conditions, with a thoracic kyphosis and a lordosis of the entire lumbar region, the center of rotation is located in the thoracic spine, according to the joint orientation and the load-bearing relationships in the center of the vertebral body. While in the lumbar spine, due to the more dorsally situated axial load-bearing relationships, it is typically located at the base of the spinous process of the vertebral body. Right: In an idiopathic scoliosis with an inversion of the sagittal profile, the joint orientation is indeed the same, but the center of the axial rotation is shifted conversely into a pathological one. As a result, the spine becomes unstable and cannot ably resist deforming forces (modified from Burwell 2003).*

In accordance with these findings, sagittal corrective elements must be employed, not only in physical rehabilitative treatment but also when bracing. If we regard idiopathic scoliosis as a truly three-dimensional deformity, then blocking effects/hypomobility will develop when we consider the perspective of two-dimensional corrective measures, making an optimal correction impossible. It is for this reason that the sagittal profile of a patient suffering from scoliosis must be taken into consideration in appropriate and advanced concepts of rehabilitation and brace treatment.

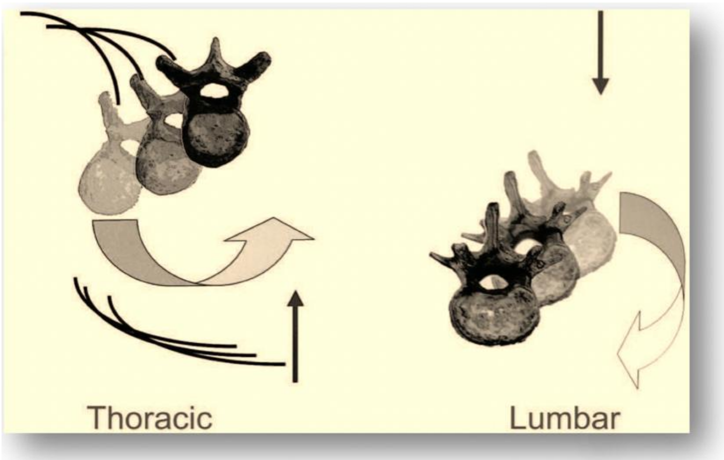


Fig 6.5. *Left - With the evolution of an idiopathic scoliosis, the apical vertebra in a thoracoc curve slides initially in a ventral direction before the lateral deviation and the rotation appear. In the lumbar region, shown on the right, the apical vertebra slides more in a dorsal direction. Therefore, in the ribcage region, a clear correction force is required, from ventral to dorsal. Right - In the lumbar spinal region, a correction force from dorsal to ventral is necessary, as shown by the arrows.*

6.1 A simple Scoliosis Classification - The LS Classification

Now we will focus on the classification of the curve patterns. The Lehnert-Schroth (LS) classification (Lehnert-Schroth 2007) is a simple and comprehensible basis for the differentiation of the various patterns of curvature and their correction.
According to Schroth terminology (Lehnert-Schroth 2007), physiotherapy must distinguish between "functional 3-curve scoliosis" and "functional 4-curve scoliosis." With functional 3-curve scoliosis, the shoulder-neck section, the thoracic section, and the lumbar-pelvis section are twisted and askew in frontal, sagittal, and transverse planes (Fig. 6.6, 6.7).
With functional 4-curve scoliosis, the lumbar-pelvis section is further subdivided into a lumbar section and a pelvis section, with the pelvis being seen as an additional functional curvature that serves as a starting point for an independent correction principle in the context of the tailored physiotherapeutic treatment (Fig. 6.6; 6.8). With functional 3-curve scoliosis we distinguish between scoliosis with prominent hips on the thoracic concave side (= 3CH) and functional 3-curve scoliosis with a centered pelvis (= 3CN).

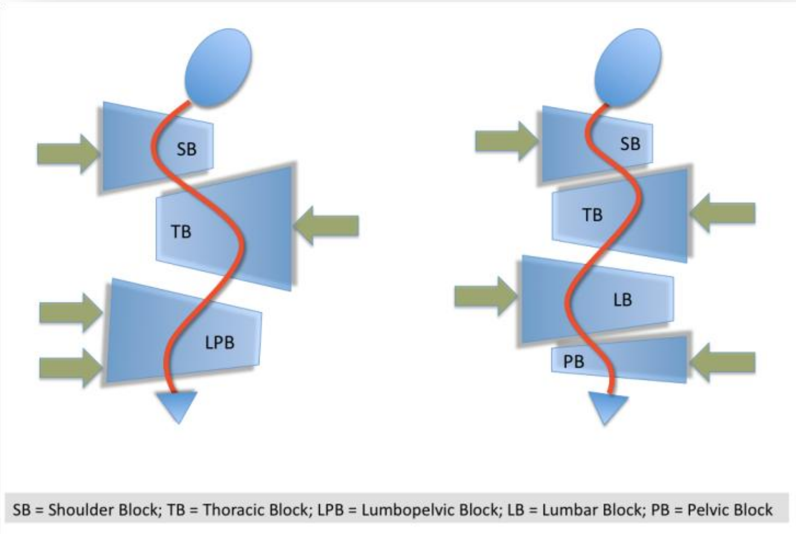


Fig. 6.6. *The LS-Classification. On the left the typical 3C scoliosis with three blocks deviated and rotated against each other. On the right the typical 4C scoliosis (double major) with four blocks deviated and rotated against each other. The arrows indicate the frontal plane correction of the blocks against each other.*

The LS-classification shall serve as a starting point for an expansion into a more comprehensive classification which covers more configurations of patterns. This expansion is explained in the following section.
However, before the individual patterns of curvature are presented in more detail, we must define a few topographical concepts:

- The parcel side is the side on which the costal hump is found; it is independent of the hump's extent and also of the pattern of curvature. Accordingly, the term parcel side always refers to the orientation of the thoracic curvature. With thoracic major curvatures, the parcel side is easy to determine. However, it can be the case that - as with lumbar curvature patterns - no costal hump is visible to the naked eye; however, we still talk of a parcel side in the case of a pure lumbar curvature, if we mean the convex side of the thoracic equalization curvature.
- The weak side is the side on which the costal concavity is found. Accordingly, the term weak side always refers to the thoracic curvature. The weak side, therefore, is always on the opposite side of the parcel side.
- The absolute decompensation is defined as the radiologically measureable deviation from the vertical line (plumbline) from C7 - Rima ani (or anal cleft).

- A relative decompensation is the clinical deviation of one of the trunk sections - shown in the following images - in the frontal plane against the other trunk sections, even when no plumbline deviation can be established radiologically.
- Simply put, we describe a decompensation on the parcel side as a thoracic decompensation, and a decompensation on the weak side as a lumbar decompensation.

In Schroth terminology, we find additional definitions (Lehnert-Schroth 2007). However, our intention is to contribute to a simplification of the treatment, so the jargon will be restricted to the most important terms.

Functional 4-curve scoliosis is distinguished by the prominence of the hip on the thoracic convex side (= 4C). Typically, there is a lumbar or thoracolumbar curvature and the lumbar spine proceeds from the sacrum in an oblique fashion (the "oblique take off"; Fisk et al. 1980). In functional terms, functional 4-curve scoliosis almost always involves a functional difference in the length of the legs, due to the biomechanical circumstances. In this case, the thoracic convex side iliac crest lies higher than on the thoracic concave side (Lehnert-Schroth 1981). In the Adams forward-bending test, this asymmetric application of force is canceled out, and in this way one can use the forward-bending test to identify pelvis balance at the horizontal position of the sacrum. The only thing that can then still lead to an incorrectly positive result concerning a shortened leg is a blockage of the sacroiliac joint.

To be clear, the functional curvature patterns mentioned here have nothing to do with the radiological terms "single curve" and "double curve." A radiological single lumbar curvature with an "oblique take off" (Fisk et al. 1980) of the lumbar spine from the sacrum is accorded the curvature pattern "functional 4-curve" and a single thoracic curvature with "straight take off" of the lumbar spine from the sacrum is classified as "functional 3-curve." In contrast to the radiological field, with the Schroth classification, equalization curvatures, which usually are not structural, are viewed as functionally independent. According to the theoretical foundation for Katharina Schroth's three-dimensional scoliosis treatment, there is a danger that if one fails to take even a small functional countercurve into consideration, then the scoliosis could be increased due to improper employment of physiotherapeutic methods (Lehnert-Schroth 2007). The issue of the correct influence of functional countercurve does, however, require observation from several angles. On one hand, we try our best to correct all existing curvatures according to the individual findings. On the other hand, particularly in the case of multiple curvatures (double major curvature, double thoracic curvature), we often find ourselves at the limits of what is biomechanically possible. The question then becomes, "What parameter should one follow when nothing seems to help with any of the existent curvatures?"

After it was recognized that double curvatures remain the most stable after completion of growth (Asher and Burton 2006), as well as being the least noticeable, the first author introduced the following paradigm: if, toward the end of growth, a *decompensated* functional 4-curve (3CL; see below) can no longer be sufficiently recompensated with a 4C treatment, we change the approach to a 3C treatment in order to achieve a final balance of the curvatures. Balanced curves are the least obvious ones and the least progressive ones after cessation of growth (Asher & Burton 2006).

6.2 A Scoliosis Classification Correlating with Exercise and Brace Treatment - The ALS Classification

For didactic reasons, the features of the original Lehnert-Schroth classification will first be explained again here in a synopsis of clinical image and radiograph before we describe the individual curvature patterns of the extended (augmented) Lehnert-Schroth classification derived from them.

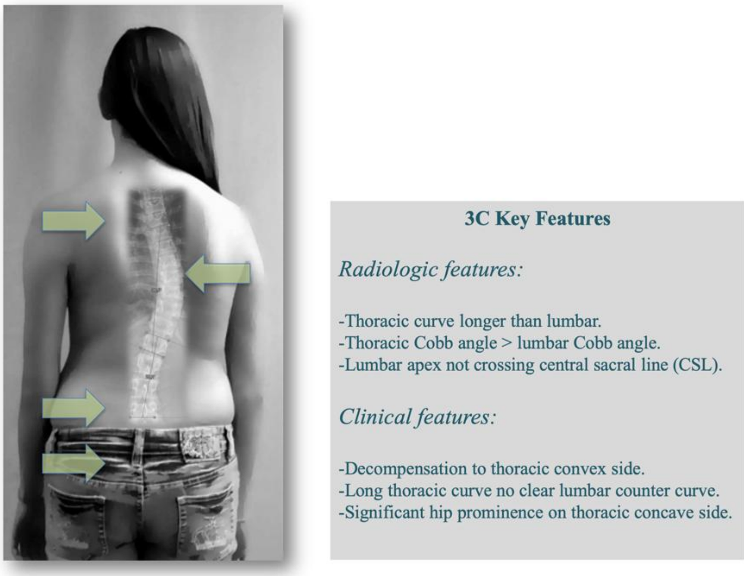


Fig. 6.7. *The main features of pattern 3C.*

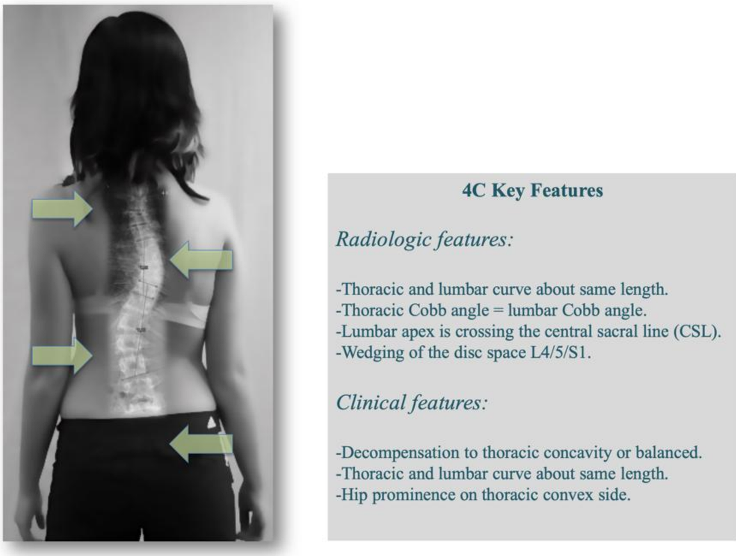


Fig. 6.8. *The main features of pattern 4C.*

The individual curvature patterns in this **A**ugmented **L**ehnert-**S**chroth (ALS) classification, which appear in the attached synopsis, are as follows (Fig. 1):

- 3CH (functional 3-curve, with hip prominence)
- 3CTL (functional 3-curve, thoracolumbar)
- 3CN (functional 3-curve, compensated)
- 3CL (functional 3-curve with long lumbar countercurve)
- 4C (functional 4-curve, double curvature)
- 4CL (functional 4-curve with major lumbar curvature)
- 4CTL (functional 4-curve with major thoracolumbar curvature)

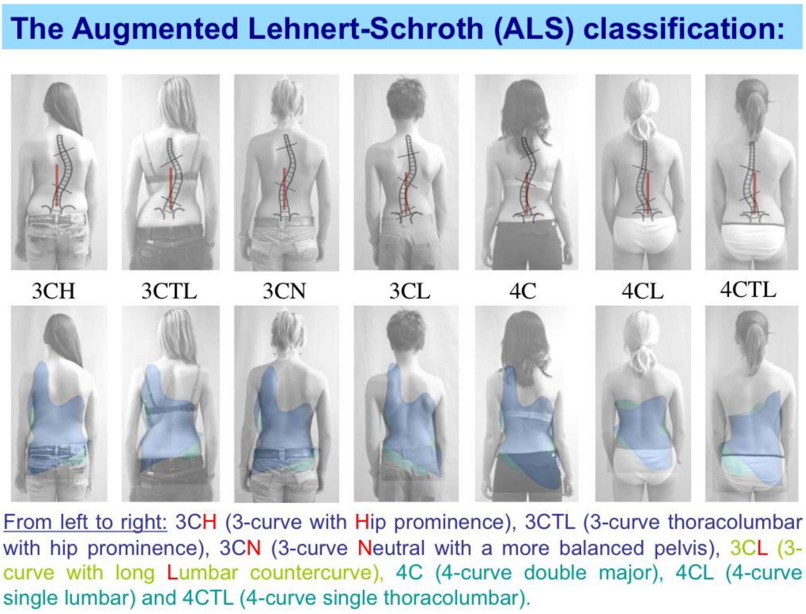


Fig. 6.9. *The Augmented Lehnert-Schroth (ALS) Classification.*

Today this classification is used for the application of Schroth Best Practice (SBP) exercises and for the application of the Gensingen brace (GBW) worldwide. For reasons of simplification we rely on the frontal plane pattern only because the sagittal plane deviations can simply be described additionally (eg. with thoracic kyphosis; with thoracic flatback). This will allow to make the classification as simple as possible without the need of extra subclassifications. While this may be not enough for planning surgery in practice it is enough when we use it for conservative modes of treatment.

Description of the Classification

3CH Key Features

Radiologic features:

-Thoracic curve longer than lumbar.
-Thoracic Cobb angle > lumbar Cobb angle.
-Lumbar apex not crossing central sacral line (CSL).

Clinical features:

-Decompensation to thoracic convex side.
-Long thoracic curve no clear lumbar counter curve.
-Significant hip prominence on thoracic concave side.

Fig. 6.10. *The key features of the pattern 3CH.*

Typical Features of the 3CH Pattern

The 3CH pattern is the first pattern described by Katharina Schroth (Fig. 6.10). Patients with this pattern typically have a major curvature in the thoracic region with one cranial and one caudal equalization curvature respectively.

Together, the pelvic and lumbar spine constitute a functioning unit. The lumbar countercurve may be fully distinguished or only visible as a partial curvature, although in this case the signs of a structural distortion are lacking.

Schematically, with the 3CH pattern there are three trunk regions which can be separated into sections that have pushed into each other and become deformed. Running from caudal to cranial, we find the following:

- The lumbopelvic section with the pelvis, abdomen, lumbar spine, and usually the lower two thoracic segments and the free ribs connected to them.
- The thoracic section with the majority of the ribcage and the thoracic spine. In addition, approximately the lower third of both shoulder blades is influenced by a thoracic major curvature.
- The shoulder-neck section with the pectoral girdle along with the upper thoracic region (cranial equalization curvature) and the cervical spine.

With a typical scoliosis involving a convex thoracic curvature on the right side of pattern 3CH, the lumbopelvic section is pushed laterally to the left, compressed in a wedge-shaped fashion on the right below the ribcage and twisted dorsally on the left side in the region of the wedge's large end. The thoracic section is pushed to the right, up against the lumbopelvic section, compressed in a wedge-shaped fashion on the left side above the lumbar bulge (if any) and twisted dorsally on the right side in the region of the wedge's large end, resulting in the appearance of a costal hump. The shoulder-neck section is pushed in a similar way to the lumbopelvic section and twisted with a back-turn of the left shoulder on the appropriate side with respect to the wedge's large end. Observed statically, the trunk of the patient with this curvature is decompensated in the frontal plane on the thoracic convex side. The prominence of the hip on the thoracic concave side enables the diagnosis of this functional 3-curve curvature. The weight appears to be overwhelmingly supported by the leg on the thoracic convex side.

With a convex thoracic scoliosis on the right side, the thoracic section is rotated to the right, and, conversely, the lumbopelvic section and the shoulder-neck section are rotated to the left.

The sagittal profile of the 3CH pattern is usually characterized by a sustained lordosis in the thoracic spinal region, appearing right down to the sacrum. Upon first glance, a reduction of the lumbar lordosis is not identifiable.

It is only by more precise observation that a relative stiffness of the lumbar spine is visible with this curvature pattern.

Typical Features of the 3CTL Pattern

The 3CTL curvature pattern (Fig. 6.11) can be viewed as a particular form of the pattern 3CH. A scoliosis with a curvature apex at T12 or L1 is defined as a thoracolumbar pattern, but curvatures with a curvature apex of T12 usually have clear characteristics of the 3CH pattern with a thoracic decompensation and thoracic flatback. This sub-categorization is therefore based more on didactic reasons than on practical ones, even though a thoracolumbar scoliosis with apical vertebra T12 in individual cases can sometimes appear to be a functional 4-curve curvature.

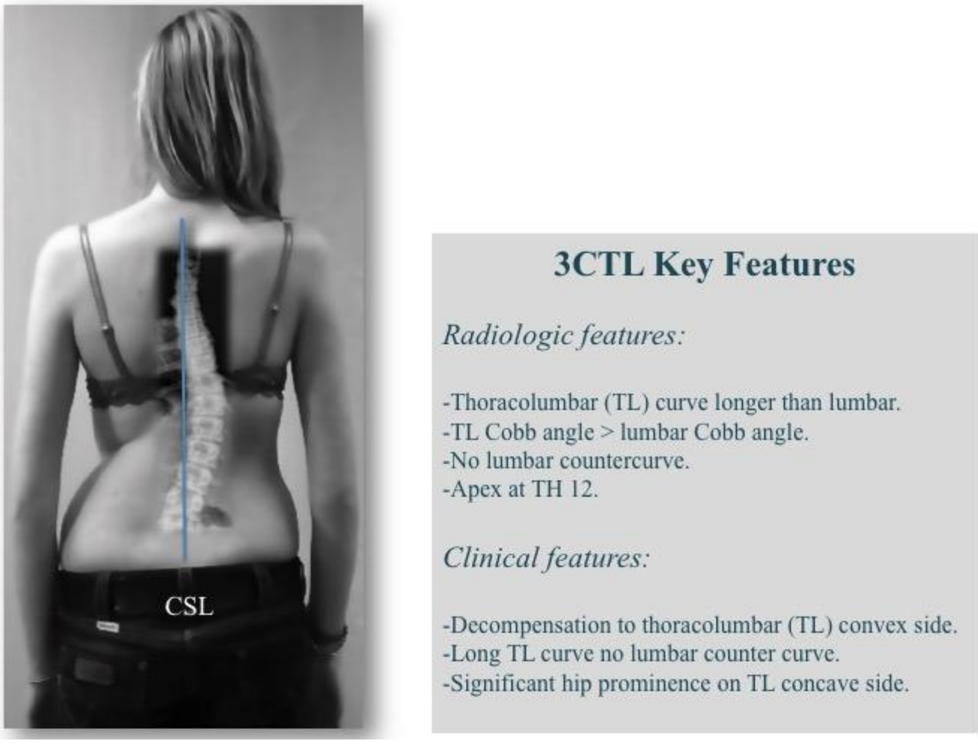


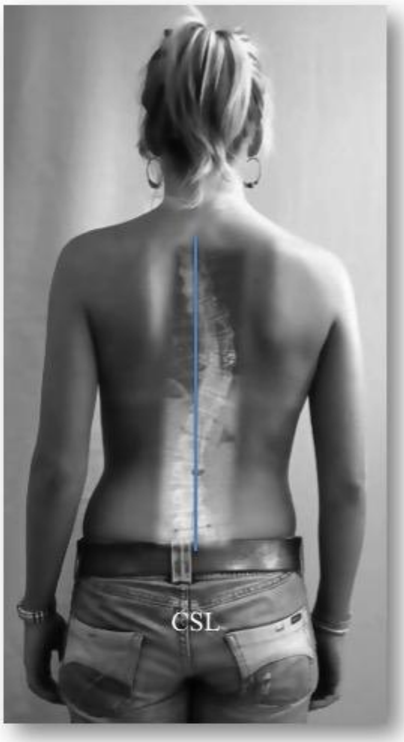
Fig. 6.11. *The key features of the pattern 3CTL.*

From a physiotherapeutic perspective, this pattern is described as a thoracic major curvature with cranial and caudal countercurves; however, in radiological terms, it is typically classified as single curve.

The thoracic major curvature is drawn out and decompensates the trunk to the thoracic convex side. In the caudal region, L5 is centered above the sacrum and L4 is already tilted to the side of the thoracic curvature. In order to clearly establish the direction of the axial spine rotation of the apical vertebra, one must often look at L2 or L3. Accordingly, the curvature reaches into the lumbar region; however, in physiotherapeutic terms, it should not be viewed as a thoracolumbar curvature, since the apical point lies in the thoracic region. The typical long costal hump (parcel) evolves out of this drawn out lateral distortion of the spine. The indentation typical of lumbar curvatures underneath the costal hump (weak side) is often difficult to recognize with this curvature pattern. Accordingly, on this side it is usually the case that no folds are visible since we rarely find a lumbar curvature with this pattern. However, the lumbar and thoracic fascicules of the erector spinae muscles, which extend through this region longitudinally, are shortened underneath the costal hump. In practice, this presents an additional challenge for correction of the posture and for the choice of exercises.

Typical Features of the 3CN Pattern

The 3C pattern is another functional 3-curve scoliosis with a major curvature in the thoracic region that is typically convex on the right side. There is an additional compensatory lumbar curvature of insignificant size, which must, however, be viewed as complete in structural terms (Fig. 6.12). This lumbar countercurve seldom exceeds the middle line and due to a very limited rotation, the vertebrae barely appear twisted against each other. The lumbar countercurve is flexible and practically totally erectable. The position of the pelvis in the frontal plane is balanced and thus there is no significant pelvic prominence seen on the thoracic concave side. With a balanced trunk above the pelvis, no static decompensation is identifiable. During the forward bending test the lumbopelvic section is only slightly asymmetric; however, a pelvic rotation is identifiable in the transverse plane.



3CN Key Features

Radiologic features:

-Thoracic curve longer than lumbar.
-Thoracic Cobb angle > lumbar Cobb angle.
-Lumbar apex is crossing the central sacral line (CSL).

Clinical features:

-Decompensation to thoracic convex side.
-Thoracic longer than lumbar counter curve.
-Hip prominence on thoracic concave side or centered.

Fig. 6.12. *The key features of the pattern 3CN.*

Viewed functionally, the 3C pattern is a functional 3-curve scoliosis with a thoracic major curvature and without significant hip prominence or radiologically clear deviation from the vertical. However, if one examines the thoracic section on its own, then this seems to be decompensated with respect to the pectoral girdle and pelvic girdle (relative thoracic decompensation).

Typical Features of the 3CL Pattern

The 3CL pattern (Fig. 6.13) is a special form of the functional 3-curve scoliosis. It is characterized by a thoracic, relatively decompensated major curvature (the defining trait of a functional 3-curve pattern), without significant deviation from the vertical in the x-ray image, and with an extended lumbar countercurve. A complete lumbosacral caudal equalization curvature is not detectable. Radiologically, it is possible to detect this equalization curvature through the fact that, between L4 and S1, one or several wedge-shaped intervertebral spaces are identifiable. With the 3CL pattern, the intervertebral spaces L4-S1 are relatively parallel and, therefore, do not satisfy the definition of a complete lumbosacral countercurve as described below. Due to the long lumbar countercurve, this pattern is primarily treated as a functional 4-curve (double major pattern), since one would considerably increase the lumbar curvature with a functional 3-curve approach.

The static changes in the case of a functional 4-curve scoliosis (double major pattern, see Fig. 6.14) were described for the first time at the end of the 70s and were first published at the beginning of the 80s (Lehnert-Schroth 1982). From an anatomical radiological perspective, with this functional pattern we observe a thoracic curvature of variable extent in combination with a structurally developed lumbar distortion that extends beyond the middle line and, furthermore, ends caudally in a complete lumbosacral compensation curvature. Thoracolumbar curvatures can also be classified under this pattern if the curvature apex is located at L1 and if the thoracolumbar curvature is larger and more rigid than the cranially located thoracic curvature.

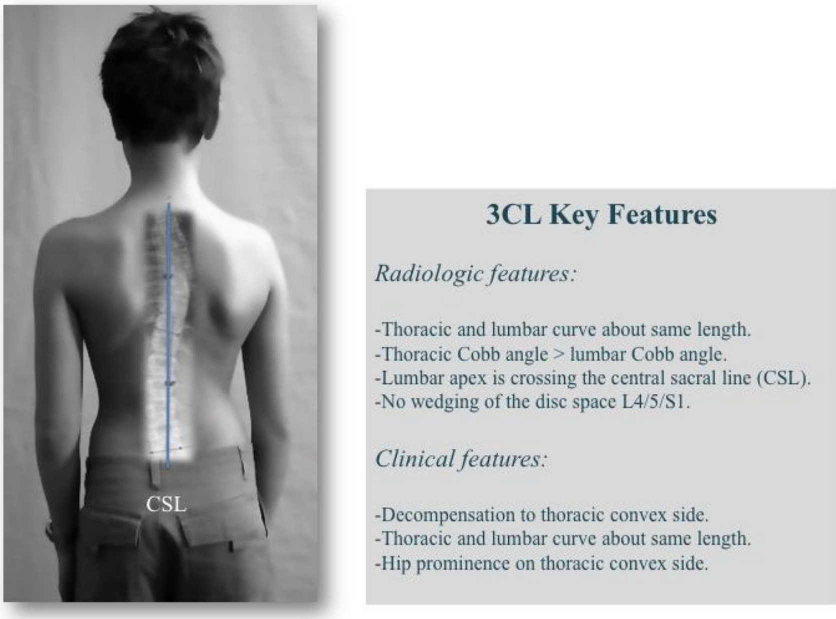


Fig. 6.13. *The key features of the pattern 3CL.*

Typical Features of the 4C Pattern

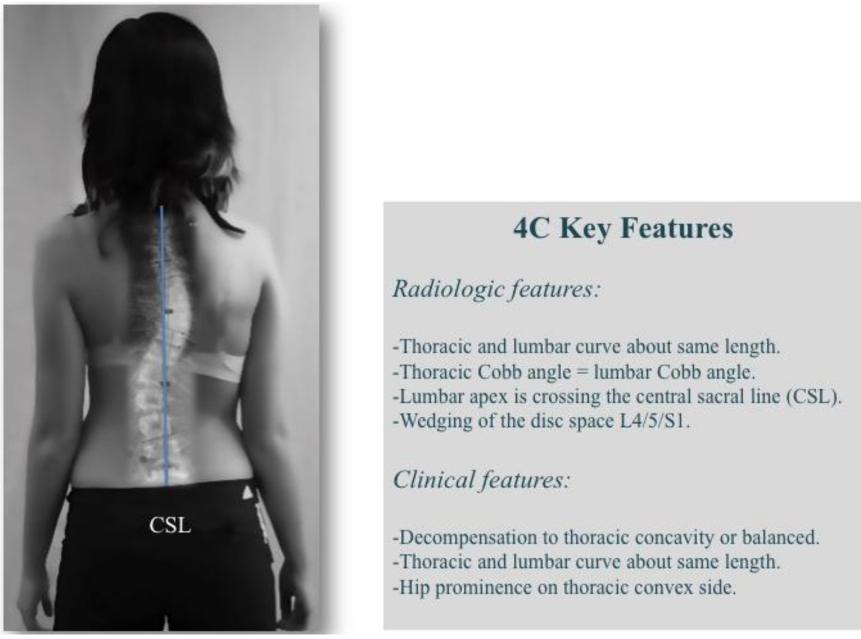


Fig. 6.14. *The key features of the pattern 4C.*

The lumbar and pelvic sections are rotated against each other and the large ends of the wedge forms are located dorsally; the tips of the wedges located ventrally. With a functional 4-curve scoliosis, the alterations of the pelvis position have been described in multiple radiological studies. When observing this curvature pattern in the frontal plane the pelvis tips on the thoracic concave side in a caudal direction and is additionally pushed toward the thoracic convex side. In the transverse plane, the pelvis sits on the thoracic convex side dorsally, due to the counter-rotation. These statements refer to the spatial position of the pelvis, taking into account a patient-

oriented coordination system. For this, we use the terms "geometric" and "spatial pelvic torsion." In contrast, the one-sided elongation of the intrinsically lumbar portion of the autochthonic back musculature, as well as the sacroiliac joint mechanism, produce an anteversion of the wing of the ilium on the thoracic convex side (on this side the transverse processes of the lumbar spine are rotated away from the iliac crest in the ventral direction which distances the origin and approach of the intrinsic lumbar musculature from each other).
Due to the static alterations described, incorrect pelvic positioning has an impact on the coxofemoral joint connection in the case of a functional 4-curve scoliosis: the hip joint on the thoracic concave side therefore experiences relative abduction, rotation outwards, and extension, while the lower part of the leg from the knee downwards is more likely to rotate inward.
The altered pelvic geometry has an unfavorable impact on the symmetry of the anatomic reference points of the lower extremities.
For functional 4-curve scoliosis, Lehnert-Schroth (1981) established a typical asymmetry in the position of the anterior superior iliac spines (ASIS). On the thoracic concave side, the anterior iliac spines stand in a ventrocaudal relation to the thoracic convex side. The anterior iliac spines on the thoracic convex side stand in more of a dorsocranial relation.
With functional 4-curve curvatures, it is usually a case of lumbar or thoracolumbar scoliosis, and these are sometimes larger and stiffer than the thoracic equalization curvatures. With this curvature pattern we may see a decompensation of the trunk toward the thoracic concave side, hip prominence on the thoracic convex side, and an increased strain on the leg on the thoracic concave side.

Typical Features of the 4CL Pattern

The 4CL pattern (functional 4-curve, lumbar or functional 4-curve with singular lumbar curvature, see Fig. 6.15) is characterized by the existence of a lumbar major curvature with the appropriate cranial and caudal equalization curvatures. A lumbosacral countercurve can be identified radiologically via the wedge-shaped intervertebral spaces L4-S1. The thoracic secondary curvature is only slightly visible and the cervicothoracic equalization curvature usually is not visible with this pattern. This pattern is normally decompensated in the lumbar convex region (weak side). One can identify the typical hip prominence on the parcel side, which is an approach for the correction maneuver.

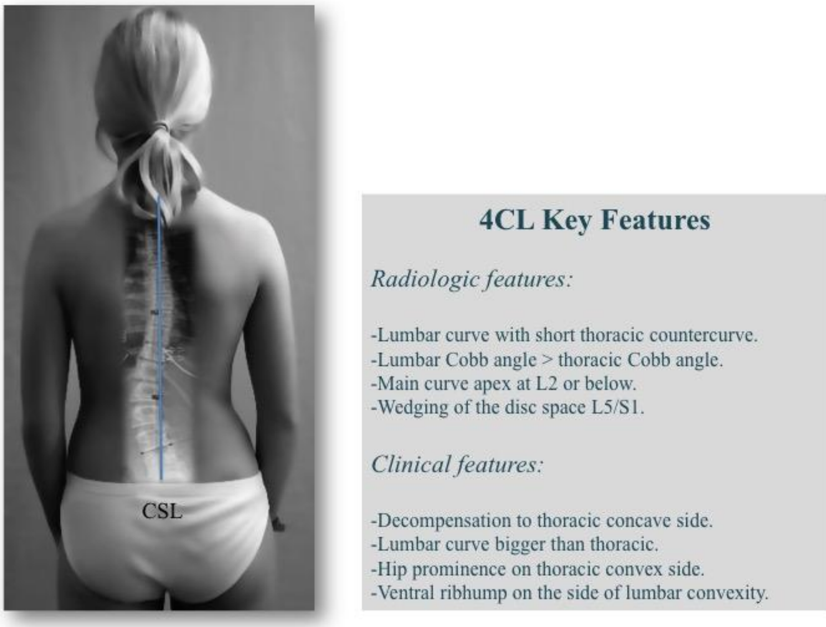


Fig. 6.15. *The key features of the pattern 4CL.*

Typical Features of the 4CTL Pattern

The pattern 4CTL (functional 4-curve, thoracolumbar, see Fig. 6.16) or functional 4-curve with singular thoracolumbar curvature is characterized by a thoracolumbar major curvature with the according cranial and caudal equalization curvatures. With the 4CTL pattern, the apical vertebra usually is L1. In rare cases (Fig. 6.20) the apex can also lie with T12/L1. An apical vertebra at T12 would be reason to opt for pattern 3CTL (compare Fig. 6.12). A lumbosacral counter-curve is by definition detectable radiologically, due to the wedge-shaped intervertebral spaces L4-S1. The thoracic secondary curvature is only slightly visible and the cervicothoracic equalization curvature usually is not visible with this pattern. This pattern is decompensated in the lumbar region (to the weak side). One can see the typical hip prominence on the parcel side, which is an approach for the correction maneuver.

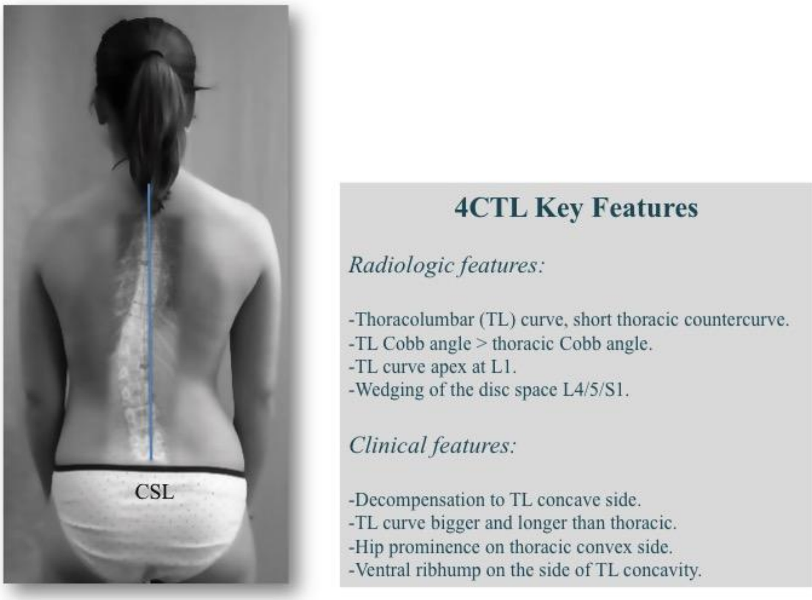


Fig. 6.16. *The key features of the pattern 4CTL.*

There are more patterns of curvature than have been presented. Some of them appear so infrequently that they cannot be treated systematically, but must be approached individually. However, double thoracic curve patterns are common and should be mentioned as a special case. Double thoracic curves can be classified either as a functional 3-curve or a functional 4-curve, and can appear along with all functional 3-curve patterns, more rarely with the 4C pattern.

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7. THE SCHROTH BEST PRACTICE® PROGRAM

In 2006, after the completion of the second edition of the German precursor of this book, the first edition of the book "Best Practice" in Conservative Scoliosis Care was published by Pflaum Press as well. The fourth edition of the German precursor of this book became available in 2012 and contains a brief description of the program detailed here, which meanwhile has been elaborated further (Weiss 2012).

The Schroth Best Practice® program has been under development since 2004, and its individual components have been undergoing scientific testing since 2006 (Weiss and Klein 2006; Weiss, Hollaender and Klein 2006). In the process, it has been determined that the sagittal configuration must be improved to optimize the results of the traditional Schroth method of treatment. Furthermore, a prospective and controlled study showed that scoliosis rehabilitation can occur over shorter periods with these updated techniques, with particular consideration given to everyday activities (Weiss, Hollaender and Klein 2006).

The developments following these new insights are now the foundation of the efficient and effective short-term rehabilitation programs which are also offered on an out-patient basis in China, Denmark, Indonesia, Ukraine and the USA, as well as in Barbados. These approaches already have undergone scientific evaluation (Weiss and Seibel 2010; Borysov and Borysov 2012; Pugacheva 2012; Lee 2014). In bracing, and via rehabilitation through optimal educational programs, practitioners instruct patients seeking ways to minimize the extent to which quality of life for those with scoliosis is compromised.

Currently, out-patient concepts of rehabilitation have similar results to in-patient intensive rehabilitation (SIR), at least in terms of the surgical incidence (Maruyama 2003; Weiss, Reiter and Rigo 2003). The results of in-patient intensive rehabilitation are based on collectives of patients treated for six-week intervals from the 1980s to the beginning of the 1990s (Weiss, Weiss and Petermann 2003).

At this stage, there are no results for the recent significantly modified contemporary concepts of in-patient scoliosis rehabilitation with reduced rehabilitation time (Yilmaz and Kozikoglu 2010). Consequently, the step to short-term out-patient rehabilitation is justified.

The Schroth Best Practice Program® contains the following components:

- The physio-logic® program for correction of the sagittal profile
- Education related to everyday activities (ADLs)
- The program "3D made easy"
- The new "Power Schroth" program
- The rehabilitation of walk
- Neuromobilisation

Use of the treatment techniques mentioned are described below.

7.1 The physio-logic® Program

Several authors have concluded that thoracic flatback can promote thoracic idiopathic scoliosis (Deacon and Flood 1984; Tomaschewski 1987; Weiss and Lauf 1995; Burwell et al. 2003; Raso 2000) (Fig. 7.1-7.2), as Farkas did in 1925. If the rotation and the lateral deviation of the spine are secondary characteristic patterns of idiopathic scoliosis, then it should be possible to correct or improve the three-dimensional deformity of scoliosis solely through the application of sagittal movements of force.

Flatback is a larger problem, at least with brace provision for patients with idiopathic scoliosis. Articles have been published showing that flatback can actually be increased by certain bracing concepts. For example, pressure zones for correcting the sagittal profile are not found on either the Boston brace or the Charleston bending brace, nor on most other types of braces. It was not until the original Chêneau brace that pressure zones for the correction of a thoracic hypokyphosis were introduced (Weiss and Moramarco 2013). Until now, therapeutic treatment programs have primarily focused on the frontal plane deformity (Klapp 1907; von Niederhöffer 1942; Ocarzuk 1994); few programs set the correction of the spinal rotation as a target (Klisic and Nikolic 1985; Mollon and Rodot 1986; Rigo et al. 1991; Lehnert-Schroth 2007). The sagittal profile has been of less interest in physiotherapeutic approaches (Tomaschewski 1987; 1992; Weiss and Moramarco 2013). Prior to 1992, Antonio Negrini pointed out that the sagittal profile should be restored using correctional exercises (Negrini 1992). In some exercise programs, flatback is of central importance; however, no favorable results were achieved with general kyphosing exercises (Ducongé 1992). All patients treated via a program that "hyperkyphosized" the entire trunk (global kyphosis) experienced a worsening of their condition within a year of dedicated treatment. Due to this latter study, it can be concluded that it is not sensible to mobilize the spine in the direction of a global kyphosis. With the Schroth program, one tries to restore the thoracic kyphosis using a special breathing technique, in conjunction with special exercises that have a thoracic kyphosis-inducing effect.

There is evidence indicating that the corrective forces operating in the sagittal plane can also correct scoliotic deformity in the transverse and frontal planes (Weiss 2004; 2005; Weiss, Dallmayer & Gallo 2006; van Loon et al. 2008). An experimental study with the goal of using surface measurement to document the short-term corrective effect of two different braces showed that sagittal corrective forces can lead to similar short-term corrections as those from the three-dimensional correctional forces that operate with the Chêneau brace (Weiss et al. 2006).

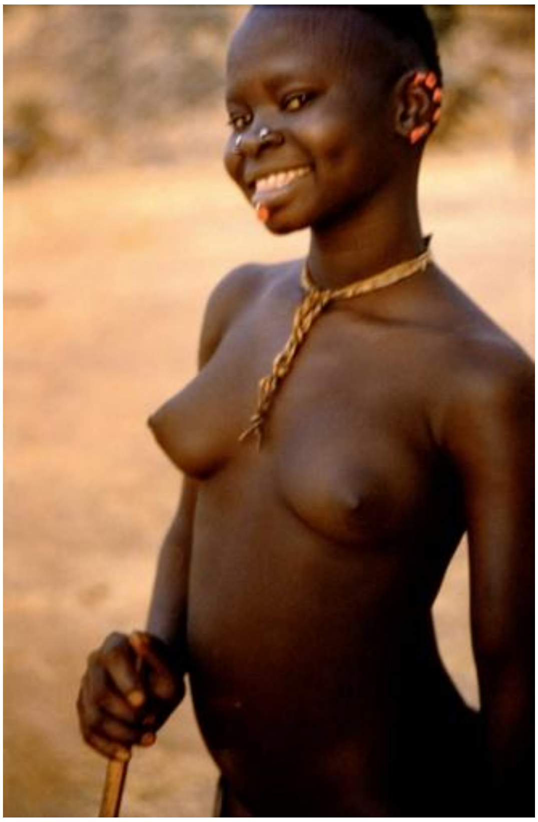

Fig. 7.1. *With 'primitive' people, a "forward placement" of the trunk can often be observed and for this reason be seen as natural and "sensible" (Photo © LRP, published in Weiss HR, Weiss G. Physiologic balance® - the simple and relaxed way to a healthy back. Pflaum, Munich, 2013). This trunk attitude, with an increased lumbar lordosis, leads to a lateral stabilization, which can also straighten out spinal distortions (Weiss 2004; 2005; Weiss et al. 2006; van Loon et al. 2008).*

Fig. 7.2. *Left: From the service pages of our newspaper (Public Gazette Nr. 182 - 8.8.2009): "Sticking-out stomach and hanging shoulders: droopy posture (left) isn't attractive. Someone who carries themselves properly (middle left) automatically makes a better impression." The posture on the far left is certainly not desirable! The "upright posture" shown looks more like the woman has swallowed a metal pole. In our opinion, the two women on the right make the best impression (middle right, optimal natural posture and far right an eight-year-old with her natural, strong posture).*

If the Lehnert-Schroth three-dimensional scoliosis treatment can achieve long-term changes for a scoliosis patient (Lehnert-Schroth 2007), then the results of the aforementioned study indicate that the quality of physiotherapeutic scoliosis rehabilitation can be improved through adding increased corrections in the sagittal plane. Working with this foundation, a new exercise program with the aim of restoring a physiological sagittal profile (Weiss & Klein 2006; Fig. 7.3-7.4) has been developed. These exercises all have the same basic principles, namely, strengthening and improving the lordosis at the level of L1/2, as well as strengthening and improving the thoracic kyphosis in the mid-thoracic region (Fig. 7.1 and 7.2, Fig. 7.5).

These exercises are the physio-logic® exercises. The results achieved in a controlled study matched with age, sex, pattern of curvature, and Cobb angle concur with the hypothesis that through the application of physio-logic® exercises, one can improve the treatment results of the Schroth program (Weiss and Klein 2006).

There are indications that the preservation of the lumbar lordosis in adulthood is of paramount importance. Glassman et al. (2005) discovered that the sagittal profile has a decisive influence on the stability of a scoliosis. Weiss (2004; 2005; Weiss et al. 2006) and van Loon et al. (2008) have shown that restoration of the lumbar lordosis leads to correction of the spinal curvature in patients with scoliosis in frontal plane as well. Taking this into account, it is now scientifically accepted that the "re-lordosation" of the lumbar spine is important for the correction of scoliosis and its stabilization.

Description of the physio-logic® exercise program

The physio-logic® exercise program consists of the following:

- symmetric mobilization exercises for improving the lordosis with a target course of L1/2 and mobilizing the kyphosis of the lower thoracic spine
- education regarding the physio-logic® approach for everyday activities and
- training of these correcting movements also in locomotion.

The symmetric mobilization exercises are done repeatedly. These exercises can only be performed with the help of passive resistance or with the help of postural reflexes. With the physio-logic® exercises, the focus is on increasing the lumbar lordosis while simultaneously channeling force into the kyphosis of the lower thoracic spine. When standing, the lumbar lordosis can be increased by tilting the pelvis. This starting position improves the kyphosis of the thoracic spine reflectively, a correction maneuver that is desirable with idiopathic thoracic scoliosis. However, the aim of this exercise is not to increase the lumbar lordosis at the L5/S1 level, because this leads to increased stress in the lumbosacral hinge. Instead, the lordosis should have its apex at the level of L2 or higher at the intervertebral disc level L1/L2. This can be ensured if both lower costal arches are brought forward (Weiss and Klein 2006). When performed optimally, a trunk position that is corrected in this way requires no noticeable muscular tension (Fig. 7.3).

Fig. 7.3. *When tensing the stomach muscles in an upright standing position, the upper trunk and shoulders automatically move forward (left). In order to remain upright, the shoulders must be held back actively (middle). This causes constant tightness, painful tension and decreased blood circulation. If one brings the front costal arches further forward (see Fig. 7.1; this figure on the right), the hollow curve in the upper lumbar region is increased, the upper body can balance itself better, the shoulders slide more loosely backwards, and the muscular tension needed to stand upright is barely noticeable.*

For the asymmetric three-dimensional correction of posture, we take the Schroth exercises and modify them according to the principles of the physio-logic® program. Tilting the pelvis and ventralization of the lower costal arch replace the first and second pelvic corrections from the original Schroth program.

Everyday activities (ADL training) are of the utmost importance to effect change in the habitual posture. For this reason, the physio-logic® everyday training program is carried out in a standing position while sitting and while walking as well (Fig. 7.4-7.6). In addition, patients also learn the catwalk, which contains the basic principles of the physio-logic® program just as the ‘NUBA’ posture (Fig. 7.1) does as a starting point. This position descended from the physiological posture of members from a North African tribe that live in a natural manner. Further exercises from the physio-logic® program are represented in Fig. 7.7, Fig. 7.8, and Fig. 7.9.

Fig. 7.4. *In order to learn the moves, the posture correction is exaggerated. Since it is usually a lifestyle with too much sitting that must be compensated for, the upper lumbar spine must become accustomed to the possibility of correction. Contractions must be eliminated so that the function can be restored.*

Fig. 7.5. *Everyday posture from the physio-logic® program in standing and seated positions.*

Fig 7.6. *As part of the physio-logic® program, the catwalk leads to a re-lordosis of the upper lumbar spine and to a re-kyphosis in the chest region. While walking, the lower costal arches should seesaw forward. In daily life, this exercise can be carried out very inconspicuously. Ideally, the physio-logic® program exercises should all be carried out with the trunk leaning slightly forward. The catwalk physio-logic® has two phases: 1. The unrolling phase (placing of the heel to the placing of the sole). 2. The free leg phase (placing of the toes to the removal of the foot from the ground). With phase 1 (left), the lumbar hollow curve is maximized; with phase 2 (3rd image from the right) it is reduced. Left (1), middle (2), right (1) other leg.*

Fig. 7.7. *The exercise "snake on the ledge" can be carried out either standing (a, b) or sitting (below). With it we achieve passive counter-support of the lumbar lordosis and mobilize the thoracic spine by using kyphosis-inducing synergy effects via pulling the arms downward against the resistance of an elastic band, going into inner rotation/abduction.*

Fig. 7.8. *A passive counter-support of the lumbar spine while simultaneously mobilizing the thoracic spine into the kyphosis. In this exercise, the upper trunk should not be elevated to the extent that the full contact between the lumbar spine and the cushion lying underneath is separated*.

Fig. 7.9. *The "catwalk," used here with a group of patients, takes the physio-logic® principles into consideration.*

7.2 Instruction in Everyday Activities (ADL)

Utilizing Schroth exercises in everyday situations can be a decisive factor in generating motivation, and the exercises are more easily performed than strict exercises with a defined starting position. However, concern is not only with integrating exercises in everyday situations (the muscle cylinder can easily be carried out while cleaning your teeth, see Fig. 7.10), but also so the patient learns positions of rest where the spine can be put in a corrective position to decrease the asymmetric loading on the vertebral bodies and intervertebral discs.
It is usually more comfortable to rest in a curved position as defined by a scoliotic curve. This is, therefore, a hurdle that the patient must overcome. The practitioner shows the patient how to become comfortable in a position that is at least partially corrective for their curvature pattern. Precise instruction is necessary so patients are educated on how to change habits properly.

Fig. 7.10. *A patient brushing her teeth in the morning in the "muscle cylinder" starting position.*

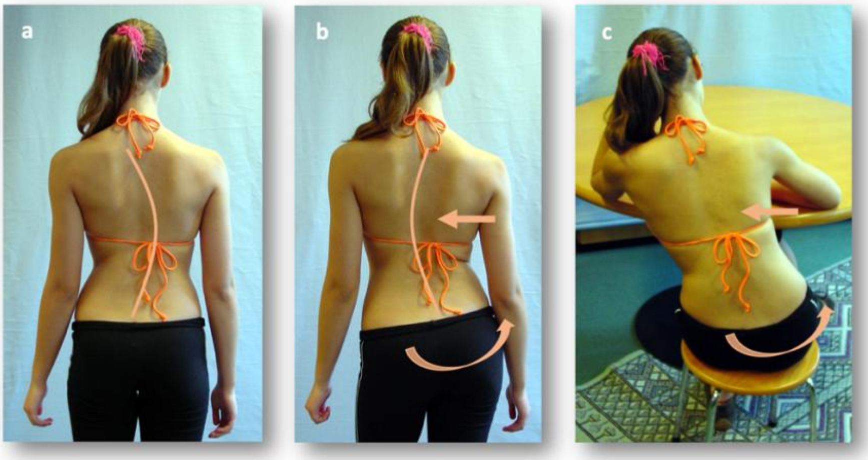

Fig. 7.11. *(a) Patient with scoliosis pattern 3C to the right uncorrected, (b) with load on the right leg tilting the pelvis underneath the ribhump. When sitting (c) the patient should try to support the frontal translation movement shifting the shoulder girdle to the left. In a 3CH pattern the right leg crosses over the left leg in order to reinforce the pelvic tilt.*

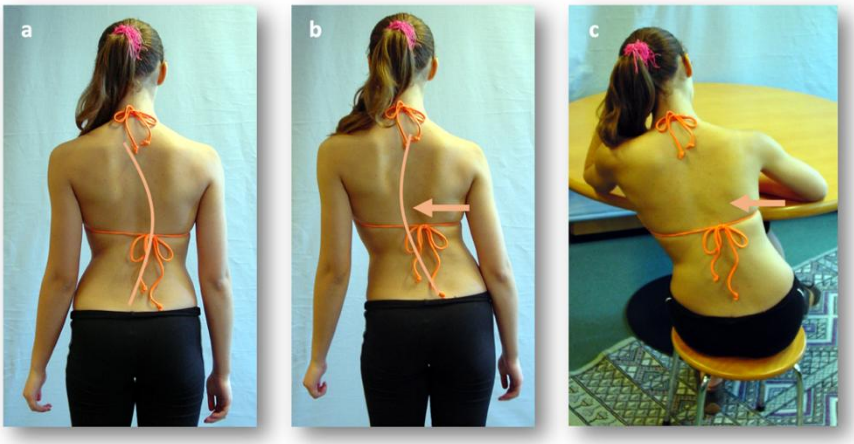

Fig. 7.12. *(a) Patient with scoliosis pattern 3C to the right uncorrected, (b) with load on the left leg shifting the pelvis underneath the ribhump. When sitting (c) the patient should try to support the frontal translation movement shifting the shoulder girdle to the left. In a 3CN pattern the left leg crosses over the right leg or both feet rest on the floor in order to reinforce the pelvic shift and prevent pelvic tilt.*

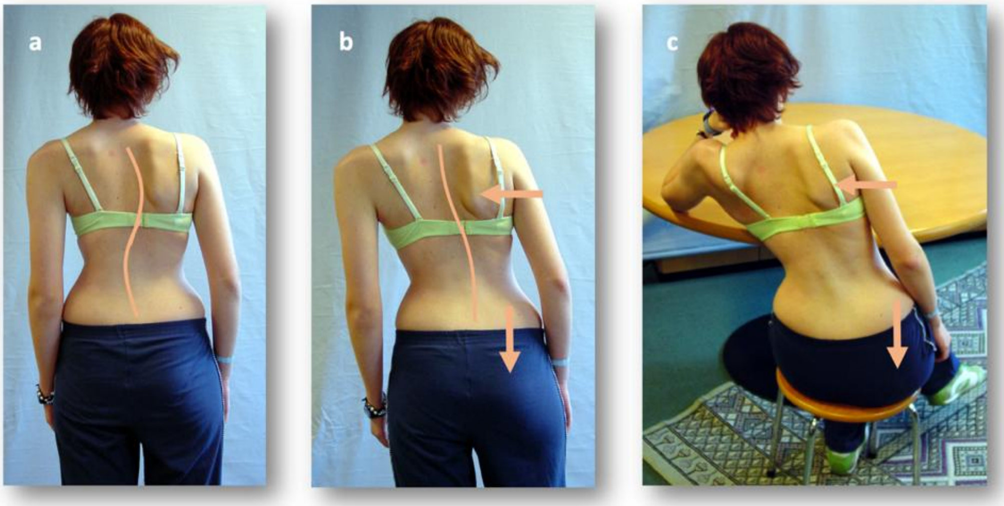

Fig. 7.13. *(a) Patient with curvature pattern 4C right with a double major curve. During everyday activities one must take care to introduce a translation movement to the left (b) which is supported by the shoulder girdle shift to the left. Here, it is important that the right pelvis not be raised, in order to open the lumbar curvature. When seated, the left leg is crossed over to the right leg in order to keep the right pelvis down which keeps the lumbar concavity open (c).*

There seems to be a mechanism according to which a mental engram is developed during the execution of exercises - a process which when carried out in in-patient conditions can be as much as four hours or more each day allowing the patient to experience the corrected posture. However, in some instances this engram seems to be switched off immediately once the exercise period is over, or even eliminated from the patient's awareness. This might be linked to the fact that the scoliosis is internalized as a deforming disease, with negativity, and may cause an individual to subconsciously reject everyday management (ADL). Consequently, it is crucial to integrate exercise and everyday activities during daytime whenever possible. What is the correct relaxed sitting position? What is the correct lying position? How can one best lean against something while standing? These questions can only be answered via analysis of each individual case.

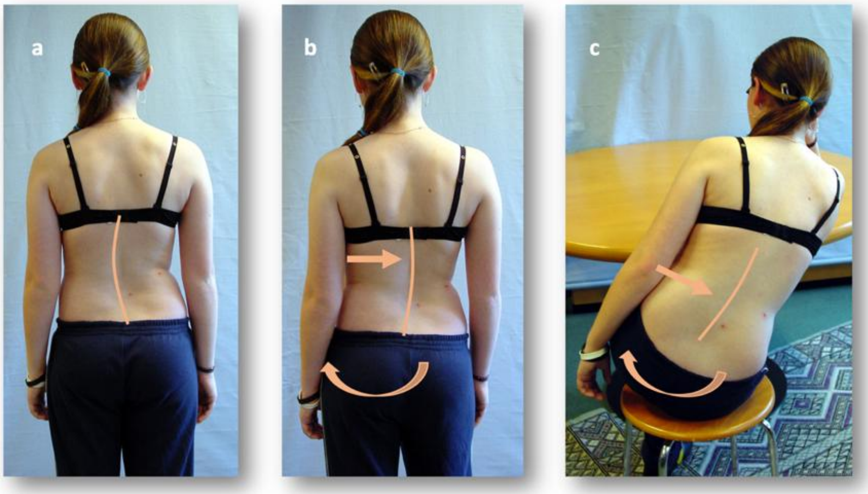

Fig. 7.14. *(a) Patient with functional curvature pattern 4CL with single lumbar curve. In this case, during everyday activity, focus does not need to be on the smaller secondary nonstructural thoracic curvature. The main visible feature is the hip protruding to the right, which can be centered with an appropriate loading on the left leg while standing (b). When sitting, the load should lie in the right lateral gluteal region, which automatically brings the pelvis to the left in the direction of correction, opposing gravity (c).*

With radiological single curve patterns, the approach is simple. The patient must be instructed in postures that open up the major curvature in positions of rest. However, with double curve patterns, both major curvatures must be taken into account with resting positions, which is why a longer training period is necessary for this pattern of curvature. In Figs. 7.11, 7.12, 7.13, and 7.14 the possibilities of correction for the basic patterns of curvature are demonstrated. The instruction concerning everyday rest positions must be considered separately from Schroth thoroughly thought out correction program for the three-dimensional scoliosis treatment. It is not possible to take all functional equalization curvatures into consideration during one of these everyday rest positions. The main aim is to avoid 'hanging' in the major curvature in a way that encourages progression.

The following rules should be considered:

1. Radiologic single curvatures, including thoracic, thoracolumbar, or lumbar:

a) When standing and sitting, leaning should be done principally to the concave side to open up this side.
b) Lying should be on a soft bed on the concave side of the single curvature so that this can droop. When lying in bed, the aim is not to regulate sleeping positions, but rather for the patient to become accustomed to a lying position that can be internalized over time and perhaps be adopted during sleep. This is difficult to accomplish, but worth striving for because even two hours spent reading in bed can have a negative effect when on the wrong side, and a positive effect when on the correct side (Fig. 7.15-7.17).

2. Radiologic double patterns of curvature:

a) When standing and sitting, the patient should lean to the thoracic concave side; a sinking of the thoracic convex side pelvic half should also be achieved when sitting and standing by letting the thoracic concave side leg take on the burden.
b) Lying should be done on a soft bed: for this, no general recommendations can be given since in the case of two opposing major curvatures, one curvature will always be encouraged when lying on soft bedding. One can, however, recommend that with radiologic double curve patterns, hard bedding be chosen since this will at least address the lower-lying curvature.

Fig. 7.15. *Sitting on a stool in a lop-sided fashion. The patient (pattern 3CH, still very flexible) cannot lean to the right into the costal hump without slipping from the stool. Therefore, an automatic correction of the posture is carried out in the frontal plane without previous skills or previous practice.*

Fig. 7.16. *"Wipe your neighbor away from the table!" The patient (pattern 3CH, still very flexible) can completely correct her curvature using this exercise from the ADL program. The right hip can move upwards. The patient therefore crosses her right leg (the leg on the costal hump side) over the left leg. For pattern 4C, the left leg (the leg on the costal cavity side) must be crossed over the right leg in order to prevent the right hip from moving upward. In doing so, an increase of the lumbar countercurve can be prevented.*

Fig. 7.17. *Leaning to the thoracic concave side using the wooden bars. The patient (pattern 3CH, still very flexible) can completely correct her curvature using this exercise from the ADL program. She is making a correction in the sagittal plane that improves the thoracic flat-back (chin out).*

7.3 The Program 3D Made Easy

The program 3D made easy has been derived from everyday activities (ADLs). In principle, every exercise is initially learned in a standing position, but the everyday posture can be strengthened from a seated position as well. Two exercises form the basis: one exercise for the treatment of functional 3-curve scoliosis (thoracic scoliosis, 3CH, 3C, 3CTL) and one for the treatment of functional 4-curve scoliosis (double major, lumbar scoliosis, 4C, 4CL, 4CTL, and the pseudo functional 4- curve scoliosis 3CL).
These exercises are easy to learn (Weiss 2010) and ideally suited for mild curvatures, or in combination with the physio-logic® program. These exercises have been tested in a prospective and controlled fashion in 2006 and were judged relatively time-saving (Weiss, Hollaender and Klein 2006). One 3D made easy exercise, consists of four stages that always proceed in the same order: (1) pelvic corrections in the frontal plane; (2) spiral-form shoulder girdle correction (3D); (3) selective breathing into the weak side, and (4) maximal tensing of the trunk muscles in optimal correction.

Fig. 7.18. *3D made easy for the treatment of curvatures of category 3C (with the exception of 3CL). On the far left we see the clinical image; middle left is the schematic diagram with x-ray; middle right is the pelvis correction with the shifting of the hip under the costal hump and on the right is the pectoral girdle correction with retroversion/adduction of the shoulder blade, which also automatically corrects the sagittal profile. Finally, the patient breathes into the thoracic concavity and the correction result is stabilized with the muscles*.

3D made easy for the treatment of a curvature pattern of category 3C (with the exception of 3CL)

The 3D made easy program for treating 3C pattern curvatures is an exercise for the best possible three-dimensional correction of a functional 3-curve scoliosis (with the exception of 3CL). In Figure 7.18, this exercise is represented for pattern 3CTL - it is carried out in the same way for patterns 3CH and 3C. The treatment of functional 3-curve scoliosis takes place in a step-by-step fashion.
Initially, the hip is shifted under the costal hump by buckling the thoracic concave side leg (1).
Subsequently, the shoulder girdle correction takes place with retroversion/adduction of the shoulder blade of the thoracic convex side; the sagittal profile is also corrected through this process (2).
Through the opening up of the thoracic concave side, which has now been achieved, and through intentional guidance, the breath is directed into the concavity, correcting the ribs (that are rotated ventrally) in a dorsal direction (3). At the end of the correction, the trunk musculature should be tensed completely during the breathing-out phase in order for the tension pattern to be better perceived (4).

3D made easy for the treatment of a curvature pattern of category 4C (including 3CL)

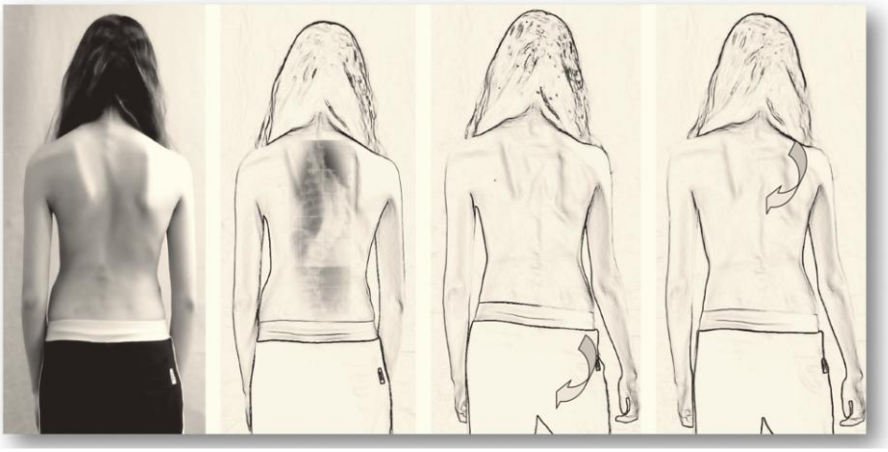

Fig. 7.19. *3D made easy for the treatment of curvatures of category 4C (including 3CL). On the far left we see the clinical image; middle left is the schematic diagram with x-ray; middle right is the pelvis correction with the shifting of the hip under the lumbar bulge and on the right the pectoral girdle correction with retroversion/adduction of the shoulder blade, which also automatically corrects the sagittal profile. Finally, the patient breathes into the thoracic concavity and the correction result is stabilized with the muscles.*

3D made easy for treating 4C pattern curvatures is an exercise for the best possible three-dimensional correction of a functional 4-curve scoliosis (including 3CL). In Fig. 7.19 the exercise is represented for pattern 3CL - it is carried out in the same way for pattern 4C and, if necessary, for patterns 4CL and 4CTL. The treatment of functional 4-curve scoliosis takes place in a step-by-step fashion as well.

Fig. 7.20. *3D made easy for the treatment of curvatures of category 3C (with the exception of 3CL). On the far left we see the clinical image of a patient at rest; middle left is the pelvis correction with shifting of the hip under the costal hump; middle right is the pectoral girdle correction with retroversion/adduction of the shoulder blade, which also automatically results in a correction of the sagittal profile. Finally, the patient breathes into the thoracic concavity and the correction result is stabilized with the muscles (right). Shoulder girdle rotation should be limited to approximately 30°.*
**In this figure, the rotation of the shoulder girdle is clearly exaggerated at 60° and leads to an enhancement of the ventral rib hump on the left side.*

Initially, the hip is shifted under the lumbar bulge by buckling the thoracic convex side leg (1).

Subsequently, the shoulder girdle correction takes place with retroversion/adduction of the shoulder blade of the thoracic convex side; the sagittal profile is also corrected automatically by this process (2).

Through the opening up of the thoracic concave side and through intentional guidance the breath is directed into the concavity, correcting the ribs (that are rotated ventrally) in a dorsal direction (3).

At the end of the correction, the trunk musculature should be tensed in total during the breathing-out phase in order for the tension pattern to be better perceived (4).

Corrections are much harder to achieve with a functional 4-curve pattern of curvature than with a functional 3-curve pattern. The benefits of the compensated functional 4-curve patterns, however, are: They are cosmetically less obvious and are less likely to increase after completion of growth (Asher and Burton 2006). The exercises from this program are effective and assist the patient when incorporating exercises from the Lehnert-Schroth program. These are also ideal “preliminary exercises” for the Schroth program in cases of more severe curvatures. In addition, the fundamental differences between functional 3- and 4-curves in the approach to exercises are demonstrated in the 3D made easy program. The sole difference is the positioning of the pelvis. In the frontal plane, the pelvis is shifted under the costal hump with a functional 3-curve scoliosis (Fig. 7.20) - i.e. to the parcel side - and is shifted to the weak side with a functional 4-curve scoliosis.

This principle is also maintained in the three-dimensional physiotherapy according to Lehnert-Schroth’s method. It has been tailored according to the current state of scientific knowledge, which has made it possible to increase the 3D correction effect further. Hence, this treatment technique is termed “Power Schroth.”

7.4 "Power Schroth" - The Advanced Development of Three-Dimensional Scoliosis Treatment according to Katharina Schroth's Method

The original Schroth program consisted entirely of exercises for the treatment of functional 3-curve scoliosis. It was only in the late 1970s that the functional 4-curve scoliosis was discovered by Lehnert-Schroth, along with the functional leg shortening that accompanies this curvature pattern. Scoliosis was thus classified accordingly, allowing for the most appropriate therapy based on the curve pattern. The Lehnert-Schroth classification (functional 3-curve scoliosis/functional 4-curve scoliosis) was also used by Chêneau in his construction of pattern-specific braces. As noted in the previous chapter, this classification remains in use today. However, the classifications that are widely used today are more precise, but are also more complex, and therefore, more difficult to understand.

In a previous precursor of this book, Schroth exercises for the various patterns of curvature were presented. However, three-dimensional scoliosis treatment according to Katharina Schroth's method is by no means a simple collection of exercises; it is more a principle of treatment. The multitude of exercises presented in Lehnert-Schroth's book was developed in order to provide patients with a certain amount of variation in their exercises during participation in a three to six-month rehabilitation program. This historical meaning is often misunderstood today, which is precisely why a multitude of exercises often obscure the principles behind them.

In this chapter, we therefore focus on the principle of the exercises, rather than presenting a confusing multitude of different exercises for different patterns of curvature, particularly since these exercises are presented in the book, Three-Dimensional Treatment for Scoliosis, from Christa Lehnert-Schroth - a work of great historical significance (2007).

The exercises in the selection described by Lehnert-Schroth can always be used with functional 3-curve or functional 4-curve patterns. It has become standard practice for therapists to perform the majority of the exercises in a lying position while crouching near the patient in attempt to provide corrective assistance. However, this means that in this starting position an important "correction booster" is lacking, namely the use of automatic corrective positioning reflexes. It is precisely these positioning reflexes that are absolutely essential for constructing a corrected sense of posture, because it is only via asymmetric trunk muscle tension that the corrected posture can be perceived. With the patient lying down, the therapist must work laboriously on the asymmetric correction tension, alongside many other elements of the exercises (props, intricacies of the exercise) that demand one's attention. However, in an upright position it happens automatically.

Fig. 7.21. *It has become prevalent to carry out the majority of exercises in a horizontal position. Furthermore, it has become commonplace to employ more and more aids during the exercises. Stools, rolling devices, cushions, and elastic bands are used for the exercises, which only removes the patient further from everyday activities. This tendency is not a positive practice, particularly since flatback is actually worsened in this position.*

It has become typical to use many aids in the exercises (Fig. 7.21). Stools, rolling devices, cushions, elastic bands, and many other objects are used, even though they neglect to take the importance of everyday activities into account. The exercises have tended to become more acrobatic and about themselves, resulting in an exercise with no significant engram processed for application in everyday life. Therefore, nothing is applied which can contribute to the correction or relief of the distorted spine during daily activities. Of significant importance is a simplification of the exercises to focus the patient's attention on the sense of posture, and also to make the exercises more relevant to everyday activities. The goal is to influence the patient's everyday activities via beneficial movements and exercises, since with only twenty minutes per day of exercises, one cannot make a significant impression on the prognosis of scoliosis.

Therefore, it is necessary to concentrate on only five important exercises in the program, along with simple tactile stimulation reminders which a practitioner can use effectively to help the patient facilitate the execution of the exercise. When utilizing these simple techniques, the patient need only recall the therapeutic reminders to be able to trigger the optimal attitude for the exercise automatically and without “wooden hip bars” [Hüftholz], or other aids which are not readily available at any place. Since these aids were not available at the beginning of the development of this method, it is justified in seeing this approach to the exercises as “Ur-Schroth” - as the original approach to the treatment.

Finally, the most recent insights regarding the extremity-induced synergism should be recognized: when both arms are brought into an elevated position, this leads to an anti-kyphotic synergy in the thoracic spine. If both arms are placed into retroversion (and additionally, also into inner rotation and abduction), then a kyphosis-inducing synergy in the region of the thoracic spine is achieved. However, if the arm on the parcel side is brought into an elevated position and the arm on the weak side is brought into retroversion, then one achieves an anti-kyphosis-inducing effect on the parcel side and a kyphosis-inducing effect on the weak side that specifically and selectively counteracts the thoracic concave side flatback - generally desired with idiopathic scoliosis. We call this *'Extremity Induced Postural Response'* (EIPR).

The position of the arms when using the “Power Schroth” treatment is herewith clearly defined. A deviation is allowed with the rare kyphoscoliosis.

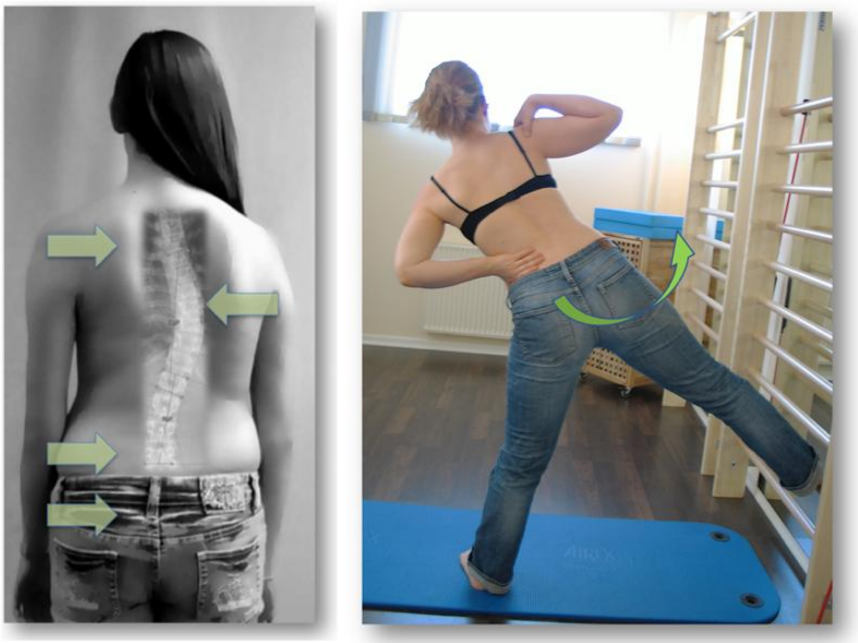

Fig. 7.22. *Muscle cylinder being executed - functional 3-curve with pelvis position either straight or tilted underneath the parcel.*

The Musclecylinder

The Musclecylinder can be carried out on the knees - as we described in the German precursor of this book - on the side, or in a standing position. We have chosen the last of these positions here, since this is probably the

most effective and, at the same time, the most pleasant starting position for the execution of this exercise, which, with an upright starting position, is highly laborious.
This exercise addresses the autochthonous back musculature unilaterally: in the lumbar region it addresses the intrinsically lumbar part that is characterized by an oblique orientation from the pelvis up to the transverse processes. As a result, a de-rotation of the lumbar concave side transverse processes (which are twisted in a ventral direction) occurs, while simultaneously erecting the lumbar curvature. In the thoracic spinal region, the autochthonous back musculature pulls in more of a longitudinal direction and is able to erect the thoracic convex side and simultaneously de-rotate the ribhump. For this reason, the muscle cylinder is equally suited to functional 3- and functional 4-curve patterns (Figs. 7.22-7.23).

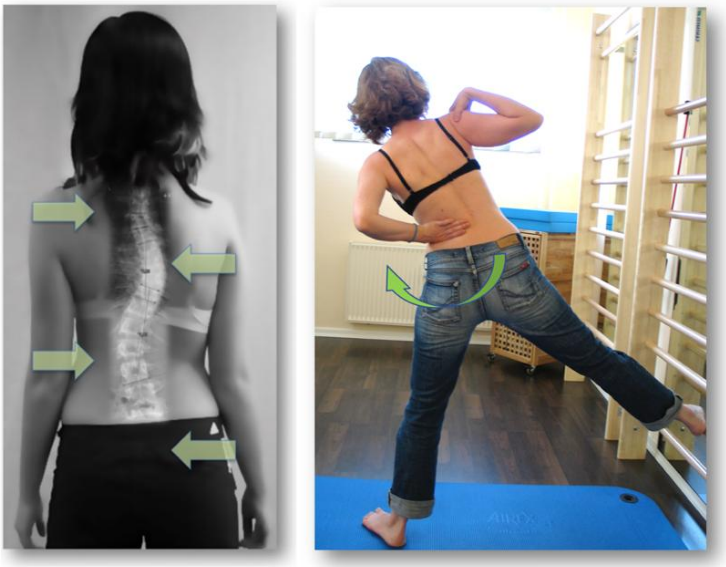

Fig. 7.23. *Muscle cylinder being executed - functional 4-curve with pelvis position either straight or tilted underneath the weak side. The last-mentioned execution is, however, very difficult and is not possible with all patients. However, with a straight pelvis position, this exercise is ideal for both patterns.*

<u>Starting position:</u>

The leg on the thoracic convex side lies stretched out on its side, on a support of some kind (stool, wooden gymnastic bars). The upper body is lowered to the thoracic concave side, as an extension of this leg. The deflection of the thoracic convexity is led through the "shoulder countertension[1] on the thoracic convex side. Simultaneously, the thoracic concavity can additionally be opened up via a concave side shoulder tension, obliquely, out of the concavity, and in the case of flatback, out of the inner rotation position of the thoracic concave-side arm.
The starting position is completed with a physiological sagittal positioning with tilted pelvis and ventralization of the costal arches (see also physiologic® program).

<u>Active corrections:</u>

Prior to executing the standing muscle cylinder, a pre-correction of the deformity in the thoracic and lumbar region must be established. In the case of thoracic major curvatures, a clinical overcorrection of the curvature of the thoracic spine via an increase of the concave side shoulder tension should occur. With pronounced lumbar curvatures, the pelvis should be lowered on the thoracic convex side via a forefoot push with the thoracic convex side leg (to create the desired lordosis rather than the heel push used earlier), thereby opening up the lumbar curvature. However, the thoracic correction should not disappear in the process.

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[1] *"Shoulder counter-tension" and "shoulder tension" describe the efforts of the patient to push strongly outwards with the shoulders in the frontal plane. The shoulder countertension takes place on the thoracic convex side and is the cranial resistance against the costal hump correction in the frontal plane. In contrast, the shoulder tension helps to open up the thoracic concave side and thus leads the thoracic shift to the thoracic concave side.*

The rotational breathing technique:

The Schroth rotational breathing technique enables further improvement of the corrections, as well as the approach to one's posture. The patient breathes in, selectively, into the thoracic concave side (weak side) in a lateral/dorsal direction and the ribs that are oriented ventrally are de-rotated dorsally; this correction is, if possible, increased with every inhalation. Skilled patients can selectively effect a correction of the thoracic concave side (weak side) or the lumbar concave side (weak spot), or both areas simultaneously.

Stabilization:

After using the rotational breathing technique in the inhalation phase, in every subsequent exhalation the trunk musculature is tensed as much as possible with an optimal overall correction. In this way, depending on the condition of the patient, the inhalation correction from the rotational breathing and the tension during exhalation can be repeated many times. It is, however, required that the patient be able to keep up the fundamental correction.

The 50x Exercise

Katharina Schroth's original 50x exercise is described in various ways in the literature. Initially, it was meant to be executed in a cross-legged position with corrections during inhalation with the task being to pull oneself upwards on the wooden wall bars during the exhalation phase. However, the crosslegged position leads to a kyphosis in the lumbar region and therefore contradicts current knowledge since the sagittal profile must also be taken into consideration during treatment. For this reason, one needs a higher sitting position. This can be achieved by sitting on an exercise ball or appropriate stool. This allows a slight lordotic positioning of the lumbar spine (Figs. 7.24-7.25).

Fig. 7.24. *50x exercise being executed - functional 3-curve with pelvis position straight or tilted under to the parcel side. In the middle, the execution for an anti-kyphotic kyphoscoliosis; on the right, the execution for idiopathic scoliosis with thoracic flatback.*

Starting position:

The patient sits on the exercise ball in a frontal position, in front of the wooden wall bars; the thighs are abducted and rotated outwards to create a stable starting position. The starting position is actually oriented towards the frame of the wooden wall bars on the thoracic convex side (parcel side), to allow the trunk for a lateral shift to the weak side.

If the exercise is performed on a stable stool in patients with pattern 4C, the leg of the thoracic convex side can be guided backwards laterally besides the stool until the thigh of this leg points vertically downwards. This derotates the thoracic convex side pelvic half ventrally and caudalizes it.

Fig. 7.25. *50x exercise being executed - functional 4-curve with pelvis position tilted under to the weak side. In the middle, the execution for an anti-kyphotic kyphoscoliosis; on the right, the execution for idiopathic scoliosis with thoracic flatback.*

The hand on the parcel side grabs hold of a bar at eye level, one hand width medial of the frame; the hand on the weak side grabs hold of a bar at waist level, one hand width medial of the frame. Both elbows are bent so that the upper arms are oriented as parallel to the plane of the bars as possible in the frontal plane. Via the orientation of the starting position near the frame of the wall bar on the thoracic convex side (parcel side) and by the exercise direction to the frame of the wall bar of the thoracic concave side, the patient must perform an oblique pull to the thoracic concave side (weak side), thus opening up the weak side.

In the case of functional 3-curve scoliosis, the pelvis, on the weak side, is allowed to roll a little on the ball towards the thoracic convex side (parcel side); in the case of functional 3-curve scoliosis with structural lumbar countercurve, a neutral pelvic position is favored. In the case of functional 4-curve scoliosis, the pelvis remains horizontal on the ball and the half of the pelvis on the parcel side is lowered as much as possible.

Active corrections:

Prior to executing the the 50x exercise, a pre-correction of the deformity in the thoracic and lumbar region must be established. In the case of thoracic major curvatures, a clinical overcorrection of the curvature of the thoracic spine via an increase of the concave side shoulder tension and shift should occur. With pronounced lumbar curvatures, the pelvis should be lowered on the thoracic convex side, thereby opening up the lumbar curvature. However, the thoracic correction should not disappear in the process.

Rotational breathing:

The rotational breathing technique enables further improvement of the corrections as well as the approach to one's posture. One breathes in, selectively, into the thoracic concave side (weak side) in a dorsal direction and the ribs that are oriented ventrally are de-rotated dorsally; this correction is, if possible, increased with every inhalation. Skilled patients can selectively induce a correction of the thoracic concave side (weak side) or the lumbar concave side (weak spot), or both areas simultaneously.

Stabilization:

After using the rotational breathing technique in the inhalation phase, in every subsequent exhalation the trunk musculature is tensed as much as possible with an optimal overall correction. In this way, depending on the condition of the patient, the inhalation correction from the rotational breathing and the tension during exhalation can be repeated many times. It is, however, required that the patient be able to keep up the fundamental correction.
In addition, in the case of thoracic flatback, one of two things can be performed: either the arm on the weak side is pressed inwards against the bar during the exhalation phase, or the elbow on the weak side is held firmly against resistance provided by the therapist (later also against virtual resistance).

The door handle exercise

Just like the 50x exercise, the original exercise is described with a deep sitting starting position. However, the cross-legged position leads to a kyphosis in the lumbar region and therefore contradicts current knowledge, which says that the sagittal profile must also be taken into consideration during treatment. For this reason, one needs a somewhat higher sitting position, e.g. by sitting on an exercise ball. In addition, this allows a slight lordotic positioning of the lumbar spine (Figs. 7.26-7.27). In the original version of the exercise, the patient was meant to pull upwards using the arm on the weak side - which is rotated outward - but this clearly favors flatback. For this reason, this exercise is still used in its original version with kyphoscoliosis.

Starting position:

The patient sits on the exercise ball in front of the wooden wall bars; the thighs are abducted and rotated outwards in order to create a stable starting position - the thoracic concave side is turned laterally toward the wooden wall bars.

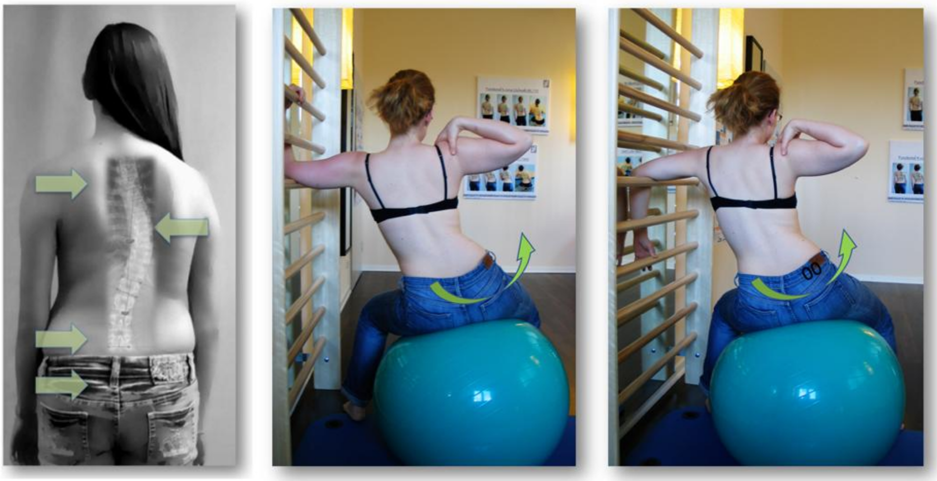

Fig. 7.26. *The new door handle exercise being executed - functional 3-curve with pelvis position straight or tilted under the parcel. In the middle, the execution for a kyphoscoliosis; on the right, the execution for idiopathic scoliosis with thoracic flatback.*

The hand on the parcel side grabs hold of the shoulder on the parcel side for shoulder counter-traction; the upper arm is positioned to act as an extension of the shoulder girdle plane; the hand on the weak side grabs the bar at waist level through the gap between the bars at shoulder level. Both elbows are bent so that the upper arms are oriented as vertically as possible to the wall bar in the frontal plane.
Due to the starting position being at a distance from the wall bars, an oblique tension is applied to the thoracic concave side (weak side) and thus, the weak side is opened up. In the case of functional 3-curve scoliosis, the pelvis on the weak side is lowered slightly on the exercise ball toward the wall bars; in the case of functional 3-curve scoliosis with structural lumbar countercurve, a neutral pelvic position is favored. In the case of functional

4-curve scoliosis, the pelvis remains horizontal on the ball and the half of the pelvis on the parcel side is lowered as much as possible.

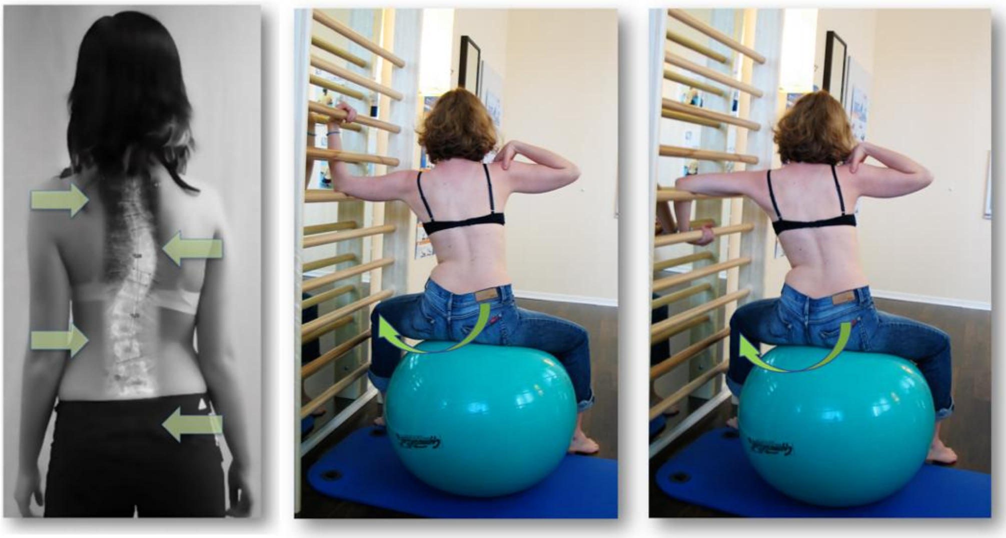

Fig. 7.27. *The new door handle exercise being executed - functional 4-curve with pelvis position tilted under the weak side. This is achieved through caudalization of the thoracic convex side half of the pelvis. In the middle, the execution for a kyphoscoliosis; on the right, the execution for idiopathic scoliosis with thoracic flatback.*

Active corrections:

Prior to executing the door handle exercise, a pre-correction of the deformity in the thoracic and lumbar region must be established. In the case of thoracic major curvatures, a clinical overcorrection of the curvature of the thoracic spine via an increase of the concave side shoulder tension should occur. With pronounced lumbar curvatures, the pelvis should be lowered on the thoracic convex side. However, the thoracic correction should not disappear in the process.

Schroth rotational breathing:

The rotational breathing technique enables further improvement of the corrections as well as the approach to the patient’s posture. One breathes in, selectively, into the thoracic concave side (weak side) in a dorsal direction and the ribs that are oriented ventrally are de-rotated dorsally; this correction is, if possible, increased with every inhalation. Skilled patients can selectively induce a correction of the thoracic concave side (weak side) or the lumbar concave side (weak spot), or both areas simultaneously.

Stabilization:

After using the rotational breathing technique in the inhalation phase, in every subsequent exhalation the trunk musculature is tensed as much as possible with an optimal overall correction. In this way, depending on the condition of the patient, the inhalation correction from the rotational breathing and the tension during exhalation can be repeated many times. The patient is required to keep up the fundamental correction.
In addition, in the case of thoracic flatback, the exercise can be performed one of two ways: either the arm on the weak side is pressed inward against the bar during the exhalation phase, or with the patient grasping the wall with his/her hand, on the weak side, squeezing firmly while maintaining a stationary position and pulling back with the hand during the exhalation phase.

The frog at the pond

The muscle cylinder can be carried out at home without any aids; the 50x exercise and the new door handle exercise can be carried out using a doorframe or chair. However, achieving the motivation to carry out these exercises without the wooden wall bars is not easy. Therefore, a new exercise has been developed which is designed to have the same effect, and can be performed at home without any aids. This "Power Schroth" exercise, called the frog at the pond, satisfies these demands (Figs. 7.28-7.29).

Starting position:

The patient sits back on their heels with their legs folded under them, on soft padding with the knees hip-width apart. The hand on the weak side is positioned next to the knee on the weak side with a straightened elbow with the same spacing as the distance between the knees. The hand on the parcel side grabs hold of the same shoulder, on the parcel side, to provide shoulder counter-tension, with the upper-arm positioned so as to be an extension of the shoulder girdle axis.

Active corrections:

Prior to executing the frog at the pond, a pre-correction of the deformity in the thoracic and lumbar region must be established. The goal is to achieve a reduction of the flatback by a retroversion of the arm on the weak side against resistance from the floor (kyphosis-inducing synergy). We refer to this mechanism of action as *'Extremity Induced Postural Response'* (EIPR).

In the case of pronounced lumbar curvatures (functional 4-curve), the pelvis should be lowered on the thoracic convex side, which opens up the lumbar curvature. This is encouraged through the starting position, in which the pelvis is fixed parallel to the floor (Fig. 7.29). However, in doing so, the shift movement to the thoracic concave side becomes more difficult. With functional 3-curve scoliosis, one can try to position the pelvis on the weak side next to the lower leg, which will open up a decompensated single thoracic curvature (Fig. 7.28).

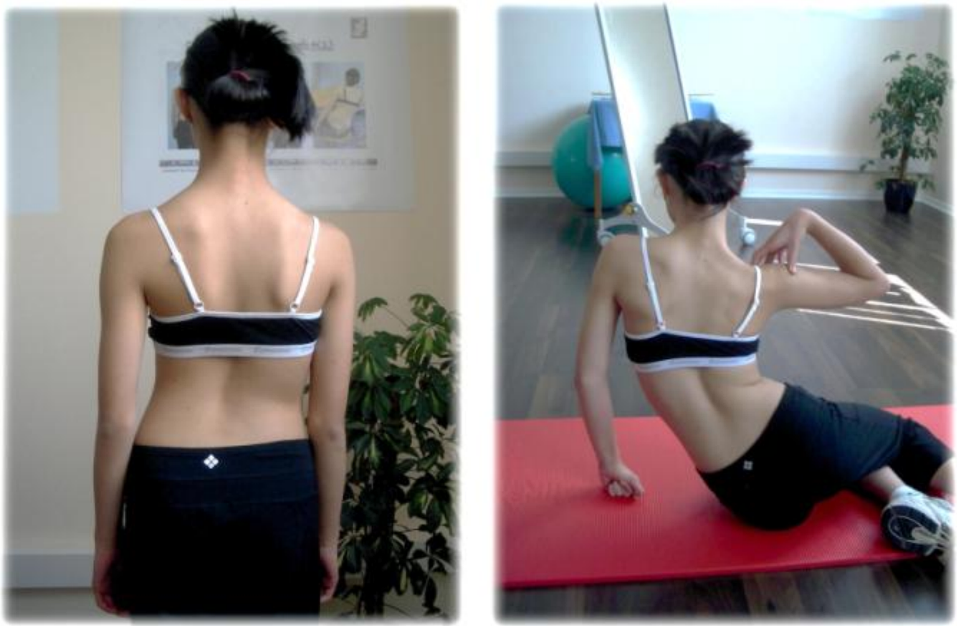

Fig. 7.28. *The "frog at the pond" exercise being executed - functional 3-curve with pelvis position tilted under the parcel (sitting, with legs folded back, heels folded back next to the body). The patient has a thoracic curvature of 43°, however, since she is only twelve years old, she is still very flexible. This exercise is for the patterns 3CH and 3CTL, only! All other patterns (including 3CN) with some lumbar counter curve should execute this exercise like shown on Fig. 7.29.*

Fig. 7.29. *The "frog at the pond" exercise being executed - functional 4-curve with horizontally stabilized pelvis position (legs folded under the buttocks, sitting on the heels). In this way, the right half of the pelvis is prevented from coming free, which protects the lumbar correction. The nearly fifteen-year-old patient is classified as 3CL with a stiff thoracic curvature with a 50° Cobb angle.*

Schroth rotational breathing:

The rotational breathing technique enables further improvement of the corrections as well as the approach to the patient's posture. One breathes in, selectively, into the thoracic concave side (weak side) in a dorsal direction and the ribs that are oriented ventrally are de-rotated dorsally; this correction is, if possible, increased with every inhalation. Skilled patients can selectively induce a correction of the thoracic concave side (weak side) or the lumbar concave side (weak spot), or both areas simultaneously.

Stabilization:

After using the rotational breathing technique in the inhalation phase, in every subsequent exhalation the trunk musculature is tensed as much as possible with an optimal overall correction. In this way, depending on the condition of the patient, the inhalation correction from the rotational breathing and the tension during exhalation can be repeated many times. However, the patient is required to keep up the fundamental correction.

Depending on the patient, during the exhalation phase the arm on the weak side can be tensed against resistance from the floor in a ventral lateral or ventral medial direction; however, with thoracic flatback the resistance should be pushed against in a dorsal direction.

Raising the Pelvis

Raising the pelvis is an original exercise derived from Christa Lehnert-Schroth's collection. It is actually more energy-draining than specific. However, it is presented here to satisfy patients who desire additional intensity.
This exercise can be tailored specifically for functional 3- or functional 4-curve scoliosis, if the patient's strength is sufficient. The fundamental principle of Schroth exercise execution, the inhalation with correction of the concavities and the trunk muscle tension during exhalation phase, are all employed.
It is quite an achievement to use the exercise nonspecifically for the correction of a thoracic curvature. With functional 3-curve execution, the top leg is bent slightly, and the pelvis is lifted slightly through the abduction of the lower leg. In the functional 4-curve execution, the bottom leg is bent and the upper leg is straightened in order to open up the lumbar curvature; the pelvis is raised through the adduction of the upper lying leg (Figs. 7.30-7.31).

Starting position:

The patient lies on their side on soft padding, propped up on their elbow on the weak side. The hand on the weak side is resting on the floor as far as possible in a caudal direction in order to achieve an inward twisting of the arm on the weak side (kyphotic synergy against the concave side flatback; EIPR). The hand on the parcel side grabs hold of the shoulder on the parcel side to create shoulder counter-tension, with the upper arm positioned so as to be an extension of the shoulder girdle axis.

Active corrections:

Prior to executing the raising the pelvis exercise, a pre-correction of the deformity in the thoracic and lumbar region must be established, as explained above. With the functional 3-curve execution, the top leg is slightly bent, the bottom leg is straightened, with the pelvis raised during the exhalation phase through the abduction of the lower leg. With the functional 4-curve execution, the bottom leg is bent and the top leg is straightened to open up the lumbar curvature. The pelvis is then raised during the exhalation phase through an adduction of the top leg with the help of an abduction of the lower leg (without the knee making contact with the floor).

Fig. 7.30. *Raising the pelvis exercise being executed - functional 3-curve. With the execution of this exercise, the leg lying on top is slightly bent and the pelvis is lifted over the abduction of the leg lying underneath.*

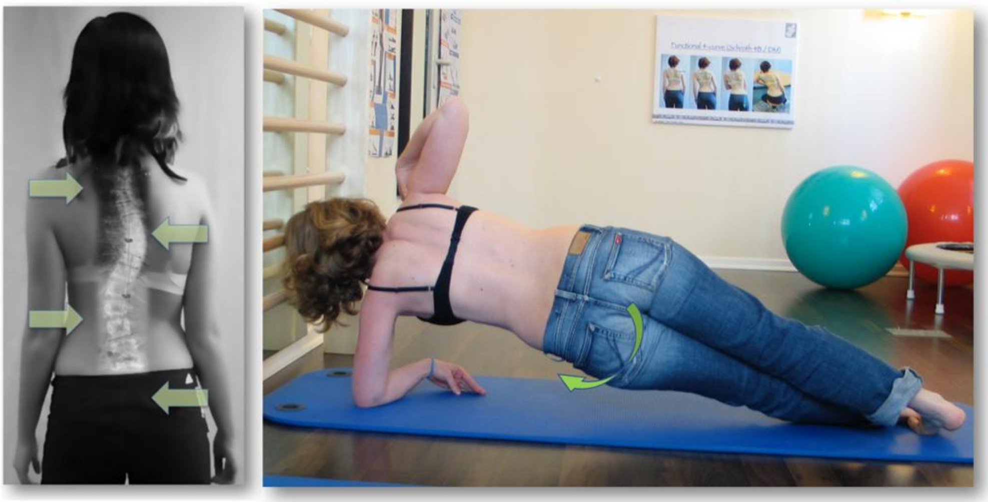

Fig. 7.31. *Raising the pelvis exercise being executed - functional 4-curve. With the execution of this exercise, the leg lying on the bottom is slightly bent and the pelvis is lifted over the adduction of the leg lying above. In doing so, the lumbar curvature opens up (see text).*

Schroth rotational breathing:

The rotational breathing technique enables further improvement of the corrections as well as the approach to the patient's posture. One breathes in, selectively, into the thoracic concave side (weak side) in a dorsal direction and the ribs that are oriented ventrally are de-rotated dorsally; this correction is, if possible, increased with every inhalation. Skilled patients can selectively induce a correction of the thoracic concave side (weak side) or the lumbar concave side (weak spot), or both areas simultaneously.

In the exhalation phase, the pelvis is raised and maintained for as long as possible for additional phases of the rotational breathing.

Stabilization:

After using the rotational breathing technique in the inhalation phase, in every subsequent exhalation the trunk musculature is tensed as much as possible with an optimal overall correction. If possible, a reduction of the flatback is achieved through retroversion of the arm on the weak side against resistance from the floor (kyphosis-inducing synergy). Depending on the condition of the patient, the inhalation correction from the rotational breathing and the tension during exhalation can be repeated many times. However, the patient is required to keep up the fundamental correction.

Correction strengtheners

Correction strengtheners are tactile stimuli or resistances that are specifically applied by qualified practitioners. A correction strengthener can be, for example, the tactile stimulation of the weak side, if necessary, the weak point as well, in order to guide inhaled air into the hollow trunk area. Bridging stimuli are applied making it easier for the patient to intuitively comprehend the opening character of the corrective movement. Along with tactile stimuli, which are intended to promote the expansion of the concave trunk areas, there are also resistances against the corrective movement from the shoulder and pelvic girdle. These resistances are applied in the exhalation phase after rotational breathing has been executed.

Correction strengthener at the elbow on the weak side:

During the 50x exercise, in the exhalation phase and with optimal alignment of the shoulder girdle with the upper arms, positioned in one line, a resistance is applied at the elbow on the weak side against the shoulder girdle shift to the thoracic concave side. This correction strengthener leads directly to increased tension of the thoracic convex side autochthonous back musculature. Practitioners must be careful not to apply or remove the resistances too abruptly and that the resistance is not so strong that the desired correction is lost.

Correction strengthener at the shoulder blade on the parcel side:

For correction of thoracic curvatures, the shoulder blade on the parcel side plays a key role. Through resistance against the adduction/retroversion movement of the shoulder blade from the practitioner's thumb, the complex correction movement of the shoulder girdle is learned easily. Additionally, a feeling for posture and correction for everyday corrections with this pattern of curvature can be acquired quickly.
Initially, the thumb serves as a reference point for the shoulder blade. The adduction/retroversion movement is carried out as far as possible. With larger curvatures, initially this may seem insufficient; however, it's important to note that these curvatures can be very rigid. On the other hand, mild curvatures may be overcorrected using this maneuver and sometimes even without any additional corrections.
After the end-range position of the shoulder blade correction, the practitioner applies maximum resistance with their thumb allowing the patient to experience the tension/activation pattern necessary for the correction, and instructs the patient how to incorporate this maneuver into everyday activities.
This correction aid is used as a point of reference for facilitating the exercises from the 3D made easy program during the instruction phase. With the patterns 4C and 3CL, a counter-shift from the shoulder and pelvic girdle is desired. To facilitate this correction maneuver with these patterns, the focus is on the adduction correction of the shoulder blade to decrease the retroversion component.

Correction strengthener at the iliac crest on the weak side:

For correction of a lumbar curvature, the dorsal iliac crest on the weak side plays a key role. Through resistance applied cranially of the spina iliaca posterior superior on the weak side against the dorsal positioning and the "cranialization" of this half of the pelvis by the practitioner's hand, the complex correction movement of the pelvic girdle can be learned easily. Additionally, a feeling for posture and correction for everyday corrections with functional 4-curve patterns of curvature can be acquired quickly.
We want to achieve a static overcorrection of the prominent pelvis, a "relordosation" and a simultaneous de-rotation of the lumbar bulge. The correction isn't always easy to achieve using this grasp; sometimes many post-corrections are necessary, perhaps because the pelvic position is less clearly determined in a person's posture engram.

The three most important correction strengtheners can be seen in Fig. 7.32.

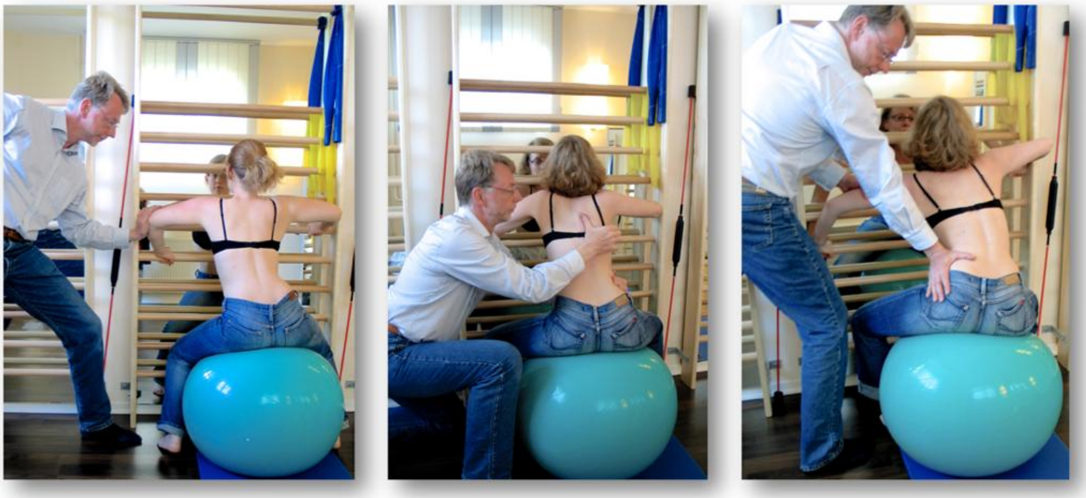

Fig. 7.32. *Representation of the three most important correction boosters. Even after a brief period of learning, an engram for the correction value evolves and one only needs to remind the patient without any given resistance once that the appropriate resistances have been set priorily and a clear increase in correction will be observed. This effect is called the "virtual therapist." On the left, the correction booster at the elbow joint on the weak side for the correction of thoracic curvatures. In the middle, the correction booster at the shoulder blade of the parcel side for the correction of thoracic curvatures. On the right, the correction booster at the iliac crest on the weak side for the correction of lumbar curvature.*

Peculiarities of functional 4-curve correction mechanisms

According to the clinical findings, with a functional 4-curve pattern, the hip on the parcel side protrudes. Logically, according to the original correction principles, this hip should be shifted medially. This is also possible with the simple functional 4-curve patterns 4CL and 4CTL, particularly since these patterns will present with a prominent hip as the major cosmetic feature. Interference of the pelvis corrections with the thoracic countercurve is minimal and, in fact, insignificant.

With patterns 4C and 3CL, we are concerned with a double curvature and both elements must be corrected. If one curvature is corrected too much, then the other curvature will be increased. Due to this challenge, some practitioners give in when using the intermediate Schroth program (Bad Sobernheim / Barcelona School) and accept a style of exercise that is more compensatory in nature and therefore, less effective. However, for this pattern of curvature, new and far more effective correction principles have been developed thanks to corrections occurring during Chêneau-brace treatment, as documented radiologically.

In the past, during brace treatment of pattern 4C, focus was only on recompensating the shoulder and pelvic girdle, and a very respectable and compensated clinical pattern of correction resulted. The cranial flank of the thoracic curvature and the caudal flank of the lumbar curvature became well erected, but tilted positioning of the neutral vertebra was always observed in the transition zone between the two curvatures, resulting in a Cobb angle that was still not corrected sufficiently.

The only solution in this case is a trunk shift to the weak side with a simultaneous caudal positioning of the parcel side hip in order to open up the lumbar curve (Fig. 7.33). Relatively speaking, the parcel side hip still protrudes here, but the corrections that are achieved are excellent for this curve pattern.

Fig. 7.33. *Patient with the curvature pattern 4C, on the left in neutral position and on the right in the 50x exercise from the "New Power Schroth" program. One sees that it was possible to mirror not only the thoracic curvature, but also the lumbar major curvature in the exercise. Through the strong 'shift' to the thoracic concave side, the patient appears 'askew' in the exercise. (With kind permission of Maksym Borysov, Kharkiv, Ukraine).*

Fig. 7.34. *If you turn the image of the patient (from Fig. 7.33) in the 50x exercise on its side, the scale of the correction achieved becomes clearly visible. Both curvatures are clinically over-corrected. (With kind permission of Maksym Borysov, Kharkiv, Ukraine).*

Therefore, with both curve patterns, the maximum possible shift to the weak side must be attempted. However, one exception when considering treatment of functional 3-curve and functional 4-curve scoliosis is the position of the pelvis. With functional 3-curve scoliosis, the pelvis may be tilted cranially on the parcel side. With functional 4-curve scoliosis (4C, 3CL, and with holistic treatment of the patterns 4CL and 4CTL including the thoracic correction in the early phase during the major growth spurt), the pelvis must be oriented caudally on the parcel side in order to open up the lumbar curvature. This is seen clearly when the exercise image in Figure is tipped (Fig. 7.34). Further examples of exercises for functional 3- and functional 4-curve scoliosis can be seen in Figs. 7.35-7.40.

Fig. 7.35. *A 12-year-old patient with a thoracic curvature of 43° Cobb angle; on the left, in a position of rest and on the right executing the 50x exercise - functional 3-curve. With this curvature pattern, the hip should be brought under the costal hump during the exercise. Since the patient is still young, the curvature is still relatively flexible and can thus be corrected well using this exercise.*

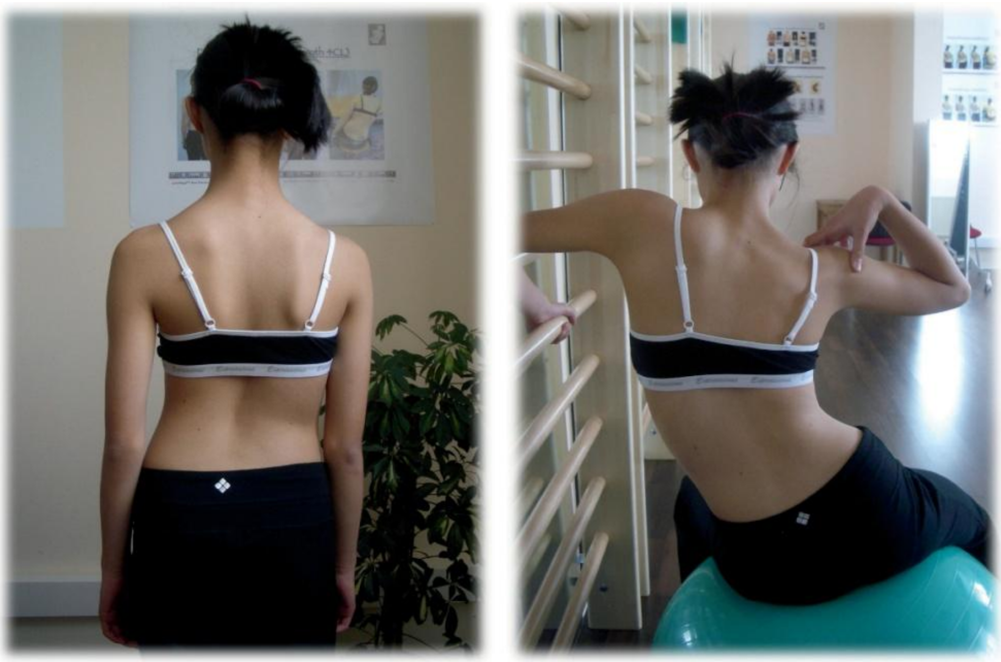

Fig. 7.36. *A patient executing the door handle exercise.*

Fig. 7.37. *A patient executing the muscle cylinder exercise. A correction of the sagittal profile is evident.*

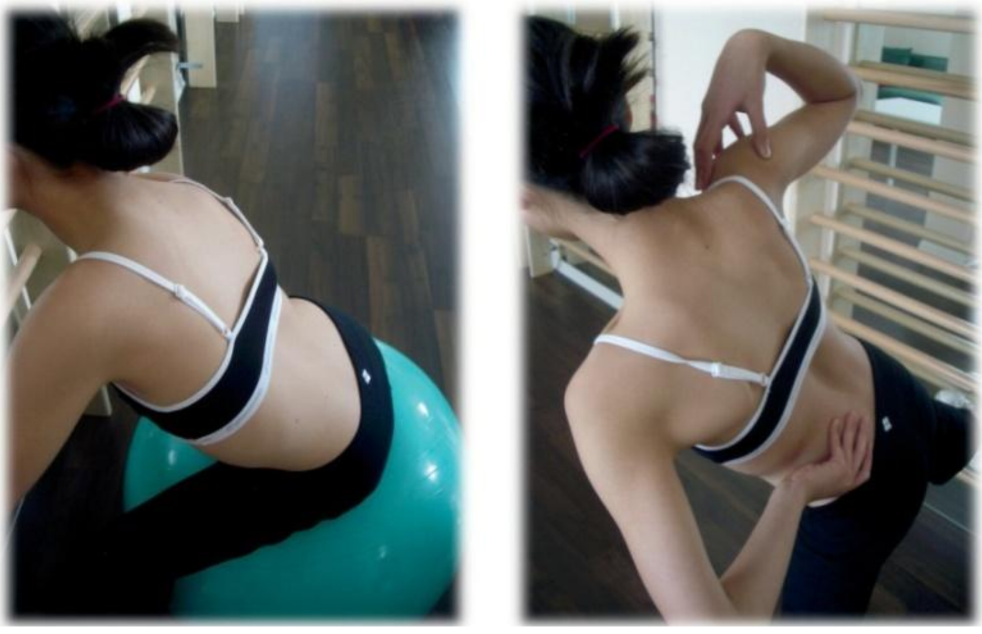

Fig. 7.38. *A patient during exercises from the "New Power Schroth" program. In these images a good correction of the sagittal profile with a re-lordosis in the lumbar region and a re-kyphosis in the thoracic region is evident.*

Fig. 7.39. *This patient has a stiff thoracic curvature of 53°, pattern 3CL, initially treated as functional 4-curve. During the door handle exercise only a small re-compensation to the left, to the thoracic concave side, is initially possible. The thigh on the thoracic convex side (parcel side) is lowered laterally to the caudal fixture of the pelvis and the foot is pushed in a dorsal direction and thus pushes the right, pushed-back half of the pelvis forward.*

Fig. 7.40. *The patient from Fig. 7.39 executing the muscle cylinder exercise. One can see an excellent correction of the trunk, although the position of the cervical spine is not yet optimal. Using an optimally practiced trunk position, this will eventually be improved. Ideally, the head position should be in line with the cervical spine which should align with the thoracic and lumbar spine. After proper execution of the trunk corrections now head alignment can be improved further*.

7.5 Rehabilitation of Walk

It is important to address walking, one of the most common everyday activities. The catwalk has been described previously. So, our focus will turn to education for rehabilitation of walk.

As a basic symmetric pattern for correcting scoliosis in the sagittal plane, the catwalk can be expanded through asymmetric movements for 3D correction. 3D made easy is the basis for 3D correction while walking. As a result, we have now elevated 3D correction to a higher psychomotor level.

When executed optimally, rhythmically, and in a relaxed fashion, the catwalk can be used for locomotion, symmetrically, in various ways to facilitate 3D correction:

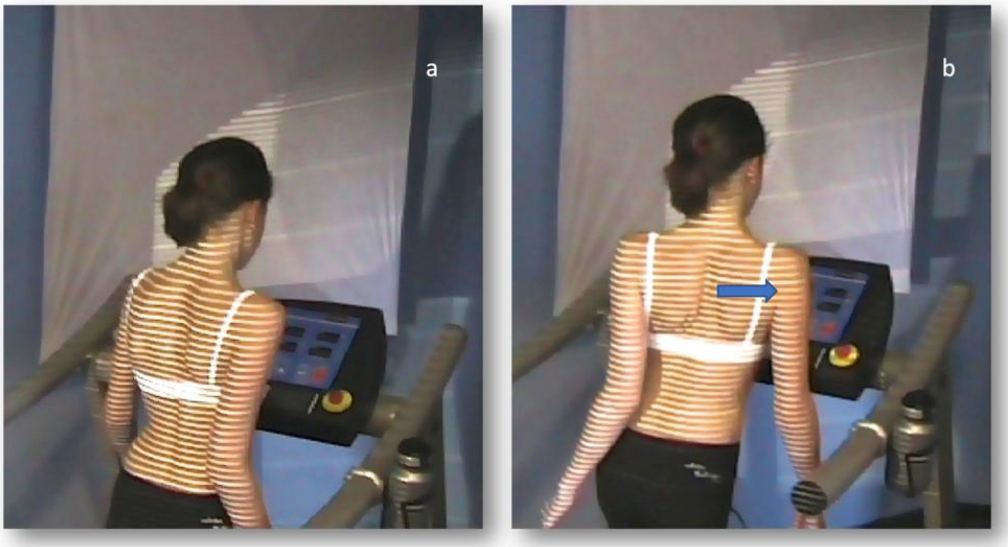

Fig. 7.41. *Correction on the treadmill using simultaneous 3D analysis with the Formetric® walking analysis. The patient has a left thoracic curvature of the 4C pattern (a) and, during the load-bearing phase on the leg on the parcel side shifts her pectoral girdle correspondingly in a rhythmic fashion over to the weak side, e.g. in this case to the right (b). In addition, the clear scapula adduction on the thoracic convex side (left side in this case) can be recognized as a visible feature of a (partial) three-dimensional correction of the main thoracic curvature.*

1. With patterns 3C, 3CH, and 3CTL, through an increase of the shoulder girdle rotation into the correction in accordance with the shoulder blade pattern described in the previous section: during the load-bearing phase of the leg on the parcel side, the patient shifts their shoulder girdle rhythmically from the parcel side to the weak side and simultaneously directs the parcel side shoulder blade in a caudal and medial direction.
2. With patterns 4CL and 4CTL, through an increase in the lateral pelvic tilt to the weak side: during the load-bearing phase of the leg on the weak side, the patient shifts - or oscillates - their shoulder girdle rhythmically, also to the weak side.
3. With patterns 4C and 3CL, through an increase in the lateral shift from the shoulder and pelvic girdles against each other (Fig. 7.41): during the load-bearing phase of the leg on the parcel side, the patient shifts their shoulder girdle to the weak side. The correction maneuvers described are to be rhythmically accentuated, increased and exaggerated, in accordance with the sequence of the steps. After, a correction that was conspicuous during exercise can then be downgraded in everyday situations. The best way to instruct the patient in 3D walking is on a treadmill; however, it is possible to teach this technique in a span of approximately thirty feet, but this requires slightly more effort on the part of the practitioner.
4. In addition to the pure shift of the individual torso sections against each other in the frontal plane, as described above, the shoulder girdle correction from the 3D-made-easy program can also be applied. This leads to a three-dimensional curvature correction for all curvatures with a main thoracic curvature (3CH, 3CTL, 3CN, 3CL, 4C), as described above. With every 2nd step, this correction movement is practiced and accentuated in execution (Fig. 7.41a-b).

7.6 Short-term Rehabilitation

There is now a record of short-term out-patient rehabilitation with children and adolescents. Training courses concerning posture can be carried out effectively in a matter of days. Patients learn how they can avoid everyday behaviors that promote their curvatures in scoliosis-specific back schools. In contrast, there is a lack of scientific results for the extended in-patient rehabilitation the way it is currently executed (Yilmaz and Kozikoglu 2010), meaning that improvement in the functional abilities of scoliosis patients has not been proven after the current available in-patient program. When the patient training is carried out in a standardized way, quality of results is consistent and reproducible objectives are attainable.

Moreover, the target for scoliosis treatment is clearly defined in Schroth Best Practice methodology: it is for the development of a sense of posture and movement that allows the patient to avoid behavior that encourages an increased curvature. Therefore, focus shifts from the execution of a multitude of exercises, with instantaneous correction, to a methodology promoting objectives which include a sustainable educational result.

The group dynamic during in-patient rehabilitation may undoubtedly have a positive effect on patients' motivation. Patients are visibly happy to meet others experiencing similar circumstances. However, this social bonus is more about a shared experience rather than the individual attainment of specific abilities and skills. According to in-patient experiences, this means that for camaraderie, in-patient rehabilitation is highly valued, but over time it is questionable that the educational objectives are able to be summoned upon demand, in the long-term. This is likely due to the "schooling" concept that is currently used in in-patient rehabilitation and its fixed teacher-pupil setting which may simply lead to short-term memorization. Certainly, the most motivated patients do learn from this didactic approach and are able to retain the concepts on a long-term basis, but others may experience difficulty. Furthermore, the first treatment week of in-patient rehabilitation consists of extensive theoretical content (anatomy, physiology etc.) rather than practical executions. This has little to do with improving the motivation necessary to help most patients accomplish their goals. In contrast, short-term out-patient rehabilitation has been modified, so the patient begins to learn exercise movements almost immediately. In the newest teaching approach, the didactic concepts have been abandoned and replaced with self-discovery, or experiential learning. The foremost reason for this is that when patients are taught to discover the needed concepts on their own, and develop their own sense of body awareness, they are more likely to retain those concepts over the long-term (Weiss 2012).

In the U.S., Moramarco's scoliosis-specific back school follows Schroth Best Practice, and patient instruction is often on a one-to-one basis. Some patients prefer the individual attention, time-efficiency, and scheduling flexibility. With individual instruction, what the patient lacks in companionship, they gain in depth and breadth of knowledge for their specific curve pattern and individualized activities. Peer support via referrals is provided for those individuals and families wanting to connect with other patients with similar circumstances.

Obviously, pros and cons exist for group versus individual instruction - from the patient's, and from the practitioner's perspective. Either way, when using Schroth Best Practice, the most important component of a successful out-patient rehabilitation approach is accomplished: experiential learning and the acquisition of the needed concepts to manage one's scoliosis over the long-term.

In fact, this is an additional benefit of short-term out-patient therapy - it allows for either group or individualized training and offers each patient the option for that flexibility based on learning style. The individual practitioner can decide which method suits his/her style and which method suits each particular patient best. Whichever approach is utilized, the patient can be sure that experiential learning and self-discovery will be an integral part of their short-term rehabilitation program and that the foundational concepts of focus will be:

- standardized learning content (for high process quality);
- the most modern pedagogical approaches;
- modern evidence-based rehabilitation methods (with established results).

The possible structure of the short rehabilitation program is outlined in the following section. Specific content can only be learned in the context of the practitioner training course.

Prior to starting the rehabilitation program, the physician must examine the patient, review x-rays and educate the patient on their scoliosis. It is helpful for the patients to understand their unique three-dimensional deformity prior to beginning the rehabilitation program. As part of the examination, ATR measurement, lung capacity and chest expansion should be assessed. These measurements are simple to perform and allow for progress monitoring without radiation.

Possible structure of a short scoliosis rehabilitation program

Day 1

Module1: Meet-and-greet session, physio-logic® (standing, sitting, walking, catwalk);
Module 2: Self-discovery (experiential) learning: recognition of patterns of curvature;
Module 3: (a) physio-logic®, (b) Verification of patterns of curvature, (c) ADL (standing, sitting, and walking).

Day 2

Module 4: a, b, c, and (d) 3D made easy;
Module 5: Self-sufficient exercise practice (Objective: improved execution of exercises);
Module 6: Self-sufficient exercise practice (Objective: improved execution of exercises) a, b, c, d, and (e) Schroth exercise (50x exercise on ball and door handle exercise). 3D corrections are added and built into the catwalk walking training (a).

Day 3

Module 7: a, b, c, d, e, and (f) Muscle cylinder, the frog at the pond;
Module 8: Complete program with all exercises (self-sufficient improved execution of exercises);
Module 9: Practical test of the entire program (60 min.), optional written test (30 min.).

The individual modules last 90 - 120 min. The sequence of the contents must be adhered to for unified quality standards and results.
The short rehabilitation program (Weiss 2010; Borysov and Borysov 2012; Pugacheva 2012; Lee 2014) is not only geared toward treatment of children and adolescents, but also for adults who want to learn an effective scoliosis management program. Patients with severe secondary functional impairments (vital capacity, chronic pains) should seek individualized out-patient instruction by an experienced practitioner or look for in-patient treatment.
In addition to individual 'one to one' treatments, the training centers of the Schroth Best Practice Academy also offer group treatments, as well as short-term rehabilitation, which can sometimes be extended to five days if a brace is being adjusted at the same time.

7.7 Physiotherapeutic Treatment of Scoliosis for Children

The findings-specific exercises in the Schroth Best Practice program can be used in a routine fashion with most children. The exercises aim to develop postural awareness and are achieved through treatment protocols which show the patient how to integrate this awareness and new-found knowledge into everyday activities. The goal of scoliosis management is teaching the patient to avoid everyday behaviors which may encourage progression. It is a psychomotor conditioning process that always requires the active collaboration and concentration of the patient, especially initially. Some children under age ten lack necessary cognitive skills and are unable to engage in the active collaborative work to the extent required. Early in the learning process, significant effort is required by the patient since the goal is to find ways to influence the spinal curvature utilizing purely reflex mechanisms. Not all young children have the ability to sustain the necessary effort, so in this case we defer to PEP as described below (Weiss 1993).

Considering the knowledge that favorable posture reactions can be triggered through Feldenkrais exercises (awareness through movement) or the Vojta principles, corrective posture reactions were examined to determine to what extent those reactions can be encouraged in scoliosis patients through intensive facilitation. After investigating and understanding the principles behind these techniques, it became clear that through the starting positions for reflex crawling and reflex turning, the corrective route can sometimes become blocked. The Vojta grip technique was performed in a relaxed belly position allowing a certain corrective movement to be achieved by reflex. So, we had to consider that the human body instinctively tries to remove itself from external pressure as a type of fleeing reflex, and when it is impossible to flee, the body will instinctively put up resistance to this pressure. As a result, the following simple treatment technique has been developed and called periphery evoking postural reaction (PEP).

Fundamental principles of the PEP exercises

The standard way of proceeding, as described below, is that a pressure is built up in the direction of the apical vertebra on the concave side of a curve with both hands placed on the concave side. This pressure is held against the ribcage's breathing expansion for ten to twenty breaths. A flat contact between the hands and the concave side of the trunk deformity is necessary. This pressure is applied in the direction of the spinal distortion.

After ten to twenty breaths, the pressure is slowly released allowing the body to feel the region under pressure being released. In this instance, not only do the automatically correcting position reflexes activate themselves, but the previously pressed and pressurized region of the body triggers body awareness. Exercises, which include the shoulder and pelvic girdle are also possible. These exercises are used according to the pattern of curvature. With a lumbar curvature, the pelvic girdle can be integrated into the exercise; with a thoracic curvature, the shoulder girdle can also be integrated. In a slightly altered form, these exercises can also be integrated into the Schroth exercises to manifest the feeling of posture, and also to improve the breathing direction of the patient while performing the exercises.

Fig. 7.42. *Starting position for the treatment of a thoracic curvature with the PEP program in a lateral position on the costal hump side. The thoracic concave side is facing the therapist. The index finger is pointing to the thoracic apical vertebral region.*

Description of exercises

The PEP program for the thoracic curvature: When performing a PEP exercise for a thoracic curve (1), the patient lies on the thoracic convex side (Fig. 7.42). The practitioner fits the closed fingers of both hands up to the metacarpus bone to the contours of the body on the concave side of the trunk. The contact surfaces of the two hands are initially positioned parallel to the skin with a distance of one or two finger-widths between them (Fig. 7.43a). After, a pressure is applied into the concavities and the hands are brought together under increasing pressure. The pressure is shifted to the radial side of the hands (Fig. 7.43b). The pressure is held for twenty breaths and slowly reduced again with the inhalation phase; then, the hands slide away from each other.

When performing PEP thoracic exercise (2), the principle is initiated from the same starting position. The pisiform bone in the cranially placed hand contacts the acromion and presses the shoulders against the pressure of the caudally placed hand, in a lateral and caudal direction. The caudally placed hand lies as it did in thoracic exercise (1) and executes the same pressure in the same direction (Fig. 7.44a-b).

The PEP program for the lumbar curvature: When performing PEP lumbar exercise (1) the patient lies on the lumbar convex side (Fig. 7.45). The procedure is identical to thoracic exercise (1) in the previous section. The pressure is applied against the lumbar concave side (Fig. 7.46a-b).

When performing PEP lumbar exercise (2) the starting position remains as it was in exercise (1); the hand placed caudally with the pisiform bone contacting the ischial tuberosity and pushes the hip cranially and laterally against the cranially placed hand in the lumbar concavity. The same maneuver with the cranially placed hand is performed as in lumbar exercise (1). The pressure onto the concavities is applied with a slight force vector in a ventral direction and is fitted to the respective torsion behavior of the section of the trunk being treated (Fig. 7.47a-b).

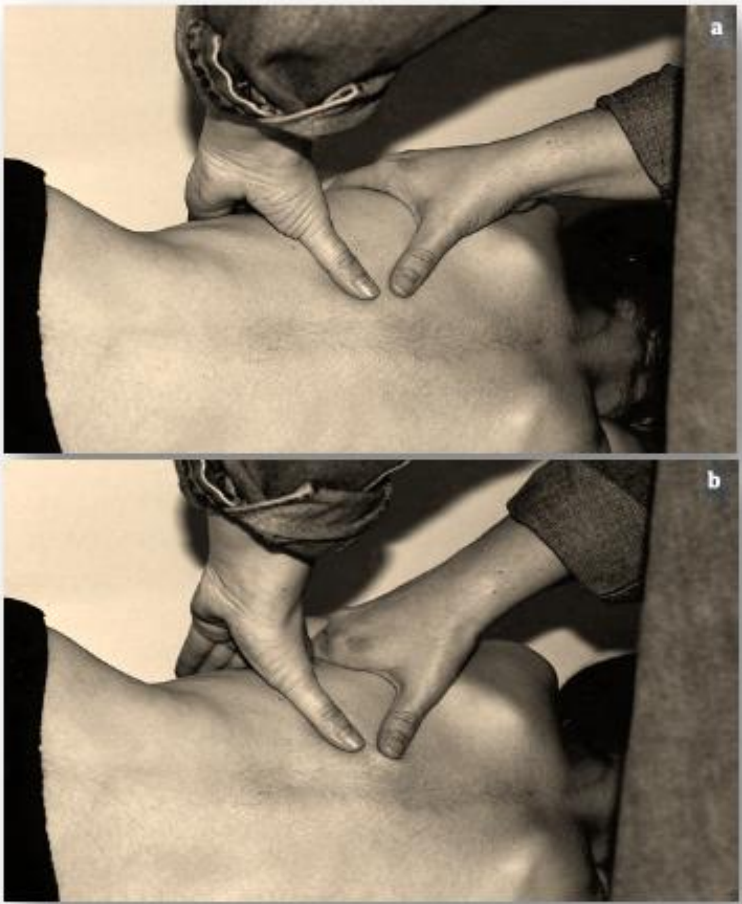

Fig. 7.43. *(a) Two-dimensional alignment of the hands to the thoracic concave side. (b) There should be a small gap between the hands so that they can be brought together with increasing pressure. The pressure is transferred on the radial side of the hands and thus increased in the region of the curvature's apex. This pressure is held for twenty breaths and then slowly reduced with the inhalation phase (PEP exercise 1 thoracic).*

Fig. 7.44. *(a) Grip technique and starting point for PEP exercise 2 for thoracic curvature: the cranial correction hand links up with the pisiform bone on the acromion; the caudal hand does the same as in exercise 1. (b) Bringing together of the hands.*

Fig. 7.45. *Starting position of exercise 1 for a lumbar curvature. The index finger is pointing to the lumbar apical vertebra.*

Fig. 7.46. *(a) Exercise 1 for the lumbar curvature. Similar to PEP exercise 1, this is carried out for thoracic curvatures. The patient lies on the lumbar convex side and pressure is applied to the lumbar concave side. The hands are again applied in a planar fashion and are kept a certain distance apart. (b) Bringing together of the hands with a relocation of the pressure point to the radial side. The direction of the force approaches the apical vertebra.*

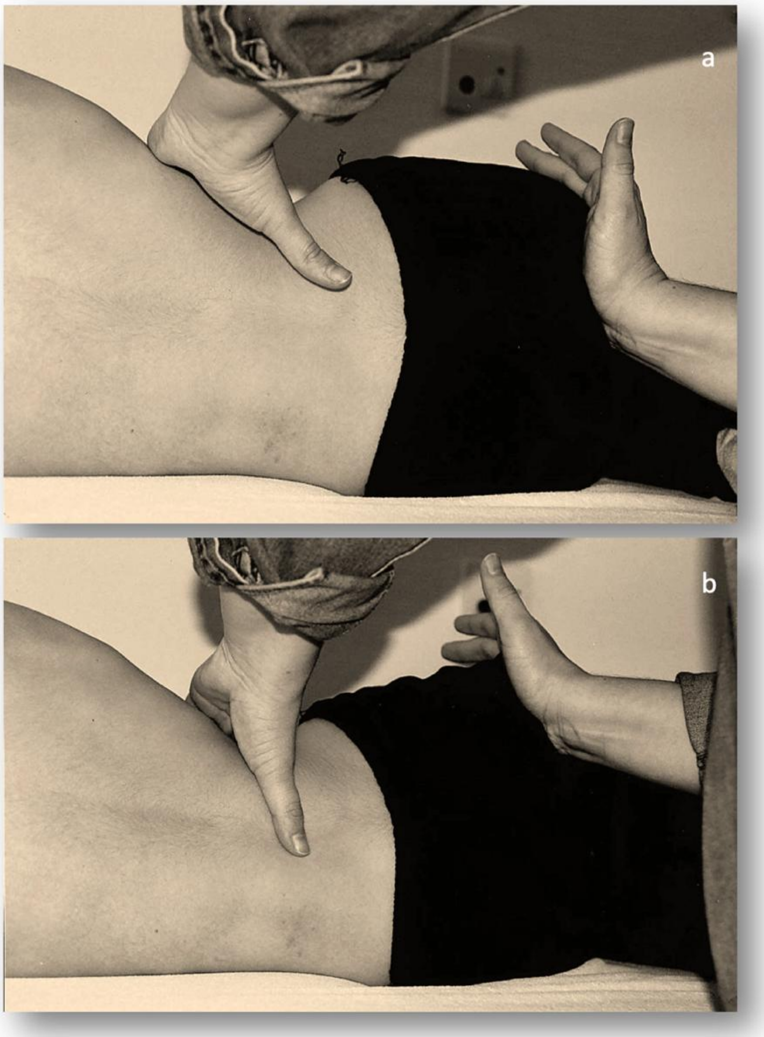

Fig. 7.47. *(a) Starting position of exercise 2 for a lumbar curvature. The practitioner's pisiform bone links up with the patient's ischial tuberosity. (b) The final position in exercise 2 for a lumbar curvature, from the PEP program. It is held for more than twenty breaths.*

With double curve scoliosis, both curvatures are treated in rotation. With a significant counter-curve, one begins with the major curvature and finishes again with the major curvature, with treatment lasting twenty minutes per day, which can be split up into ten minutes in the morning and ten minutes in the afternoon.

The primary responses immediately after treatment with the PEP exercises show that favorable reactions in posture are achieved as a primary effect (Weiss 1993). These primary effects can also be observed with adult patients; however, it can be the case that six to ten sessions must take place before this purely reflex treatment program brings forth responses.

Currently, there are no long-term results for the PEP method. However, it is easy to learn and can be integrated into other treatment systems, meaning it can be considered an enrichment of the therapeutic possibilities in the treatment of scoliosis, particularly in the case of younger children.

7.8 Treatment of Decompensated Thoracic Curvatures with a Cobb Angle of more than 70° (Schroth's Original System)

Thoracic curvatures greater than 70º Cobb angle without significant lumbar countercurves are usually so rotated that the Schroth Best Practice program should not be solely relied upon. Sagittally, the thoracic profile appears kyphotic due to the pronounced costal hump. The lumbar profile appears lordotic, partially with a short-arched lordotic curve above the sacrum. This type of scoliosis should be treated according to Schroth's original system. It was with Katharina Schroth's experience when treating such severe thoracic curvatures that she developed her method (cf. Chapter 2.1).
In contrast to treatment of mild idiopathic scoliosis and more severe lumbar curvatures in adulthood, the decompensated thoracic curvature with a Cobb angle greater than 70° is treated like a kyphoscoliosis. For this reason, we have chosen to focus on the most important exercises from Schroth's original system. Further exercises can be found in Three-Dimensional Treatment for Scoliosis (Lehnert-Schroth 2007).
However, maneuvers which are applicable to all exercises are a requirement for the exact execution of these exercises. Therefore, a description of these preliminary maneuvers is included. It is assumed that most of these curvatures are right thoracic convex curvatures. In the following descriptions, 'right' always means the side of the costal hump (parcel side) and 'left' always means the weak side.

General correction principles of Schroth's original system

The five pelvic corrections

With a functional 3-curve scoliosis, every exercise should contain the five pelvic corrections:

1. Pelvis backwards, as far above the middle position as possible so that the upper body can easily bend forward.
2. If a lumbar lordosis is present, lift the front edge of the pelvis.
3. Shift the protruding hip from the trochanter major in the frontal plane. If the pelvis is in the middle position, this pelvic correction can be omitted.
4. The hip (Ilium) beneath the costal hump is rotated dorsally; the other hip is moved ventrally in order to de-rotate the pelvic girdle as a fixed point against the ribcage corrections.
5. The hip beneath the costal hump is lowered in order to broaden the weak point allowing for increased expansion during inspiration (open) (Lehnert-Schroth 2007).

Rotational breathing

Every exercise includes the pelvic corrections in combination with rotational breathing mainly on the thoracic concave side; a right angle is cultivated along the flank. The first direction goes in the desired exercise direction; the second direction always goes cranially, together with the occiput push (neck is along the back).
Each of these right-angle breathing movements occurs with the diaphragm consciously descending. However, this must first be practiced and felt. The patient should also feel this manually and perceive it emotionally (Lehnert-Schroth 2007).

Correction cushions

Correction cushions (approx. 200g bags of rice) are used as a passive correction aid in almost all starting positions, so that the patient is reminded of the untwisting feeling in everyday life and at rest. One must take care that these are placed correctly. When lying on the back, a cushion is placed along the m. gluteus maximus on the thoracic concave side in order to de-rotate the pelvis unilaterally, ventrally. One cushion is placed directly under the shoulder blade on the thoracic concave side, so that not only the shoulder height, but also the entire shoulder girdle is pushed forward on this side. At the costal hump (thoracic convex side), the cushion lies transversely under the scapula so that the ribs located above and below this, as well as the shoulder girdle on this side, can be lowered (Lehnert-Schroth 2007).

Shoulder counter-tension

Shoulder counter-tension and shoulder tension describe the efforts of the patient to push laterally with the shoulders in the frontal plane. The shoulder counter-tension takes place on the thoracic convex side and is the

cranial resistance against the costal hump correction in the frontal plane (costal hump medially, shoulder girdle laterally). In contrast, the shoulder tension helps to open the thoracic concave side and thus leads the thoracic shift to the thoracic concave side.
The elbow is bent here and is held at 90°, with the hand encompassing the shoulder on the same side. The elbow pushes laterally (Fig. 7.48 on the right).

The occiput push

The occiput push is built into every exercise. The patient wriggles with their spine in the direction of their head, over the neck, and up to the occiput. This creates a feeling of length. The chin is taxed in such a way that one feels like one has a stand-up collar on (Lehnert-Schroth 2007).

The hold-to-twelve exercise

After correction, the best exercise results - identified in the mirror - are securely tensed; that is, the entire trunk musculature is stretched in the correction position, which creates an asymmetric feeling of tension/posture:
In the first inhalation phase, the rotational breathing takes place in the weak point in the lumbar region underneath the costal hump. While breathing out, the muscular result is held. When doing this, the patient can also press down on a wooden bar.
In each further inhalation, the correction result of the rotational breathing is improved and the air is guided into the thoracic concave side. Subsequently, the trunk muscle tension is repeated in the exhalation phase. Depending on the exercise, two bars can be pushed against the ground during this section.
After, the narrow ventral side is moved anterior via the breath and everything is stabilized again. The patient must breathe out with the greatest trunk muscle tension possible, counting to four and with the best correction.
With the next inhalation, the patient corrects again counting to four, and during exhalation the correction position is held under tension. With the third exhalation, the patient counts to four again and, while sitting in a rotated position, for example, the backrest is pulled ‘apart’ isometrically. After this, the patient will need to rest in a lying position (Lehnert-Schroth 2007).

Rest phases

Rest phases take place in a horizontal position with legs attached, if possible, without a head cushion, lying on the correction cushions so that the intervertebral discs which in an upright position experience maximum trunk muscle tension can fill again. The cushion support should convey a sense of the corrective posture that becomes unconscious through repetition, enabling the untwisting of the trunk section to occur easily in everyday situations (Lehnert-Schroth 2007).

The twisted seat exercise (Fig. 7.48)

Starting position: The patient sits with the left half of the pelvis (the pelvis half on the thoracic concave side) on a stool. The right half of the pelvis can overhang laterally to a certain extent (third pelvic correction). The right leg is stretched out behind and rotated outwards in the hip joint. The ankle pushes further in a distal direction (fifth pelvic correction). A correction cushion lies in front of the right half of the pelvis in order to twist it backwards (fourth pelvic correction).

The upper body is obliquely positioned forward as an extension of the leg that is stretched out behind (first and second pelvic corrections result here of their own accord) and slightly to the left. During the execution, both hands press bars into the floor or pull on a fixed bar at the appropriate height during the exhalation phase. Alternatively, the hands lie on the backrest and push it "apart."

Fig. 7.48. *Twisted seat in the execution of exercises with shoulder counter-traction on the right side.*

Execution of the exercise begins with the occiput push and opening up of the concave side with a simultaneous broadening of the weak point underneath the costal hump.

- Weak point (free-floating ribs, right) sideways and cephalad while the diaphragm is lowered. Hold while exhaling. With the next inhalation, the free-floating ribs are forced dorsally and cephalad while lowering of the diaphragm occurs. Hold while exhaling.
- Weak side is arched sideways and outward while the diaphragm is lowered. This correction is held while exhaling. The same ribs are moved dorsally and cephalad while lowering the diaphragm and held while exhaling.
- The breath into the right ventral zone is forward and in the direction of the head, always with a lowering of the diaphragm.
- If the patient is observing themselves corrected in the mirror, the whole body is made “fixed and solid” through isometric tension (twelve tensions). As the patient observes their body corrected in the mirror, during the exhalation (stabilization phase) a whole-body isometric contraction is performed.

Because this is a laborious exercise, the patient should lie down on their back with their legs up on correction cushions that help the trunk to untwist, and run through the exercises once more as a film in their head.

The 50x exercise (Fig. 7.49a + b)

This exercise is one of the most important exercises for the correction of a costal hump. The patient sits cross-legged in front of the wooden wall bars; the right knee is cushioned against the nearby bar (fourth pelvic correction). The hands reach for a bar above head height and the patient squiggles up against this with an occiput push so that all concave sections of the trunk are relieved of any load. The constricted, right ventral side of the chest now comes to the front and the patient breathes in a right angle upward (towards the head), which erects the costal hump. While keeping the neck straight, the head is brought as far backward as possible, flattening out the costal hump from above. This can take place over several breaths, making sure to observe the previous correction result during each exhalation.

After correction, the best exercise results - identified in the mirror - are held firmly; that is, the entire trunk musculature is tensed in the best possible correction position, which creates an asymmetric feeling of tension/posture.

As Katharina Schroth saw the effect that this newly developed exercise had with one of her patients, she cried out joyfully, “You must do this exercise 50 times a day!” which is how this exercise got its name.

The patient must carry out the “big arch” for the concave side after this exercise, once the patient has rested in order to complete the untwisting of the upper body (Lehnert-Schroth 2007).

Fig. 7.49. *(a) The 50x exercise commences in front of the wooden bars, pushed over to the right on the parcel side (left-hand image). Since the exercise is oriented to the left (right-hand image), one has enough room for maneuver in this manner. (b) The 50x exercise in comparison with an uncorrected stance.*

Fig. 7.50. *The muscle cylinder in execution, on the knees.*

Muscle cylinder (Fig. 7.50)

This exercise can be performed while standing, kneeling or under special circumstances (pain, muscular weakness) as a special modification while sitting on a chair.

Standing: The patient stands with the first and second pelvic corrections in place on the left leg. The right leg is in a stretched position and rotated outward (fourth pelvic correction) - the foot is on a stool or resting on one of the wooden wall bars. The upper body is bent slightly forward and a little to the left, making an extension of the leg (third pelvic correction), forcing the right-side waist muscles to support it. The right heel pushes in a distal direction (fifth pelvic correction). This starting position remains unchanged during the exercise.

The rotational breathing is carried out for the right false ribs, the left weak side, the constricted right front side, and the right underarm ribs. Supporting the hip, the left shoulder can sometimes be pulled or pushed too strongly outward/upward, and the shoulder counter-tension is applied simultaneously, on the right-hand side, obliquely outward/backward.

On the knees (see image): For the exercise, the patient kneels on the left knee. The right leg is straight and rotated outward (fourth pelvic correction). Otherwise, the exercise proceeds as described above.

Door handle exercise (Fig. 7.51a + b)

The door handle exercise is called such because in the beginning, due to a lack of wooden wall bars, Katharina Schroth used a door handle as a hold.

The starting position is kneeling, with the bottom resting on the heels. The patient kneels with their left side facing the wooden wall bars and with the outstretched left arm, grabs hold of the highest bar they can reach above their head. The right lower leg is located roughly five cm behind the other leg in order to untwist the pelvis. The knees are positioned asymmetrically. The right hip (half of the pelvis) is lowered outward and backward (first, second, and third pelvic corrections). The upper body is now positioned obliquely to the left and leaning a little forward (Fig. 7.51a).

Fig. 7.51. *(a) The starting position of the original door handle exercise. (b) The finishing position of the door handle exercise.*

The exercise: By bending at the elbow, the left arm pulls the upper body up so that the patient is on their knees while breathing rotationally against the resistance of the untwisted pelvis. The back of the head pulls in the same oblique direction left, until the patient is on their knees. Now the left arm applies resistance while the right hip stretches outward and backward and the arm slowly extends (Fig. 7.51b).

The hip loop (Fig. 7.52)

The patient kneels against the third wall bar, possibly with a correction cushion in front of the right knee, which rotates the right pelvis backward (first, second, and fourth pelvic correction). This is also pushed to the right (third pelvic correction).

The hands reach up to a bar above the head. The pelvis is lowered and both sides stretch. The patient performs a slight occiput push upward and to the left. This is the starting position.

Fig. 7.52. *Execution of the hip loop. For comparison purposes on the left: uncorrected in a position of rest*.

The exercise: The patient moves the pelvis in a circle, laterally, dorsally, and caudal (fifth pelvic correction), broadening all concave sections of the trunk and filling them via the rotational breathing in each rotation. In opposition, the right side of the chest pulls ventrally in order to diminish the costal hump.

This exercise helps to improve (mobilize) the pelvis correction with stiff functional 3-curve curvatures and opens the so called ‘Weak Spot.’.

The selection of exercises described here for the treatment of decompensated thoracic curvatures with a Cobb angle greater than 70° are according to Schroth’s original system and are sufficient for treating this special pattern of scoliosis. Differences may be observed in the execution of these exercises when compared to the “Power Schroth” exercises, particularly with the door handle exercise, described here.

The rotational breathing technique is simplified with the “Power Schroth” program. The most important consideration is the optimal execution of the exercises, oriented toward the individual, with simplified methods or exactly as described in Schroth’s original system (Lehnert-Schroth 2007).

7.9 De-Tethering Exercises

The importance of neural structures in the treatment of scoliosis

While searching for the cause of the formation and development of idiopathic scoliosis, a working group, the International Research Society of Spinal Deformities (IRSSD), was established with Prof. Burwell (Nottingham), Prof. Dangerfield (Liverpool), and Prof. Winnie Chu (Hong Kong) at the core (Chu et al. 2008). A series of MRT examinations have been conducted, which support the hyphothesis that a functional tethered cord is the starting point for the formation of scoliosis (Chu et al. 2006). An examination conducted by Deng and colleagues discovered signs of a functional tethering of the spinal cord and reports were made concerning misalignment and deformities of the spinal cord in the vertex area of the examined thoracic curvatures. The more pronounced these indications were in patients, the more difficult it was to halt the increase in curvature with the symmetrical corsets manufactured in Hong Kong (Deng et al. 2015).
Dorsal growth is slowed by the tethering of the spinal cord and its mantle, which results in increased ventral growth. The spine becomes unstable and the constant heartbeat against the spine on the left enables the formation of a thoracic right convex curvature. In turn, it favors the progression of this curvature (Raso VJ 2000). Indeed, typical idiopathic thoracic scoliosis is convex to the right. To date, no corresponding approach to ascertain the cause of idiopathic lumbar scoliosis exists.
But what do these insights mean for the treatment of idiopathic scoliosis? How can the restrictions in spinal cord mobility be influenced? The answer is to mobilize the neural structures (nerve tissue and mantle) within their surrounding structures (Butler 1991; Santos 2010).

Neural mobility techniques (de-tethering) for treating spinal deformities

Mobilization options can be either passive (manipulation, chiropractic therapy) or active (exercises) in nature. In a pilot study that was meant to justify further investigations, extracorporeal shockwave therapy (ECSWT) provided limited treatment success (Weiss et al. 2013; Weiss 2016). Additionally, another case study demonstrated effectiveness of ECSWT. Both the finger-to-floor distance and the scoliometer angle as a measure of spinal rotation was significantly improved with repeated treatments (Weiss 2017a). However, the positive effects were short-lived, giving rise to the question of which exercises can provide a similar effect. As the segmental mobilization of individual spinal segments with ECSWT achieves an effect, it should be possible to influence the described functional disturbances by conducting exercises within the maximum ranges of movement. Mobilization of the spinal cord and its mantle in the spinal canal should be possible by twisting the torso (turning the pelvis against the direction of the shoulders) or by other complex movements. Peripheral neural structures should also be mobilized in order to loosen any peripheral adhesions that could contribute to impairing the mobility of the spinal cord and mantle.

To this end, the primary author recommended a series of exercises that have been successfully tested by members of the Schroth Best Practice Academy (Weiss 2017b). These exercises serve to mobilize the neural structures in different parts of the body. The first exercise is designed to primarily mobilize the cervical marrow (neural structures in the cervicooccipital area). The second exercise serves to mobilize the neural structures in the thorax and lumbar spinal area. The third exercise mobilizes the central neural structures in the lumbar area, and also the peripheral neural structures in the area of the upper extremities; the fourth exercise mobilizes the central neural structures in the thorax and lumbar spinal area, and also the peripheral neural structures in the area of the lower extremities.

One may consider mobilizing the pelvis against the shoulders with some added momentum. However, this would involve a certain danger of injury, especially for patients with spinal deformities. For this reason, we recommend only active mobilization techniques and with slight passive pressure if needed. We also recommend only slight added pressure when using passive mobilization, as in the case with neuromuscular scoliosis without the capacity for active movement.

Fig. 7.53. *First, lean on internally rotated and outstretched arms. Tilt the cervical spine as far as possible to the side using a complex movement while simultaneously turning the chin as far as possible to the opposite side. These illustrations are from the first publication. Today, the exercise is performed in the long seat with the cervical spine flexed.*

Exercise #1

This exercise was developed by the physiotherapist Grita Weiss to self-treat her headaches (Figs. 7.53 & 7.54).

Starting position: Sit in an open lotus position or better in the long seat. By sitting, the pelvis is fixed and provides resistance to the movements of the upper extremity and/or cervical spine. In the long seat position, the sciatic nerve is pre-stretched, which pretensions the spinal cord and thus facilitates local neuromobilization.
Internally rotate the arms and stretch out as much as possible to support the torso above the pelvis, directly next to which the fists are located. The pelvis will begin to hover slightly. In this position, the brachial plexus is distally tethered so that the main movement of the neural structures to be mobilized takes place in the cervical occipital spinal cord area.

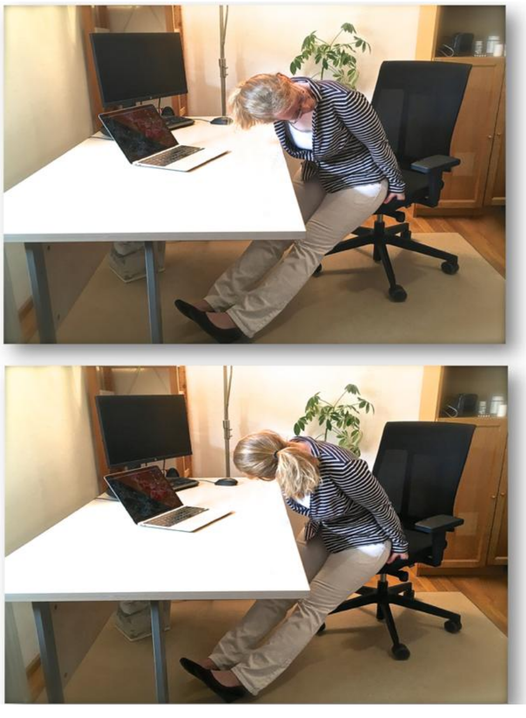

Fig. 7.54. *Exercise #1 can also be performed at the workplace. Here, the long seat has been modified. Execution: Forefoot raised, knees extended, hips flexed 90° or more. The cervical spine is in flexion during the exercise.*

Exercise performance: First, lean on internally rotated and outstretched arms. Then, tilt the cervical spine as far as possible to the side using a complex movement; at the same time turn the chin as far as possible to the opposite side. Since the neural structures in the spinal area tend to run dorsally, the performance of the exercise is strengthened by increased pre-stretching by slightly bending the cervical spine.
Aim of the exercise: By tethering the brachial plexus distally, mobilization of the peripheral parts of the neural structures can be largely prevented. Thereby, the movements of the cervical spine predominantly reach the neural structures of the cervical marrow and the cervical occipital passage.
Frequency: Since this exercise can be performed relatively easily and without any significant aids, it can be performed several times a day. We recommend performing this exercise three times a day with 20 repetitions on each side.

Exercise #2

This exercise originally comes from a Qi Gong Program (Weiss 1999) and serves to mobilize the neural structures in the area of the thoracic spine.

a b

Fig. 7.55. *Twist the torso along the longitudinal axis. Alternate turning the head and shoulders to the right and left with the nose leading the movement. Loosely swing the arms, which are carried along by the shoulders, in the direction of the movement and cross the hands over the opposite thigh. At the end of the complete twisting motion, lightly push the back of the hand against the opposite thigh to increase the strength of the twist slightly. Today, the exercise is performed in the long seat with the cervical spine flexed*.

Starting position: Sit in an open lotus position or in the long seat on a bed or stretcher. By sitting, the pelvis is fixed and provides resistance to the movements of the upper extremity and/or cervical spine. In the long seat position, the sciatic nerve is pre-stretched, which pretensions the spinal cord and thus facilitates local neuromobilization.
Exercise performance: Twist the torso along the longitudinal axis. Turn the head and shoulders alternately to the right and left with the nose leading the movement. Loosely swing the arms, which are carried along by the shoulders, in the direction of the movement and cross the hands over the opposite thigh. At the end of the complete twisting motion, slightly increase the strength of the twist by lightly pushing the back of the hand against the opposite thigh.
Since the neural structures in the spinal area tend to run dorsally, the performance of the exercise is strengthened by increased pre-stretching by slightly bending the entire spine including the cervical spine.
Aim of the exercise: By moving the head / shoulders within the maximum range of motion against the fixed pelvis, the spine and neural structures twist. This twisting leads to a relative shortening. Since the spine cannot shorten significantly, the relative shortening of the neural structures and the corresponding soft tissue during this exercise leads to a lengthening tension on existing functional tethering of the dura mater on the wall of the spinal canal. The spinal canal cannot shorten. The twisting also leads to a transverse tension of the spinal cord and its mantle against the inner wall of the spinal canal.

The neural structures in the thoracic spine area are predominantly reached.

Frequency: Since this exercise can be performed relatively easily and without any significant aids, it can be performed several times a day. We recommend performing this exercise three times a day with 20 repetitions on each side.

Fig. 7.56. *Exercise #2 can also be performed at the workplace. Here, the long seat has been modified. Execution: Forefeet raised, knees extended, hips flexed 90° or more. The cervical spine is in flexion during the exercise.*

The following factors are important for optimal exercise execution (from caudal to cranial):

- Both forefeet are pulled up to pre-stretch the sciatic nerve.
- Both knees are straight
- Both hip joints are flexed at least 90°
- The cervical spine is always in clear flexion during mobilization by side bending (#1) or twisting (#2).

All of these adjustments result in pretensioning of the entire (dorsal) spinal cord and facilitate spinal cord mobilization (Figs. 7.54 & 7.56).

Exercise #3 (Compass)

This exercise is based on the so-called Nei Gong Program, a very effective form of Qi Gong (Weiss 1999).

Fig. 7.57. *Bend the torso firmly to the right side so that the arms, which are stretched out above the head, point as horizontally as possible to the right. For the second phase of this exercise, lower the torso from the side to the front above the right foot, and reposition the arms so that they are curved towards one another, the stretched-out fingertips pointing towards each other, and the palms of the hands facing towards the ground diagonally above the top of the right foot.*

<u>Starting position:</u> Stand with the feet slightly wider than shoulder-width apart. Point the front of the feet inwards and the heels outwards, and stretch the knees out.

<u>Exercise performance:</u> Move the arms upwards along the side until they are positioned above the head and pointing upwards. Keep a slight bend in the elbow. Stretch the hands and feet out with the palms facing the front. Bend the torso firmly to the right side so that the arms, which are stretched out above the head, are pointing as horizontally as possible to the right. Remain in this position for 2 to 5 breath cycles.

For the second phase of this exercise, lower the torso from the side to the front above the right foot. Reposition the arms so that they are curved towards one another with the fingertips stretched out and pointing towards each other and the palms of the hands facing towards the ground diagonally above the top of the right foot. Keep the legs stretched. Remain in this position for 2 to 5 breath cycles. For the third phase of the exercise, stretch the upper body out to the front to a flat back position. Hold the hands out towards the front so that the hands and upper body form a horizontal line. The hands do not face the floor, but face one another at an angle of 30 to 45 degrees. Remain in this position for 2 to 5 breath cycles.

To reach the fourth phase, bend the upper body towards the left and curve the arms again towards one another with the palms facing the top of the left foot (as in the second phase, but over the top of the left foot); the fingertips do not touch here. Keep the legs stretched. Pay attention to the curved position of hands and arms. Again, remain in this position for 2 to 5 breath cycles.

Fig. 7.58. *In the third phase of the exercise, transition from the second exercise. Stretch the upper body out to the front to a flat back position, and stretch the hands to the front so that the hands and upper body form a horizontal line. After this, bend the upper body towards the left, the arms again curved towards one another, the palms facing the top of the left foot (as in the second phase but over the top of the left foot).*

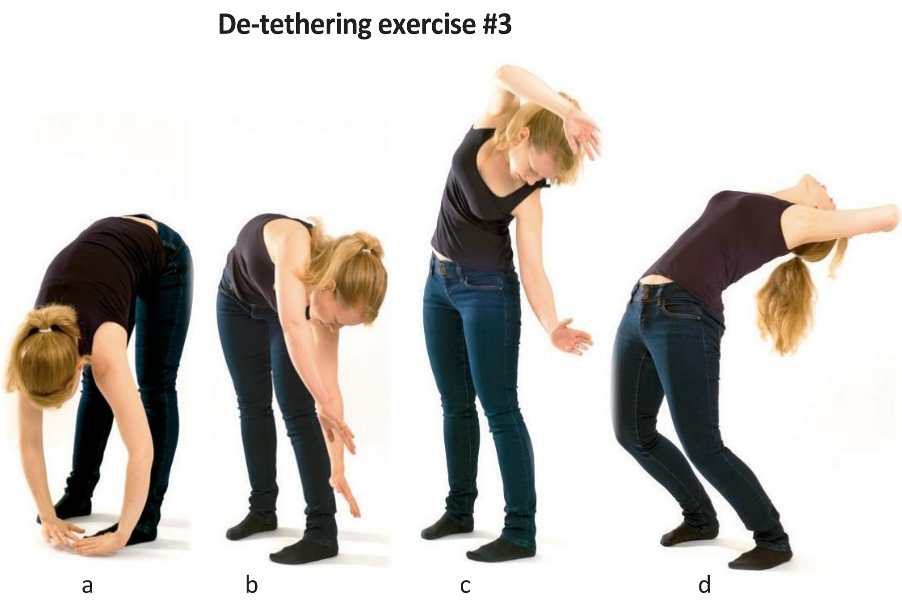

Fig. 7.59. *The fifth phase of the exercise: With the torso come up over the left side with arms stretched above the head, turn the torso with the front again to the front and tilt the torso in coming up from the side to the back, stretch the arms, as far as possible, back over the head, bending the back to the back. The legs are slightly bent at the same time.*

To reach the fifth phase of the exercise, move the torso over the left side and stretch the arms upwards above the head. Turn the upper body to again face the front. While moving upwards, tilt the torso from the side to the back. Stretch the arms out as far as possible to behind the head; at the same time, bend backwards. Keep the knees slightly bent. Again, remain in this position for 2 to 5 breath cycles (Fig. 5.59 a-d). After this, bend the torso firmly to the right so that the arms, which are stretched out above the head, point as horizontally as possible to the right. From here, repeat the exercise sequence on the opposite side by beginning with a left-side bend of the torso from the upright position.

Aim of the exercise: This exercise mobilizes the central neural structures in the lumbar area and the peripheral neural structures in the area of the upper extremities.

Frequency: Repeat this exercise sequence 3 to 5 times. Then, repeat the exercise sequence in the opposite direction. This exercise should be performed at least once a day.

Exercise #4 (double dragon leaps from the ocean; short form)

This exercise is also based on the so-called Nei Gong Program, a very effective form of Qi Gong (Weiss 1999).

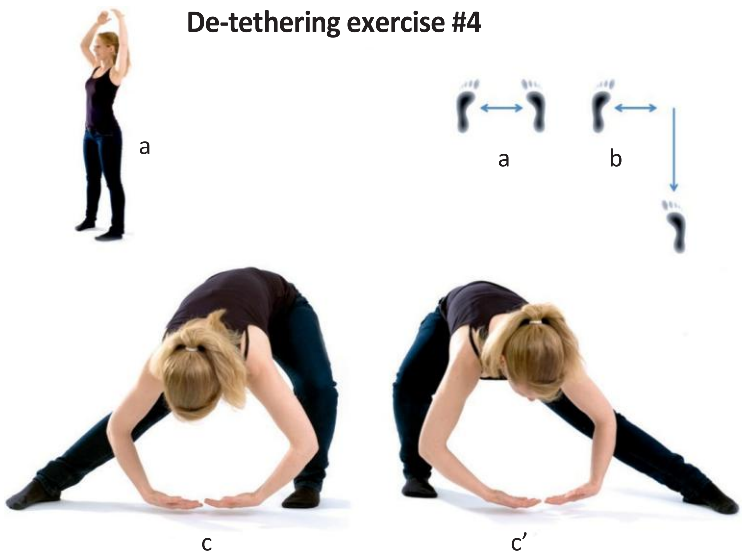

Fig. 7.60. *Stand with feet shoulder-width apart. Slightly rotate the feet internally and rotate the knees externally. Then, with a large stride, position the right leg backwards and straight. Bend the torso to the front. During this torso movement, bend and rotate the right knee externally. Bring the hands together in a curved position in front of the body without changing the bent over position of the torso.*

Starting position: Stand with the feet slightly wider than shoulder- width apart. Point the front of the feet inwards and heels outwards. Stretch the knees out.

Exercise performance: From the shoulder-width stance with slightly internally rotated feet and externally rotated knees, position, with a large stride, the right leg backwards and straight. Bend the torso over to the front. During this torso movement, bend and further externally rotate the right knee while the left knee is streched. After this, bring the hands together in a curved position in front of the body, without changing the bent-over position of the torso. Let the palms face the face, but do not let the hands touch. Remain in this position for 2 to 5 breath cycles. Then, on an inhale, slowly lift the torso and bring the legs back to the starting position. Repeat these exercise phases on either side.

Aim of the exercise: This exercise mobilizes the central neural structures in the thoracic and lumbar spinal areas, and the peripheral neural structures in the area of the lower extremities.

Frequency: Repeat this exercise 3 to 5 times per side. Perform this exercise sequence at least once a day.

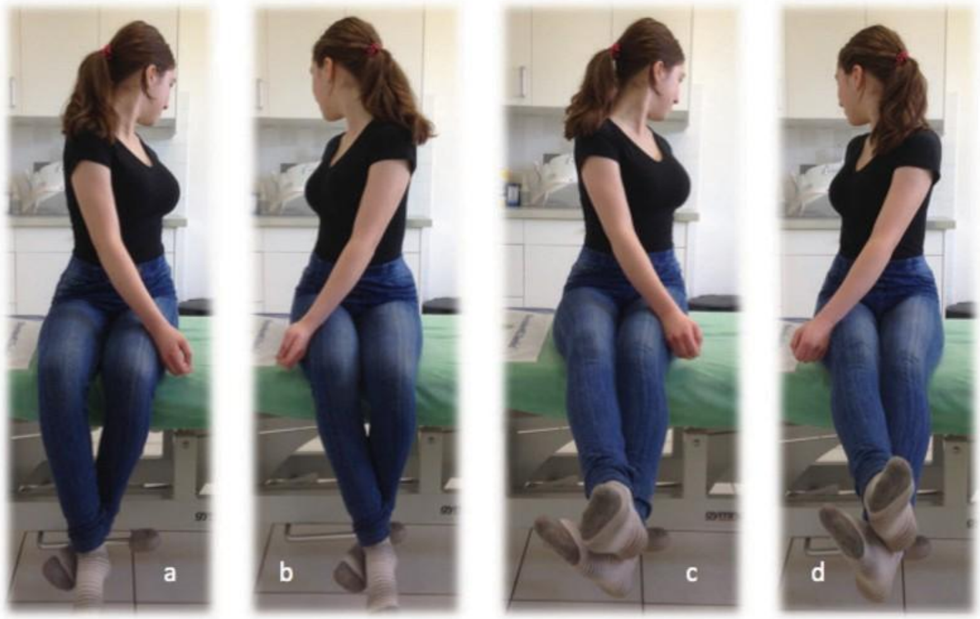

Fig. 7.61. *Exercises #1 and #2 can also be done when seated on a bed or stretcher. These exercises are done first with resting calves (a, b) and then with stretched knees (c, d). By pre-stretching the sciatic nerve, the spinal cord and its structures are further stretched.*

QR code to a short video demonstrating de-tethering exercises #3 and #4.

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8. BIOFEEDBACK IN PHYSIOTHERAPY FOR TREATING SCOLIOSIS

The term biofeedback refers to a method that uses technical (frequently electronic) means to make it possible to observe bodily functions (i.e. pulse, blood pressure, respiration, muscle tension, EEG) that cannot be directly perceived by the senses, thereby making them accessible to the consciousness. The focus of biofeedback is akin to that of behavioral therapy and learning theory approaches. This treatment technique allows for many different applications. What is more, it is also used for relaxation during rehabilitation (Rief and Bierbaumer 2011).

Due to the fact that the consciousness is frequently unable to directly perceive the body's own regulatory mechanisms, it is not possible for the senses to be consciously influenced when they are not working properly. A benefit of biofeedback is that it serves to make the consciousness aware of a bodily function by means of physiological measurements. In treating scoliosis, for example, the patient uses this feedback in order to achieve better posture.

More than 100 years ago, devices were already in use for treating scoliosis - partly to support physiotherapy, partly to straighten posture (Fig. 8.1). A few corrective devices were similar to a brace, while others were used as corrective aids for exercises (Schanz 1904; Weiss 2013).

Katharina Schroth introduced a new kind of biofeedback to scoliosis treatment in 1921. Her goal was to achieve the best possible postural correction by using the exercises described. Perception of the best possible posture - "postural consciousness" - was developed by observing visible corrections in a mirror (cf. chapter 2.1). The reflected image enables postural consciousness to be gauged in connection with the current corrective position, with the result that, after a certain amount of practice, the degree of correction can be achieved with certainty in everyday life even without using a mirror to check. This concept has been developed further and is well evaluated (Borysov & Borysov 2012; Pugacheva 2012; Lee 2014).

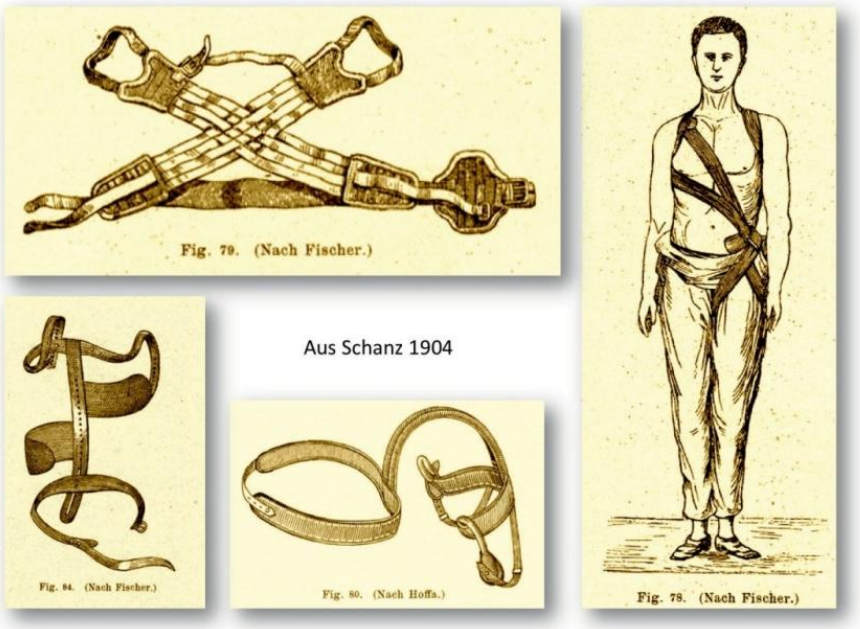

Fig. 8.1. *Corrective devices, some of them stemming from the 19th century. These were used to straighten posture or in support of physiotherapy and even as braces (Schanz 1904, Weiss 2013)*.

Although actual biofeedback systems (Rief and Bierbaumer 2011) were first described in the 1980s (Dworkin et al. 1985; Nowotny et al. 1987; Bogdanov et al. 1990; Weiss and Michely 1992; Birbaumer et al. 1994; Wong et al. 2002; Bazzarelli et al. 2002), they have not yet gained acceptance for scoliosis treatment. This is partly because, in the past, wearing the devices involved a great deal of discomfort and partly because rather large units - which had to be attached to the body, were needed for the electronic components (Fig. 8.2).

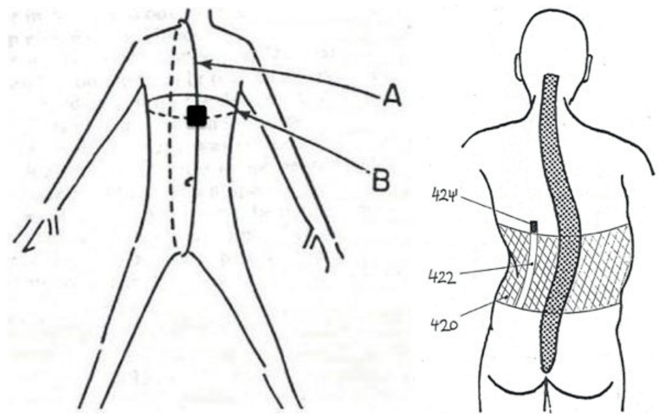

Fig. 8.2. *Left, schematic drawing of a biofeedback system (modified according to Dworkin et al. 1985). The system was basically used to measure length when treating both scoliosis as well as kyphosis. Discomfort was caused by the location of the longitudinal measurement strap from walking movements and by the placement of the box holding the electronic measuring equipment on the chest. Right, schematic drawing of another system designed to measure the concavity of curvature in scoliosis using a sensor (Weiss and Michely 1992).*

Tests and methods for improving postural correction based on electromyography were employed for scoliosis treatment in the last century (Weiss 1991; see also Fig. 8.3). Early on, such applications were very unwieldy (Fig. 8.4) due to the large hardware that was required (Weiss 1993). However, today's EMG devices are smaller and more manageable and sometimes do not even require a cable. This allows EMG feedback for gait analysis. So, it is possible that biofeedback for scoliosis may experience a comeback.

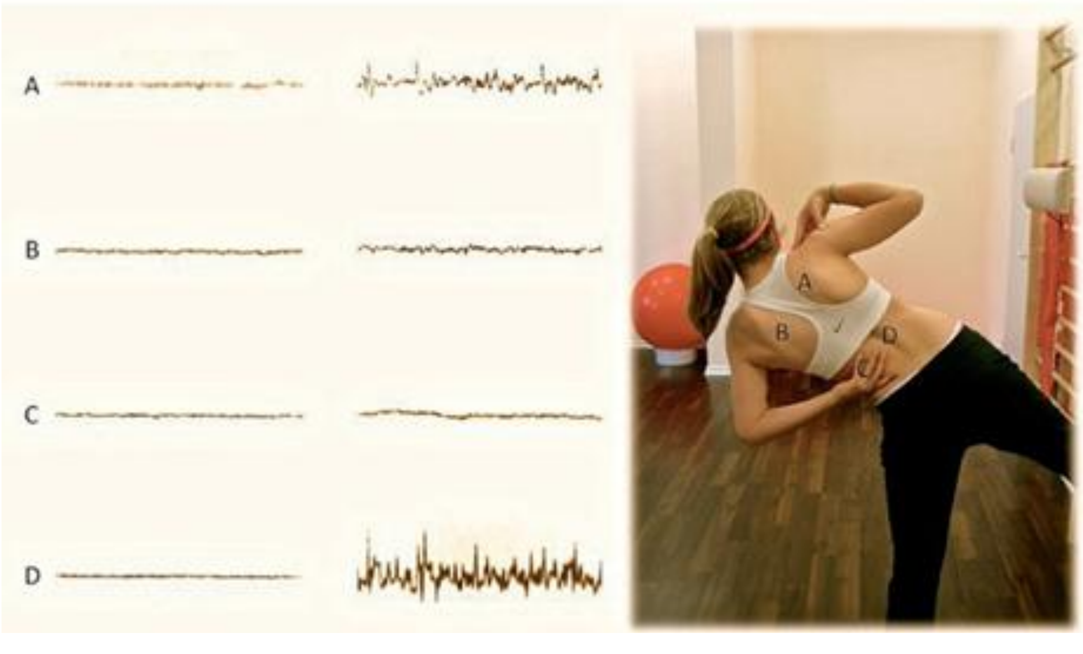

Fig. 8.3. *Using EMG in support of targeted physiotherapy. Far left, 4-channel EMG in a resting position, recording (A) the thoracic erector spinae (ES) on the convex side at the apex of the curvature, (B) the thoracic ES on the concave side at the apex of the curvature, (C) the intrinsic lumbar portion of the lumbar ES on the convex side in the direction of the fibers, and (D) the intrinsic lumbar portion of the lumbar ES on the concave side in the direction of the fibers. Center, activity pattern during the muscle cylinder exercise. Right, sample exercise performed for clinical hypercorrection of both lumbar and thoracic scoliosis in patients with right-hand thoracic curvature greater than 50° Cobb (EMG measurements from Weiss 1991). After proper execution of the trunk corrections now head alignment can be improved.*

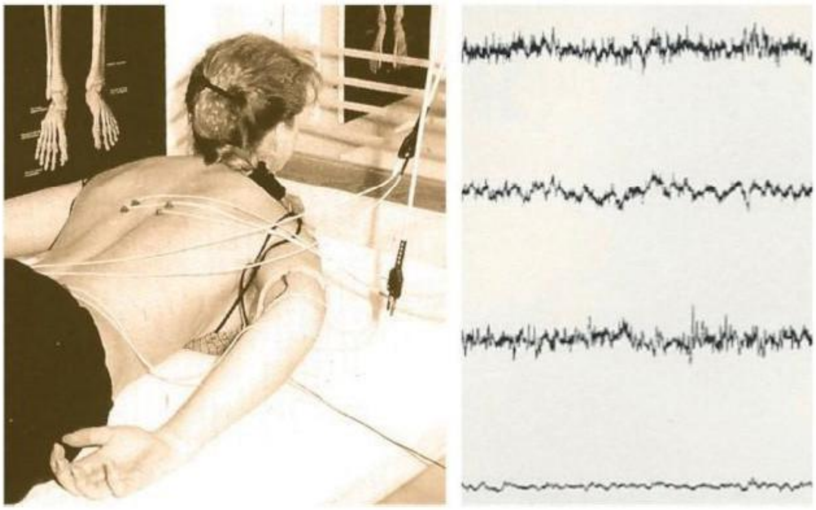

Fig. 8.4. *Standardized head-raise test to monitor progress during rehabilitation (Weiss 1993)*

Fig. 8.5. *Prototype of the Spinealite® biofeedback system used for right convex thoracic curvature with left convex lumbar countercurvature.*

In 2011, a new biofeedback system was developed (Fig. 8.5) using the time-tested corrective principles of the Schroth Best Practice program (cf. chapter 7.3; 3D made easy).

The straps of the Spinealite® biofeedback system were partly elastic, so once their tension threshold has been reached (unlike fully elastic belt systems) retention force is maintained, even over months of continuous use.

It is possible to adjust the corrective strength of the system - and thus the tensile strength as well. When ideally adjusted, the system has an excellent corrective effect (Fig. 8.6) that can be substantiated radiologically (Weiss 2013). For slight corrections, the system is hardly noticeable; at its maximum corrective setting, there is a relatively strong pull on the shoulder.

Fig. 8.6. *Top, hypercorrection effect using the Spinealite® biofeedback system in a patient with adolescent idiopathic scoliosis (AIS) and a thoracic curvature of 27° according to Cobb. Bottom, view of the Spinealite® biofeedback system without a patient.*

If worn by patients when sleeping at night or when otherwise unconscious, the effectiveness cannot be guaranteed, possibly leading to improper use. That is why, unlike braces, this biofeedback system is intended for patients, when awake, and without limited conscious awareness. This is one reason, we do not refer to it as a brace, which may be worn when sleeping.

The biofeedback character of the system results from an increase in shoulder tension that causes greater wearing discomfort when posture is poor (when the curvature is aggravated). Thus, an aversive stimulus is associated with improper posture, and a pleasant feeling with corrective posture. The more a patient grows accustomed to the corrective pull, the less aware he or she is of the biofeedback response, and increasingly, it becomes a corrective system. Consequently, this system may be used in conjunction with hard-shell braces to provide relief for more pronounced and/or decompensated curvatures, and with the potential for managing physical growth.

When the Spinealite® biofeedback system was used, we recommended initially limiting correction to a range that was easy to tolerate, increasing it every two to three days, or even once a week, until the full corrective effect was reached. This could easily be accomplished independently by patients and/or their parents at home once proper instruction by a competent specialist occurs.

However, this system has not caught on and has therefore been taken off the market as a medical product.

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9. BRACE TREATMENT

Fig. 9.1. *Single curvature patterns can be overcorrected if the curvature is not too large and not too stiff.*

The efficacy of brace treatment (Fig. 9.1) is confirmed by a number of studies and is supported by a Cochrane review (Negrini et al. 2010) and a recent randomized controlled study known as BrAIST (Weinstein et al. 2013; Weiss et al. 2021a). Scoliosis bracing is an effective, albeit involved treatment, which must be carefully planned and carried out. When fitting a brace, the experience of the orthopedic technician is of immense significance and brace fit should be approved by the attending physician. Brace treatment should be delivered by a team providing a minimum of fifty braces annually and/or under the guidance of an experienced bracing specialist.
With bracing, the end result correlates with corrective effect and wear time. Unfortunately, even with bracing there will still be cases which progress. Brace type is critical and braces vary nationally and internationally. It is up to the brace technician and doctor to ensure the best corrective effect and wearability. It is up to the patient to comply with the recommended wear time for the best opportunity for a positive outcome.

Wearing a brace is necessary if it is suspected that physiotherapeutic measures alone may not be sufficient. This should be assumed in the following cases:

1. When a child shows the first signs of maturation and the angle of curvature exceeds 20°. While it has been stated that eight to ten percent of scoliosis patients may spontaneously remit, this usually only occurs in curvatures of 15° or less in children who are not yet near maturity. With a 20° curvature in a growing child, it is only prudent to assume that a scoliosis will progress unfavorably once the main growth spurt begins. Under this scenario, early treatment at an immature stage is necessary for a beneficial outcome (Fig. 9.2). During this phase, drastic deterioration in scoliosis can occur within a matter of weeks (sometimes more than 30° a year), making growth-channeling measures necessary. It is not uncommon for scoliosis in the high mild to mildly moderate range (20° to 30°) to be able to be corrected significantly at this age, or even overcorrected, meaning that regular wear of a properly designed, manufactured, and adjusted orthosis may result in significant final corrections (Fig. 9.2). In rare instances, perhaps even curvature straightening may potentially occur after the patient has been weaned off the brace. In other words, for a few, sometimes there is the opportunity to take advantage of a growth spurt to improve a curvature that could increase without a brace. Once menstruation or voice break has set in, the peak of the growth rate is generally past and sustained curvature improvement can no longer be expected in the majority.

2. If a curvature in excess of 20° degrees deteriorates by more than 5° after menstruation or voice break has set in, the scoliosis is categorized as progressive, and wearing a brace to safeguard against expected curvature growth is indicated.

3. When the angle of curvature is more than 30°, full time brace wear is effective up to one year after the onset of menstruation. In cases of delayed bone maturity and curvatures over 40°, full time bracing is often advisable even though the end of the second year after the onset of menstruation.

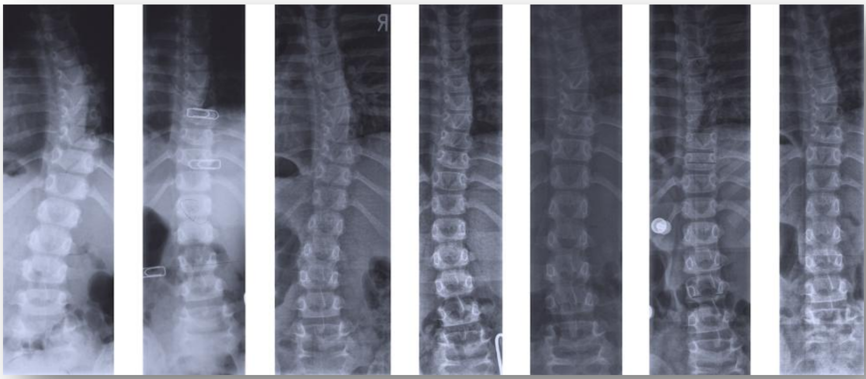

Fig. 9.2. *Course of a juvenile idiopathic scoliosis (early onset scoliosis) with a curvature angle of more than 30° at age 6. A continuous reduction in the curvature was attained by constantly wearing a CAD Chêneau brace for approximately sixteen-hours/day. This patient entered the pubertal growth spurt with less than 20° and therefore only required a wearing time of twelve-hours/day during the main growth spurt.*

X-rays are always at the forefront for assessing different treatment strategies. However, an x-ray portrays the spine on one plane only, while scoliosis is, in reality, a three-dimensional deformity with lateral curvature and distortion. When choosing a brace, the patient and family must understand that positive radiological results do not always result in a favorable cosmetic outcome at the conclusion of brace treatment; this is a function of the type of brace selected.

Fig. 9.3. *Lateral view of a brace that promotes flatback. The normal sagittal curvatures of the spine are prevented by the brace.*

A curvature may appear corrected on the x-ray, but often a rib hump will be visible when observing the spine. In other instances, braces which do not address the sagittal profile can create extremely stiff flatback (Fig. 9.3) which, in itself, can appear visually abnormal.
Unfortunately, non-surgical treatment has sometimes contributed to the formation of flatback. In the past, this problem has plagued more than one brace type and the patients who have worn them. Examples are the Boston Brace, and also the German treatment concepts derived from wearing an earlier Chêneau brace (Hopf and Heine 1985). This functional disturbance occurred in spite of well-corrected appearances on frontal plane x-rays.
Scoliosis bracing should always be administered by a physician or a specially trained orthopedic technician with an intimate knowledge of the scoliotic spine. When fit properly, the right brace can potentially prevent further trunk deformity and facilitate significant improvements in appearance when the opportunity for residual growth remains.
Most physicians are of the belief that bracing is only effective for curves of 40º or less. However, favorable outcomes with curves of greater magnitude are being experienced by those fitted with the Gensingen brace® (Weiss and Moramarco 2013a; Fig. 9.4).
Brace treatment of scoliosis patients is a responsible task of specialized teams consisting of orthopedic physicians or rehabilitation specialists, orthopedic technicians, possibly also physiotherapists. If carried out properly, it can not only prevent further trunk deformation, but also enable significant cosmetic improvements if there is any residual growth. However, such improvements can only be achieved if the three-dimensional deformation of the torso in the case of scoliosis is optimally taken into account. In addition to the lateral deviation, it is also possible to reduce the disturbing rib hump with braces from the latest CAD / CAM series (CAD: computer-aided design, CAM: computer-aided manufacturing) (Fig. 9.5 and 9.6).
Numerous bracing concepts (trunk orthoses) are available, but most of them have led to limited treatment success.
Unfortunately, skilled orthopedic technicians able to achieve sustainable optimal corrective effects are few and far between.

Fig. 9.4. *Progression of adolescent idiopathic scoliosis in an adolescent boy to a curvature of 56° at the beginning of brace treatment. Afterwards, the curvature in the x-ray is reduced, markedly compensated, and clinically all but invisible (Weiss and Moramarco 2013a).*

Fig. 9.5. *Girl with a right thoracic curve of 42° treated in a CAD/CAM Chêneau brace of the Gensingen library with an intermediate correction in the frontal plane after six months of brace treatment - visible on the right.*

Fig. 9.6. *Girl with a right thoracic curve of 42° treated in a CAD/CAM Chêneau brace of the Gensingen library with an intermediate correction of the rib hump - visible on the right.*

Chêneau was the first brace developer to point out that idiopathic scoliosis of the thoracic spine generally involves flatback and is to be treated accordingly via bracing (Weiss et al. 2000). For this reason, the most effective Chêneau braces are characterized by how they reproduce the sagittal curvature of the thoracic spine (lateral profile).

The objective of brace treatment is not to straighten the image on the x-ray and dismiss the patient with a case of flatback. As a result, important advances have been made since the time the original Chêneau brace was developed (Fig .9.7) and this bracing concept has been updated consistently to the point where braces are now able to be produced via plaster-free brace libraries using computer assistance (CAD/CAM). This allows the opportunity for effective correction, for all curve patterns, and the braces created are made expressly for the individual's body based on precise measurements, scans, and consideration of curve pattern. Measurements are then translated into a three-dimensional brace that provides the optimal correction according to each unique curvature.

Fig. 9.7. *CAD/CAM Chêneau braces (Gensingen brace according to Dr. Weiss / GBW) to treat a double curve pattern. Left, from the U.S. (with kind permission from Dr. Moramarco) and right, from China (with kind permission from Xiaofeng Nan). The lateral view shows nearly normal sagittal curvature of the spine, rounding in the thoracic spinal area and a hollow in the lumbar spinal area. The arrows show the region of the ventral pressure area.*

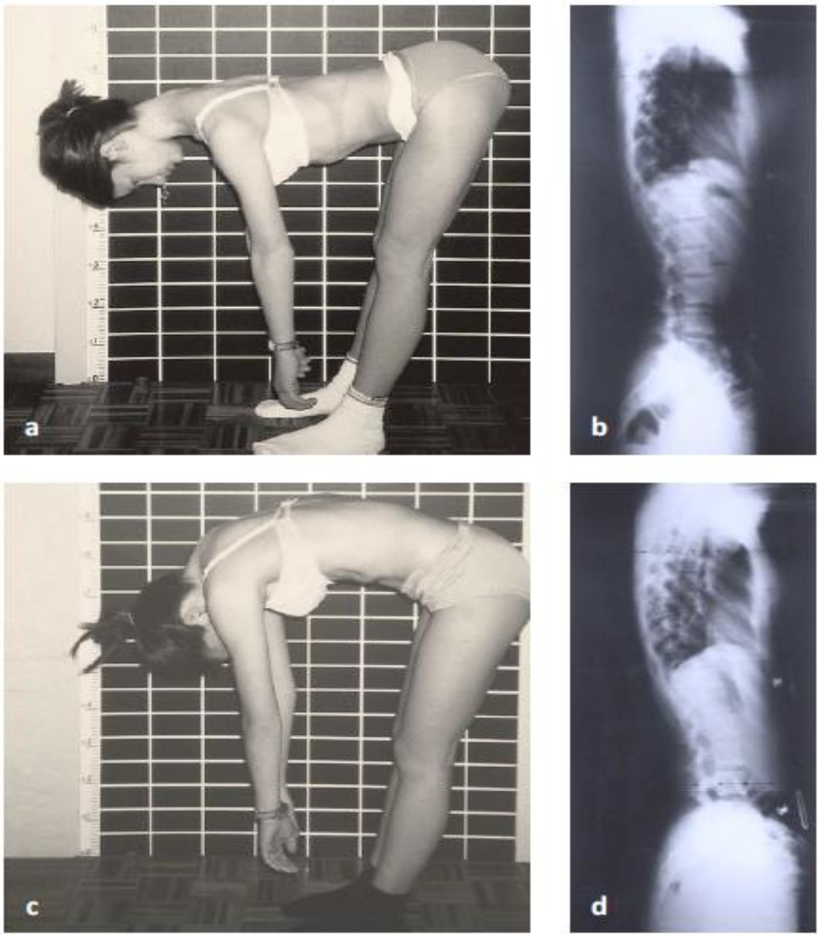

Fig. 9.8. *Stiffened extreme flatback (a), also visible on the x-ray (b), caused by improper brace treatment. Below (c and d): after twelve months of treatment with a Chêneau brace, nearly normal conditions are observable from the side (modified from Weiss, Rigo, Chêneau 2000).*

Designed via CAD/CAM, the Chêneau-Gensingen® brace is also fully compatible with Schroth-based exercise rehabilitation concepts and addresses the trunk in three-dimensions. For the adolescent with scoliosis, this brace strives to address the necessary improvements in trunk deformity, and as a result, halted progression is not its only goal. Due to the comprehensive CAD/CAM library, these advancements in Chêneau bracing are now achievable outside of Germany.

It has been demonstrated, repeatedly, (Weiss and Moramarco 2013b) that the best cosmetic results are obtainable when, assuming adequate wear time, a significant correction can be achieved and when derotation occurs as well. Patients treated with a Gensingen brace® (GBW) improve appearance of the spinal shape, as seen from the side, and gain improved spinal function. The stiff flatback caused by other brace treatment concepts no longer compares to the functionally well-balanced spine with improved cosmetic results (Fig. 9.8) that patients now have the opportunity to achieve.

Unfortunately, restoring the hollow-back (lordosis) in the lumbar region, which is typically reduced by scoliosis, is often still neglected by most other brace forms as well as other Chêneau derivative braces. This omission occurs, despite our having had the knowledge for several years that restoring the lumbar lordosis can help correct scoliosis (Weiss 2004; Weiss et al. 2006; van Loon et al. 2008). Those research results were recently reconfirmed and are accounted for in the design of the Gensingen brace® (GBW). Although the CBW successfully addresses the lumbar lordosis, to date, there is no brace which succeeds at correcting the sagittal profile in the thoracic spine.

One of the potential positive outcomes of wearing the GBW is improved cosmetic appearance. Patients, and parents, must understand that the recommendation for scoliosis surgery is also for cosmetic purposes, yet, it is often implied that surgery is necessary to reverse curvature to avoid progression and potential cardiopulmonary problems. In truth, there is only a small risk that those with adolescent idiopathic scoliosis, or late onset scoliosis of unknown origin, will ever develop severe cardiopulmonary problems. This is based on the conclusions of a study stating curvatures of 80° to 90° are rarely attained (Asher and Burton 2006). Furthermore, the expectation is that serious problems due to lung function impairment will only occur beyond these levels. Studies cite no substantial increased susceptibility for scoliotics in comparison to a control group of adults without scoliosis (Weinstein et al. 2003; Asher and Burton 2006) with regard to pain for those with late onset scoliosis (initial onset at an age between ten and fourteen years). For these reasons, surgery for scoliosis should be questioned and considered only when the spinal curvature is causing extreme psychological distress or physical impairment. Consequently, brace wear with the goal of improving appearance should be the preferred choice offering far less risk for the patient (Weiss et al. 2021b).

Design Variants of Trunk Orthoses in Scoliosis Therapy

Corrective trunk braces designed for scoliosis treatment and made from a plaster cast can vary significantly with regard to their quality and effectiveness. In most instances, braces made according to a plaster cast bear the signature of the technician making them. Technicians often specialize in certain curvature patterns and thereby some are also capable of attaining outstanding corrective effects for these, yet corrections for alternate curvature patterns may result in an inferior fitting brace. Computer-aided design (CAD) which employs an extensive expert- created database, for all curve patterns, enables quality braces to be manufactured without a plaster cast. Moreover, expert-supported quality assurance serves to mitigate potential sources of error.

Today most brace variants neglect to restore physiological or natural lumbar lordosis, even partially. The Chêneau light® brace (no longer available) and the current GBW allow for a marked correction of lumbar lordosis that is typically reduced in idiopathic scoliosis (Weiss and Moramarco 2013a).

The design variants now possible for the updated GBW have solved the problems other braces encounter and has elevated brace creation to the next level.

The Boston brace, as well as other brace variants with an abdominal press, end up aggravating flatback (Danielsson et al. 2007). Flatback is precisely what needs to be avoided as much as possible in light of the assumption that the concomitant loss of a hollow back (in the lumbar spine) favors chronic back pain in adults (Glassman et al. 2005; Asher and Burton 2006).

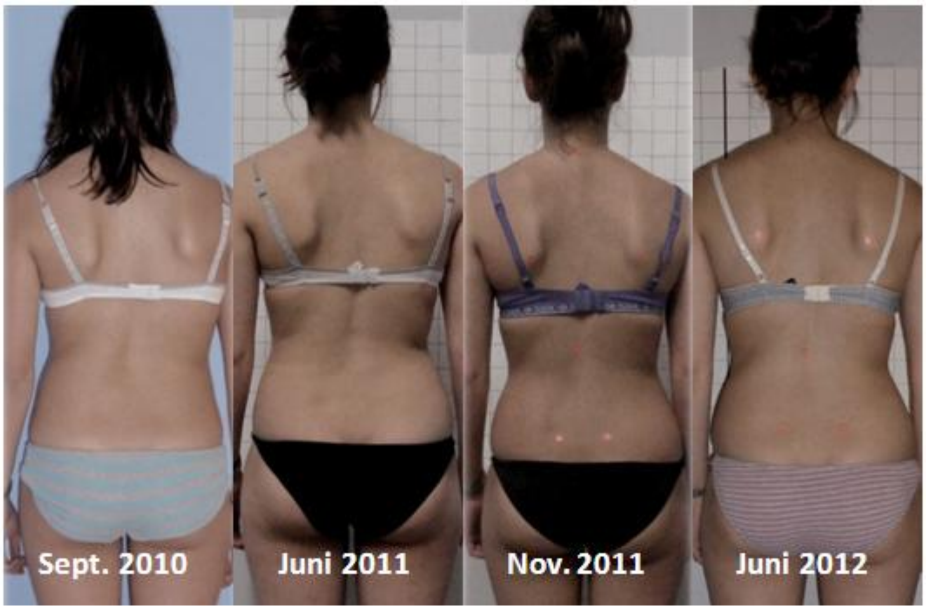

Fig. 9.9. *A thirteen-year-old girl with a thoracic curvature of more than 50° at the beginning of treatment with a CAD Gensingen brace®. At the end of treatment, there is good balance and trunk symmetry that reveals almost no sign of scoliosis (Weiss and Moramarco 2013a).*

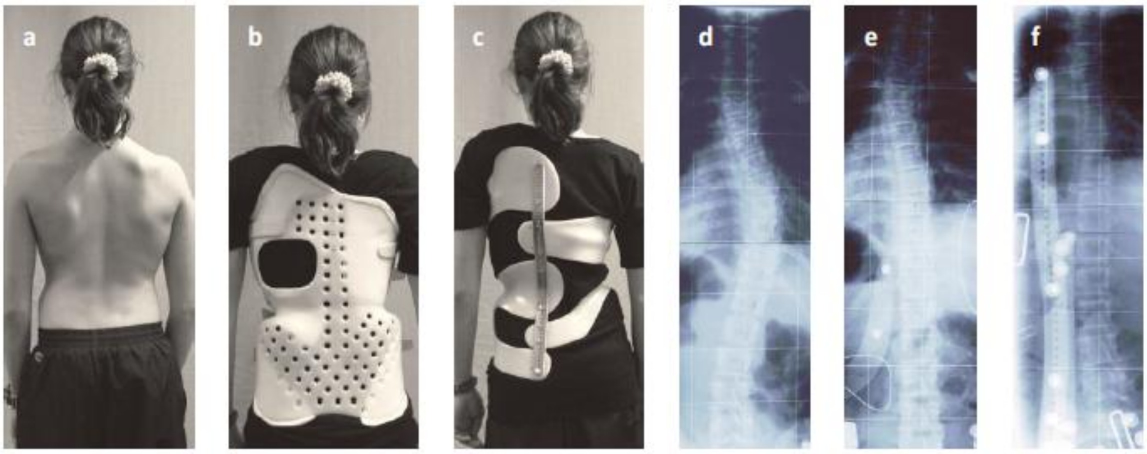

Fig. 9.10. *A thirteen-year-old girl with thoracic-type adolescent idiopathic scoliosis of 39° according to Cobb (a, d). In the kyphoscoliotic brace (b, e), high thoracic 22°, thoracic 12°, lumbar 5°; in the Chêneau light brace (c, f), high thoracic 22°, thoracic 8°, and lumbar 11°. In the lumbar area, the corrective force was purposely reduced in order to better compensate the appearance after brace treatment. There was severe pain with the brace in illustration (left brace), which was eliminated after switching to the brace as shown in the middle picture.*

Meanwhile, it has been demonstrated that it is not only possible to ably correct scoliosis with higher degree values by using this particular Chêneau brace (Fig. 9.9), but also that successful brace treatment may even approach cosmetic improvements comparable to surgery (Weiss and Moramarco 2013a). However, brace treatment for higher-degree curvatures will only manage to be relatively pain-free if the necessary corrective measures with respect to the lateral profile (i.e. consistent correction of flatback) have been implemented. In the meantime, there is considerable evidence pointing to the fact that the corrective effects of severely painful brace treatment regimens are not forfeited when a non-painful brace providing satisfactory lateral profile correction is used instead (Fig. 9.10).

Corrective Effect of the Brace

The corrective effect of the brace, previously given in percentage of the initial value, determines the final result within certain limits (Landauer et al. 2003). However, it is necessary to consider the question, "What is the purpose of an outstanding x-ray result if a stiffened flatback ensues, resulting in functional loss and/or pain?"
Furthermore, the following additional questions should be considered: Is it worthwhile wearing the brace if the corrective effect is only slight? How can the percentage of the corrective effect be assessed for major curvatures? Is the radiologic outcome of brace treatment predictible? Is cosmetic improvement possible?
In principle, the corrective effect is of great significance. According to Landauer (2003), at least a 40% primary correction with a wearing time of > 20 hours daily sustained improvement can be expected, resulting in a 7° correction, on average. Therefore, it stands to reason that, when bracing, the goal should be to constantly exceed this percentage correction to ensure that brace treatment is worthwhile. Of course, not all curvatures are equally correctable. Much depends on the curvature pattern, curvature strength, and individual stiffening. At a curvature of 40°, we sometimes experience overcorrection to -14° (Fig. 9.1). In contrast, sometimes only a correction from 40° to 32° is achieved, despite the fact that braces are designed according to current knowledge, state-of-the-art methods and of superior quality.
The average corrective effect can now be markedly improved even for curvatures with more pronounced stiffening. Accordingly, a well-made and fitted brace is usually effective even when the corrective effect is slight, enabling halting of curvature progression, in most cases, at minimum. Curvatures beyond 60° pose unique challenges and can only rarely be corrected by 50% in-brace. However, with more substantial curvatures, even corrections of less than 40% have led to sustained curvature corrections in individual cases (Fig. 9.11). It is certainly worth considering whether the absolute correction attained, expressed in angular degrees, might not be better suited for establishing a prognosis rather than a percentage correction.

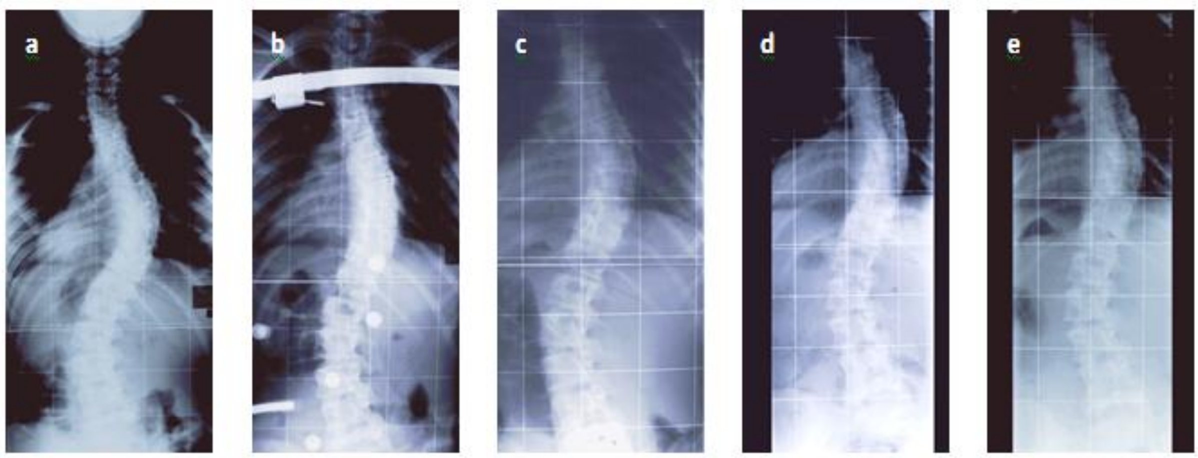

Fig. 9.11. *(a) A thirteen-year-old girl with progressive thoracic condition at 62° with qualitatively insufficient initial treatment in December, 1995. (b) Correction in the new brace to 46° in January 1996. (c) 47°/40° (February 1998); (d) 45°/40° (April, 2001) after weaning off the brace and; (e) 41°/37° (November, 2002) twenty months after weaning off the brace. The condition was stable, through 2007, six years after weaning off the brace. The patient has gone on to establish her own business and does not feel cosmetically impaired. (Weiss HR, 2007).*

Based on clinical experience, a corrective effect of at least 15° should be attained for curvatures beyond the 50° limit in order to stop progression. With a 20° correction and greater, lasting corrections have been achieved, even with curvatures exceeding 50°.
During brace treatment, the problems which sometimes must be solved are not always covered by normal orthopedic or technical orthopedic training. It is necessary that the practitioner have a deep understanding of 3D in-brace corrective movements to avoid compression. The practitioner must also possess the ability to identify challenges and demonstrate the skills needed to solve these stumbling blocks, if and when they appear, after a brace has been fitted or adjusted. Therefore, specific braces should be applied at specialized centers, only.

Correction on the x-ray / Cosmetic Correction

The corrective effect of the brace and the compliance of the patient are two decisive parameters for successful treatment. As long as we measure treatment effectiveness with the x-ray and use the Cobb angle as a parameter for determining success, we will wind up with an inadequate view of the overall treatment results. While it is true that Cobb angle is an important measurement parameter, it does not reveal anything with respect to three-dimensional changes or cosmetic improvements.

Appelgren and Willner (1990) revealed that many braces tend to aggravate the flatback typically associated with thoracic scoliosis, thus exposing patients to the risk of mechanical functional impairment that in certain circumstances may lead to future complaints.

In current brace variants made according to a precise pattern of curvature, the central concern - apart from correcting lateral deviation - is restoration of the normal spinal curvature of the lateral profile. The starting point of the modeling technique is the idea that it needs to be possible to restore the kyphotic (outwardly round) components in the thoracic area and the lordotic (outwardly hollow) components in the lumbar region. This form must be addressed by the brace. Skilled pressure distribution that only permits kyphotic expansion of the thorax (back rounding) must be successful in restoring the lateral profile without bringing about other cosmetic defects in the thoracic region.

According to the latest scientific findings, correcting the lateral profile flattened in scoliosis also has a positive effect on lateral deviation and on spinal rotation. This treatment principle has already been realized in the physio-logic® brace, which is able to correct scoliosis of the lumbar spine (Fig. 9.12). This brace can be used when “normal” brace treatment is not possible due to a concomitant disease or a lack of collaboration on the part of the patient. Long-term results for patients during the main growth spurt are not yet available, which is why this brace is only to be recommended when the above-mentioned restrictions apply. With that said, this brace has already proven itself in the medium-term during growth and in adult scoliosis patients with complaints of pain (Fig. 9.13). Prior to its fitting, the effect of the brace can be simulated by a motion test to find out whether this treatment principle has the potential to be effective for the patient (Weiss 2005; Weiss et al. 2009; Weiss & Turnbull 2020).

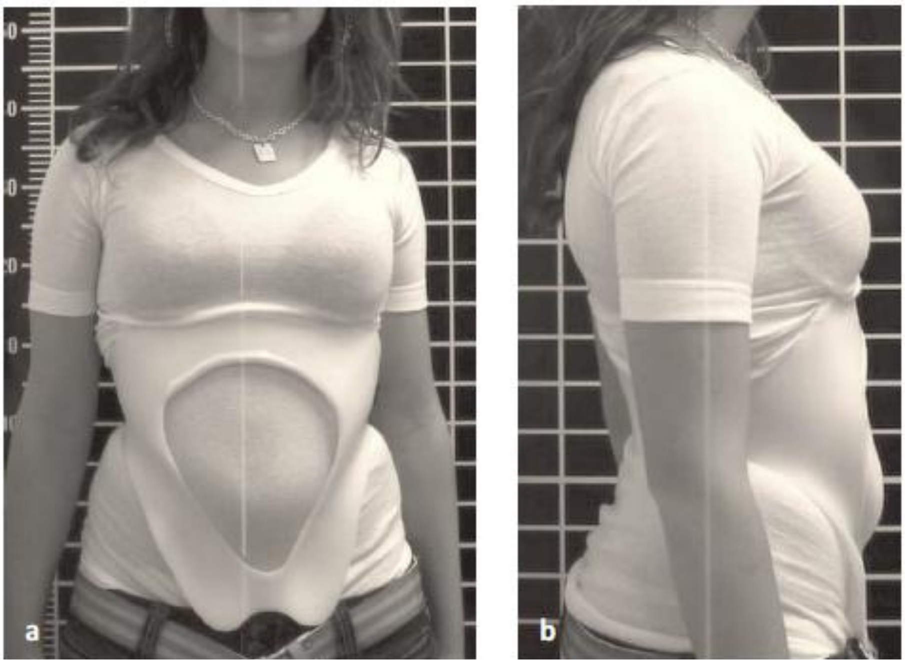

Fig. 9.12. *Physio-logic® brace from the very first series 2004, as seen from the front and from the side (Weiss 2005).*

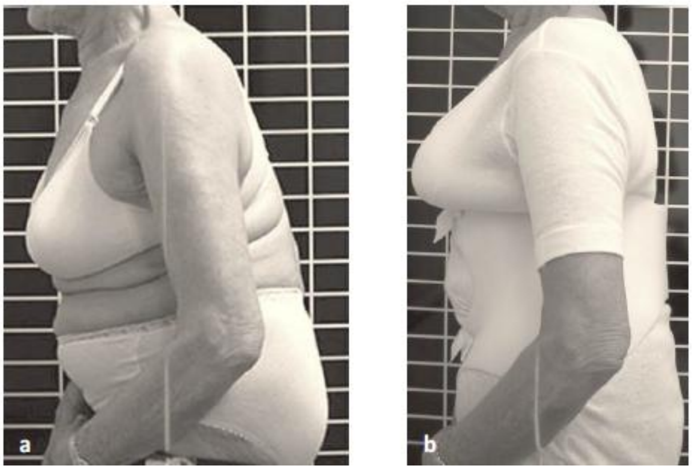

Fig. 9.13. *Patient with severe thoracolumbar scoliosis and chronic low-back pain. The physio-logic® brace (first generation) was used to treat her pain. The straightening effect is evident (Weiss 2005).*

Psychological Problems Related to Brace Treatment

Wearing a brace during the main growth spurt for more than 20 hours a day may decrease quality of life considerably. This is why very few patients are actually enthusiastic about wearing a brace. If the doctor - patient rapport leaves the patient feeling insecure, it is not surprising that they may ultimately refuse an essential element of treatment participation. Females are frequently hesitant to expose their braces, and so sometimes their wear time unfortunately amounts to no more than sixteen hours, an insufficient amount to gain improvements during the main growth spurt.

However, understanding and empathy usually help to improve the wearing time, especially if the parents manage to maintain composure and deal with issues concerning the brace. Unfortunately, this is not always the case since this situation is frequently unsettling for parents as well as the adolescent. What's more, parents often feel guilty ("How could this have happened?") and are now looking for the 'best way'' to treat their children "as quickly as possible."

The parent must exercise caution in this instance. Inquiries are made to all types of practitioners, including those marketing heavily on the internet. This leads to uncertainty and added stress for families due to the opinions of self-proclaimed experts who are not necessarily trained scoliosis professionals or those who are using techniques which lack documentation or a record of success. The result for families is added confusion and doubt.

The mental stress that children and parents are subjected to when making decisions sometimes requires psychological support. In very few cases are the fears and self-reproach justified. In fact, such feelings are by no means a solid foundation for the necessary decision-making process and may even prevent treatments from attaining their potential for success. Expert physiotherapists have a good opportunity to support those affected and their parents, as they usually spend significantly more time with their patients than the technician or the doctor treating them.

It is clear that brace treatment compromises the quality of life of those who wear them, which is why it is not only important for specialists to incorporate the latest technical advances in their work, but also to work to advance brace treatment. Efforts must continue until it is established, with certainty, that quality of life impairment is offset by successful treatments - treatments that reliably avert surgery and result in a satisfied patient.

Learning to Wear a Brace

In some braces, major problems and discomfort may occur. This is the reason that patients are often advised to get accustomed to wearing a brace slowly. Fortunately, the recent CAD/CAM developments usually result in a brace which can be worn full time from the start. Once the initial fitting and adjustments for improving the wearing comfort of the brace have been administered, it should be worn as regularly as possible, immediately, and throughout the main growth spurt. To relieve pressure as necessary in a minority of patients, it is sufficient to simply open the clasps of the brace for 15-20 minutes and then re-tighten them. These periods of rest allow the skin to recover, thus enabling the body to frequently tolerate an uninterrupted wearing time of more than twenty hours, even on the first day.

Generally, after about a week of brace wear, the brace should then be tolerated for up to twenty-three hours daily. However, if there is any difficulty sleeping while learning to wear the brace full-time, it is recommended to wait three days before attempting to wear the brace at night again. Otherwise, the loss of sleep from repeated attempts, night after night, can have a demoralizing effect.

When the patient is adjusting to brace wear, any complaints should be taken seriously. It is extremely important to recognize and eliminate problems so that at the end of the introduction period, the only pressure still felt is at the necessary pressure points and the patient is pain free.

If the truss pad covers a large patch of skin around the main pressure areas, then a good corrective effect will be achieved with a minimum amount of physical impairment. Pain occurs if there is no clearance (voids) in the brace for the corrective movement to take place. The lack of such clearance squeezes the trunk, which is not generally tolerated well. The solution to this problem does not come from reducing the pressure (and thus diminishing the corrective effect), but rather by addressing the lack of clearance areas via increased space. Unfortunately, the clearance areas make the brace a little bulkier, but this is precisely the way to achieve the best effect. Should there still be pain after any problems have been eliminated, it will be necessary for the patient to be re-examined. In individual cases, rib blocking may prevent the brace from being tolerated. In such instances, physiotherapy, manual therapy, or chiropractic manipulation should be sought to reduce the pain caused by functional joint issues; medications and massages, medicinal baths, electrotherapy, or simply rest may also be prescribed if there is costovertebral joint inflammation.

Another part of the process of brace adjustment is for the practitioner to provide extensive information and answers to every question. Patients often attend the consultation sessions with their parents. If, in the course of the conversation and examination it is evident that the parents may react emotionally, it is advisable for the attending doctor to speak with them alone and present the issues in a disarming manner. In certain cases, remarks made by the parents could potentially result in the child declining the necessary brace treatment or viewing it as something awful. At the same time, the attending physician should not exert pressure, but, after extensive information and consultation, rather allow the child or adolescent to be responsible for making the decision on his or her own as much as possible. Showing understanding and providing ample information is usually more than sufficient to awaken a sense of personal responsibility, even in children under ten years of age. This acceptance helps contribute to a favorable course of treatment.

On the other hand, during the course of early treatment, parents who are overzealous must not admonish their child regarding time in the brace since during this phase of personality development it might foster resistance and result in outright refusal to wear the brace. It is far better for the child to successfully become accustomed to brace wear on their own terms, even if it is fourteen days into the future, rather than rejecting the brace from the onset.

At the beginning of the wearing phase, in more stiff curvatures it is sometimes necessary to treat the pressure points of the skin by brushing them and applying rubbing alcohol. Creams should be avoided, as they soften the skin, thereby making it less resistant to pressure. A slight reddening of the skin is normal at the beginning of brace treatment and not an alarm signal.

The Gensingen brace ® is standardized and fine-tuned to such an extent that the above-described skin care usually only needs to be recommended when treating curvatures beyond the 60°. Skin irritations occur infrequently in curves below 60º.

Treatment duration and Weaning Off the Brace

Treatment duration can vary widely. Should the wearing-in period of the brace result in completely correcting or even overcorrecting a relatively slight curvature angle, it may well be that the process of weaning off the brace can be started after the onset of menstruation - before a marked curvature in the opposite direction ensues. For more pronounced scoliosis curvatures (approximately 40°) which typically do not correct as well as curves under 40°, it is necessary to wear the brace for as long as possible. In the past, girls almost always weaned from the brace at fifteen or sixteen years of age. It has been demonstrated that longer wearing times lead to better (cosmetic) results. This can probably be attributed to the fact that spinal growth still continues to some small degree for more than two years after the growth plates visible on the x-ray have closed. With more pronounced curvatures, e.g. 60º or more, weaning off the brace at age fifteen to sixteen is not usually recommended. Typically, it is best to begin weaning closer to seventeen to eighteen years, depending on the state of maturity.

Braces worn full time may be taken off for school sports. However, the brace should be put back on again immediately after sports participation so the wearing time is not reduced unnecessarily. Competitive sports should mostly be avoided by scoliosis patients with a brace if it could cause the spine to become hypermobile. This does not rule out deciding in favor of competitive sports in individual cases (e.g. swimming).
Should problems surface when wearing a brace, such as pain, tingling sensations, or even nausea and shortness of breath, the attending specialist physician should be consulted. The cause can be determined and then any technical problems addressed. For technical problems with the brace (torn off clasp, cracked frame, etc.), the fitting technician should be consulted.
X-rays are necessary for checkups and result in a certain amount of radiation exposure. In slender persons, this can be reduced by taking x- rays with the brace on (1) with half of the exposure time and (2) by reducing the field of exposure to the region of interest (ROI) as described by Weiss and Seibel (2013). In thin children, when exposure time is reduced by half, all details of the bone structure are still recognizable (Fig. 9.14). Even an overlay of the radiation field on the curvature area allows the radiation exposure to be reduced considerably (Weiss and Seibel 2013). For the trunk muscles to become accustomed to being without the brace, it is necessary for gradual weaning from the brace to take place at the treatment conclusion. To do this, wearing time is reduced by 3-4 hours a day for a period of three months after which the brace is only worn at night for the final six months.

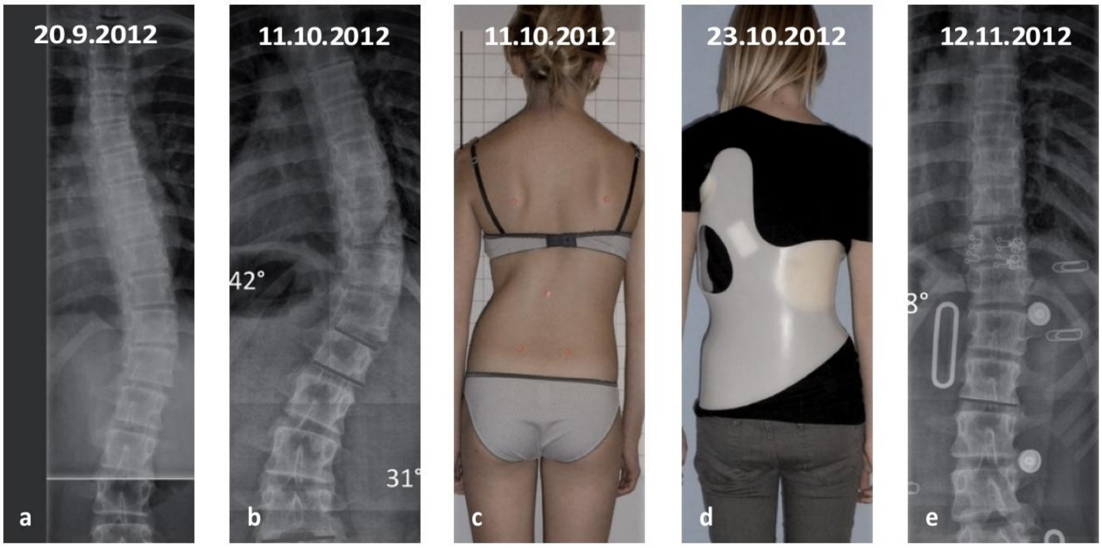

Fig. 9.14. *Patient with scoliosis and vast progression in the short-term prior to brace treatment with the x-rays made according to the least possible exposure to radiation. The region of interest (ROI) is clearly visible and in this girl even with a reduction of the exposure time the structural entities of the bony tissue are visible.*

Frequently Asked Questions (FAQ) - What Can Patients Expect from Bracing?

Brace treatment for patients with scoliosis can be regarded as a long-lasting impairment of quality of life and therefore a great challenge. To undertake this task, the patient needs to be informed not only about the realistic aims of treatment, but also about problems arising from the spinal deformity itself. It is only under this precondition that the patient can decide about brace treatment and take responsibility for treatment.
The objective of this section is to address the most important issues involved with brace treatment. Addressing these issues is beneficial for the professionals who regularly treat patients with scoliosis and is necessary since there are so many inappropriate and scientifically unacceptable claims and false statements made on the Internet. For example, it is necessary to minimize the fears of the patients and their families when preconceived notions dictate that a brace must be painful to wear to be effective. This is categorically untrue.
Answers concerning the percentage of an in-brace correction cannot be reduced to a simple number. This may cause uncertainty in patients and their parents, although there will sometimes be a beneficial outcome even with an in-brace correction of less than 50%. However, a true professional will not be satisfied with an in-brace correction of 50% when the curvature will easily permit a far greater amount of correction. Of course, the best

possible in-brace correction is not worth anything if the patient is not compliant with brace wear. The following is a brief list of questions that arise on a daily basis in the practice of a conservative scoliosis specialist, followed by the appropriate answers which are based on scientific evidence.

Is brace treatment painful?

A good brace corrects the deformity to the best possible extent without causing pain. An actual correction can only take place when there is room for the corrective movement, not by applying compressive forces.
Sometimes the corrective effect of compression braces can be satisfactory, but this correction is pointless if the brace cannot be worn due to pain.

What degree of in-brace correction can be expected?

We strive for a 50% reduction in-brace, but due a variety of factors, this is not always achieveable. In-brace correction is dependent upon the patient and the individual brace.

a. Patient-dependent factors:

- Curve pattern
- Patient age
- Curvature stiffness
- Capability of the patient
- Compliance

b. Brace-dependent factors:

- Pattern specificity
- Shifting of the trunk areas against each other
- Exact fit

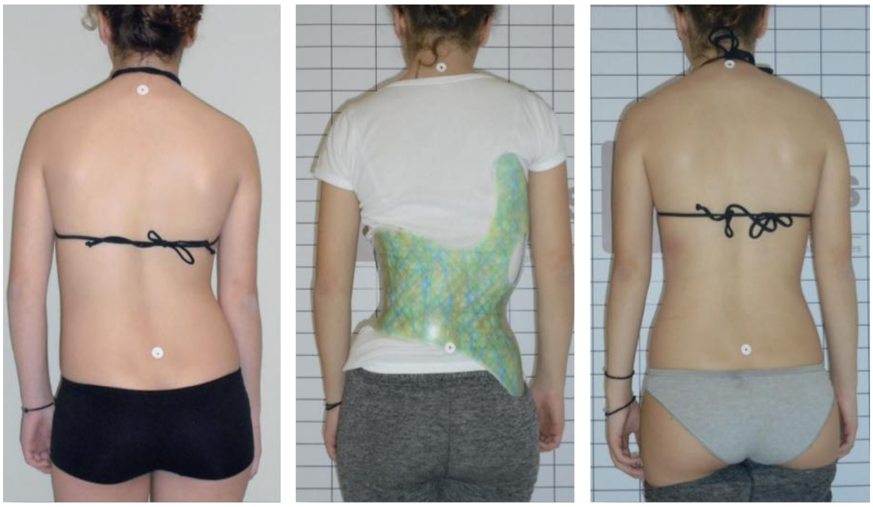

***Fig. 9.15**. Full correction in a single thoracic curve pattern. On the right clinical picture after 12 months of brace treatment (with kind permission by Nicos Tournavitis).*

Double or triple curve patterns allow far less correction than single curve patterns. The curve of an eleven-year-old girl can be corrected more easily than the curve of a sixteen-year-old girl with comparable Cobb angles and comparable curve patterns wearing the same brace type.
According to scientific findings (Weiss 2007; 2011) the in-brace correction should exceed 15°; however, in stiff curvatures this is not always possible (see Fig. 9.15-9.18). Nevertheless, a true professional will not readily accept a low in-brace correction. When the pattern of curvature in the brace is obviously not corrected, the lack of in-brace correction may not be due to curvature stiffness. However, when a brace is designed according to the

current “state-of-the-art” standard and improvements to the brace do not lead to an increased in-brace correction it can be attributed to the stiffness of the curvature (e.g. tethered cord). Only the experienced specialist will be able to distinguish between these facts.

Fig. 9.16. *More than 50% of correction in a girl with a thoracic curve exceeding 45° in a GBW. On the right the patients scan and the patients’ CAD brace model is visible.*

Fig. 9.17. *More than 50% of correction in a boy with a thoracolumbar curve exceeding 60°in a GBW. On the right the patients scan and the patient’s CAD brace model is visible.*

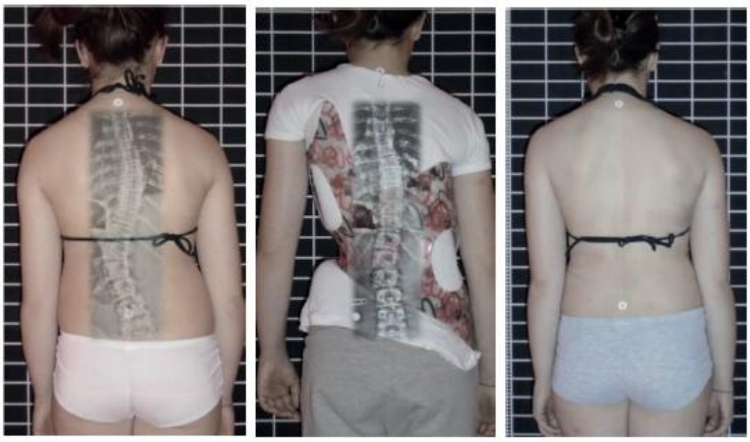

Fig. 9.18. *More than 50% of correction in a girl with a double curve pattern. After 6 weeks of brace treatment a slight clinical correction already is visible (right).*

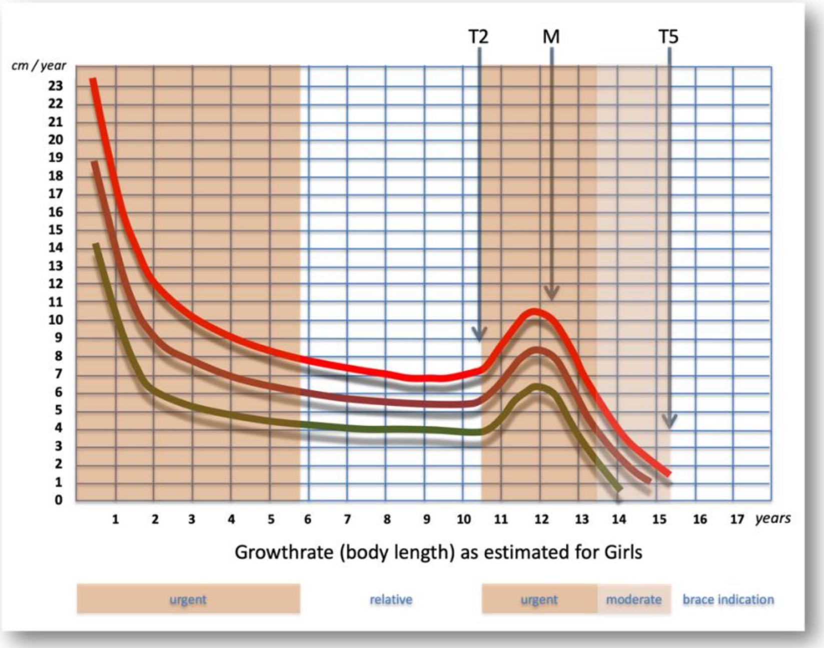

Fig. 9.19. *The growth curve for girls: Between age six and the onset of the first signs of maturity, there is generally no significant increase in curvature. Once the first signs of maturity ensue (T2 = Tanner 2), a considerable increase in curvature can be expected. Depending on the severity of the curvature, timely brace treatment may be necessary since an increase in curvature can occur within only a few weeks during the main growth spurt. The regions marked in red / ochre color show phases of increased growth momentum. (M = onset of Menarche; T5 = Tanner stage 5).*

Do I need to be braced with a curvature of 20°?

This question can only be addressed when a wider range of facts are taken into account. For example, a seven-year-old child usually has not yet reached the pubertal growth spurt (Fig. 9.19) and, therefore, does not yet require a full-time brace, but may benefit from nighttime bracing. Likewise, a sixteen-year old girl with the same 20° curvature usually has no further residual growth and does not necessarily require brace treatment. However, an 11-year-old girl with a 20° curvature, according to current knowledge, needs full-time bracing because she is in the pubertal growth spurt, is at 80% risk for being progressive and has the opportunity for final correction with a brace of higher quality (Fig. 9.15 - 18).
If a patient is braced at an early stage and achieves an acceptable in-brace correction, there is a good chance for brace wear time to be cut back early if the curve is below 15° after 6 months of brace treatment. This is not as easily achieved in more mature patients with larger angles of curvature (Fig. 9.17 and 9.18).
During the pubertal growth spurt, curvatures of 15° should also be braced at least part-time, especially when there is a large deformity in comparison to the Cobb angle (large rotation, slight lateral deviation). In such a case, if no treatment commences, an unfavorable prognosis can be assumed.

What can be regarded as successful brace treatment?

When the Cobb angle of a curve at high risk of progression is kept stable within the limits of the accepted measuring error (+/-5°) until growth ends, this is regarded as successful brace treatment. For the Boston brace, the success rate appears to be 70%, and for the old Chêneau brace (1999 standards), 80%. Recent publications show the success rate of the CAD/CAM Chêneau brace (Gensingen library) is about 90% for the skeletally immature (Weiss and Werkmann 2012; Weiss et al. 2017; Weiss et al. 2019; Weiss et al. 2021a). In curvatures between 20 and 40°, a final correction of the curve and deformity may be achieved when the brace is worn full time during residual growth (Fig. 9.20-9.22).

Nevertheless, even in patients of relative maturity and with little residual growth remaining, cosmetic improvements (e.g., a recompensation of the trunk) can be achieved using braces from the Gensingen library.

Such cosmetic improvements significantly reduce deformity-dependent stress that the patient might experience and thereby reduce the desire to undergo surgery (Budi & Varani 2022).

Unfortunately, even patients being treated with the best brace may quit brace wear prematurely. In addition, growth dynamics are unpredictable and sometimes the brace - initially adjusted properly - is unsuitable at a checkup due to patient growth. When it is decided at the checkup to leave the brace as is or with minor corrections for another three months and the patient grows drastically and the brace no longer fits well, in rare instances the curvature can increase because of the fast growth and unpredictable growth timing (growth peak at the wrong time). A combination of factors could result in the brace becoming unsuitable; yet, braces cannot be renewed too often due to cost.

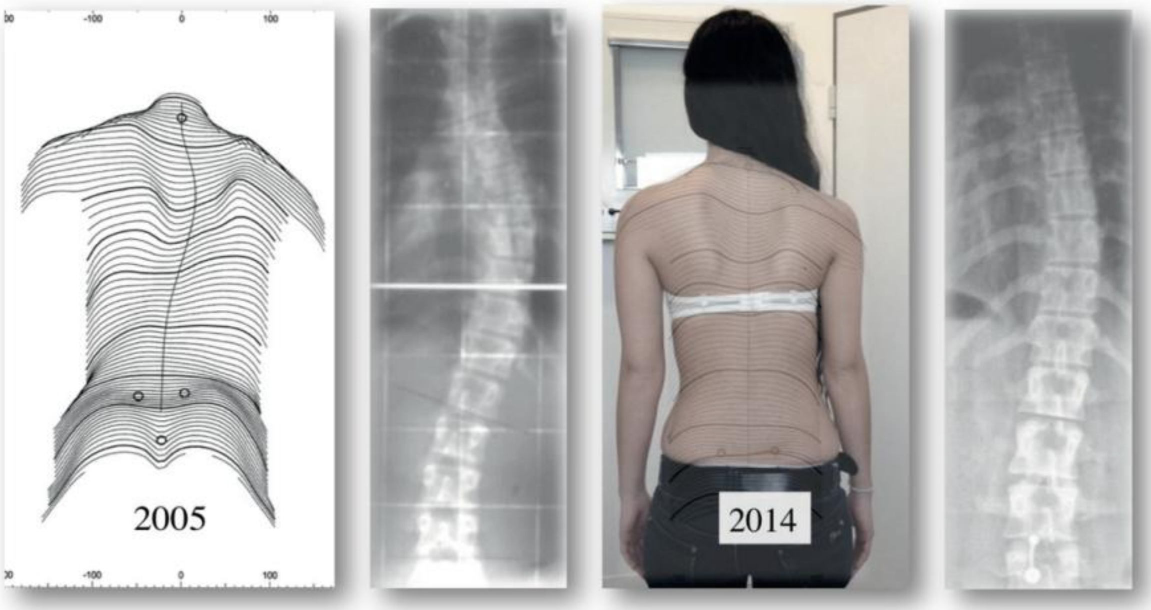

Fig. 9.20. *Girl with a 38° thoracic curvature at the start of treatment with a significant deformity as visible in the surface scan (left). On the right long-term result 5.6 years after brace weaning 19° showing that corrections achieved with recent Chêneau braces may be stable in the long-term.*

Finally, a significant end-result correction, as seen on x-ray, can only be achieved in patients with significant residual growth and full-time brace wearing time (Weiss and Moramarco 2013a). In more mature individuals (girls of fourteen, and boys of sixteen-years-old), residual progression may easily be stopped and an improvement to the clinical aspect (cosmesis) is possible. However, as with improvements as a result of surgery, long-term data is lacking and there is no evidence validating that cosmetic improvements achieved via bracing can be regarded as stable in the long term.

In curvatures beyond 40°, significant and stable improvements of the Cobb angle persisting five years after brace weaning seem to be rare; however, progression can be stopped in most of these cases using recent CAD/CAM-based Chêneau derivatives (Fig. 9.23).

Fig. 9.21. *Clinical improvement after only six weeks of full wearing time.*

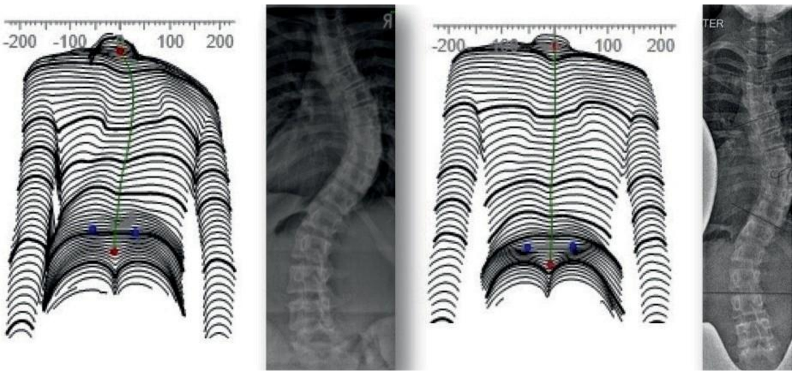

Fig. 9.22. *Cosmetic and radiologic intermediate result after 4 months of wearing a Gensingen Brace (GBW).*

Fig. 9.23. *Recent technology: Gensingen brace printed in 3D in China (Xiaofeng Nan). This brace, designed for a double major curve pattern, can fully correct both curves.*

How long will it be necessary to wear the brace?

The indication for brace treatment for growth-channeling is best applied during the main phase of growth. The reason for this is that it is not completely unheard of for a 20° to 30° progression to occur within a matter of weeks in an unbraced patient. At the end of the pubertal growth phase (fifteen years of age in girls and seventeen years in boys), progression exceeding 15° within a single year will not usually occur. However, it should be noted that even at the end of the pubertal growth spurt, significant improvements to balance and clinical appearance are possible with treatment via the Schroth-based Gensingen brace®. Brace treatment at this juncture will help to improve postural appearance and reduce the patient's desire to undergo surgery.
In general, in a compliant patient with a curvature of less than 30°at the start of treatment, weaning can usually begin around the age of fifteen in girls and seventeen in boys. In curvatures exceeding 30° at the start of treatment, brace weaning should be delayed and prolonged to allow for stabilization. After brace weaning is complete, it is only natural that the curvature may increase to some extent but this should not be regarded as deterioration.
When an overcorrection in skeletally immature patients is achieved, parents are advised to check their children every two weeks and follow up with the attending professional every six weeks. In some cases, brace wearing time can be reduced in a skeletally immature patient with a radiologic overcorrection.
When clinical overcorrection is attained, brace wear time should be reduced from > 20 hours to 16 hours per day. If overcorrection persists, then brace wear may be reduced to 12 hours. If the clinical correction later reduces, then wear time is increased again. This type of active management produces the best possible clinical outcome and trunk balance.

Is it necessary to undergo physical rehabilitation continuously during brace treatment?

As discussed previously, physiotherapeutic instruction may have a beneficial effect on patients with scoliosis when applied curve-pattern specifically. Nevertheless, during growth, the effect of brace treatment should be regarded as the primary treatment method (Fig. 5.1). In children and adolescents under brace treatment, there is no reduction in muscle activity while wearing a brace (Güth et al. 1976; 1978). Rehabilitation instruction at certified centers can provide psychological support and help embolden the patient during brace treatment. Obviously, effective, corrective, evidenced-based conservative measures which share correlating principles may be helpful and contribute to an improved outcome at skeletal maturity; however, if physiotherapeutic approaches create undue stress, use of an effective brace, at minimum, should be the first recommended approach during the pubertal growth spurt.

At brace weaning, it is advisable to step up Schroth Best Practice rehabilitation instruction to reinforce concepts which show how to avoid postures which may increase the curvature and overload the spine during daily activities. Intensive treatment based on curve-pattern and curve severity should be prescribed if rehabilitation instruction has never previously occurred.

How do you recognize a brace of high quality?

A high-quality brace is recognized by the correction movement it produces. In a thoracic right convex curvature, the brace should mirror the curvature pattern, so it should at least clinically lead to a thoracic left convex appearance (Fig. 9.24). If braces do not lead to a mirroring of the curvature pattern, one cannot expect any or only a low correction. Such braces (Fig. 9.24 c-e) with an insufficient in brace correction will usually not be able to stabilize a curvature.

Fig. 9.24. *a: Patient with a thoracic curvature to the right. b: In the GBW, a mirroring of the curvature pattern is clearly recognizable. c and d: obsolete Chêneau braces based on plaster casting from 2016. These clinically show no corrective movement and therefore are of very limited effectiveness. e: M-Brace from the Netherlands without any correction for a right thoracic curve. Again, no mirroring of the curvature pattern can be seen. The curvature seems to be fixed in its form.*

Future Developments in Brace Treatment - a Perspective

With the advent of CAD technology, it has become possible to reinforce the corrections to the limit of what is tolerable (Figs. 9.15-18; 9.23). However, more pronounced trunk displacement is a consideration and can be conspicuous and keep the adolescent from wearing such a "lopsided" brace at school.
With the possibilities of 3D printing, there are a variety of possibilities for an improvement of comfort. So far, printed braces have no advantages over braces that are vacuumed on a carved brace model. The entire potential of the 3D printing is only developed by targeted variations of the wall thickness, through the combination of different materials and different textures.

Brace Treatment for Non-Idiopathic Scoliosis

Most reports of brace treatment involve patients with idiopathic scoliosis. Minimal information is available regarding the effects of bracing on symptomatic and syndromic cases of scoliosis (see also Chapter 1).

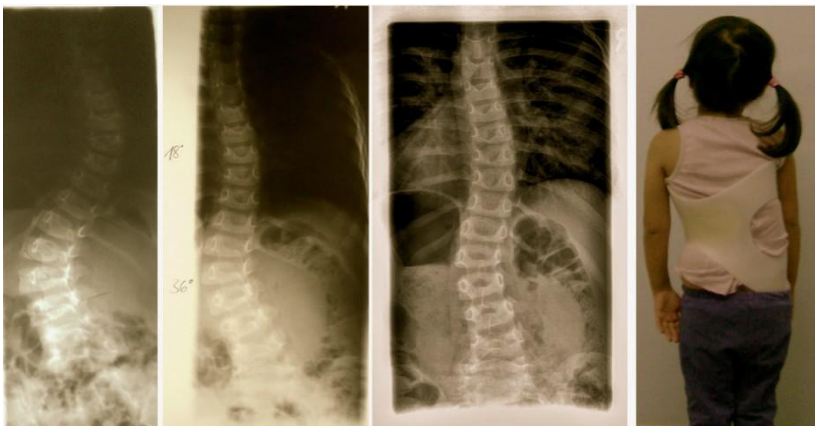

Fig. 9.25. *A 2-year-old girl with Marfan syndrome who was brought to the first author with a double major curvature and a Cobb angle of 20°. At first, the course of the condition was observed. Within 6 months, there was progression to a Cobb angle of 50°. Right away, specific CAD/CAM Chêneau brace treatment was initiated. Through consistent treatment with this method, the curvature was reduced to a Cobb angle of 24° without the brace at the age of 4.6 years.*

Symptomatic scoliosis and/or syndromic scoliosis (Winter 1995; Chik 2020) usually has an unfavorable prognosis with brace treatment, except in the case of balanced formation defects which often do not require treatment with a brace at all. According to current findings regarding scoliosis surgery, medium and long-term complication rates are high and evidence for surgery is lacking (Bettany-Saltikov et al. 2013; Cheuk et al. 2014; Weiss et al. 2021b). As with idiopathic scoliosis, conservative treatment measures must be considered in cases of symptomatic scoliosis and/or syndromic scoliosis.

Due to the scarcity of individual clinical information accompanying the less common types of congenital scoliosis, little comprehensive research has been conducted to study how patients are affected by conservative treatment. One reason for the scarcity may be that symptomatic scoliosis and/or syndromic scoliosis is often operated on at an early stage - in spite of the uncertain outcomes. There are a few encouraging case descriptions of brace treatment (Fig. 9.25) in patients with an unfavorable prognosis and documented progression before the beginning of treatment (Weiss 2012).

The corrective results from braces according to the current CAD/CAM standard are not as significant with congenital scoliosis when compared to idiopathic scoliosis (Fig. 9.26). Also, with congenital scoliosis, there are still cases which are progressive following surgery.

Fig. 9.26. *Good corrective effect in a child with a congenital formation defect (thoracolumbar hemivertebra).*

The question is whether the newest corrective bracing technology should generally be the first treatment approach before a surgical intervention occurs. Figs. 9.27 and 9.28 are illustrations/photos of a young boy with progressive congenital scoliosis after surgery. At first this boy was fitted with a low corrective CAD/CAM brace in order to determine whether a partial correction would cause a complication post-surgery.

Fig. 9.27. *Boy with progressive congenital scoliosis after an operation who was originally fitted with a CAD/CAM brace with a low corrective effect in order to find out whether a partial correction would cause a complication in the postoperative condition. This treatment did not result in any complications; however, the curvature increased, but halted clinically (ATR improved) by means of Gensingen brace (GBW) treatment offering a pronounced shift.*

Fig. 9.28. *Second brace for the boy in Fig. 9.27. This treatment initially halted the progression. The first brace with less correction did not create complications so we applied the full corrective movement in the brace with a reasonable in-brace correction (compared to 9.27).*

Bracing did not result in any complications; however, the curvature increased in this first brace with minor correction. Later, he was fitted with a Gensingen brace with a pronounced shift and a reasonable in-brace correction without any complications.

Using the current CAD/CAM standard, small children can also receive brace treatment. Younger patients with symptomatic scoliosis and/or syndromic scoliosis experience corrective results and comparatively few problems or difficulties with acclimatization. Fig. 9.29 shows a boy with a severe deformity in conjunction with neurofibromatosis who tolerated the CAD/CAM Gensingen brace® extremely well.

As with idiopathic scoliosis, symptomatic scoliosis and/or syndromic scoliosis also needs to be treated specifically, i.e., precisely according to its pattern, both during physiotherapy and brace treatment. At the conclusion of treatment, the x-ray image appears to be much less critical than a sound, cosmetically inconspicuous torso silhouette (Fig. 9.30). There is an art to selecting the appropriate therapeutic method to achieve this result (Weiss and Moramarco 2013a).

Fig. 9.29. *Boy with severe scoliosis deformity in conjunction with neurofibromatosis. Clear decompensation of the thoracic curvature to the right. Clearly visible clinical correction in the USA-produced Gensingen brace® (Scoliosis 3DC).*

Fig. 9.30. *Left: immature girl with a decompensated thoracic curvature and a high risk of progression. Other photos show improvement over the course of treatment with specific Chêneau braces and, as of 2009, with the Gensingen brace®. Clear recompensation resulted in an improved postural appearance after complete maturation, in this case even without full compliance.*

Pattern specific physiotherapy for scoliosis uses the same corrective principles as pattern specific brace treatment. These corrective principles have been derived from decades of experience in physiotherapeutic treatment, a variety of experimentation with the various corrective options, and foremost, as a result of studying tens of thousands of x-ray examinations taken over the course of brace treatment and evaluating the corrective effects.

For this reason, the 'Best Practice' program described and the specific brace treatment corresponding to the individual curvature pattern in accordance with the 'Best Practice' standard (Gensingen brace®) is regarded as the most up-to-date, evidence-based development and backed by a wealth of clinical experience (Weiss et al. 2019; Weiss et al. 2021a).

Conservative scoliosis treatment, according to the Schroth 'Best Practice' standard, is a time-saving, simple, and, most-importantly, effective treatment approach that enjoys outstanding acceptance by the patients (Borysov and Borysov 2012; Pugacheva 2012; Lee 2014; Weiss et al. 2017).

During a growth spurt, however, bracing must be regarded as the primary mode of treatment. The practitioner must be cognizant that physiotherapy alone is unlikely to halt a rapidly progressive scoliosis during a growth spurt.

QR codes on the left to a state-of-the-art article on brace treatment for patients with scoliosis and on the right to a case report of a patient in the main pubertal growth spurt with a severe scoliosis after two heart surgeries in early childhood.

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10. OPERATION AND SURGICAL PROCEDURES

If, despite all efforts, the curvature continues to increase and the extent of curvature exceeds 50 degrees according to Cobb, an operation is generally recommended by spine surgeons. To begin with, this begs the question: "Why an operation at all?"

In late onset, so-called adolescent idiopathic scoliosis, an operation is not necessarily required from a medical viewpoint, and to date there is no scientific evidence in support of the hypothesis that the resulting health conditions of scoliosis left without treatment (as is would be considered) as being worse than those who had a scoliosis operation (Bettany-Saltikov et al. 2015; Bettany-Saltikov et al. 2016; Cheuk et al. 2015; Westrik und Ward 2011; Weiss und Goodall 2008 a&b; Ward et al. 2015; Weiss et al. 2016). It has been demonstrated that such curvatures do not, as a rule, grow so large that life-threatening restrictions on the cardiovascular system are to be feared. There is no direct correlation between Cobb angle and pain either. For these patients, therefore, there needs to be another reason why they would decide to have themselves operated on with a curvature angle exceeding 50 degrees.

If the patient can avoid perceiving scoliosis as a curvature of his or her own spine or viewing it day by day as a "deformation," thereby suffering mental anguish and feeling depressed or fearful for their future, and perhaps disadvantaged with respect to quality of life, then it is possible to do something about it. It does not seem to be for purely medical reasons, but the psychological viewpoints that determine the outlook. If there is no motivation for physiotherapy and brace treatment either, then no other therapeutical procedure is left for treating the deformity besides an operation.

According to the findings of health psychology, mental stress caused by the deformity may also lead to physical complaints.

Fig. 10.1. *A 14-year-old patient, bone age 14.9, 98.8% mature, without any significant cosmetic impairment, satisfied with her appearance. Curvature angle: thoracic 43°, lumbar 32°. An urgent indication for surgery was determined. Prognosis: Only slight tendency towards progression, even without therapy; no significant cosmetic deterioration to be expected.*

Without a doubt, therefore, in such cases it is not a question of just a cosmetic operation. By no means should indications for surgery only depend on radiological findings if corresponding psychosocial impairments are not present *(Fig. 10.1)*.

With the more rare, early onset curvatures and in some cases of congenital spinal scoliosis, which even in early infancy may be quite pronounced, an operation is justified early on even for purely medical reasons due to the prognosis being much worse than an idiopathic case. This sometimes applies to a subset of children with nerve and muscle disorders, as well as the often, severe spinal deformities resulting from these underlying conditions. A Cochrane review, however, has not found evidence for spinal fusion surgery in neuromuscular scoliosis due to Duchenne muscular dystrophy (Cheuk et al. 2015).

What surgical procedures are there?

Basically, we differentiate between posterior and anterior surgical access.

Posterior Access

In the posterior approach, the incision is in the midline of the trunk over the spinous process row, and there will usually be an incision over one of the two iliac crests as well. Various rod systems are currently being used for this operation. They are attached to the spine by hooks or - nowadays almost exclusively - by pediclescrews, thus spanning large sections. For better stabilization, these long rods may sometimes be adjusted with cross connections to prevent any mobility at all in the spanned spinal region directly after the operation. This promotes subsequent osseous strength with the aid of the patient's own bone material, which is deposited during the operation. Patients who have an operation via posterior access can generally leave the clinic once the stitches have been taken out, no later than on the 14th day after the operation. What may be seen as a drawback to this procedure, however, is that the spine must be fused over a longer section than with anterior access.

The spine is thus more restricted in its overall mobility than when the anterior access method is used. There is usually freedom to choose between the two procedures with single-curve spinal curvature. In so-called "combined scoliosis" with very pronounced thoracic curvature and significant lumbar curvature, the posterior access operation is the most commonly used method.

Anterior Access

Anterior access does not lie in the centre of the trunk. As a rule, the incision is made along the ribs. One rib is removed, which, after being broken up into small pieces, is later inserted in the intervertebral spaces as the patient's own bone material for spanning purposes. Then, once the thoracic cavity and/or abdominal cavity is opened, the spine is exposed from the front (anterior). In this technique, the operating surgeon has free access to the vertebral bodies and intervertebral disks. For the corrective procedure, the intervertebral disks from the selected area are removed at first, and then screws are inserted into the sides of the vertebral bodies being corrected. These screws are connected to a rod and, once correction is done, affixed to it. Taking the place of the removed intervertebral disks is the prepared bone material taken from the patient; in the lumbar region, this is sometimes additionally supported by small metal cages that are better able to maintain the space of the disk. This can prevent development of kyphosis (humpback) in the lumbar region. If the size of the vertebral body allows, modern surgical procedures implement two rods for better initial stability at the anterior access.
The anterior access operation has the disadvantage in that the abdominal and/or thoracic cavities must be opened for access. Even today, these operations may rarely require post-operative brace treatment as well to secure the results. The indisputable benefit of the anterior procedure is that a smaller number of vertebral bodies are involved in the area being fused, meaning that better residual mobility and trunk function remain after the operation.
Furthermore, a rib hump and lumbar prominence can in some patients be almost eliminated with an anterior access operation directly after operation. A posterior access operation usually requires additional cosmetic surgery on the ribs to reduce the size of the rib hump.
The fact that the scar is concealed may well be regarded as another advantage of having an anterior access operation. It lies largely underneath the arm in the resting position and is not even visible when girls and women thus afflicted are seen from behind in bathing suits.

History of Modern Spinal Fusion Surgery

The operation according to Harrington was the first procedure with a rod using the posterior access method and was being applied worldwide by the end of the 1960s. The next innovative step came when Dwyer, an Australian, developed the anterior access operation, which Zielke from Germany then further developed as VDS, or "Ventral De-rotation Spondylodesis." VDS has likewise been disseminated around the world.

The double rod systems that are now in use for posterior access were first introduced by Cotrel and Dubousset (CD) in 1984. This procedure has been globally applied since the end of the 1980s. Initially the CD bars were attached to the spine with hooks, later with pedicle screws.

Today the modern dorsal instrumentations usually are attached to the spine with pedicle screws (Dickson 2010).

Current State of Development of Instruments Used for Scoliosis Correction

There are now many hundreds of different implants available for spine-fusing operations.

Fig. 10.2. *The bracket of the Halm- Zielke instrumentation, which is fastened to the sides of the vertebrae with two screws (anterior access). A threaded rod and a solid profile rod are inserted through the holes in the screw head or the bracket, giving the instrumentation the necessary stability*.

The new developments do, however, have some advantages. Thanks to the new ventral double-rod systems, anterior access operations can now be performed without post-operative brace treatments. Furthermore, the fractures that occurred over time in the threaded rod of the original VDS are a thing of the past due to the durable rods currently being used. An example of the ventral (anterior) double-rod system is the Halm-Zielke Instrumentation (HZI), which allows the threaded rod to be reliably guided via a solid frame-plate that is fastened by two screws (Fig. 10.2).

Fig. 10.3 shows the radiological result of a 16-year-old girl with curvature straightening from 68° to 14° according to Cobb. The side profile was stretched as well, with the kyphosis that was more pronounced than normal in the transitional area between the thoracic and lumbar spines being likewise straightened, as can be seen on the lateral images. Excellent treatment results without rib hump resection are clinically possible through three-dimensional form correction alone as well *(Fig. 10.4)*. It has even been possible to improve the correction options for posterior access surgical procedures by increasing the use of so-called pedicle screws. In *Fig. 10.5*, one can see on the left the scoliosis of a 14-year-old girl with idiopathic combined scoliosis, which was able to be corrected almost completely through a posterior access operation.

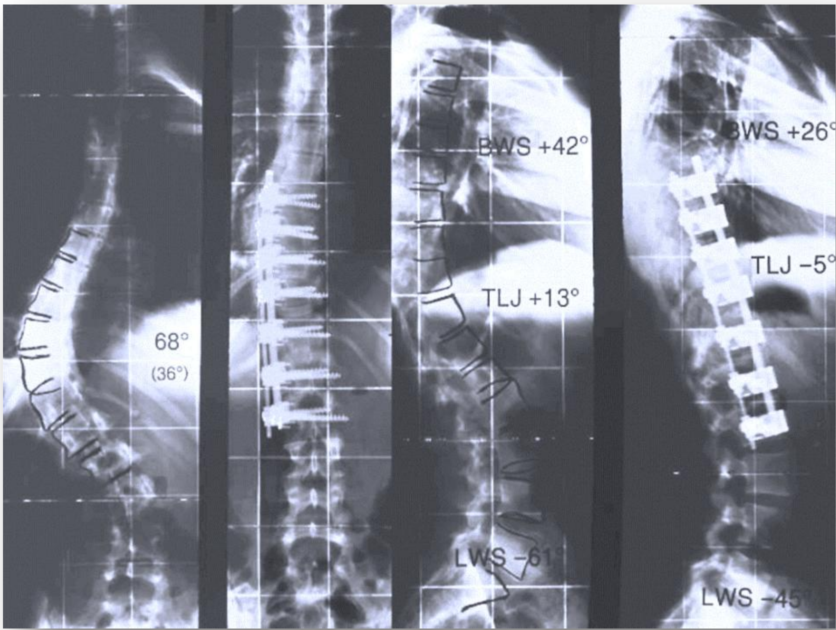

Fig. 10.3. *A 16-year-old girl with idiopathic thoracolumbar scoliosis. Curvature straightening of 68° to 14° was achieved with the aid of the Halm-Zielke Instrumentation (HZI), which also enabled the kyphosis clearly visible from the side to be straightened.*

Both anterior as well as posterior versions of this operation are standard procedure in the specialised spinal surgical centres of today. The choice of which operation is performed should solely be determined by the extent of curvature, the curvature pattern, and the stiffness of the curvature, not by any limitation on the part of the surgeon.

These two surgical options are sometimes used in combination for particularly stiff and severe curvatures. This means that it is possible to carry out ventral (anterior) straightening and additional dorsal (posterior) spondylodesis on the same day in a single operation, with the patients having to be turned during the procedure. *Fig. 10.6* shows the X-ray with a curvature angle of 112° according to Cobb, which was able to be corrected to 28°. In this case, not only was the curvature straightened, but the result attained in the end was also very appealing from a cosmetic perspective.

More recent surgical procedures such as stapling described by *Betz* (Trobisch et al. 2010) have not yet had any genuine indication. On the one hand, there are no long-term results available, and the short to medium-term follow-ups show that this treatment procedure is not at all effective in curvatures beyond the 40° limit. With curvatures up to 40° and sometimes even greater, as shown above, can be excellently improved with currently standard braces and that this kind of brace treatment has been increasingly less likely to involve significant impairment, this form of operation should take careful consideration (Weiss 2011) and cannot be recommended.

In a more recent study concerning stapling, it was demonstrated that, within 2 years after an initial operation, about half of the patients had to be re-operated upon (O'Leary et al. 2011). It is thus clear that this procedure has not yet been perfected.

In the growing age there are already promising results with a more current non-stiffening (non-fusion) procedure. This is called 'dynamic scoliosis correction' or 'Vertebral Body Tethering' (VBT) (Hoernschemeyer et al. 2020). A flexible plastic cable is attached to the side of the patient's spine with screws. Strong tension is placed on the band to straighten the crooked spine (Fig. 10.7). However, the medium to long-term complication rate cannot yet be estimated (Weiss et al. 2021).

Fig. 10.4. *Severe spinal curvature in a 17-year old boy left before the operation using the anterior access. The clinical correction is considerable and no additional surgical procedure was necessary to reduce the ribhump.*

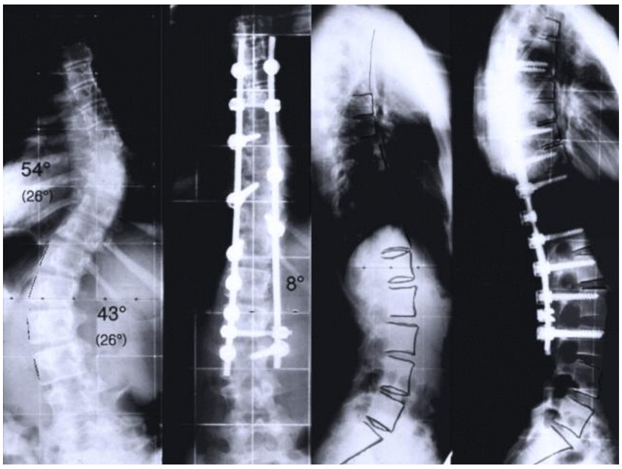

Fig. 10.5. *A 14-year-old girl with idiopathic double-curve scoliosis. There was 54° in the thoracic area before the operation that was almost completely straightened afterwards with the use of so-called MPDS instrumentation via posterior spinal column access. The lateral profile of the spinal column was also positively affected by this operation.*

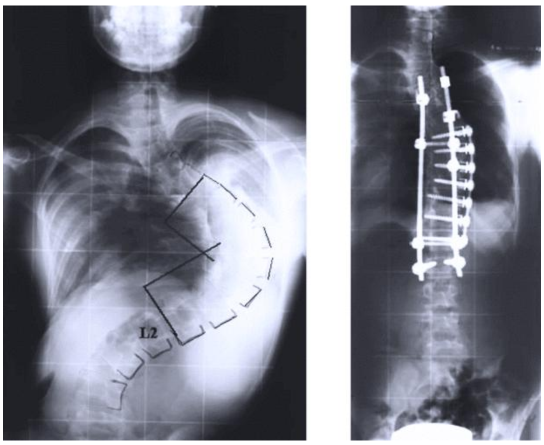

Fig. 10.6. *Severe spinal curvature of 112° before the operation, performed combining both the anterior and posterior access methods on the same day. Straightening to 28° is considerable and out of the question if only one of the two forms of instrumentation is used.*

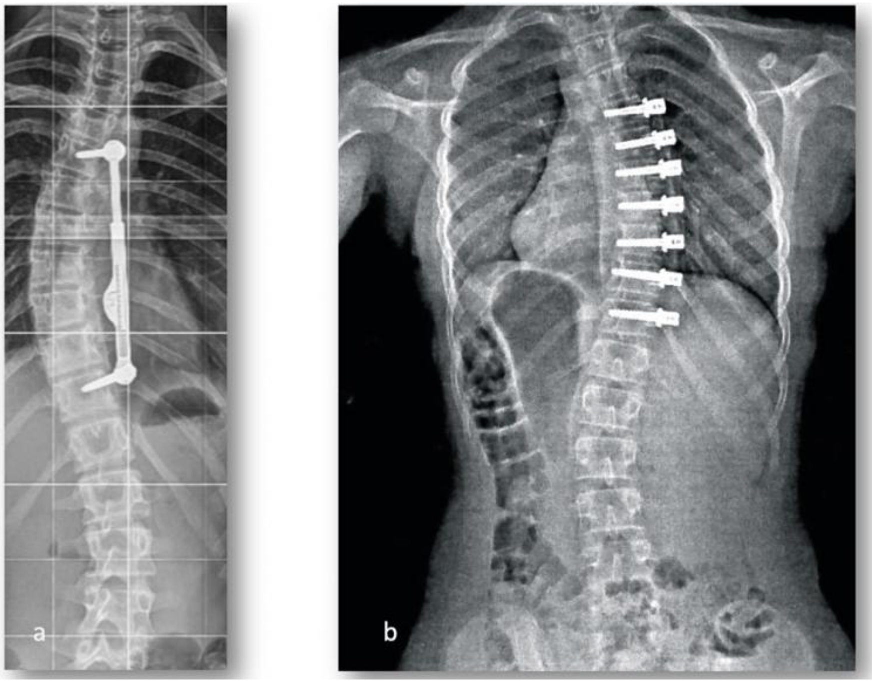

Fig. 10.7. *Non-fusion surgical techniques for the treatment of adolescent scoliosis. a: Apifix; b: VBT.*

In summary, we can state that the anterior access operation is a more cosmetically pleasing and less functionally inhibiting option. Today it can be guaranteed that a posterior access and anterior access operation can in the uncomplicated case be performed without the need for a brace. Admittedly, the posterior access operation does not offer such favourable cosmetic results without additional rib-hump correction.
The overall short-term risk quoted for an operation to treat idiopathic scoliosis is about 5%. That means that 95% of the patients operated on can leave the hospital without any complications whatsoever, usually after no more than 14 days. The complications - in about 5% of the operations - can be broken down into:

- inflammations, which can generally be controlled by antibiotics,
- adverse respiratory effects due to postoperative bleeding, which can generally be alleviated with suitable suction drainage,
- rod or hook tear or rod fracture, necessitating follow-up surgery,
- or nervous disorders (less than 1%). In most cases, post-operative paralysis goes away again, and only a handful of patients can expect to have lasting nerve damage.

In major surgical centres, the operation risks appear to be low. The colleagues from those centres usually state that no cases of nerve damage from scoliosis operations have been determined in the last five to seven years.
This means that operations to treat idiopathic scoliosis can be regarded as having relatively few complications in the short-term. However, the international literature has reported on the possibility of post-surgery pain occurring several years or even decades later, as well as a not insignificant number of patients requiring repeated follow-up surgery due to late complications. A fairly recent publication containing the long-term results of the Cotrel-Dubousset procedure reported that practically half of the patients had to undergo another operation within 20 years (Müller und Gluch 2012). From the latest review studies, it is slowly becoming clear that afflicted persons tend to suffer far more problems down the road after an operation than by going untreated (Müller und Gluch 2012; Weiss und Goodall 2008b; Weiss und Moramarco 2013; Weiss et al. 2013).
According to the latest knowledge a medical indication for spinal fusion surgery in patients with scoliosis does not exist (Weiss et al. 2021). This has been found in two Cochrane reviews (unbiased reviews guided by the Cochrane collaboration) and in other systematic reviews (Bettany-Saltikov et al. 2015; Bettany-Saltikov et al. 2016; Cheuk et al. 2015).
Additionally, patients should be made aware that the clinical corrections as achieved by spinal fusion surgery are not necessarily stable.

More recent non fusion developments like Vertebral Body Tethering™ (VBT) and Apifix™ (Fig. 10.7) seem promising at the first glance, however, there are no long-term results available, and the immediate risk currently still is high because the learning curve of spine surgeons applying these procedures has not yet reached its zenith (Abdullah et al. 2021).

Fig. 10.8. *Late result after spinal fusion surgery. The correction as achieved in the x-ray (left) can be regarded as being good, however, the rib hump 5 years after surgery has reappeared (right).*

QR code for a review article on the operation of patients with spinal deformities. There is no medically justified general indication for such an intervention.

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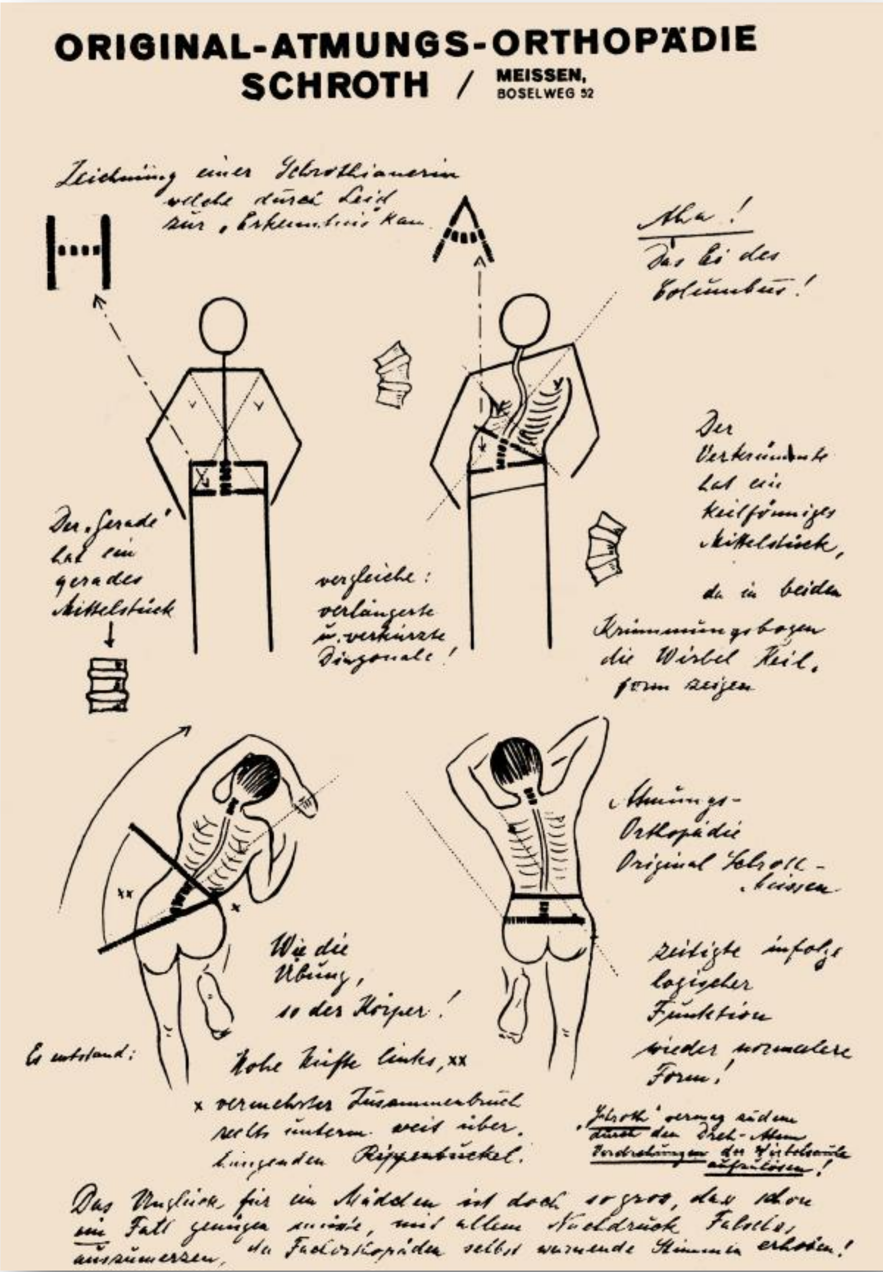

Original manuscript by Kathartina Schroth

This book presents comprehensive and practice-oriented physiotherapy and brace treatment for scoliosis patients. The treatment examples are based on the differentiated findings of the curvature patterns. Their approach follows - albeit in an expanded form - the basic ideas of the scoliosis therapy of Katharina Schroth, the pioneer in this field.

The third edition of the book has been thoroughly revised, taking into account the latest literature and the updated and now scientifically evaluated indication guidelines. The basic modules "physio-logic", “Activities of daily living, ADL", "3D made easy" and "Schroth" merge into an evidence-based overall concept, which can be used in a differentiated manner depending on the individual indication.

The specific exercises have been simplified without sacrificing effectiveness. In fact, when all the tips and tricks described here are taken into account, clinical overcorrections are even possible in the exercise, which were not even attempted in the past. The “Schroth Best Practice” program (SBP) allows effective rehabilitation including patient training within a few days. Thus, this book is also addressed to all those who attend the course program provided by the Schroth Best Practice Academy and want to start effective treatment of their scoliosis patients after just one week of the course.

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