SCREENING AND NON-OPERATIVE MANAGEMENT OF ADOLESCENT IDIOPATHIC SCOLIOSIS

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A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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CERTIFICATE OF ORIGINALITY

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ZHENG YU (Name of student)

ABSTRACT OF THESIS

"Screening and Non-operative Management of Adolescent Idiopathic Scoliosis"

Submitted by ZHENG Yu

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Idiopathic scoliosis is a common disease developed in adolescents. The prevalence of adolescent idiopathic scoliosis (AIS) varied in different regions. Diversified results of previous epidemiological studies on AIS were noticed in Mainland China. After a careful review of all the relevant studies, several studies were found to have substantial limitations. Based on the experience learned from previously published studies, the first part of my PhD project was a cross-sectional study determining the epidemiology of AIS based on a representative sample city, Wuxi (the east part of China), not only to overcome the limitations of previous studies, but to fill the epidemiological blank in this area since no large-scale study on the prevalence of AIS in this area has been performed. Primary and secondary school students aged 10-16 years were enrolled in this study. Physical examination and the Adam's forward bending test (FBT) combined with the Scoliometer were applied at school-based screening. Those who had angles of trunk inclination of 5° or more were referred for whole spine X-ray examination. The threshold for confirmed diagnosis was the Cobb angle of 10° or more. A total number of 79,122 students were screened. The overall prevalence of AIS in Wuxi City was estimated as 2.4%. Girls had higher overall prevalence (3.12% *versus* 2.14%) as well as higher prevalence in each age subgroup as compared to boys.

Higher prevalence was found in individuals with lower body mass index (BMI). Mild and moderate curves were the most common types in this study. To conclude, the prevalence of AIS in this region was slightly higher. Medical resources should be considered for the children with lower BMI and high risk of scoliotic progression. Application of the Scoliometer would be suitable for mild to moderate scoliotic deformities while alternative methods should be developed for those with severe deformities or higher BMI. To the best of our knowledge, this study was the largest scoliosis school screening program ever conducted in the east part of China and filled the epidemiological blank of AIS in this region and may serve as the reference for future studies. Apart from that, longitudinal screening data are strongly suggested to collect, the effectiveness of the specific treatment can be partially reflected by the trend of the prevalence.

A number of well-designed studies comparing non-operative management of AIS have been performed and the evidence becomes stronger. After a long period in which research on non-operative management of AIS continuously increased, the situation changed in the last 10 years. Nevertheless, there is a strong need to continue this research, recommendations also stress the need for high quality studies, not simply studies with low level of evidence, for searching the correct indications and contraindications. There is no high-level evidence supporting the effectiveness of orthotic intervention *versus* exercise. Based on the concerns mentioned above, a prospective randomized controlled trial (RCT) was planned right after the screening. Specifically, it was designed to investigate the effectiveness of orthotic intervention *versus* exercise on spinal curvature, body symmetry and quality of life (QoL). The inclusion criteria recommended by the Scoliosis Research Society (SRS) and the Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) were

applied during enrollment. Eligible patients were randomly assigned to either the orthotic intervention group or the exercise group. Patients in the orthotic intervention group were prescribed with a rigid thoracolumbosacral orthosis (TLSO) and requested to wear 23h/day, while patients in the exercise group were treated with the protocol of the scientific exercises approach to scoliosis (SEAS). Data regarding angle of trunk inclination (ATI), Cobb angle, shoulder balance, body image, QoL were collected every 6 months. Twenty-four patients in the orthotic intervention group and 29 patients in the exercise group participated in this study. For the inter-group comparison, the orthotic intervention group showed better results about the correction of spinal curvature (5.88±6.37° in the orthotic intervention group *vs.* 2.24±3.19° in the exercise group, p=0.01). For scores concerning QoL, especially function (4.88±0.14 in the exercise group *vs.* 4.71±0.13 in the orthotic intervention group at the 12-month follow-up evaluation, p<0.001), mental health (4.48±0.20 in the exercise group *vs.* 4.18±0.25 in the orthotic intervention group at the 12-month follow-up evaluation, p<0.001) and total score (102.17±1.87 in the exercise group *vs.* 99.00±2.32 in the orthotic intervention group at the 12-month follow-up evaluation, p<0.001), were higher in the exercise group than that of the orthotic intervention group. The results of body symmetry evaluation did not differ significantly between the two groups. For the intra-group comparison, parameters of spinal curvature (baseline *vs.* 12-month, p<0.03 in the exercise group and p<0.001 in the orthotic intervention group), QoL (baseline vs. 12-month, p<0.001) and scores of the trunk appearance perception scale (TAPS) (baseline vs. 12-month, p<0.033) significantly improved over the studied period. Shoulder balance (baseline vs. 12-month, p<0.005) showed significant improvement only in the orthotic intervention group. To conclude, both interventions of orthotics and exercise showed significant treatment effectiveness on the patients with AIS.

Orthotic treatment was superior to capture corrections in parameters of spinal curvature and body symmetry, while the QoL, especially in aspect of the functional and psychological status, was significantly better in the exercise group. Significant correlations were detected between the internal deformity (spinal deformity reflected by Cobb angle and trunk deformity reflected by shoulder balance) and the external deformity (body image evaluated by the TAPS). The dynamic changes of corresponding parameters due to the intervention were also significantly correlated. Although generally no significant correlation was detected between mental health and items representing deformity in this study, the total scores of SRS-22 and scores of satisfaction were significantly correlated with mental health. Finally, better compliance can lead to better treatment outcomes and in turn improve the satisfaction of the treatment, the latter would positively affect the compliance and the general QoL. In conclusion, both orthotic intervention and exercise showed significant treatment effectiveness on patients with AIS in this study and it was the first RCT study designed to answer the clinical question "Whether orthotic intervention and exercise are equally effective to the patients with mild to moderate AIS?". Although the short-term effectiveness of orthotic intervention *versus* exercise has been verified in the current study, it is strongly suggested that efforts should be donated to long-term RCTs with high quality according to the recommendations published by the SRS and the SOSORT though the difficulties in performing RCTs have generally reached a consensus.

LIST OF PUBLICATIONS

Journal articles

1. Zheng Y., Dang Y.N., Wu X.J., Yang Y., Reinhardt J.D., He C.Q. & Wong M.S. (2017) Epidemiological study of adolescent idiopathic scoliosis in eastern china. *Journal of Rehabilitation Medicine*, 49: 512-519.
2. Zheng Y., Dang Y.N., Yang Y., Sun N., Wang T., Li H.B., Zhang L.J., He C.Q. & Wong M.S. (2017) A case-control study of body composition, prevalence, and curve severity of the patients with adolescent idiopathic scoliosis in the east part of China. *Spine Deformity*. (Accepted)
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Conference presentations and publications

1. Zheng Y., Wu X.J., Dang Y.N., Sun N., Yang Y., Wang T., He C.Q. & Wong M.S. (2016) Prevalence of idiopathic adolescent scoliosis among primary and middle school students in Wuxi, China. *The first combined meeting of the International Research Society of Spinal Deformities and the Society on Scoliosis Orthopaedic and Rehabilitation Treatment*, 25-28 May 2016, Banff, Canada.

2. Zheng Y., Dang Y.N., Wu X.J., Yang Y., Reinhardt J.D., He C.Q. & Wong M.S. (2016) An epidemiological study on the prevalence of adolescent idiopathic scoliosis: findings from school screening in China. *The Prosthetics and Orthotics Scientific Meeting 2016*, 24 September 2016, Hong Kong, China.

3. Zheng Y., Dang Y.N., Wu X.J., Yang Y., Sun N., Wang T., He C.Q. & Wong M.S. (2017) A case-control study of body composition, prevalence and curve severity of the patients with adolescent idiopathic scoliosis. *The 16th World Congress organized by the International Society for Prosthetics and Orthotics*, 8-11 May 2017, Cape Town, South Africa.

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LIST OF ABBREVIATIONS

AAOS: American Academy of Orthopedic Surgeons

AAP: American Academy of Pediatrics

AIS: adolescent idiopathic scoliosis

ATI: angle of trunk inclination

BMI: body mass index

CA: clavicular angle

CCT: case controlled trial

CHD: coracoid height difference

CRID: clavicle-rib cage intersection difference

CSB: clinical shoulder balance

CTAD: clavicular tilt angle difference

FBT: Adam's Forward Bending Test

ICC: inter-/intra-observer correlation coefficient

NPV: negative predictive value

POSNA: Pediatric Orthopaedic Society of North America

PPV: positive predictive value

QoL: quality of life

RCT: randomized controlled trial

SD: standard deviation

SEAS: scientific exercises approach to scoliosis

SOSORT: International Society on Scoliosis Orthopedic and Rehabilitation Treatment

SRS: Scoliosis Research Society

TAPS: trunk appearance perception scale

TLSO: thoracolumbosacral orthosis

USPSTF: United States Preventive Services Task Force

CHAPTER 1 INTRODUCTION

1.1 Background

AIS develops at the age of 11-17 years and is characterized by a side-to-side curvature of 10° or more, usually combined with a rotation of the spinal vertebrae. The term AIS is applied to all patients in which it is not possible to find a specific disease causing the deformity (Negrini et al., 2012). As a common spinal deformity in adolescents, it is essential for early detection of AIS. School-based AIS screening has been performed in many countries since 1950s, while its necessity and efficacy are always controversial due to the evidence of over-prescription of brace, high unnecessary radiological exposure rate and low investment-benefit ratio (Luk et al., 2010). Professional associations like the American Academy of Orthopedic Surgeons (AAOS) and the SRS support it while the United States Preventive Services Task Force (USPSTF) advised against it (Richards et al., 2008). Nonetheless, it is still the most effective method not only for detecting patients in early stage but also for preventing curvature progression and reducing surgical rate.

Many studies on the prevalence of scoliosis have been carried out in Mainland China. After a careful review of all the relevant studies, several studies were found to have substantial limitations. For example, researchers used varying definitions of AIS and study protocols for research conduction which made it difficult for data comparison across studies; only 40% of studies had access to large sample size and only 60% of studies trained their evaluators before screening; very few studies summarized the participating rate thus the representative of the sample were unknown

and very rare studies handled the missing data therefore bias may be launched due to the incomplete information (Zhang et al., 2015). Based on the experience learned from previously published studies, an AIS screening was conducted in the east part of China, not only to overcome the limitations of previous studies, but to fill the epidemiological blank in this area since no large-scale study on the prevalence of AIS in this area has been performed. It is hypothesized that the well estimated prevalence in Wuxi City can be used to serve as reference and power future studies.

Approximately 10% of children diagnosed with AIS require non-operative management. Orthotic management and exercise play primary roles in the so-called non-operative management of AIS (Negrini et al., 2012).

Orthotic treatment can be defined as the application of external corrective forces to the trunk. This is usually achieved through rigid supports, but elastic bands are also used. Treatment commences when the curve is diagnosed as progressive or exceeds a threshold, which is considered to be above 20-25° Cobb (Korbel et al., 2014). Braces should generally be worn full-time (at least 23 hours per day) with treatment usually lasting from a minimum of two to four or five years, until the end of bone maturity (Kuroki et al., 2015). When prescribing, however, some potential limitations of braces should be taken into consideration, including the need for radiographs to monitor brace fit and curve response, out-of-pocket direct and indirect medical expenses, interference with sports and other activities, limited clothing choices, and psychological sequelae, for instance because wearing brace is a constant reminder of their medical condition for many patients. All this causes a significant impact on the lives of children and adolescents (Uyttendaele et al., 2006).

Scoliosis specific exercises include a series of individualized physical movements performed with a therapeutic aim of reducing the deformity. However, the effectiveness of scoliosis specific exercise has been under controversy for decades. The statement that exercises are not useful for scoliosis treatment which comes from an old paper published down in 1979 (Stone et al., 1979). More recently, two comprehensive systematic reviews published by the same group have exhaustively evaluated studies on the efficacy of scoliosis specific exercise programs (Fusco et al., 2011; Negrini et al., 2003). These reviews found that the general methodology used in studies published so far has generally been of poor quality, even though, except for 1 study, all studies indicate that treatment is useful making the results less reliable (Negrini et al., 2012).

The goals of non-operative management of AIS may be divided into two groups: morphological and functional (physical and psychological functions). The first aspect influences aesthetics that has been proposed as the first goal of treatment by the SOSORT experts, while both aspects determine patients' QoL, psychological well-being, and disability. Typically, while few long-term studies exist, they suggested that AIS does not cause any health problems during growth (except for extreme cases) (Ascani et al., 1986; Goldberg et al., 1994; Mayo et al., 1994; Pehrsson et al., 1992; Poitras et al., 1994; Weinstein et al., 2003). However, the resulting surface deformity frequently has a negative impact on adolescents that can give rise to QoL issues and in the most severe cases, psychological disturbances. Apart from that, it has been reported that several factors play a part, such as the concern of the physicians and parents or the image of the twisted spine on radiographs.

After a long period in which research on non-operative management of AIS continuously increased, the situation changed in the last 10 years. Several RCTs

published in the literature showing the effectiveness of orthotic intervention (Coillard et al., 2014; Weinstein et al., 2014) and also of scoliosis specific exercises (Monticone et al., 2014; Negrini et al., 2014). Nevertheless, there is a strong need to continue this research, recommendations also stress the need for high quality studies, not simply studies with low level of evidence, for searching the correct indications and contraindications (Negrini et al., 2015). In addition, the Cochrane Institute and modern epidemiology call for the need to focus on primary outcomes in this research field such as QoL or appearance, the patient oriented results, those that really change the life of patients. In this perspective, secondary outcomes such as Cobb angle or surface measurements can predict the primary outcomes, which are directly connected to the life of patients. Overall, it is hypothesized that the results of the current study can provide evidence to further guide the clinical practice.

1.2 Research objectives

The specific objectives were as follows:

- To investigate the overall prevalence of AIS, prevalence by age, gender and BMI, and prevalence by curve magnitude in Wuxi City, Jiangsu Province, China.
- To investigate the PPV of the Scoliometer followed by the SRS criteria.
- To compare the epidemiological data of the current study with other studies and investigate its representativeness.
- To compare the effectiveness of orthotic intervention *versus* exercise on the correction of spinal curvature and body symmetry, and the improvement of QoL in patients with AIS across the intervention period.

- To investigate the independent effectiveness of orthotic treatment or exercise on the correction of spinal curvature and body symmetry, and the improvement of QoL in patients with AIS across the intervention period.
- To investigate the correlations among spinal curvature, body symmetry and QoL in patients with AIS.

1.3 Organization of the thesis

The remainder of the thesis is organized as follows. Chapter 2 provides the brief introduction of the current status of the scoliosis school screening projects and epidemiological knowledge of AIS, and the exercise and orthotic treatment for patients with AIS. Chapter 3 details the research methodology of both the screening study and the intervention study (a randomized controlled trial comparing the effectiveness of orthotic intervention *versus* exercise on the patients with AIS). Chapter 4 presents the results of both studies and Chapter 5 discusses the results, highlights the strength and limitations of both studies as well as recommendations for further studies. Finally, Chapter 6 covers the conclusions which can be drawn from both studies.

CHAPTER 2 LITERACTURE REVIEW

2.1 Brief introduction of AIS

Scoliosis, which has been introduced by Hippocrates, means the existence of abnormal lateral spinal curvature (Vasiliadis et al., 2009). However, with the development of the modern medicine, it is known not to be limited as the deformity in the frontal plane, and can be defined as a 3-dimensional deformity of the spine. It not only causes a lateral curvature in the frontal plane, but also an axial rotation in the horizontal plane and kyphosis or lordosis in the sagittal plane.

Apart from the congenital scoliosis and scoliosis due to acquired disorders, approximately 80% are cases of idiopathic scoliosis. It applies to all patients in which it is not possible to find a specific reason leading to the spinal deformity. Efforts have been donated to find its causes by numerous researchers in the past several decades. The impact of genetic factors has been noticed, with evidence showing the abnormal expression and function of oestrogen receptor (Grivas et al., 2006), melatonin (Burwell et al., 1992), calmodulin (Kindsfater et al., 1994), IL-6, MMP-3 (Aulisa et al., 2007) or leptin (Tam et al., 2016). However, the etiology of idiopathic scoliosis is far from being elucidated and it can only be assumed with a multifactorial origin.

The most common type of scoliosis is AIS which developed in subjects aged 10-17 years old. Its most marked progression occurred at the beginning of pubertal growth spurt. Girls experience menarche during the pubertal growth spurt, which indicates a slow, gradual decrease in progression. The progression risk increases in curves surpass 30°, while less severe cases may remain stable (Negrini et al., 2012).

The curvature of AIS, measured on the frontal radiograph according to Cobb method, is recognized as one of the decisive factors in treating AIS since it is directly correlated to the choices of therapeutic options. Several classifications have been proposed to direct the treatment, however no consensus has been achieved. Nonetheless, there is an agreement on some thresholds:

- Subjects with a curvature under 10°, the diagnosis should not be made;
- Patients with a curvature of 10-20°, the risk of progression is low, observational follow-up or exercise training is suggested;
- Patients with a curvature of 20-40°, the risk of progression is high (especially in those who with a curvature above 30°), exercise training or orthotic treatment is suggested;
- Patients with a curvature above 40°, there is a consensus that it is going to progress in adulthood and cause health issues and reduction of QoL (especially in those who with a curvature above 50°), therefore surgical treatment is suggested.

Here, the non-operative management is mainly discussed. The goals of non-operative management of AIS can be divided into two aspects: morphological and functional. Both aspects determine patients QoL and psychological status. Specifically, the basic objectives of non-operative management of AIS are to stop curve progression and improve aesthetics, and finally improve the long-term QoL in their adulthoods.

2.2 Screening and epidemiology of AIS

2.2.1 Significance of screening

Over the past decades, there has been much debate about the necessity and efficacy of screening for AIS. The controversial points were the accuracy of the screening test, the cost and time efficiency, the unpredictable natural history and the insufficient evidence for postponing orthotic treatment or reducing surgical rate. The AAOS, the SRS, the Pediatric Orthopaedic Society of North America (POSNA) and the American Academy of Pediatrics (AAP) support this action, while the USPSTF recommended against the routine screening for AIS. Nonetheless, screening for AIS is still the most efficient way to detect AIS patients in the early stage so that non-operative management can be applied, further progression of the curve may be avoided and the rate of surgical treatment may be reduced.

2.2.2 Screening outcomes

The prevalence of AIS in general population was in a wide range from 0.93-12% (Negrini et al., 2012), 2-3% was the value the most often found in the literature. The prevalence of AIS in Hong Kong was around 3.5% based on a screening of 394,401 students (DY et al., 2015) and Soucacos et al. reported a prevalence of 1.7% in Greece (Yawn, 1998). Many studies conducted in mainland China also reported the prevalence of scoliosis in primary and secondary schools, which varied from 0.11% to 2.64% (Zhang et al., 2015). The pooled prevalence of scoliosis in mainland China was 1.02% and the female to male ratio was 1.54 according to the meta-analysis conducted by Zhang et al. (Zhang et al., 2015). However, there was no nationwide

study on the prevalence of AIS and the current studies were believed to have medium to low quality, which made the results unconvinced and the government difficult to improve current policies against AIS. Furthermore, to the best of our knowledge, none of the screening studies conducted in mainland China mentioned the following treatment right after the screening.

2.3 Orthotic treatment for AIS

2.3.1 Current status of orthotic treatment for AIS

Among the various AIS treatment options, orthotic treatment plays a primary role in treating moderate idiopathic scoliosis (the Cobb angle ranges from 25-40° according to the SRS criteria). It relies on the mechanical forces, the external and proprioceptive in-puts reducing unnatural loading and asymmetrical movements, improving neuromuscular control, and preventing the vicious cycle. Different spinal orthosis designs utilizing similar mechanisms are now available in routine clinics, i.e. Cheneau and derivatives, Dynamic Derotating, Lyon, PASB, Sforzesco, TLI, TriaC in Europe and Boston, Charleston, Milwaukee, Providence, Rosenberger, SpineCor, Wilmington in North America (Zaina et al., 2014). Following a long-term debate between the supporters and those who are skeptic, it is still difficult to evaluate the effectiveness of orthotic treatment on reducing the likelihood of progression and avoiding or withdrawing orthotic and surgical treatment due to the inconsistent and inadequate research evidence. In addition, orthotic treatment has been linked to the decreased QoL and increased psychological problems (Negrini et al., 2012). A review of the knowledge in this specific research field will help both researchers and clinicians to decide whether orthotic treatment is indeed worthwhile.

2.3.2 Clinical outcomes of orthotic treatment

Given the heterogeneity of the studies and their various methodologies, a real meta-analysis cannot be performed. Nevertheless, a general summary of these studies was possible. Here, 22 recently published studies enrolled a total number of 1146 patients with AIS, 1044 of whom had been treated with spinal orthosis for an average time of 25.2 months. The male to female ratio was 1:5. The average age across these studies was 12.9 years old, and the spinal curvature was 30.5° Cobb. For those designed as controlled studies, observation, casting or alternative treatments (other orthotic designs) were applied in the control groups.

2.3.2.1 Prospective randomized controlled trial

In 2008, Wong et al. randomized 43 patients to the SpineCor group (22 patients with 12.4±0.9 years of age and 24.2±2.6° of curvature) or the rigid orthosis group (21 patients with 12.6±0.7 years of age and 24.3±2.8° of curvature). With an observation period of 45 months, 68% of the subjects in the SpineCor group and 95% in the rigid orthosis group were stable or progressed less than 5° (Wong et al., 2008). In 2014, Guo et al. reported another RCT which confirmed the results published by Wong et al. (Guo et al., 2014; Wong et al., 2008). The similar study design was applied, the authors randomly allocated 38 female subjects into two groups undergoing treatment of SpineCor soft brace (n = 20) or rigid brace (n = 18). The baseline average cobb angle in both groups were comparable to those in Wong's study. Finally, they found a success rate (with improvement or stabilization) of 94.4% in rigid brace group and 65% in SpineCor group (Guo et al., 2014). The similar results of these two RCTs have an

important impact on the confidence in the estimate of the effectiveness of SpineCor and rigid brace. Coillard et al. reported another RCT which had a similar baseline prognostic factors as compared to the one conducted by Wong et al. (Coillard et al., 2014; Wong et al., 2008). Sixty-eight patients (32 in the SpineCor group and 36 in the control group) with a Cobb angle between 15 and 30° participated in this study. They reported the success rate as 81% in the SpineCor group and 43% in the control group after a three-year follow-up. The results were in favor of SpineCor soft brace. However, there was no significant difference detected between groups regarding the success rate (73% in the SpineCor group and 57% in the control group) at the five-year timepoint (Coillard et al., 2014).

In the RCT which was supported by the US government from 2007 to 2011, a total of 51 patients in the randomized cohort were assigned to orthotic intervention group and 65 were assigned to observation group. No significant difference was detected at baseline. With the intention-to-treat analysis, the author reported a success rate of 75% in the orthotic intervention group and 42% in the observation group. The trial was stopped early due to the efficacy of brace treatment. In 2014, two more RCT were published. Wiemann et al. also conducted an RCT using the strategy of orthotic intervention group *versus* observation group while they applied the night-time brace rather than full-time brace (Wiemann et al., 2014). Although the authors claimed that the Charleston night-time brace could reduce progression to full-time orthotic treatment threshold, the success rate of 29% in the Charleston night-time brace and surprising 0% in the observation group make it difficult to demonstrate its effectiveness. Moreover, the initial average Cobb angle was lower than that in Weinstein`s study, therefore it is difficult to compare the results of the two studies (Weinstein et al., 2014; Wiemann et al., 2014).

2.3.2.2 Prospective cohort study

This sub-group includes five studies. Three were uncontrolled (Aulisa et al., 2015; Coillard et al., 2007; Rahman et al., 2005) while other two were controlled (Lusini et al., 2014; Weiss et al., 2005).

Rahman et al. enrolled 30 females and 4 males with an average age of 12 years in their study. Neither orthosis design or initial Cobb angle was presented. The success rate was 56% after an average treatment period of 23 months (Rahman et al., 2005). In 2007, 170 AIS patients (158 females and 12 males) treated with SpineCor was reported to reach a success treatment rate of 59%, the authors did not provide any demographic or initial radiographic data (Coillard et al., 2007). More recently, the authors proved in 102 female AIS patients with initial curvature of 31.5±4.3° the efficacy of Lyon brace in a relative long term (average treatment period of 62.9 months), with a success rate of 98.5% (Aulisa et al., 2015).

In 2005, a controlled study comparing the effectiveness of SpineCor soft brace and Cheneau brace was proposed. Although the demographic data were comparable, the initial average curvatures (21.3° *versus* 33.7°) were significantly different between groups as well as the clinical change (the success rate of 8% *versus* 80%) (Weiss et al., 2005). Although the authors achieved a success rate of 76.5% in the orthotic intervention group, all patients in the observation group progressed more than 5 degree after an average treatment period of 63 months. It should be highlighted that this study mainly focused on investigating the effectiveness of orthotic treatment in AIS over 45° (Lusini et al., 2014).

2.3.2.3 Retrospective cohort study

From 2005 to 2015, nine retrospective cohort studies were published. The effectiveness of spinal orthosis was widely explored from full-time (Boston, Milwaukee, Lyon, SPoRT, Cheneau) (Danielsson et al., 2006; Gammon et al., 2010; Janicki et al., 2007; Kuroki et al., 2015; Maruyama et al., 2015; Negrini et al., 2011b; O'neill et al., 2005; Weigert et al., 2006) to night-time brace (Providence) (Bohl et al., 2014; Janicki et al., 2007) and from rigid to soft (SpineCor) brace (Gammon et al., 2010). 378 AIS patients 13.3 years old, with 33.5° Cobb, had been treated for 31.7 months. Success treatment rates were also various across studies. O`Neill et al. reported a success rate of 49% with the utility of Boston brace (O'neill et al., 2005), Danielsson et al. and Weigert et al. also analyzed similar cohorts, however, they did not present the data regarding those who progressed less than 5 degree (Danielsson et al., 2006; Weigert et al., 2006). Two papers used the TLSO for treatment, in the study by Janicki, a relative low success rate of 21% was reported as compared to the one (60%) published by Gammon (Gammon et al., 2010; Janicki et al., 2007) though a good homogeneity could be found in two studies. However, two studies focusing on the Providence night brace achieved a good consensus (success rates of 40% *versus* 50%) (Bohl et al., 2014; Janicki et al., 2007). In 2015, Kuroki et al. and Maruyama et al. also proposed good results on orthotic treatment by using Osaka Medical College brace (67.7%) and Cheneau brace (75.8%) respectively (Kuroki et al., 2015; Maruyama et al., 2015).

2.3.2.4 Prospective cohort study with a retrospective arm

This sub-group includes three studies which compared prospective experimental groups with retrospective control groups (Negrini et al., 2006b; Yrjönen et al., 2006; Zaina et al., 2015). All these three studies applied same strategy to enroll patients: the control groups were matched to the experimental groups according to age, gender, Cobb severity, pattern and localization of the curve. Therefore, the homogeneity across groups was excellent.

The early one over the recent decade proposed by Yrjonen et al., which studied AIS patients with initial average Cobb angle of 28°, achieved excellent success rates in both groups, 73% in Providence night brace group and 78% in Boston brace group (Yrjönen et al., 2006). Negrini and Zaina investigated the effectiveness in more severe cases (average Cobb angle more than 45°), Zaina, in 2015, confirmed the results proposed by Negrini in 2006 with a similar sample with the same methods (utility of SPoRT brace). Patients in both studies did not progress more than 5° after a treatment period of 6 months (Negrini et al., 2006b; Zaina et al., 2015).

2.3.2.5 Summary

Over the past decade, five RCTs (Coillard et al., 2014; Guo et al., 2014; Weinstein et al., 2014; Wiemann et al., 2014; Wong et al., 2008) and 17 more papers of different methodological quality have been published. The general results are consistent with different study designs and confirmed a possible efficacy of orthotic treatment in stopping the progression of AIS (Negrini et al., 2016). The evidence is still not such

strong, however more RCTs have been published therefore it is better than decades ago. “The RCT is the strongest research design on the basis of which to draw valid conclusions regarding the effectiveness of a therapeutic intervention because, if well conducted, it minimizes the risk of bias” (Reilly et al., 1989). Nonetheless RCTs are difficult in many clinical settings due to some impractical or unethical reasons. Difficulties often encounter those who attempt to conduct RCTs: homogenous samples are difficult to be obtained. Due to the lack of eligible patients, the concerns from the parents and the delay of action, Bunge et al. were only able to enroll 4 patients after a period of 1.5 years (Bunge et al., 2010a). Additionally, no intervention control designs would probably face ethical and practical problems. Additionally, it is almost impossible to perform double-blinded study in a clinical situation. Valid alternatives could be controlled or uncontrolled non-randomized designs taking confounding factors and sources of bias into consideration, prospectively and retrospectively.

Nevertheless, RCTs comparing different orthotic designs, or designs of orthotic treatment *versus* other interventions have been done (Coillard et al., 2014; Guo et al., 2014; Weinstein et al., 2014; Wiemann et al., 2014; Wong et al., 2008). Two studies compared two orthotic design (Guo et al., 2014; Wong et al., 2008), and three compared braces *versus* observation (Coillard et al., 2014; Weinstein et al., 2014; Wiemann et al., 2014). Among these studies, only Weinstein et al. was able to adjust for the most important confounding factors (Weinstein et al., 2014). They used propensity score model reduce bias generated by treatment selection. Therefore, this study was marked as at low risk of bias, at least among the recently published 5 RCTs. Unfortunately, in 2013, the ethical committee requested to stop this trial due to the evident success of orthotic treatment. Thus, it had finally been changed from an RCT to a case controlled trial (CCT), although it was possible to publish the RCT data.

Six of the included studies were uncontrolled and the results of which were difficult to interpret into that from controlled designs, neither prospective nor retrospective ones. This kind of design cannot reasonably conclude that the improvement achieved was due to the effects of the specific interventions, or it may occur naturally or be due to other kinds of therapy. Eleven studies (apart from RCTs) were controlled concurrent controls or historical controls. Among which, authors from three studies marched the prospective experimental group with a retrospective control group, this could help to increase homogenous across groups. In addition, most studies included in this review failed to meet some methodological criteria. It is therefore impossible, on the basis of the data proposed in this review, to draw strong conclusions on the effectiveness of orthotic treatment in AIS. Further RCTs or properly designed observational studies with adjustments for confounding factors are required. The study conducted by Weinstein could be regarded as a milestone in this research field, thus the probability of RCTs of orthotic treatment *versus* observation is very low (Weinstein et al., 2014). Orthotic intervention *versus* exercise may be an alternative option for scientific and clinical reasons in the future.

The most important element should be considered when deciding whether a new treatment can be applied is its real effectiveness. In this review, "progression less than 5° Cobb after the treatment period" is served as the criteria for those who are successfully treated. Only two studies failed to report the success treatment rate (Danielsson et al., 2006; Weigert et al., 2006). Full-time rigid braces (Aulisa et al., 2015; Guo et al., 2014; Lusini et al., 2014; Maruyama et al., 2015; Negrini et al., 2006b; Negrini et al., 2011b; Weiss et al., 2005; Wong et al., 2008; Yrjönen et al., 2006; Zaina et al., 2015) were still in most favor regardless of the study designs. The results are consistent with previous reviews (Negrini et al., 2016). However, results of full-time

soft brace (Coillard et al., 2014; Gammon et al., 2010; Guo et al., 2014; Weiss et al., 2005; Wong et al., 2008) and night-time braces (Bohl et al., 2014; Janicki et al., 2007; Yrjönen et al., 2006) studies were controversial, more evidence is need for some newly developed designs as well (Lusini et al., 2014; Negrini et al., 2006b; Negrini et al., 2011b; Zaina et al., 2015). In some cohorts, the mixed using of two or more orthotic designs in the same study arm made it difficult to judge their continuous effects and the source of the efficacy (Danielsson et al., 2006; Lusini et al., 2014; Negrini et al., 2011b).

Another aspect should be taken into consideration is the clinical relevance of the included studies. Five of 22 studies included only females (Guo et al., 2014; Weiss et al., 2005; Wiemann et al., 2014; Wong et al., 2008; Yrjönen et al., 2006), which reflected the fact that the ratio of female to male in AIS patients was 8:1 (Nachemson et al., 1995; Wong et al., 2008). In fact, this may increase the difficulties in enrolling eligible patients, especially when discussing in performing a RCT. When planning this review, "either Cobb degrees or percentage of patients improved/worsened following the SRS brace study criteria" served as one of the inclusion criteria since most articles published this secondary aim for AIS treatment. This also reflects clinicians` attitude which focus on avoiding or slowing the curve progression to prevent future physical and psychological problems. Therefore, that is the reason why the radiological parameters were chosen to evaluate the effectiveness of brace. However, long-term, primary outcome results are extremely essential to this specific intervention and should be paid more attention. Relevant researches are also needed in the future.

The clinical conclusion is that full-time rigid brace is more reliable than other orthotic designs based on the knowledge summarized in this review. More scientific

evidence is needed on the effectiveness of full-time soft brace and night-time brace. Some kinds of orthotic design are far from clinical application.

The research conclusion is that solid and comparable data from RCTs and long-term well designed observational studies on both primary and secondary outcomes are consistently needed. For future studies, it is necessary to make a comparison between different techniques. Since the possibility of conducting orthotic treatment *versus* observation is low, the design of orthotic intervention *versus* exercise may be an alternative option.

2.4 Exercise for AIS

2.4.1 Current status of exercise treatment for AIS

Based on the natural history of AIS, the patients are normally treated when the disease is diagnosed. Till now, no intervention claims its fully correction the spinal deformity. Orthotic treatment is one of the widely accepted interventions for treating patients with AIS, while the use of exercise is controversial. Although exercise is widely used in Italy, France and Germany, most hospitals in the UK, the US and mainland China do not advocate its use. However, it has been reported that scoliosis specific exercise was able to stabilize and reduce curve magnitude and reduce the incidence of surgery (Negrini et al., 2008a; Weiss et al., 2003). Scoliosis specific exercise consists of individually adapted exercises that are taught to the patients in the hospital that is dedicated to scoliosis treatment. The personalized exercise protocol is developed according to the medical and physiotherapeutic evaluations. Scoliosis specific exercise includes a series of specific physical movements performed with a therapeutic aim of reducing the spinal deformity and changing the musculature and other soft

tissues along the spine. It is also believed that scoliosis specific exercise can alter the motor control of the spine by affecting the interaction between the motor neurons (Hawes, 2003). Today, the current evidence regarding the effectiveness of scoliosis specific exercise for AIS remains extremely insufficient.

2.4.2 Clinical outcomes of exercise treatment

The same searching strategy used in the last section was applied here. The evidence was examined to answer the clinical question that "Whether scoliosis specific exercise is effective in stopping/delaying the progression or reducing the incidence of surgery?" Finally, only 2 studies (one RCT and one prospective controlled cohort study) met the Cochrane methodology (Li, 2005; Negrini et al., 2008b).

2.4.2.1 Prospective randomized controlled trial

Wan et al. enrolled 80 AIS patients (43 females and 37 males) with an average age of 15±4. The mean Cobb angles at the baseline were 25±13° at the thoracic region and 23±11° at the lumbar region. Electrostimulation on the lateral body surface, traction therapy, postural training and advice during normal activities were prescribed to both groups. The experimental group also performed scoliosis specific exercise once a day. Follow-up evaluation was performed 6 months after the interventions. Both in the thoracic and lumber region, the experimental group showed better results as compared to the control group. The authors concluded that the scoliosis specific exercise was capable to control the progression as compared to the application of electrostimulation alone (Li, 2005).

2.4.2.2 Prospective cohort study

In 2008, Negrini et al. enrolled 74 eligible AIS patients and assigned them into either the experimental group (n=35) or the control group (n=39). Patients in the experimental group followed the SEAS protocol while those who in the control group followed different exercise protocol according to the preferences and experience of their corresponding therapists. In this one-year prospective controlled cohort study, the number of braced patients was statistically reduced in the control group while the experimental group (28.9% of correction) achieved better improvements in term of Cobb angle as compared to the control group (5% of correction) (Negrini et al., 2008b).

2.4.2.3 Summary

After a very careful review of the current literature, only 2 studies met the strict Cochrane criteria (Li, 2005; Negrini et al., 2008b). Due to their low evidence quality, the evidence of exercise is far from verifying its effectiveness. The results indicated that scoliosis specific exercise added to other interventions was more effective than the application of other interventions alone. When it was applied alone, the scoliosis specific exercise has almost similar results to usual physiotherapy. No result was reported on QoL, back pain, psychological and aesthetic aspects. Therefore, based on the current very limited evidence, hardly any clinical recommendations can be made. Till a high-quality RCT is conducted, it is difficult to know whether exercise is effective or comparable to other interventions. In addition, further studies should focus

on defining the appropriate types of exercise for different curve types as well as the most effective treatment protocol in terms of training frequency and intensity.

CHAPTER 3 RESEARCH METHODOLOGY

This study aimed to compare the effectiveness of orthotic intervention *versus* exercise on the patients with AIS in terms of all the aspects related. This project mainly contained two parts. The first part was a screening study, which screened all the primary and secondary school students in Wuxi city, China. It aimed to fill the epidemiological blank of AIS in the east part of China and more importantly it was a preparation of enrolling target patients for the second part. The main portion of the project was the second part, the intervention study. In the intervention study, a design of RCT was adopted, in which the effectiveness of orthotic intervention *versus* exercise on the correction of spinal curvature and body symmetry, and improvement of QoL was compared.

3.1 Screening study

The primary aim of the screening study was to better understand the epidemiology of AIS in the east part of China based on a representative sample in Wuxi City. The specific aims were to estimate the prevalence of AIS in east part of China and explore the representative of this study sample in China. Moreover, in an ideal situation, children of target age groups were screened in a scoliosis school screening program, such as in this study. However, resources are limited in any screening program, therefore it is important to target the screening at an optimal population group in whom non-operative management, such as exercise or orthotic treatment, can be instituted to control curve progression and reduce the needs for surgery. Thus, this study was further a preparation of enrolling target patients for the second part, the intervention study.

The screening study was launched by the Wuxi Disabled People's Federation as part of health services, conducted by the Scoliosis Center of Wuxi Rehabilitation Hospital and administered by Dr. MS Wong from Department of Biomedical Engineering in the Hong Kong Polytechnic University, Prof. Chengqi He from Institute for Disaster Management and Reconstruction in Sichuan University and Mr. Yu Zheng (the candidate) from Department of Biomedical Engineering in the Hong Kong Polytechnic University. The screening database was built and administered by Prof. Reinhardt Jan Dietrich and Mr. Yu Zheng (the candidate) from Institute for Disaster Management and Reconstruction in Sichuan University.

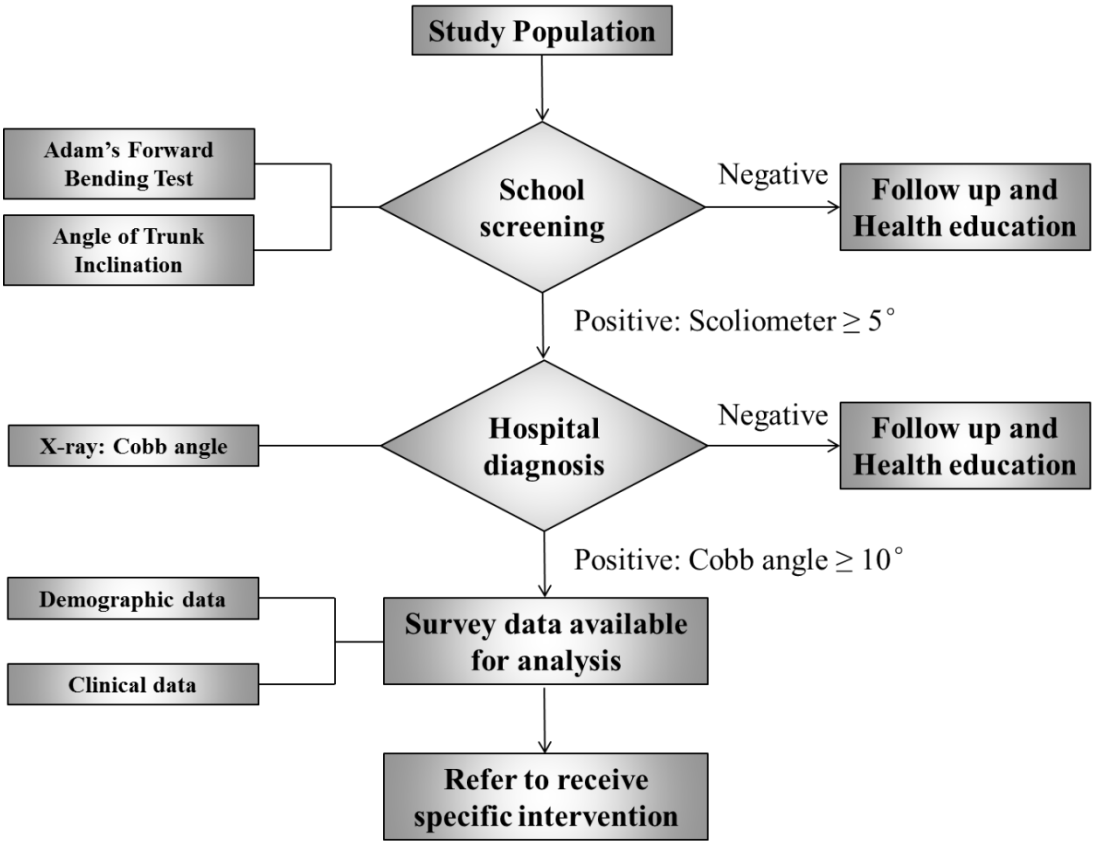
3.1.1 Study design and sample

This observational, cross-sectional study was performed between April and December 2015 in Wuxi City, Jiangsu Province, eastern China. Since the definition of adolescent in mainland China is those who aged 10-17 years old. However, those who aged 17 years studying in the high schools and are difficult to approach, therefore primary school (5th and 6^{th} grades) and secondary school (7th to 9th grades) students aged 10-16 years were screened for AIS while undergoing an annual physical examination issued by the National Health and Family Planning Commission and Ministry of Education of the People's Republic of China. All schools in central Wuxi City were enrolled irrespective of their geographical, economic or ethnic background.

A 2-step screening method including school-based screening (first phase) and hospital-based diagnosis (second phase) was applied in this study. Ethical approval (ChiECRCT-20150021) was obtained from China Ethics Committee of Registering Clinical Trials ahead of the screening. Its guidelines and regulations, as well as the

principles of the Declaration of Helsinki were followed. Teachers, parents and students were informed about the objectives of the study and the details of the examinations, and written consent forms were obtained from all participants and their parents. The research flow-chart was given in Figure 3.1.

Figure 3.1 Research flow-chart



3.1.2 School-based screening

School-based screening was conducted in schools by an experienced screening team consisting of 3 orthopaedic surgeons, 4 rehabilitation physicians, 6 therapists and 2 nurses from Wuxi Rehabilitation Hospital using a standardized screening protocol.

Schools were required to provide two independent rooms for screening, so that boys and girls were examined separately.

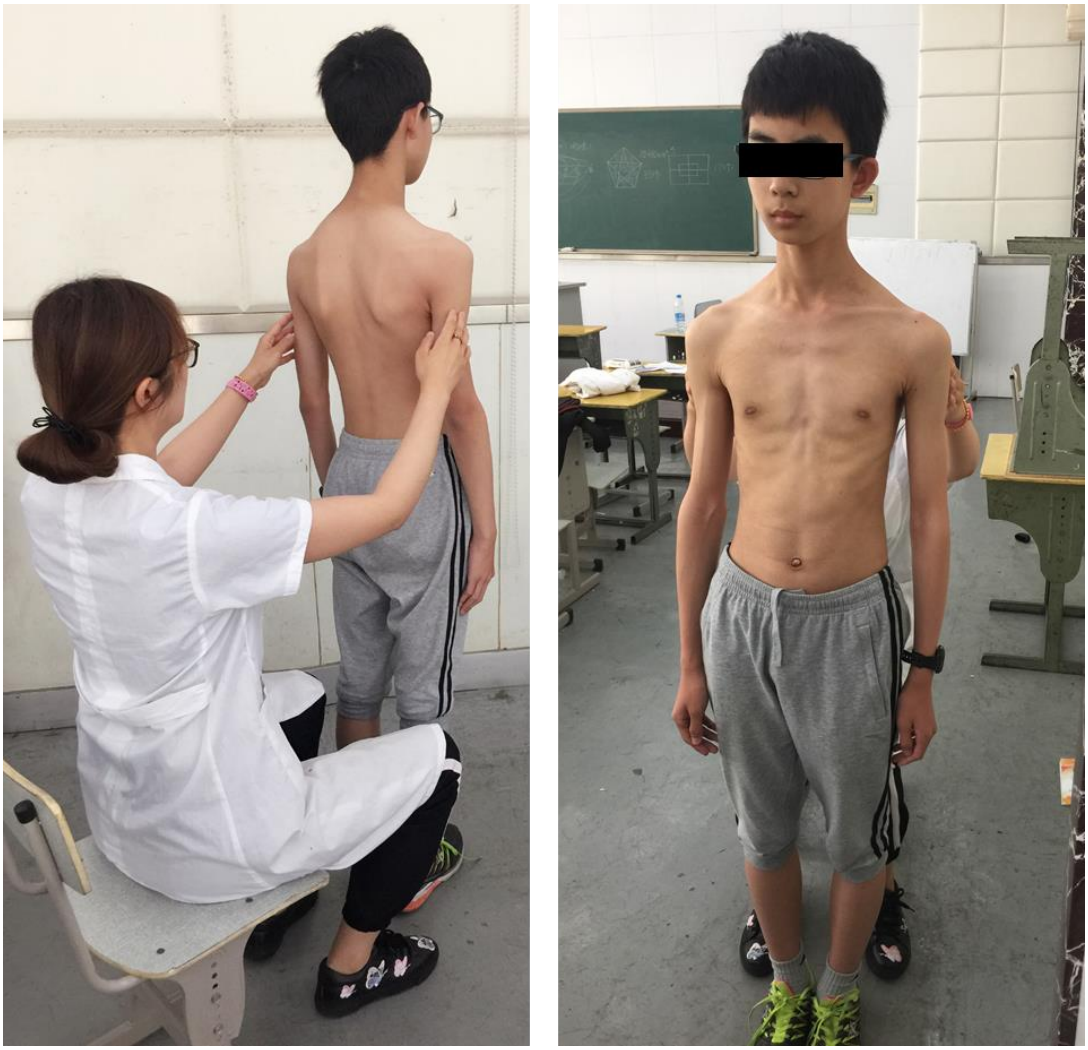
To target the potential AIS patients, physical examination, FBT and the Scoliometer were adopted at this phase (Berg, 1993; Bunnell, 1984, 1993; Côté et al., 1998; De et al., 1998; Grosso et al., 2002). All the examinations were mainly conducted by female professionals. The detailed procedure was described below.

3.1.2.1 Physical examination

The students were required to enter the room one after the completion of the previous one's examination. Cold heat air-conditionings were provided to ensure a comfort environment for the testing in both summer and winter since the testing required the students to take off the clothes and expose the upper part of the body.

The standard visual inspection begins with the students standing straight, head up and arms relaxed at the sides. With the students in this position, spine alignment, shoulder asymmetries, scapula prominence, breast asymmetry, unequal waistline or arm distances, and lower limb length inequality were checked (Figure 3.2) (Fan et al., 2016). Any significant clinical sign was recorded.

Figure 3.2 Physical examination



3.1.2.2 FBT and the Scoliometer examination

After the physical examination, the FBT combined with determination of ATI by the Scoliometer (Orthopedic systems Inc., Union City, California, USA) were performed while allowing the upper extremities to hang freely with the palms opposed in a relaxed manner, and the exposed back was viewed from the front as well as from the side (Figure 3.3) (Bunnell, 1984, 1993). This process took about 1 min for each student.

Afterwards, the Scoliometer was located on the most obvious hump which was identified during the FBT and the ATI reading was recorded (Bunnell, 1984). Students with an ATI reading of at least 5° on the Scoliometer (Figure 3.4 and 3.5) or with 2 or more significant clinical signs were re-screened and those screened positive were referred to Wuxi Rehabilitation Hospital for further evaluation with whole spine anteroposterior or posteroanterior and lateral radiograms (De et al., 1998; Grosso et al., 2002).

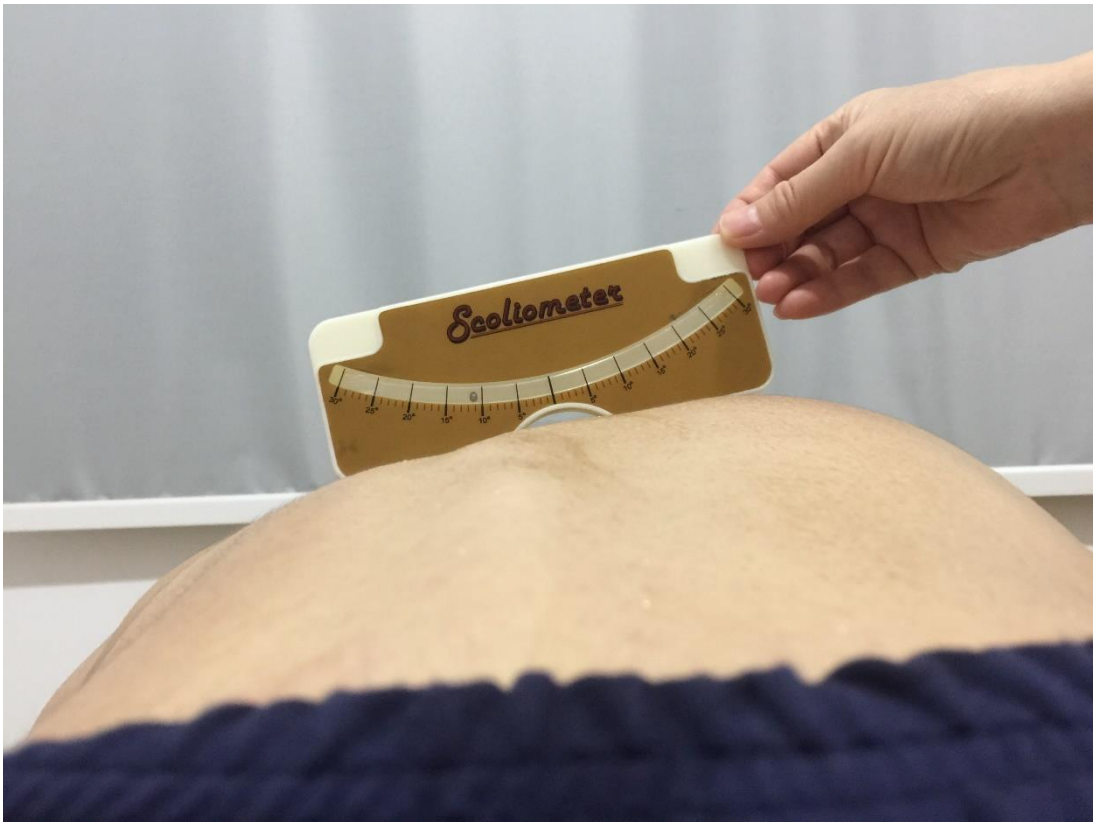
Based on the results of the pilot study, the inter- and intra-observer correlation coefficient (ICC) in measuring the ATI reading was 0.855 (95% confidence interval (95% CI): 0.835-0.875) and 0.880 (95% CI: 0.865-0.895), respectively.

Another two properties are also important to the Scoliometer evaluation, they are sensitivity and specificity. Sensitivity (also called the true positive rate) measures the proportion of positives that are correctly identified as such (i.e. the percentage of sick people who are correctly identified as having the condition), while specificity (also called the true negative rate) measures the proportion of negatives that are correctly identified as such (i.e., the percentage of healthy people who are correctly identified as not having the condition). In this case, it is better not to miss any true AIS patients. Therefore, for the sensitivity of the Scoliometer, the high the better. According to the data published previously, the Scoliometer has a sensitivity of approximately 100% and a specificity of approximately 47% at an ATI reading of 5° (Côté et al., 1998), while the sensitivity decreases to 83%, but specificity increases to 86% at an ATI reading of 7° (De et al., 1998; Grosso et al., 2002; Huang, 1997). Therefore, a threshold for referring was set at 5° of ATI reading in the current study.

Figure 3.3 The Adam's forward bending test

Figure 3.4 The Scoliometer

Figure 3.5 ATI degree determined with the Scoliometer



3.1.3 Hospital-based diagnosis

In the Scoliosis Center of Wuxi Rehabilitation Hospital, referred students were first to again undergo the FBT combined with the Scoliometer examination, followed by a standing posterior-anterior whole-spine X-ray examination when deemed necessary (Beauchamp et al., 1993; Negrini et al.).

3.1.3.1 Cobb angle measurement

For the measurement of curves in AIS, an anteroposterior or posteroanterior radiograph was used (Beauchamp et al., 1993; Negrini et al.). However, it has been

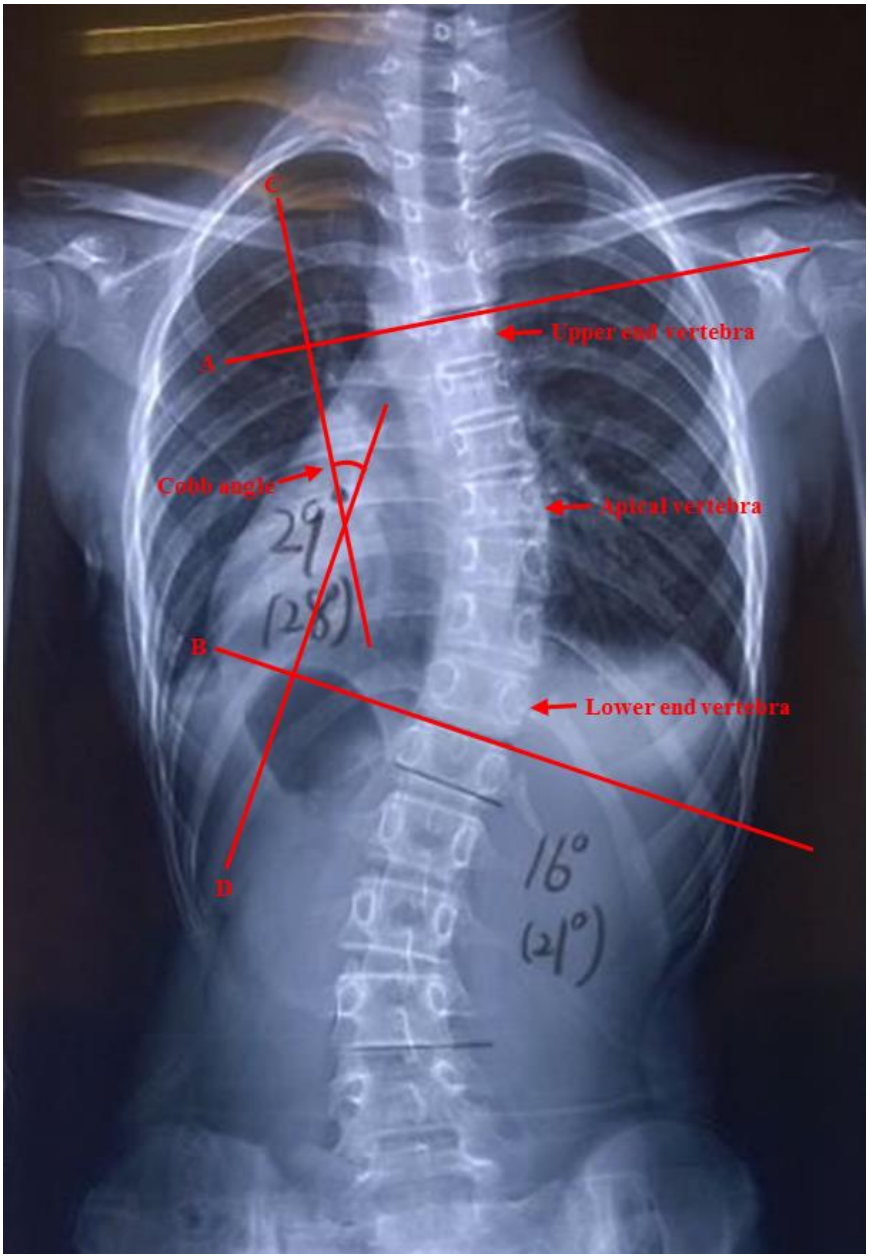
reported that there is a strong relationship between the radiation dose and the incidence of breast cancer in girls. Therefore, a posteroanterior X-ray examination is preferred for girls.

When measuring a curve, the apical vertebra (apical vertebra is vertebra most deviated laterally from the vertical axis that passes through the patient's sacrum) was first identified. This was the most likely displaced and rotated vertebra with the least tilted endplate. The end vertebrae were then identified through the curve above and below. The end vertebrae were the most superior and inferior vertebra which were least displaced and rotated and had the maximally tilted endplate. A line was drawn along the upper endplate of the upper end vertebra and a second line was drawn along the lower endplate of the lower end vertebra. The angle between these two lines or lines drawn perpendicularly to them was measured as the Cobb angle (Figure 3.6) (Cobb, 1948).

The final diagnosis of AIS, as defined by the SRS, was based on Cobb angles of 10° or more, as measured by 2 independent observers (Negrini et al., 2012). When differences occurred, consensus was achieved by discussion. Students who were diagnosed with non-idiopathic scoliosis (mainly neuromuscular scoliosis) were excluded at this phase and referred for specific interventions in the corresponding departments.

Based on the results of the pilot study, the inter- and intra-observer correlation coefficients in measuring the Cobb angle were 0.856 (95% CI: 0.850-0.862) and 0.954 (95% CI: 0.932-0.976), respectively.

Figure 3.6 Cobb angle measurement



Line A: a line drawn parallelly to the upper endplate of the upper end vertebra; Line B: a line drawn parallelly to the lower endplate of the lower end vertebra; Line C: a line drawn perpendicularly to Line A; Line D: a line drawn perpendicularly to Line B.

3.1.3.2 Recommendations after diagnosis

Students diagnosed as AIS were recommended for specific interventions including observation (for those with Cobb angle of 10-15°), exercise (for those with Cobb angle of 15-25°), orthotic treatment (for those with Cobb angle of 25-40°) or surgical treatment (for those with Cobb angle above 40°) by a senior specialist (Negrini et al., 2012). Students who were screened positive (ATI reading of 5° or more) at the school-based screening phase, but not diagnosed as AIS patients (Cobb angle of 9° or less) were followed up every 3-6 months.

3.1.4 Data collection

At the school-based screening phase, data regarding gender, age, height, weight, BMI, body fat (measured by Omron Body Fat Analyzer HBF-306; Omron, Japan), resting metabolism, ATI degree and contact information (i.e. name, home address and phone number) were recorded for screened-positive students, while radiological data regarding curve level, Cobb angle and Risser scores were collected once they participated in the hospital-based diagnosis. Students who attended the hospital-based diagnosis and were screened positive were documented as respondents in the database. Students who took radiographs in the other hospitals were reached by electronic communications, and were asked to send digital photographs of the radiographs. Conversely, those who were referred for radiography were documented as non-respondents if they did not respond to the reminders (Figure 4.1 in Chapter 4) or rejected to take radiographs.

3.1.5 Statistical analysis

All analyses were performed with SPSS 20.0 (IBM Corporation, USA).

Firstly, the inter- or intra-rater correlation coefficient (ICC) was predicted based on the results of repeated two-way ANOVA in terms of height, weight, ATI degree, body fat and resting metabolism.

PPVs were calculated according to different categories, i.e. diagnosis (Cobb angle of 10° or more), follow-up or exercise training (Cobb angle of 10-24°), orthotic treatment (Cobb angle of 25-39°) or surgical treatment (Cobb angle of 40° or more), to release the accuracy of tests used in the school-based screening. The PPVs for diagnosis were calculated with the number of diagnosed cases and the number of cases referred by initial screening. The PPVs for intervention were calculated with the number of cases referred to specific interventions (follow-up or exercise training, orthotic treatment and surgery) and the number of diagnosed cases (Fan et al., 2016).

Age-and-sex growth charts developed by the U.S. Centers for Disease Control and Prevention were used to categorize each student into one of the following BMI subgroups: obesity (BMI ⩾ 95th percentile), overweight (BMI ⩾ 85th and <95th percentile), normal weight (BMI⩾5th and <85th percentile), and underweight (BMI <5th percentile) ("National Center for Health Statistics. CDC Growth Charts: United States,"). Overall prevalence and prevalence by age, gender, BMI subgroups and curve magnitude were estimated. Curve distribution by age and gender was also estimated and shown with line chart.

To avoid the over- or under-estimation of the overall prevalence, unit-non response, i.e. non attendance of the hospital-based diagnosis although screened

positive (ATI degree of 5° or more), was adjusted for by inverse probability weights based on the propensity score method (Vives et al., 2009). In this study, the basic idea of propensity scores was to replace covariates of both respondents and non-respondents with the predicted probabilities of attending the physical examination among those screened positive. The inverse propensity scores were estimated from a logistic regression model with backward selection of response status on demographics and predictive factors (gender, age, height, weight, BMI), body fat, resting metabolism, ATI degree) as well as weighted analysis. The idea was to give respondents who were similar to non-respondents a higher weight in the analysis. This method also allowed to estimate the prevalence of AIS in non-respondents. All analyses were provided for weighted data since no significant difference was detected between weighted and unweighted data. P value less than 0.05 was considered statistically significant and 95% confidence interval (95% CI) was also presented.

3.2 Intervention study

After the screening, it is essential to refer the AIS patients with different severity to specific interventions, i.e. observation, exercise, orthotic treatment or surgical treatment (Negrini et al., 2012). For the purposes of early detection and prevention, this study combined screening and intervention together, so that the patients with AIS were able to start their treatment right after the screening.

In addition, since the evidence for either orthotic treatment or exercise on the patients with AIS is still not sufficient (Bunge et al., 2010a; Bunge et al., 2008; Coillard et al., 2014; Danielsson et al., 2007, 2010, 2012; Lou et al., 2012; Lusini et al., 2014; Lusini et al., 2013; Nachemson et al., 1995; Negrini et al., 2006c; Negrini et

al., 2008a; Weinstein et al., 2013, 2014; Wong et al., 2008), the other aim of this study was to compare the effectiveness of orthotic intervention *versus* exercise on the patients with AIS. To achieve the highest evidence in this research field, a design of RCT was adopted.

3.2.1 Study design and sample

This was a two-group designed RCT study comparing the effectiveness of orthotic intervention *versus* exercise in the patients with AIS. The target population for this study was those with moderate AIS who met the consolidated inclusion criteria recommended by both the SRS and the SOSORT (Table 3.1) (Korbel et al., 2014; Negrini et al., 2012; Negrini et al., 2015). Eligible participants included those who diagnosed in the screening study or patients with AIS visited the Scoliosis Center of Wuxi Rehabilitation Hospital.

This study was pre-registered in the Chinese Clinical Trial Registry (ChiCTR-IPR-15006136). All procedures performed in studies involving human participants were in accordance with the ethical standards of the China Ethics Committee of Registering Clinical Trials (ChiECRCT-20150021) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Information regarding this trial study was presented by the doctors and therapists, thereafter informed consent forms were signed by the patients or the parents once their children were eligible and agreed to participate in.

Table 3.1 Inclusion and exclusion criteria according to SRS and SOSORT recommendation

a) Diagnosis of AIS
Presenting without associated musculoskeletal, neurological, or other conditions possibly responsible for the curvature
b) Maturity
Aged 10-17yr
Risser sign 0, 1, or 2
c) Curve magnitude
Cobb angle of 25-40°
d) Treatment
No history of previous physical, orthotic or surgical treatment
Physical and mental ability to adhere to orthotic treatment and exercise protocol
e) Language
Ability to read and write simplified Chinese

AIS: adolescent idiopathic scoliosis.

3.2.2 Sample size calculation

Assuming a mean difference of 0.4 (mental health component of SRS-22) after intervention (minimal detectable difference according to Bago 2009) (Bagó et al., 2009) and a pooled standard deviation of 0.5 (based on a previous Chinese study from Qiu 2008) (Yong Q, 2008), the sample size for a power of 80% and an alpha error of

5% is 25 patients for each group (30 patients for each group after allowing for 20% loss-to-follow up). An alternative strategy could be conducted with the parameter of coracoid height difference (a component of shoulder balance): assuming a mean difference of 4.4 after intervention (minimal detectable difference according to Uzumcugil 2012) (Uzümcügil et al., 2012) and a standard deviation of 5.8 (based on a previous study from Ibrahim 2008) (Akel et al., 2008), the sample size for a power of 80% and an alpha error of 5% is 11 patients for each group (13 patients for each group after allowing for 20% loss-to-follow up).

3.2.3 Randomization

Assignment of a patient to the orthotic intervention or exercise group was based on a computer-generated randomization list and allocation (1:1) concealed by consecutively numbered, sealed opaque envelopes. Once a patient had consented to participate in an envelope was opened, then the corresponding doctor was informed with the allocated treatment regimen through phone calls by the envelope administrator in the remote study center in the First Affiliated Hospital of Nanjing Medical University (Donovan et al., 2009).

3.2.4 Treatment protocol

3.2.4.1 Treatment protocol for orthotic intervention group

The study was limited to the use of full-time, rigid TLSO. Participating doctors and orthotists prescribed and fabricated the custom-made TLSO used during routine clinical practice. The mechanisms of TLSO correction are: 1) passive mechanisms:

convex to concave tissue transfer achieved by a 3-point system acting in multiple dimensions with the aim of curve hypercorrection, elongation, and unloading; derotation of the thorax; and bending; and 2) active mechanisms: vertebral growth acting as a corrective factor, asymmetrically guided respiratory movements of the rib cage, repositioning of the spatial arrangement of the trunk muscles to provide physiological action, and anti-gravitational effect (Kotwicki et al., 2008). The TLSO was reported to obtain an average primary in-brace correction of 41% (thoracic, lumbar, double) and a long-term correction of 14.2% thoracic, and 9.2% lumbar double curves: 5.5% thoracic and 5.6% lumbar. It was also reported at the end of treatment about 25% of Cobb angle correction. Therefore, the TLSO not only halts progression, but possibly improves the scoliotic curve (Zaborowska-Sapeta et al., 2011).

At the first visit, patients whom were assigned to the orthotic intervention group were prescribed with a rigid brace and received initial pre-treatment evaluation for the brace fabrication. The orthotist recorded evaluations of the curve, coronal decompensation, and shoulder and pelvis asymmetry and prescribe the type of brace to be fabricated along with the specific customizations. To achieve optimum correction, patients were invited to the Scoliosis Clinic for brace checking and modification at the first month of intervention and then every three months. The orthotist observed the patients both in and out of the brace. Brace fitness (curve correction, and the condition of skin and bony prominences under the brace) was also checked regularly. Any additional modifications were recorded in the clinical report form. All the patients were requested to wear the orthosis 23 hours a day (at school, at home, in bed, etc.) except time of shower and sport activities (Rowe et al., 1997).

3.2.4.2 Treatment protocol for exercise group

An exercise protocol based on the SEAS approach, a name related to the continuous changes of the approach based on results published in the literature, was adopted for treating the patients in the exercise group. It is based on a specific active self-correction technique performed without external aid, and incorporated in functional exercises. And it is also an evidence-based individualized exercise program adapted to all situations of non-operative management of scoliosis. Several studies have been conducted over the past decades and provided essential results indicating the effectiveness of the SEAS approach in different phases of scoliosis treatment (Negrini et al., 2006a; Negrini et al., 2007a; Rivett et al., 2014; Romano et al., 2015).

Another reason to adopt the SEAS approach in the current study is that it is an approach to scoliosis exercise treatment with a strong modern neurophysiological basis, to reduce requirements for patients and possibly the costs for families linked to the frequency and intensity of treatment and evaluations. Therefore, the SEAS approach allows treating a large number of outpatient patients coming from far away. Even if the SEAS approach appears simple by requiring less physiotherapist supervision and by using fewer home exercises prescribed at a lower dose than some of the other scoliosis-specific exercise approaches, real expertise in scoliosis, exercises, and patient and family management is required. In addition, this approach has no copyrights, and teachers are being trained all over the world. One of the senior therapists was certified by a professional training and now is qualified to treat the patients in the Scoliosis Center of Wuxi Rehabilitation Hospital.

Simply, the protocol used in the current study required patients to learn how to perform a 3D self-mediated correction of their scoliosis, muscular stabilization of

the corrected posture, and how to perform these postural correction strategies during activities of daily living. The patients were required to take part in a single session of 1.5 hours (learning the core content of the intervention sessions) every month at the scoliosis clinic, in which they were evaluated by a therapist with expertise in scoliosis, learnt their own personalized exercise protocol, and engaged in a meeting for family counseling with regard to scoliosis. The patients continued treatment at the scoliosis clinic once a week (40 minutes) plus one daily exercise at home (5-20 minutes) (Romano et al., 2015).

Theories and characteristics of the SEAS approach

The main aim of SEAS approach is to reverse the Stokes vicious cycle, so that the abnormal loading created by the curves with an asymmetric growth leading to worsening of curves that will lead to further asymmetric growth due to increased asymmetrical loading (Stokes et al., 2006; Stokes et al., 1996).

The SEAS approach works with a specific difference with orthotic treatment: in fact, while an orthotic device can passively change the posture making it somehow fixed, exercises can only determine behavioral and automatic changes of posture through different motor control strategies (Bettany-Saltikov et al., 2014; Bia et al., 2011; Dobosiewicz et al., 2008; Maruyama et al., 2008; Negrini, 2008; Negrini et al., 2011a; Negrini et al., 2016; Negrini et al., 2010; Negrini et al., 2007b; Rigo et al., 2008; Romano et al., 2012; Romano et al., 2013; Sanchez et al., 2013; Stokes et al., 2004; Weiss, 2011; Weiss et al., 2006; Zaina et al., 2014). This is particularly important for a bodily system like the trunk and spine, that has been reported to be driven more by automatic, feed-forward schemes than voluntary control (Smania et

al., 2008). Moreover, active movement has also been demonstrated to be more effective than passive positioning in determining changes of spinal deformity (Stokes et al., 2004).

Based on this theoretical framework, the SEAS approach was developed and it shared different characteristics with other approaches. The specific characteristics are listed as bellows:

- Active 3D self-correction instead of the former auto-elongation (Negrini et al., 2006a; Negrini et al., 2007a).
- Spinal stabilization concept according to the actual physiotherapeutic literature (Hodges, 2003; Macdonald et al., 2006).
- Research of an automatic correct reflex response, namely, a subconscious self-correction which should help to obtain the better integration in the daily life (Smania et al., 2008).
- Focus on the cognitive-behavioral approach of the patient to increase compliance to treatment (Ostelo et al., 2009).
- Variability of exercises stimuli instead of absolute repetitive precision of movements, according to modern neurophysiologic knowledge (Krakauer et al., 2011; Ranganathan et al., 2013).

Postural rehabilitation

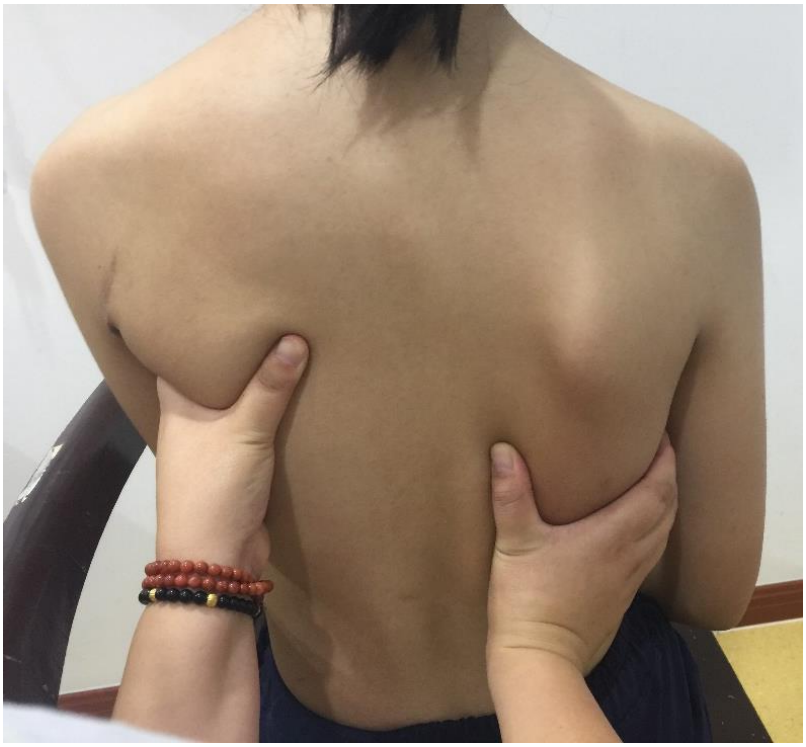
It included becoming aware of body posture, becoming aware of defects of posture and active self-correction on the three spatial planes. Becoming aware of body posture and defects of posture was obtained through visual (mirror) and tactile (contacts in the various postures) biofeedback and therapists' guidance.

Active self-correction on the frontal plane

The first phase included becoming aware of curve apex translation. The word "translation" means the frontal displacement of the apical vertebrae towards the mid-line. For example, in the case of a double-curve scoliosis, the patient was firstly taught how to execute thoracic curve translation and then lumbar curve one, subsequently associated the two movements beginning with lumbar translation.

The therapist put his/her fingers on the spinous processes correspondent to thoracic curve apex, while the patient let the vertebrae shift towards concavity side and let the apical vertebrae move towards the mid-line (Figure 3.7). Then, the therapist put his/her fingers on the spinous processes correspondent to lumbar curve apex, while the patient let the vertebrae shift towards concavity side and let the apical vertebrae move towards the mid-line. The counter-support of the therapist's hand on the hemithorax and hemipelvis opposed to curve convexity avoids imbalances. The patients were required to remember the positions where the spinous processes and apical vertebrae were through repetitive practice with the help of therapists so that afterwards they would be able to practice without supports.

Figure 3.7 Vertebrae shifting on the frontal plane under the help of the therapist



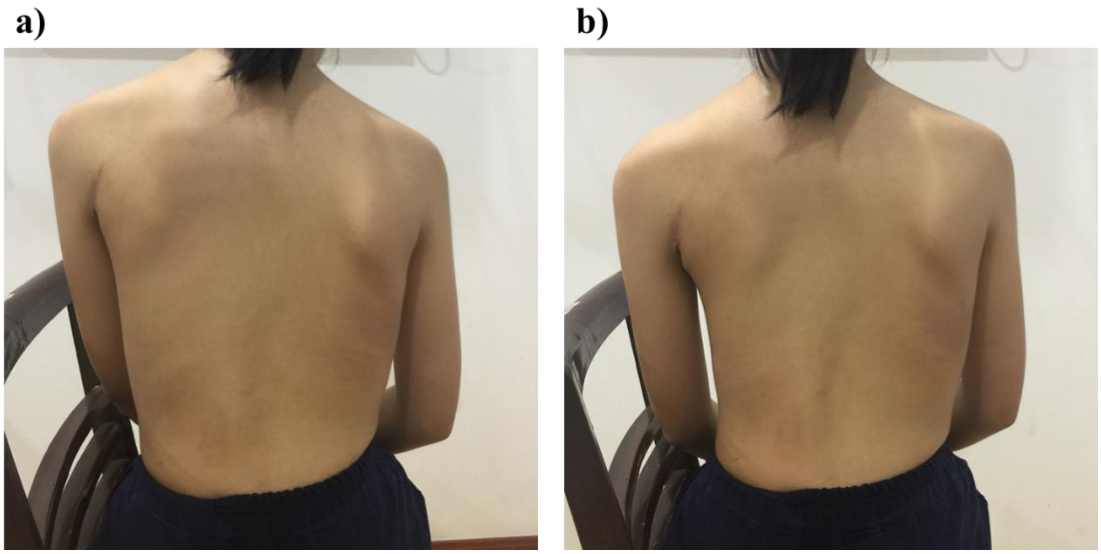
Active self-correction on the sagittal plane

The phase immediately following includes becoming aware of correction on the sagittal plane. Exercises must ensure thoracic kyphosis and lumbar lordosis. By leaning against the upright, the patient was asked to do pelvis anteversion at the lumbar level and a kyphotisation movement at the thoracic level. Then patient did the same exercise without the help of the upright, at first looking at him/herself in the mirror. Finally, active self-correction movements were associated on the frontal and sagittal planes.

Active self-correction on the horizontal plane

According to Dickson's study (Dickson et al., 1984), an action done on two spinal planes (frontal translation and kyphotisation and/or lumbar increase of lordosis) causes an involvement of the third plane (horizontal plane). Following the end of the initial learning phase, active self-correction is performed by the patient in an independent manner (Figure 3.8).

Figure 3.8 Active self-correction



a) Before active self-correction; b) After active self-correction.

Muscular endurance strengthening in the correct posture

Muscle endurance strengthening aimed at developing paravertebral, abdominal, lower limbs and scapulo-humeral girdle muscles through isometric contractions. It uses loads that are one-third to two-thirds of maximal load in active self-correction. The

patient was asked to execute an active self-correction movement and to hold it for the entire duration of isometric contraction of the chosen muscles (Figure 3.9).

Figure 3.9 Muscular endurance strengthening in the correct posture

Development of balance reactions

This was aimed at improving axial, static and dynamic balance of the trunk. Proposed exercises were always done in active self-correction, even on unstable planes, developed with growing difficulties (Figure 3.10).

Figure 3.10 Development of balance reactions

Neuromotor integration

This aimed at integrating in everyday behaviors a more correct and better-balanced spinal posture, progressively developing the ability to react with active self-correction to the different requirements of social life. Exercises were proposed, e.g., walking with a simple gait and oculo-manual education exercises, even on unstable planes. In this conclusive phase of treatment, guidance information was given so as to avoid spinal damage in adulthood.

The core content of the intervention sessions

The core content of the intervention sessions applied in the current study is listed in Table 3.2.

Table 3.2 Intervention sessions of exercise protocol

Session 1	
a)	Education regarding body posture and awareness of postural deficits on the 3 spatial planes by using visual (mirror) and tactile (contact in the various postures) and verbal (therapist) feedback
b)	Learning active self-correction on the 3 spatial planes
c)	Learning trunk muscular stabilization strategies for self-corrective postures
d)	Learning over-corrective side shift postural strategies to the opposite side of the primary curve in relaxed sitting and standing positions
e)	Patients are instructed to recognize and avoid scoliotic postures by integrating active self-correction and even relaxed over-correction side shift postural strategies as much as possible into daily activities
Session 2	
a)	Reiteration of skills learnt in session 1 and observation or skill progression
b)	Training trunk muscular stabilization and endurance in corrective postures during lower limb closed kinetic chain functional movements such as squats, forward lunges, sideways lunges and single leg standing
Session 3	
a)	Reiteration of skills learnt in session 2 and observation of skill progression
b)	Training trunk muscular stabilization and endurance in corrective postures during upper and lower limb closed kinetic chain functional movements
c)	Training of sustained over-corrective side shift mobilizations towards thoracic concavity integrated with the maintenance of sagittal plane curvature and when needed pelvic shift re-compensation of the lumbar curve

3.2.5 Assessments

3.2.5.1 Spinal deformity—Cobb angle measurement

Cobb angle measurement has been described in Section 3.1.3.1. It should be emphasized that patients in the orthotic intervention group were required to take the radiographic measurements two hours after taking off the orthoses.

3.2.5.2 Body symmetry

Shoulder balance measurement

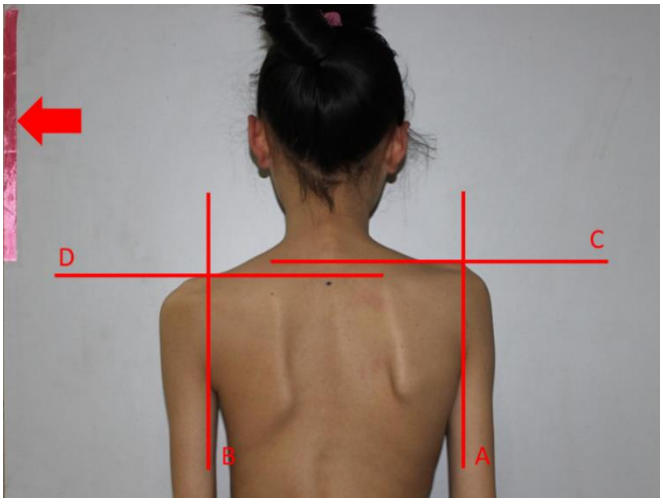
For shoulder balance measurement, digital photographs of the subjects were taken to measure clinical shoulder balance (CSB), and the standing full-spine posteroanterior films (X-ray images) were also used to measure radiological shoulder balance including coracoid height difference (CHD), clavicular angle (CA), clavicle-rib cage intersection difference (CRID), clavicular tilt angle difference (CTAD) and T1-tilt.

The digital clinical pictures were measured with a special drawing program (CorelDRAW-Version 11.0 2002 Corel Corporation). Vertical lines were drawn through the volunteers' posterior axillary folds. The points where these lines intersected with the shoulders were regarded as the reference points. The height difference between these points in millimeters was measured to reflect the clinical shoulder balance (Figure 3.11).

For the X-ray film measurement, CHD measured the height difference between the coracoid processes by tracing a horizontal line at the upper margin of each and measuring the difference, which is expressed in millimeters (Figure 3.12a); CA

represented the angle between the line connecting the highest points of the clavicles and the horizontal plane (Figure 3.12b); CRID represented the height difference between the horizontal lines passing through the point where the superior border of the clavicle intersects with the outer edge of the second rib on each side (Figure 3.12c); clavicular tilt angle was the angle between the line bisecting the proximal portion of the clavicle and the horizontal. The difference between these angles represented CTAD (Figure 3.12d). T1-tilt was the angle between the upper end-plate of the T1 vertebra and the horizontal line. The measurements expressed in millimeters (mm) were calibrated according to the scale on the digital X-rays. It was demonstrated that the above parameters were significantly correlated with the clinical appearance, thus, they can be used as direct and indirect indicators of shoulder balance (Akel et al., 2008; Han et al., 2016; Hong et al., 2013; Matamalas et al., 2015; Uzümcügil et al., 2012).

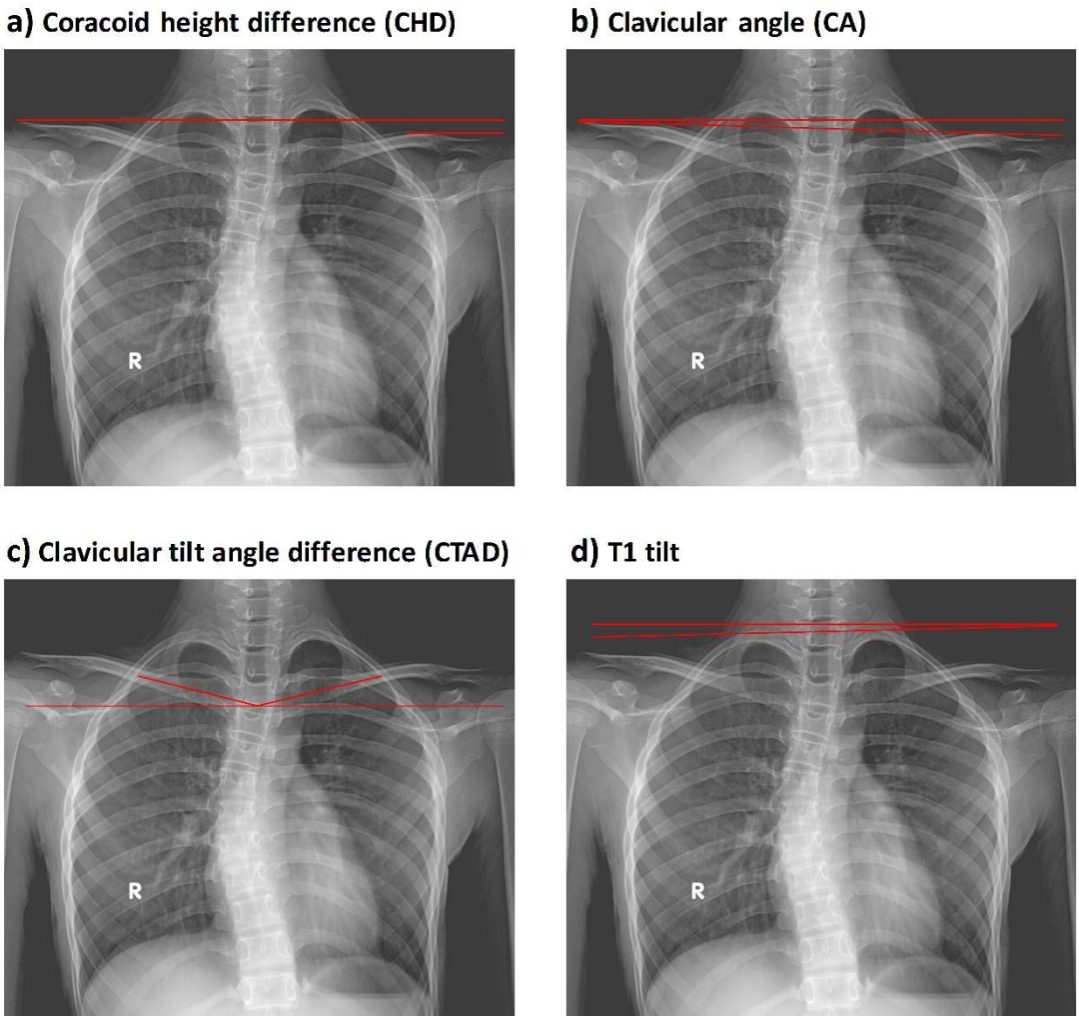
Figure 3.11 Clinical shoulder balance (CSB) measurement



Vertical line (Lines A and B) were drawn through the posterior axillary fold. The height difference between the horizontal lines (Lines C and D) where vertical lines

intersected with the shoulders reflects the CSB (the red arrow bar whose size was used as a reference for calibration).

Figure 3.12 Radiological shoulder balance measurement



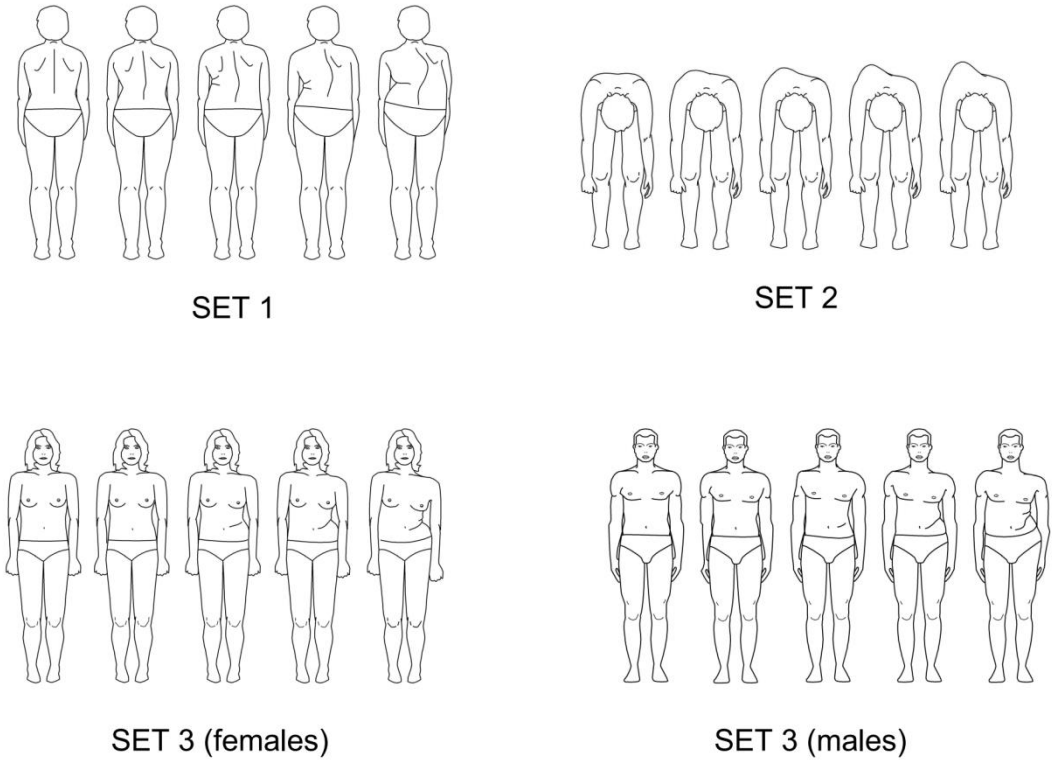
a) CHD measures the height difference between the horizontal lines that pass through the upper margin of each coracoid process; b) CA represents the angle between the line connecting the highest points of the clavicles and the horizontal line; c) CTAD is the angle between the line bisecting the proximal portion of the clavicle and the horizontal. The difference between the left and right angle represents CTAD; d) T1-

tilt is the angle between the upper margin of T1 and the horizontal line. The measurements were expressed in millimeters. The calibration was conducted according to the reference ruler on the X-ray film.

The TAPS assessment

The TAPS (Figure 3.13) includes three figures that show the trunk from three viewpoints: observing toward the back, observing toward the head in bending over position, and observing toward the front. Each figure is scored from 1 to 5 and a mean score is calculated according to the scores of the 3 drawings. The higher the score, the smaller the deformity. Juan et al. reported the floor and ceiling effects of the TAPS were 1.6% and 3.8% indicating the TAPS may be sensitive to the changes that occur following a specific treatment (Bago et al., 2010). Therefore, for subjective evaluation of physical deformity, this scale may be able to tell the corresponding differences between two interventional groups and changes across time points.

Figure 3.13 The Trunk Appearance Perception Scale (TAPS)



3.2.5.3 QoL measurement

The QoL was assessed with the simplified Chinese version of the SRS-22 questionnaire (Appendix F). Adhering to recommended protocols outlined by Beaton et al. and referencing the original English SRS-22 questionnaire (Beaton et al., 2000), the adaption of SRS-22 questionnaire was verified among 40 AIS patients who were diagnosed during the pilot screening study in Beitang District, Wuxi, China. The currently used questionnaire was based on the adapted SRS-22 questionnaire verified by the pilot study and a simplified Chinese (mainland) version of SRS-22 previously proved to be equally accessible, reliable, and psychometrically sound to mainland Chinese patients (Li et al., 2009). The SRS-22 is consist of 22 questions evaluating 5

aspects: function and activity; pain; self-perceived body image; mental health; and satisfaction with the intervention. Each item is scored from 1 (worst) to 5 (best). The results were presented with the mean score for each domain and the total score.

3.2.5.4 Compliance

Patients in the exercise group were asked to monitor their daily compliance with the scoliosis specific exercise regimen by a parent-recorded video (five to twenty minutes). The videos were used to track their compliance of the home sessions and further guide their training at home. Apart from the videos, patients in the exercise group were required to submit log-sheets while they came to the scoliosis clinic for the weekly training. Those who cannot afford a video recording device were provided with an inexpensive smart phone with video recording function covered by the research funding. Finally, none of the participants required this service. The compliance of patients in the exercise group was calculated based on the above two records.

For the patients in the orthotic intervention group, thermo-force sensors were embedded in the brace and programmed to log the wearing time (Figure 3.14) (Chan et al., 2014). The sensor specifications are as follows: operating force: 0-14.7 N, overload protection: 44 N, span: 5V, power consumption: 3.75 mW; temperature sensitivity shift: +25°C to 0°C - 0.16 mW/g, +25°C to 50°C - -0.16 mW/g; unit size: 5.6 x 13.7 x 4.0 mm, contact diameter: 1.75 mm, contact height: 0.58 mm. The data logger can store data up to 9 months for one sample per 5 minutes. Data were downloaded at least every three months by the research coordinator.

Compliance was calculated as total orthosis wearing time / total exercise training time divided by prescribed orthosis wearing time / prescribed exercise training time correspondingly.

Figure 3.14 Embedded thermo-force sensor

3.2.6 Blinding

Patients, doctors and therapists cannot be blinded but assessors were blinded as measurement of Cobb angle, etc. took place at the remote study center in the First Affiliated Hospital of Nanjing Medical University with names, age etc. of patients

concealed. The data analysts were also blinded by not revealing the labels of numeric codes assigned to the two groups.

3.2.7 Data collection

The data sources are listed in Table 3.3. For most of the data, it was collected at each visit (every 6 months) in the Scoliosis Center. However, brace quality evaluations were conducted two to three weeks after the initial fabrication of the brace, then every three months. Skin condition under brace was checked after each modification of the brace by phone calls. Data of compliance in the orthotic intervention group were collected by downloading the data from the sensor every three months. A new sensor was embedded into the brace instead of charging the old one. This action avoided the waiting time of charging the battery for the patients. Data of compliance in the exercise group were collected while the patients came to the Scoliosis Center for the weekly training. The compliance of training at the Scoliosis Center was monitored by the corresponding therapists.

Table 3.3 Data sources

a) Radiographic data
Curve level
Cobb angle
Risser sign
Radiological shoulder balance (X-ray film)
Coracoid height difference
Clavicular angle
Clavicular tilt angle difference
T1-tilt
b) Clinical data
Weight
height
Clinical shoulder balance (digital photos)
Trunk Appearance Perception Scale (for physicians and therapists)
Ortho/neuro examination
c) Orthotic data
Skin condition under brace
Orthotist clinical notes
Brace quality evaluation
d) Self-reported data
Demographic information
Menarchal status
Simplified Chinese Version of SRS-22 Questionnaire
Trunk Appearance Perception Scale (for patients)
Compliance data
Daily video recording and log-sheet data
Sensor data

3.2.8 Statistical analysis

All analyses were performed with SPSS 20.0 (IBM Corporation, USA). Descriptive statistics were utilized to describe the distribution of the results with respect to statistical quantitative features. After testing the normality, it was found that data of age, height, weight, BMI, ATI degree and Cobb degree were normally distributed. Therefore, the demographic data of the two experimental groups were compared with Independent Samples t-test.

For inter-group comparison, normally distributed continuous variables (i.e. ATI degree, Cobb angle, correction of Cobb angle, items in SRS-22, items in shoulder balance and compliance) were compared with Independent Samples t-test. Ordinal variable (i.e. TAPS) was analyzed with Mann-Whitney U-test.

For intra-group comparison, repeated one-way ANOVA was applied for continuous variables while Kruskal-Wallis one-way ANOVA by ranks was applied for the data of TAPS across different time points. Post-hoc tests were conducted with Bonferroni method.

Potential correlations between normally distributed continuous variables (i.e. ATI degree, Cobb angle, correction of Cobb angle, items in SRS-22, items in shoulder balance and compliance) were tested with Pearson correlation analysis while correlations between ordinal variable (i.e. TAPS) and continuous variables (i.e. ATI degree, Cobb angle, correction of Cobb angle, items in SRS-22, items in shoulder balance and compliance) were tested with Spearman correlation analysis.

The statistical significance was determined with p value less than 0.05.

CHAPTER 4 RESULTS

4.1 Screening study

In total, 79,122 (92%) out of 86,145 primary and secondary school students enlisted in Wuxi City at the time of the annual physical examination, issued by the National Health and Family Planning Commission and Ministry of Education of the People's Republic of China, participated in this study comprising 43,258 boys and 35,864 girls. The left 8% of students were not screened. Some of the students were due to medical issues, some were absent from the schools and some just refused to be screened. The distribution of screened students according to age and gender is shown in Figure 4.2. Among the students who participated in the school-based screening, 2,687 (1,120 boys and 1,567 girls) were referred for radiography because of the detected ATI degree (5° or more) or other significant clinical signs. Several reminders (i.e. written reminder was a few words of the necessity of the X-ray examination shown on the clinical referring sheet, message reminder and telephone reminder were texts and phone calls made by the professionals) were set to improve the participation rate of hospital-based diagnosis. Eventually, 1,911 screened-positive students participated in the hospital-based diagnostic stage and 776 students did not show up and were recorded as non-respondents after several scheduled reminders (Figure 4.1). Descriptive statistics for referred students are summarized in Table 4.1.

Figure 4.1 Flow-chart, including the school-based screening phase and the hospital-based diagnosis phase

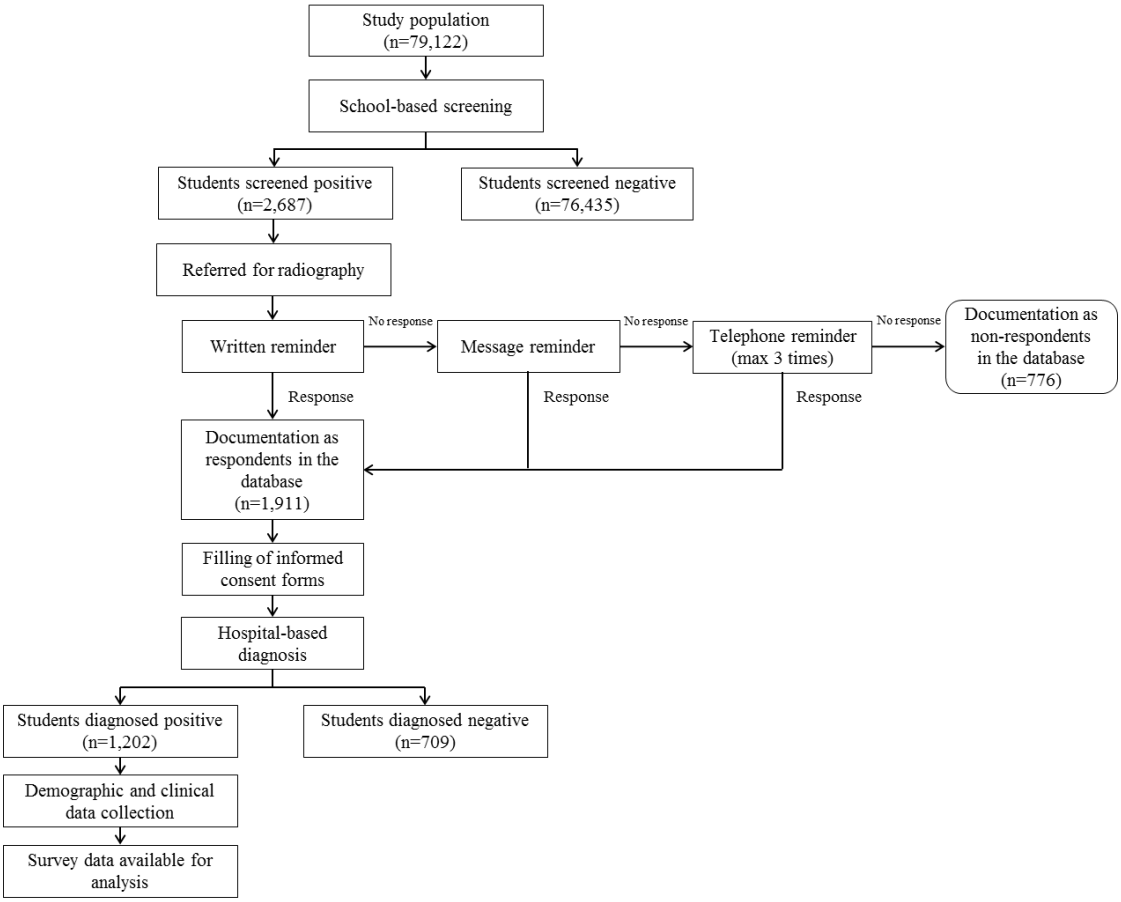


Figure 4.2 The number of students screened by age and gender

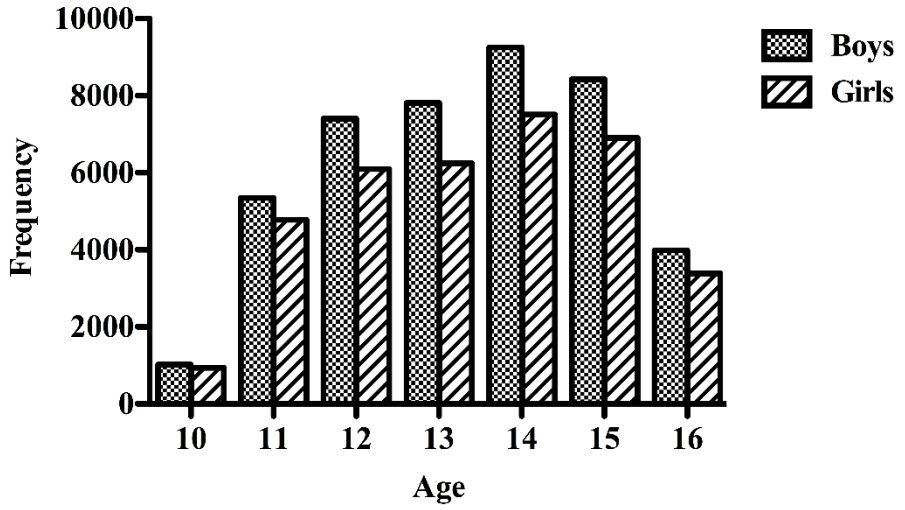


Table 4.1 Demographic data of study sample

Items	Total (n=2,687)
Male, n (%)	1,120 (41.68)
Age, mean (SD)	14.08 (1.365)
Height, mean (SD)	162.15 (9.06)
Weight, mean (SD)	49.3 (10.28)
BMI, mean (SD)	18.63 (2.64)
ATI degree, mean (SD)	6.44 (1.85)
Body fat, mean (SD)[1]	20.26 (5.13)
Resting metabolism, mean (SD)[1]	1,468.83 (249.32)

SD: standard deviation; BMI: body mass index; ATI: angle of truck rotation. [1]Body fat percentage measured by bipolar bioelectrical impedance and resting metabolism were carried out by using a hand-to-hand bioelectrical impedance meter (Omron Body Fat Analyzer HBF-306; Omron, Japan)

4.1.1 Reliability of parameter evaluation

The ICCs of all the parameters evaluated by the professionals were tested in 50 randomly selected cases. Either intra-rater correlation coefficient or inter-rater correlation coefficient ranged from high to very high. Details were listed in Table 4.2 and 4.3.

Table 4.2 Intra-rater reliability of parameter evaluation

	ICC	95% CI
First rater		
Height	0.997	0.995-0.997
Weight	0.996	0.994-0.997
ATI degree	0.880	0.865-0.922
Body fat	0.947	0.945-0.950
Resting metabolism	0.940	0.935-0.945
Second rater		
Height	0.996	0.995-0.997
Weight	0.996	0.994-0.996
ATI degree	0.840	0.830-0.855
Body fat	0.933	0.930-0.947
Resting metabolism	0.949	0.935-0.953

ICC: intra-rater correlation coefficient; CI: confidential interval.

Table 4.3 Inter-rater reliability of parameter evaluation

	ICC	95% CI
First rater *vs.* Second rater		
Height	0.981	0.980-0.984
Weight	0.988	0.986-0.990
ATI degree	0.865	0.860-0.880
Body fat	0.925	0.923-0.932
Resting metabolism	0.935	0.930-0.937

ICC: inter-rater correlation coefficient; CI: confidential interval.

4.1.2 PPV of FBT and the Scoliometer

The calculation of PPV was described in the statistical analysis section in Chapter 3. The overall PPV was 63.0% for students with a Cobb angle of 10° or more. It decreased to 48.19% in the students who needed to be followed up or receive with exercise training (Cobb angle ranged 11-24°) according to SRS criteria (Negrini et al., 2012). The corresponding PPVs for those who qualified for orthotic treatment (Cobb angle ranged 25-40°) or surgery (Cobb angle of 41° or more) were 14.08% and 0.73% (Table 4.4).

The variations of PPV by gender according to ATI degree and Cobb angle are shown in Tables 4.5 and 4.6. As compared to the overall PPV, a similar trend was

detected either in girls or in boys. No significant difference was detected between girls and boys in each subgroup (X^2=0.456, p=0.500 for diagnosis; X^2=0.886, p=0.346 for follow up and exercise training; X^2=0.721, p=0.396 for orthotic intervention; X^2=0.181, p=0.671 for surgery). In addition, the decreasing trend was similar in students with ATI degrees of 10° or below, while once it went up to 11° or more the PPVs were no longer consistent due to the small sample size in each subgroup according to Cobb angle.

Table 4.4 The overall PPVs of ATI degree followed by SRS criteria

ATI degree	Number of students (n)					PPV of ATI degree (%)			
	Cobb 0-9°	Cobb 10-24°	Cobb 25-39°	Cobb above 40°	Total	Diagnosis	FU or ET	Orthotics	Surgery
5°	270	450	3	0	723	0.6266	0.6224	0.0041	0
6°	164	177	97	4	442	0.6290	0.4005	0.2195	0.009
7°	119	140	80	5	344	0.6541	0.4070	0.2326	0.0145
8°	52	50	33	1	136	0.6176	0.3676	0.2426	0.0074
9°	32	31	13	2	78	0.5897	0.3974	0.1667	0.0256
10°	45	48	28	2	123	0.6341	0.3902	0.2276	0.0163
11°	7	10	1	0	18	0.6111	0.5556	0.0556	0
12°	10	5	4	0	19	0.4737	0.2632	0.2105	0
13°	3	3	4	0	10	0.7000	0.3	0.4	0
14°	2	1	2	0	5	0.6000	0.2	0.4	0
15°	3	5	1	0	9	0.6667	0.5556	0.1111	0
16°	0	0	1	0	1	1.0000	0	1	0
17°	0	0	2	0	2	1.0000	0	1	0
18°	0	1	0	0	1	1.0000	1	0	0
Total	707	921	269	14	1911	0.6300	0.4819	0.1408	0.0073

PPV: positive predictive value; ATI: angle of truck rotation; FU: follow up; ET: exercise training.

Table 4.5 The PPVs of ATI degree followed by SRS criteria in girls

ATI degree	Number of students (n)					PPV of ATI degree (%)			
	Cobb 0-9°	Cobb 10-24°	Cobb 25-39°	Cobb above 40°	Total	Diagnosis	FU or ET	Orthotics	Surgery
5°	139	242	3	0	384	0.6380	0.6302	0.0078	0
6°	95	111	61	2	269	0.6468	0.4126	0.2268	0.0074
7°	69	83	45	4	201	0.6567	0.4129	0.2239	0.0199
8°	34	30	17	1	82	0.5854	0.3659	0.2073	0.0122
9°	22	16	7	0	45	0.5111	0.3556	0.1556	0
10°	29	30	19	2	80	0.6375	0.3750	0.2375	0.0250
11°	6	9	0	0	15	0.6000	0.6	0	0
12°	5	4	4	0	13	0.6154	0.3077	0.3077	0
13°	1	3	4	0	8	0.8750	0.375	0.5	0
14°	2	1	2	0	5	0.6000	0.2	0.4	0
15°	2	4	1	0	7	0.7143	0.5714	0.1429	0
16°	0	0	0	0	0	/	/	/	/
17°	0	0	1	0	1	1	0	1	0
18°	0	1	0	0	1	1	1	0	0
Total	404	534	164	9	1111	0.6364	0.4806	0.1476	0.0081

PPV: positive predictive value; ATI: angle of truck rotation; FU: follow up; ET: exercise training.

Table 4.6 The PPVs of ATI degree followed by SRS criteria in boys

ATI degree	Number of students (n)					PPV of ATI degree (%)			
	Cobb 0-9°	Cobb 10-24°	Cobb 25-39°	Cobb above 40°	Total	Diagnosis	FU or ET	Orthotics	Surgery
5°	131	208	0	0	339	0.6136	0.6136	0	0
6°	69	66	36	2	173	0.6012	0.38156	0.2081	0.0116
7°	50	57	35	1	143	0.6503	0.39866	0.2448	0.0070
8°	18	20	16	0	54	0.6667	0.3704	0.2963	0
9°	10	15	6	2	33	0.6970	0.4545	0.1818	0.0606
10°	16	18	9	0	43	0.6279	0.4186	0.20936	0
11°	1	1	1	0	3	0.6667	0.3333	0.3333	0
12°	5	1	0	0	6	0.1667	0.1667	0	0
13°	2	0	0	0	2	0.0000	0	0	0
14°	0	0	0	0	0	/	/	/	/
15°	1	1	0	0	2	0.5000	0.5	0	0
16°	0	0	1	0	1	1.0000	0	1	0
17°	0	0	1	0	1	1.0000	0	1	0
18°	0	0	0	0	0	/	/	/	/
Total	303	387	105	5	800	0.6213	0.4838	0.1313	0.0063

PPV: positive predictive value; ATI: angle of truck rotation; FU: follow up; ET: exercise training.

4.1.3 Overall AIS prevalence and prevalence by age and gender

The overall prevalence of AIS for primary and secondary school students aged 10-16 years in Wuxi City was estimated at 2.4% with the prevalence of 3.12% in girls and 2.14% in boys, respectively. In addition, girls had a 1.46 times higher AIS prevalence than boys in the current study (Table 4.7). The Cobb angle on average in the diagnosed-positives was 18.68±8.16° with the average Cobb angle of 18.70±7.93° in girls and 18.30±7.17° in boys.

Detailed overall prevalence and prevalence by age and gender are shown in Table 4.8. The lowest and highest overall prevalence were found in 10 year olds (0.05%, 95% CI: 0.03-0.07%) and 16 year olds (3.77%, 95% CI: 3.64-3.90%), respectively. The data demonstrated an increasing trend in the overall prevalence with age and the prevalence in girls increased progressively from 0.53% (95% CI: 0.48-0.58%) to 4.10% (95% CI: 3.96-4.24%) and from 0.64% (95% CI: 0.58-0.70%) to 3.50% (95% CI: 3.37-3.63%) in boys. Moreover, none of the boys aged 10 years was confirmed as AIS patient, therefore estimates can only be provided for students aged 11 years and older. Girls had a higher prevalence in each age subgroup (high peak in 15yr age subgroup) as compared to that of boys (high peak in 16yr age subgroup). The highest girls to boys ratio (2.36:1) of AIS prevalence was detected in students aged 13 years.

Table 4.7 Overall prevalence and prevalence in girls and boys

	Prevalence	95% CI		Girls to Boys ratio
		Upper bound	Lower bound	
Girls	3.12	3.00	3.24	1.46:1
Boys	2.14	2.04	2.24	
Overall	2.40	2.29	2.51	/

95% CI: 95% confidence interval.

Table 4.8 Prevalence by age and gender

Age	Overall prevalence (95% CI)	Prevalence in girls (95% CI)	Prevalence in boys (95% CI)	Girls to Boys ratio
10yr	0.05 (0.03-0.07)	0.53 (0.48-0.58)	0	/
11yr	0.84 (0.78-0.90)	1.06 (0.99-1.13)	0.64 (0.58-0.70)	1.66:1
12yr	1.55 (1.46-1.64)	1.88 (1.79-1.97)	1.27 (1.19-1.35)	1.48:1
13yr	2.41 (2.30-2.52)	3.54 (3.41-3.67)	1.50 (1.42-1.58)	2.36:1
14yr	2.72 (2.61-2.83)	3.62 (3.49-3.75)	1.97 (1.87-2.07)	1.84:1
15yr	3.47 (3.34-3.60)	4.69 (4.54-4.84)	2.50 (2.39-2.61)	1.88:1
16yr	3.77 (3.64-3.90)	4.10 (3.96-4.24)	3.50 (3.37-3.63)	1.17:1

95% CI: 95% confidence interval.

4.1.4 Prevalence by BMI and gender

Prevalence, calculated according to BMI subgroups and gender, were shown in Table 4.9. AIS patients who were assigned to Thinness group had the highest prevalence either in girls (4.66%, 95% CI: 4.28-5.04%) or in boys (2.88%,95% CI: 2.58-3.18%) and the prevalence were lowest in those who were defined as obesity. Girls assigned to Normal weight group (X^2=17.639, p<0.001 *vs.* prevalence in boys) and Overweight group (X^2=14.083, p<0.001 *vs.* prevalence in boys) had significant higher prevalence than that of boys. The decreasing trends of AIS prevalence were detected by the increase of BMI value.

Table 4.9 Prevalence by BMI and gender

	Overall prevalence (95% CI)	Prevalence in girls (95% CI)	Prevalence in boys (95% CI)
Thinness[1]	3.67 (3.54-3.80)	4.66 (4.28-5.04)	2.88 (2.58-3.18)
Normal weight[1]	2.53 (2.42-2.64)	3.28 (2.96-3.60)[*]	1.82 (1.58-2.06)
Overweight[1]	1.94 (1.84-2.04)	3.19 (2.88-3.52)[#]	1.29 (1.09-1.49)
Obesity[1]	0.51 (0.46-0.56)	1.55 (1.33-1.77)	0.25 (0.16-0.34)

[1]Age-and-sex growth charts developed by the U.S. Centers for Disease Control and Prevention were used to categorize each student into one of the following categories: obesity (BMI ⩾95th percentile), overweight (BMI ⩾85th and <95th percentile), normal weight (BMI ⩾5th and <85th percentile), and thinness (BMI <5th percentile) (Korbel et al., 2014) (Korbel et al., 2014) (Korbel et al., 2014)). [*]: X^2=17.639, p<0.001 vs. prevalence in boys; [#]: X^2=14.083, p<0.001 vs. prevalence in boys. 95% CI: 95% confidence interval.

4.1.5 Prevalence by curve magnitude and curve distribution

The prevalence of AIS for different cure magnitudes according to gender are summarized in Table 4.10. The highest overall prevalence (1.16%, 95% CI: 1.09-1.24%) was found in patients with Cobb angles ranged between 10° and 24°. The overall prevalence decreased to 0.33% (95% CI: 0.30-0.38%) when the curve magnitude became moderate (25-40°), while those who were diagnosed as severe AIS patients had the lowest prevalence of 0.02% (95% CI: 0.01-0.03%). The decreasing trend of prevalence were consistent in boys and girls. Moreover, girls had a higher prevalence of AIS in each curve magnitude subgroup as compared to that in boys and the highest girls to boys ratio (3.00:1) was detected in the most severe curve magnitude subgroup (more than 40°).

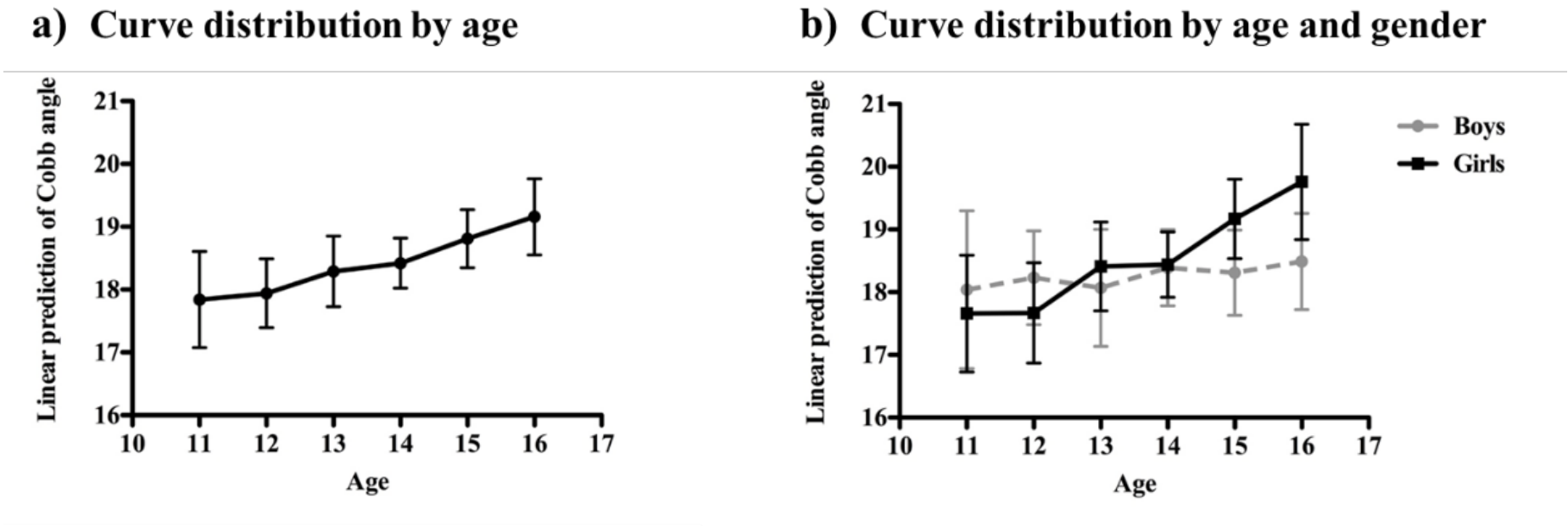
Figure 4.3 demonstrated an increase trend with age in overall curve distribution (Cobb angle on average as well as the corresponding 95% confidence interval) and distribution for girls but not for boys indicating the slight decrease of overall slope as compared to that of girls was pooled by the curve distribution of boys.

Table 4.10 Prevalence by curve magnitude and gender

	Prevalence (95% CI)			Girls to boys ratio
	Overall	**Girls**	**Boys**	
Cobb 10-24°	1.16 (1.09-1.24)	1.49 (1.36-1.61)	0.89 (0.81-0.98)	1.67:1
Cobb 25-40°	0.33 (0.30-0.38)	0.46 (0.39-0.53)	0.24 (0.20-0.29)	1.92:1
Cobb above 40°	0.02 (0.01-0.03)	0.03 (0.01-0.04)	0.01 (0.001-0.02)	3.00:1

95% CI: 95% confidence interval.

Figure 4.3 Curve distribution by age and gender



a) Estimated means and 95% CI of Cobb angle by age

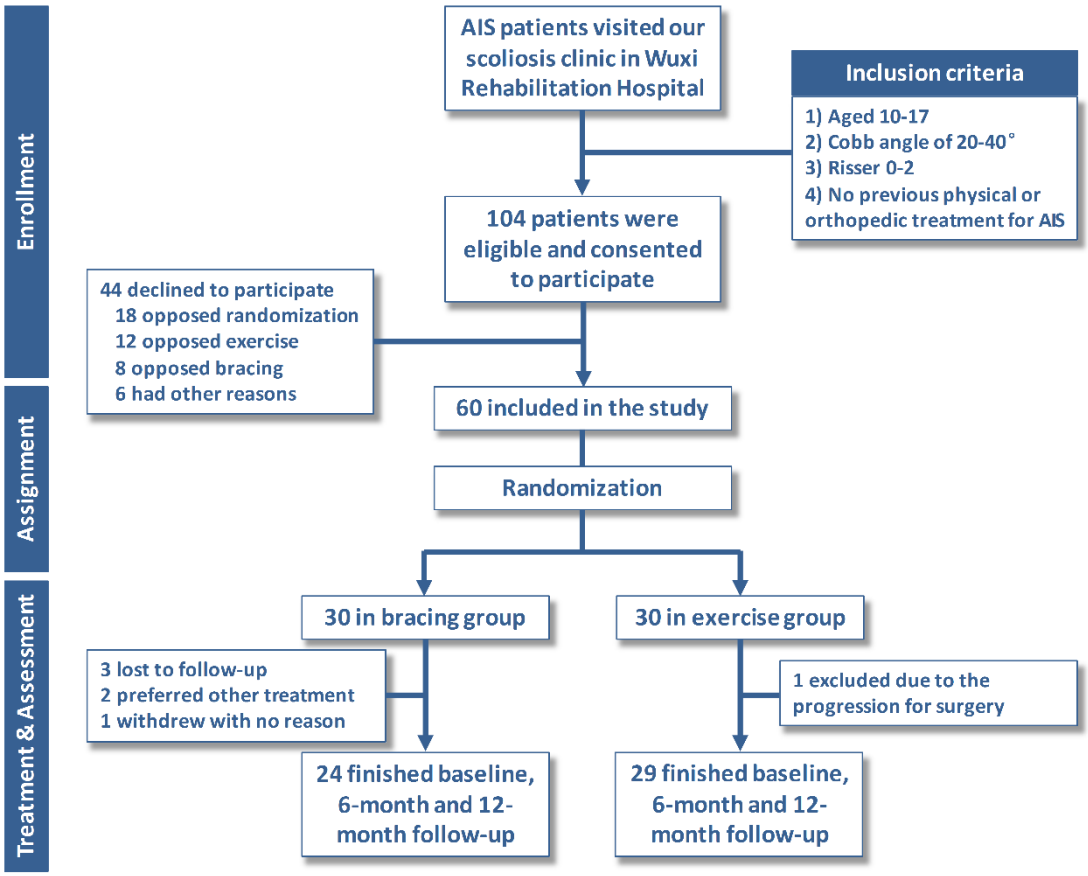
b) Estimated means and 95% CI of Cobb angle by age and gender

4.2 Intervention study

Twenty-four patients (19 females and 5 males) in the orthotic intervention group and 29 patients (22 females and 7 males) in the exercise group participated in this study. According to the data stored in the thermo-force sensor, the compliance of patients in the orthotic intervention (total orthosis wearing time divided by prescribed orthosis wearing time) and the exercise group (total exercise training time divided by prescribed exercise training time) were 57.7±0.27% and 59.1±0.2% respectively. The details of the study logistics are presented in Figure 4.4.

The mean, standard deviation and range of age, height, weight, BMI, ATI degree and Cobb angle are shown in Table 4.11. No statistical difference was detected between the two experimental groups, therefore, they were homogenous that formed a good baseline for comparing the effectiveness of the two non-operative interventions.

Figure 4.4 Study logistics of enrollment, assignment, treatment and assessment



AIS: adolescent idiopathic scoliosis.

Table 4.11 Demographic data

	Exercise group (n=29, 7M/22F)		Orthotic intervention group (n=24, 5M/19F)		t	p value
	Mean (SD)	Range	Mean (SD)	Range		
Age	12.4 (0.9)	10-14	12.3 (0.8)	11-14	0.48	0.634
Height (cm)	162.5 (7.0)	150-180	161.7 (8.2)	145-182	0.39	0.699
Weight (kg)	46.6 (6.5)	30-58	48.8 (8.2)	32-66	-1.12	0.270
BMI (kg/m^2)	17.6 (1.7)	13.3-20.6	18.6 (2.5)	14.3-23.7	-1.79	0.079
ATI degree (°)	8.6 (2.3)	5-14	9.5 (2.2)	7-14	-1.58	0.120
Cobb angle (°)	27.0 (3.6)	21-35	28.0 (3.6)	23-36	-0.98	0.334

BMI: body mass index; ATI: angle of trunk inclination; M: male; F: female; SD: standard deviation.

4.2.1 Inter-group comparison of spinal curvature, QoL and body symmetry

Table 4.12 shows the inter-group comparison of spinal curvature, QoL and shoulder balance. The baseline data of spinal curvature, QoL and body image were homogenous except the comparison concerning CA (2.41±1.74 in the exercise group *vs.* 3.54±1.72 in the orthotic intervention group). The ATI degree did not differ significantly between the two groups at all the three visits. As compared to the exercise group, the orthotic intervention group achieved significant smaller Cobb angle at 12-month evaluation (24.79±4.36° in the exercise group *vs.* 22.13±4.78° in the orthotic intervention group, p=0.039) and significant more correction of Cobb angle at 6-month (0.66±2.64° in the exercise group *vs.* 3.13±3.47° in the orthotic intervention group, p=0.005) and 12-month (2.24±3.19° in the exercise group *vs.* 5.88±6.37° in the orthotic intervention group, p=0.01) evaluation.

Although the orthotic intervention group showed overwhelming better results in terms of the correction of spinal curvature, inverse results were detected in the exercise group concerning the scores of QoL. Significantly higher functional, mental health and total score were detected in the exercise group at both the 6-month and 12-month follow-up evaluation ($p<0.001$ for all six comparison). Significant differences concerning the subscales of self-image (4.04±0.22 in the exercise group *vs.* 3.83±0.3 in the orthotic intervention group, p=0.004) and satisfaction (3.91±0.4 in the exercise group *vs.* 3.48±0.68 in the orthotic intervention group, p=0.006) were only detected at 6-month evaluation. In addition, no significant result was obtained in terms of pain. For the shoulder balance and TAPS evaluation, the results did not differ significantly between the two experimental groups.

Table 4.12 Inter-group comparison of spinal curvature, QoL and body symmetry

	Exercise group		Orthotic intervention group		t	p value
	Mean	**SD**	**Mean**	**SD**		
ATI degree						
Baseline	8.62	2.24	9.58	2.17	-1.58	0.120
6-month	8.00	1.46	8.29	1.08	-0.81	0.422
12-month	7.31	1.44	7.50	1.02	-0.54	0.591
Cobb angle						
Baseline	27.03	3.57	28.00	3.60	-0.98	0.334
6-month	25.45	3.60	25.25	3.58	0.20	0.842
12-month	24.79	4.36	22.13	4.78	2.12	0.039*
Correction of Cobb angle						
Baseline - 6-month	1.59	1.52	2.75	4.68	-1.26	0.213
6-month – 12-month	0.66	2.64	3.13	3.47	-2.95	0.005**
Baseline - 12-month	2.24	3.19	5.88	6.37	-2.69	0.010*

Table 4.12 Inter-group comparison of spinal curvature, QoL and body symmetry (Cont.)

	Exercise group		Orthotic intervention group		t	p value
	Mean	SD	Mean	SD		
SRS-22 (Function)						
Baseline	4.59	0.16	4.54	0.18	0.95	0.347
6-month	4.86	0.15	4.58	0.17	6.37	<0.001***
12-month	4.88	0.14	4.71	0.13	4.54	<0.001***
SRS-22 (Pain)						
Baseline	4.83	0.12	4.88	0.13	-1.40	0.166
6-month	4.96	0.08	4.93	0.11	0.94	0.351
12-month	4.93	0.12	4.93	0.12	0.18	0.855
SRS-22 (Self-image)						
Baseline	3.50	0.31	3.50	0.45	-0.03	0.974
6-month	4.04	0.22	3.83	0.30	3.03	0.004**
12-month	4.39	0.19	4.34	0.33	0.62	0.539
SRS-22 (Mental health)						
Baseline	4.09	0.22	4.13	0.24	-0.69	0.491
6-month	4.29	0.26	3.85	0.19	6.92	<0.001***
12-month	4.48	0.20	4.18	0.25	4.78	<0.001***
SRS-22 (Satisfaction)						
Baseline	3.79	0.25	3.71	0.25	1.22	0.227
6-month	3.91	0.40	3.48	0.68	2.88	0.006**
12-month	4.41	0.50	4.10	0.78	1.75	0.087
SRS-22 (Total score)						
Baseline	92.59	2.13	92.67	4.05	-0.09	0.926
6-month	98.55	2.31	92.88	2.47	8.63	<0.001***
12-month	102.17	1.87	99.00	2.32	5.51	<0.001***

Table 4.12 Inter-group comparison of spinal curvature, QoL and body symmetry (Cont.)

	Exercise group		Orthotic intervention group		t	p value
	Mean	SD	Mean	SD		
Shoulder balance (CBS)						
Baseline	11.21	5.53	9.62	4.92	1.10	0.278
6-month	7.84	4.21	6.24	3.39	1.50	0.139
12-month	5.54	4.10	4.06	2.15	1.59	0.117
Shoulder balance (CHD)						
Baseline	8.60	5.92	9.64	5.13	-0.67	0.504
6-month	7.25	4.99	6.81	3.76	0.36	0.718
12-month	6.30	4.57	5.30	3.25	0.89	0.376
Shoulder balance (CA)						
Baseline	2.41	1.74	3.54	1.72	-2.36	0.022*
6-month	2.14	1.27	2.83	1.76	-1.67	0.102
12-month	2.03	1.15	2.08	1.10	-0.16	0.876
Shoulder balance (CTAD)						
Baseline	4.62	3.93	5.38	2.92	-0.78	0.440
6-month	3.59	2.26	3.83	1.79	-0.43	0.666
12-month	2.93	2.07	2.96	1.57	-0.05	0.958
Shoulder balance (T1 tilt)						
Baseline	6.66	3.94	8.17	4.84	-1.25	0.216
6-month	5.66	3.06	7.08	2.52	-1.83	0.073
12-month	5.10	2.60	4.79	2.62	0.43	0.667

*ATI: angle of trunk inclination; CSB: clinical shoulder balance; CHD: coracoid height difference; CA: clavicular angle; CTAD: clavicular tilt angle difference; SD: standard deviation. *: $p<0.05$; **: $p<0.01$; ***: $p<0.001$.*

4.2.2 Intra-group comparison of spinal curvature, QoL and body symmetry

The exercise group (Table 4.13) demonstrates significant improvement detected in the comparison of baseline and 12-month evaluation in terms of ATI degree (8.62±2.24 *vs.* 7.31±1.44, p=0.017) and Cobb angle (27.03±3.57 *vs.* 24.79±4.36, p=0.03). For QoL, all the SRS-22 subscales showed significant improvement across the three visits except the comparison concerning function (4.86±0.15 *vs.* 4.88±0.14, p=0.598) and pain (4.96±0.08 *vs.* 4.93±0.12, p=0.336) between 6-month and 12-month evaluation as well as satisfaction (3.79±0.25 *vs.* 3.91±0.4, p=0.756) between baseline and 6-month evaluation. In terms of shoulder balance measurements, no significant difference was detected except the comparison of CSB between baseline and 6-month (11.21±5.53 *vs.* 7.84±4.12, p=0.021), and baseline and 12-month (11.21±5.53 *vs.* 5.54±4.1, p<0.001) evaluations.

The intra-group comparison results in the orthotic intervention group (Table 4.14) were quite different from that of the exercise group. In addition to the comparison of baseline *versus* 12-month evaluation, significant differences of the ATI degree in the comparison of the baseline *versus* 6-month evaluation (9.58±2.17 *vs.* 8.29±1.08, p=0.013) and Cobb angle in the comparison of the 6-month and 12-month evaluation (25.25±3.58 *vs.* 22.13±4.78, p=0.027). Concerning the SRS-22 subscales, functional score and total score showed significant differences between the baseline and 12-month evaluation (functional score of 4.54±0.18 *vs.* 4.71±0.13, p=0.002; total score of 92.67±4.05 *vs.* 99.00±2.32, p<0.001) as well as between the 6-month and 12-month evaluation (functional score of 4.58±0.17 *vs.* 4.71±0.13, p=0.018; total score of 92.88±2.47 *vs.* 99.00±2.32, p<0.001). Pain level did not differ significantly across

the three visits while self-image was significantly improved in every comparison. Regarding satisfaction, statistical improvement was only detected in the comparison of the 6-month *versus* 12-month evaluation (3.48±0.68 *vs.* 4.10±0.78, p=0.002). Moreover, in contrast to the exercise group, the orthotic intervention group showed statistical differences between the baseline and 12-month evaluation in terms of all shoulder balance subscales.

Table 4.15 shows the intra-group comparison of TAPS scores in patients, parents and doctors across three time points. For the comparison in patients, all the comparisons of baseline *versus* 6-month evaluation and baseline *versus* 12-month evaluation showed significant differences except the difference between the baseline and 6-month evaluation (z=-1.732, p=0.083) of Picture 1 in the exercise group. However, no significant result was detected in each comparison between the 6-month and 12-month evaluation in both groups.

According to the results of the body image evaluated by the parents, (Table 4.15) significant results of Picture 1 were detected in the comparison of baseline *versus* 6-month evaluation and baseline *versus* 12-month evaluation in both groups. Baseline data of Picture 2 also differed from the data collected at the 12-month evaluation (z=-2.179, p=0.029) in the orthotic intervention group. For Picture 3, significant results were detected in all the comparison except the differences between baseline *versus* 6-month evaluation (z=-0.905, p=0.366) in the exercise group and 6-month *versus* 12-month evaluation (z=-1.890, p=0.059) in the orthotic intervention group.

For the results of doctors' evaluation (Table 4.15), in addition to the comparison of baseline *versus* 6-month evaluation (z=-1.387, p=0.166), all the other results in Picture 1 were significant. The comparison concerning Picture 2 between 6-

month *versus* 12-month evaluation were negative either in the exercise group (z=-1.000, p=0.317) or in the orthotic intervention group (z=-0.447, p=0.655). Both groups also demonstrated significant results of Picture 3 except the comparison between 6-month *versus* 12-month evaluation (z=-1.134, p=0.257) in the view of doctors.

Table 4.13 Intra-group comparison of continuous variables in the exercise group

	Baseline		6-month		12-month		p value		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**6m *vs.* BL**	**12m *vs.* BL**	**12m *vs.* 6m**
ATI degree	8.62	2.24	8.00	1.46	7.31	1.44	0.546	0.017*	0.413
Cobb angle	27.03	3.57	25.45	3.60	24.79	4.36	0.122	0.030*	0.520
SRS-22									
Function	4.59	0.16	4.86	0.15	4.88	0.14	<0.001***	<0.001***	0.598
Pain	4.83	0.12	4.96	0.08	4.93	0.12	<0.001***	0.001***	0.336
Self-image	3.50	0.31	4.04	0.22	4.39	0.19	<0.001***	<0.001***	<0.001***
Mental health	4.09	0.22	4.29	0.26	4.48	0.20	0.003**	<0.001***	0.007**
Satisfaction	3.79	0.25	3.91	0.40	4.41	0.50	0.756	<0.001***	<0.001***
Total score	92.59	2.13	98.55	2.31	102.17	1.87	<0.001***	<0.001***	<0.001***
Shoulder balance									
CSB	11.21	5.53	7.84	4.21	5.54	4.10	0.021*	<0.001***	0.193
CHD	8.60	5.92	7.25	4.99	6.30	4.57	0.982	0.286	0.484
CA	2.41	1.74	2.14	1.27	2.03	1.15	0.459	0.309	0.781
CTAD	4.62	3.93	3.59	2.26	2.93	2.07	0.524	0.084	0.388
T1 tilt	6.66	3.94	5.66	3.06	5.10	2.60	0.733	0.217	0.519

*ATI: angle of trunk inclination; CSB: clinical shoulder balance; CHD: coracoid height difference; CA: clavicular angle; CTAD: clavicular tilt angle difference; SD: standard deviation; BL: baseline; 6m: 6-month; 12m: 12-month. *: p<0.05; **: p<0.01; ***: p<0.001.*

Table 4.14 Intra-group comparison of continuous variables in the orthotic intervention group

	Baseline		6-month		12-month		p value		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**6m *vs.* BL**	**12m *vs.* BL**	**12m *vs.* 6m**
ATI degree	9.58	2.17	8.29	1.08	7.50	1.02	0.013*	<0.001***	0.225
Cobb angle	28.00	3.60	25.25	3.58	22.13	4.78	0.062	<0.001***	0.027*
SRS-22									
Function	4.54	0.18	4.58	0.17	4.71	0.13	0.480	0.002**	0.018*
Pain	4.88	0.13	4.93	0.11	4.93	0.12	0.285	0.454	0.810
Self-image	3.50	0.45	3.83	0.30	4.34	0.33	0.009**	<0.001***	<0.001***
Mental health	4.13	0.24	3.85	0.19	4.18	0.25	<0.001***	0.450	<0.001***
Satisfaction	3.71	0.25	3.48	0.68	4.10	0.78	0.606	0.088	0.002**
Total	92.67	4.05	92.88	2.47	99.00	2.32	0.814	<0.001***	<0.001***
Shoulder balance									
CSB	9.62	4.92	6.24	3.39	4.06	2.15	0.006**	<0.001***	0.132
CHD	9.64	5.13	6.81	3.76	5.30	3.25	0.061	0.002**	0.634
CA	3.54	1.72	2.83	1.76	2.08	1.10	0.258	0.005**	0.299
CTAD	5.38	2.92	3.83	1.79	2.96	1.57	0.050	0.001**	0.503
T1 tilt	8.17	4.84	7.08	2.52	4.79	2.62	0.860	0.004**	0.079

*ATI: angle of trunk inclination; CSB: clinical shoulder balance; CHD: coracoid height difference; CA: clavicular angle; CTAD: clavicular tilt angle difference; SD: standard deviation; BL: baseline; 6m: 6-month; 12m: 12-month. *: p<0.05; **: p<0.01; ***: p<0.001.*

Table 4.15 Intra-group comparison of TAPS scores in patients, parents and doctors across three time points

TAPS items	Exercise group		Orthotic intervention group	
	z	p value	z	p value
Picture 1 (Patients)				
6-month *vs.* baseline	-1.732	0.083	-2.530	0.011*
12-month *vs.* baseline	-2.138	0.033*	-2.652	0.008**
12-month *vs.* 6-month	-1.508	0.132	-1.414	0.157
Picture 2 (Patients)				
6-month *vs.* baseline	-2.530	0.011*	-2.828	0.005**
12-month *vs.* baseline	-2.530	0.011*	-2.714	0.007**
12-month *vs.* 6-month	0	1	-0.577	0.564
Picture 3 (Patients)				
6-month *vs.* baseline	-2.714	0.007**	-2.333	0.020*
12-month *vs.* baseline	-2.496	0.013*	-2.640	0.008**
12-month *vs.* 6-month	0	1	-0.905	0.366

Table 4.15 Intra-group comparison of TAPS scores in patients, parents and doctors across three time points (Cont.)

TAPS items	Exercise group		Orthotic intervention group	
	z	p value	z	p value
Picture 1 (Parents)				
6-month *vs.* baseline	-3.317	0.001**	-2.840	0.005*
12-month *vs.* baseline	-3.638	<0.001***	-2.640	<0.001***
12-month *vs.* 6-month	-1.414	0.157	-1.890	0.059
Picture 2 (Parents)				
6-month *vs.* baseline	-1.633	0.102	-1.667	0.096
12-month *vs.* baseline	-1.890	0.059	-2.179	0.029*
12-month *vs.* 6-month	-0.577	0.564	-1.155	0.248
Picture 3 (Parents)				
6-month *vs.* baseline	-0.905	0.366	-2.828	0.005**
12-month *vs.* baseline	-2.324	0.020*	-3.357	0.001**
12-month *vs.* 6-month	-2.121	0.034*	-1.890	0.059

Table 4.15 Intra-group comparison of TAPS scores in patients, parents and doctors across three time points (Cont.)

TAPS items	Exercise group		Orthotic intervention group	
	z	p value	z	p value
Picture 1 (Doctors)				
6-month *vs.* baseline	-1.387	0.166	-2.524	0.012**
12-month *vs.* baseline	-3.500	<0.001***	-3.252	0.001**
12-month *vs.* 6-month	-3.000	0.003**	-2.449	0.014**
Picture 2 (Doctors)				
6-month *vs.* baseline	-2.138	0.033**	-3.000	0.003**
12-month *vs.* baseline	-2.517	0.012**	-2.400	0.016**
12-month *vs.* 6-month	-1.000	0.317	-0.447	0.655
Picture 3 (Doctors)				
6-month *vs.* baseline	-2.982	0.003**	-2.840	0.005**
12-month *vs.* baseline	-3.382	0.001**	-3.827	<0.001***
12-month *vs.* 6-month	-1.134	0.257	-2.673	0.008**

**: p<0.05; **: p<0.01; ***: p<0.001.*

4.2.3 Comparison of TAPS scores across patients, parents and doctors in the orthotic intervention group and the exercise group

Table 4.16 and 4.17 shows the comparison of TAPS scores across patients, parents and doctors in both orthotic intervention group and exercise group. In the orthotic intervention group, parents achieved better results of Picture 1 (z=-2.496, p=0.013) and 2 (z=-2.333, p=0.020) as compared to that of patients at baseline while doctors achieved better result of Picture 2 (z=-3.162, p=0.002) as compared to that of parents at baseline. No significant result was detected in other comparison.

For the exercise group, doctors achieved better results of Picture 1 (z=-2.000, p=0.046) and 3 (z=-2.828, p=0.005) as compared to that of patients at 12-month, and better results of Picture 3 (z=-2.449, p=0.014) as compared to that of parents at 12-month. Other comparison showed no significant result.

Table 4.16 Comparison of TAPS scores across patients, parents and doctors in the orthotic intervention group

TAPS items	Parent *vs.* Patient		Doctor *vs.* Patient		Doctor *vs.* Parent	
	z	p value	z	p value	z	p value
Baseline						
Picture 1	-2.496	0.013*	-1.890	0.059	-1.069	0.285
Picture 2	-2.333	0.020*	-0.832	0.405	-3.162	0.002**
Picture 3	-0.333	0.739	-1.941	0.052	-1.890	0.059
6-month						
Picture 1	-0.378	0.705	-1	0.317	-0.816	0.414
Picture 2	-1.134	0.257	-1.342	0.180	-2.121	0.034
Picture 3	-1.508	0.132	-0.333	0.739	-1.414	0.157
12-month						
Picture 1	-1	0.317	-0.577	0.564	-1.732	0.083
Picture 2	-1.633	0.102	0	1	-1.414	0.157
Picture 3	-0.333	0.739	-0.707	0.480	-0.378	0.705

**: p<0.05; **: p<0.01; ***: p<0.001.*

Table 4.17 Comparison of TAPS scores across patients, parents and doctors in the exercise group

TAPS items	Parent *vs.* Patient		Doctor *vs.* Patient		Doctor *vs.* Parent	
	z	p value	z	p value	z	p value
Baseline						
Picture 1	-0.707	0.480	-0.447	0.655	-0.378	0.705
Picture 2	-0.378	0.705	-1.890	0.059	-2.121	0.034
Picture 3	-0.577	0.564	-1.134	0.257	-0.816	0.414
6-month						
Picture 1	-0.447	0.655	-0.816	0.414	-0.577	0.564
Picture 2	-1	0.317	-0.577	0.564	-0.577	0.564
Picture 3	0	1	-0.378	0.705	-0.447	0.655
12-month						
Picture 1	-0.816	0.414	-2	0.046*	-1	0.317
Picture 2	-0.333	0.739	-1.134	0.257	-1.414	0.157
Picture 3	-1	0.317	-2.828	0.005**	-2.449	0.014*

**: p<0.05; **: p<0.01; ***: p<0.001.*

4.2.4 Correlations between TAPS and parameters of spinal deformity and shoulder balance

Table 4.18 shows the correlations between TAPS and parameters of spinal deformity and items of shoulder balance at each time point. Although the ATI degree was significantly correlated with TAPS in each Picture at baseline (except Picture 2) and 12-month, no significant correlation was detected at 6-month. Cobb angle was negatively correlated with TAPS in all Pictures except Picture 2 at baseline (r-square=-0.265, p=0.055) and Picture 3 at 6-month (r-square=-0.215, p=0.123). Nonetheless, correction of Cobb angle showed no correlation with TAPS.

Generally, items of shoulder balance showed very low to low correlations with TAPS. CSB showed significant low correlations with Picture 1 at each time point and Picture 3 at baseline (r-square=-0.363, p=0.007), while CHD, CA and CTAD generally showed no correlation with TAPS. In addition, T1 tilt was moderately correlated with Picture 1 at 12-month (r-square=-0.428, p=0.001) and Picture 3 at 6-month (r-square=-0.427, p=0.001), it also had low correlations with Picture 1 at baseline (r-square=-0.392, p=0.004) and Picture 3 at 12-month (r-square=-0.309, p=0.024).

Table 4.18 Correlations between TAPS and parameters of spinal deformity and shoulder balance

		TAPS					
		Picture 1		Picture 2		Picture 3	
		r-square	p value	r-square	p value	r-square	p value
ATI degree	**Baseline**	-0.343	0.012*	-0.236	0.089	-0.422	0.002**
	6-month	-0.195	0.161	-0.262	0.058	-0.173	0.214
	12-month	-0.492	<0.001***	-0.467	<0.001***	-0.440	0.001**
Cobb angle	**Baseline**	-0.416	0.002**	-0.265	0.055	-0.480	<0.001***
	6-month	-0.327	0.017*	-0.407	0.002**	-0.215	0.123
	12-month	-0.464	<0.001***	-0.344	0.012*	-0.443	0.001**
Correction of Cobb angle	**Baseline**	-0.183	0.191	-0.022	0.877	-0.148	0.291
	6-month	-0.192	0.168	-0.204	0.144	-0.120	0.393

Table 4.18 Correlations between TAPS and parameters of spinal deformity and shoulder balance (Cont.)

		TAPS					
		Picture 1		Picture 2		Picture 3	
		r-square	p value	r-square	p value	r-square	p value
CSB	**Baseline**	-0.308	0.025*	-0.058	0.678	-0.363	0.007**
	6-month	-0.307	0.025*	-0.104	0.458	-0.267	0.054
	12-month	-0.320	0.019*	-0.243	0.080	-0.189	0.175
CHD	**Baseline**	-0.154	0.270	0.048	0.735	-0.217	0.119
	6-month	-0.013	0.928	-0.106	0.450	-0.293	0.033*
	12-month	0.041	0.770	-0.022	0.873	-0.147	0.293
CA	**Baseline**	-0.204	0.142	0.033	0.812	-0.122	0.383
	6-month	-0.071	0.616	-0.114	0.417	-0.117	0.405
	12-month	-0.124	0.376	0.176	0.208	-0.080	0.571
CTAD	**Baseline**	0.017	0.902	0.300	0.029*	0.081	0.566
	6-month	0.257	0.063	0.239	0.085	0.163	0.243
	12-month	-0.223	0.109	0.160	0.254	-0.099	0.481
T1 tilt	**Baseline**	-0.392	0.004**	-0.162	0.247	-0.253	0.067
	6-month	-0.085	0.544	-0.116	0.409	-0.427	0.001**
	12-month	-0.428	0.001**	-0.057	0.686	-0.309	0.024*

*ATI: angle of trunk inclination; CSB: clinical shoulder balance; CHD: coracoid height difference; CA: clavicular angle; CTAD: clavicular tilt angle difference. *: p<0.05; **: p<0.01; ***: p<0.001.*

4.2.5 Correlations between SRS-22 and parameters of spinal deformity and shoulder balance

Table 4.19 shows the correlations between TAPS and parameters of spinal deformity and items of shoulder balance at each time point. ATI degree had low to moderate correlations with satisfaction (r-square=-0.530, p<0.001) and total score (r-square=-0.401, p-0.003) at 12-month. Although Cobb angle showed very low to low correlations with function (r-square=-0.283, p=0.040), self-image (r-square=-0.277, p=0.045) and total score (r-square=-0.304, p=0.027) at baseline, and satisfaction at 6-month (r-square=-0.371, p=0.006), it was moderately correlated with satisfaction at 12-month (r-square=-0.643, p<0.001). For correction of Cobb angle, it also had low correlations with function (r-square=-0.393, p=0.004), mental health (r-square=-0.322, p=0.019) and total score (r-square=-0.302, p=0.028) at 6-month, nonetheless, it was moderately correlated with satisfaction at 12-month (r-square=-0.662, p<0.001).

For the relationship between SRS-22 and items of shoulder balance, function was only correlated with CHD (r-square=-0.340, p=0.013) and CA (r-square=-0.360, p=0.008) at baseline, and self-image was only correlated with CSB (r-square=-0.343, p=0.012) and CHD (r-square=-0.339, p=0.013) at baseline. Pain and mental health showed no correlation with items of shoulder balance. However, satisfaction showed low to moderate correlations with CA at both 6-month (r-square=-0.336, p=0.014) and 12-month (r-square=-0.403, p=0.003), CTAD (r-square=-0.497, p<0.001) and T1 tilt (r-square=-0.607, p<0.001) at 12-month. For total score, it was also significantly correlated with CSB (r-square=-0.310, p=0.024) and CHD (r-square=-0.342, p=0.012) at baseline as well as CTAD at 12-month (r-square=-0.319, p=0.021) and T1 tilt at 6-month (r-square=-0.367, p=0.007).

Table 4.19 Correlations between SRS-22 and parameters of spinal deformity and shoulder balance

		SRS-22											
		Function		Pain		Self-image		Mental health		Satisfaction		Total score	
		r-square	p value	r-square	p value	r-square	p value	r-square	p value	r-square	p value	r-square	p value
ATI degree	**Baseline**	-0.207	0.136	-0.080	0.570	-0.216	0.120	-0.194	0.164	0.093	0.507	-0.259	0.061
	6-month	-0.049	0.729	-0.065	0.642	-0.043	0.762	-0.085	0.544	-0.190	0.173	-0.135	0.335
	12-month	-0.058	0.678	-0.038	0.787	-0.134	0.337	-0.047	0.739	-0.530	<0.001***	-0.401	0.003**
Cobb angle	**Baseline**	-0.283	0.040*	-0.019	0.895	-0.277	0.045*	-0.173	0.215	0.045	0.747	-0.304	0.027*
	6-month	0.157	0.260	0	0.999	-0.088	0.532	0.005	0.973	-0.371	0.006**	-0.103	0.462
	12-month	0.115	0.414	0.042	0.764	0.086	0.541	0.169	0.225	-0.643	<0.001***	-0.150	0.284
Correction of Cobb angle	**Baseline**	-0.114	0.414	-0.041	0.768	-0.254	0.066	-0.001	0.992	-0.193	0.165	-0.225	0.105
	6-month	-0.393	0.004**	0.010	0.943	-0.231	0.096	-0.322	0.019**	0.107	0.445	-0.302	0.028*

Table 4.19 Correlations between SRS-22 and parameters of spinal deformity and shoulder balance (Cont.)

		SRS-22											
		Function		Pain		Self-image		Mental health		Satisfaction		Total score	
		r-square	p value	r-square	p value	r-square	p value	r-square	p value	r-square	p value	r-square	p value
CSB	**Baseline**	-0.206	0.139	-0.183	0.190	-0.343	0.012*	-0.016	0.908	-0.022	0.875	-0.310	0.024*
	6-month	0.162	0.247	0.014	0.918	-0.103	0.461	0.053	0.706	-0.057	0.686	0.014	0.920
	12-month	-0.035	0.805	0.071	0.613	-0.086	0.540	0.114	0.416	-0.205	0.140	-0.082	0.558
CHD	**Baseline**	-0.340	0.013*	-0.020	0.887	-0.339	0.013*	-0.072	0.607	-0.083	0.555	-0.342	0.012*
	6-month	0.147	0.293	0.020	0.884	-0.047	0.738	0.109	0.439	-0.091	0.518	0.045	0.749
	12-month	0.012	0.934	-0.040	0.776	0.022	0.875	-0.009	0.948	-0.161	0.248	-0.080	0.568
CA	**Baseline**	-0.360	0.008**	0.189	0.174	-0.074	0.601	0.039	0.780	-0.168	0.229	-0.118	0.400
	6-month	-0.064	0.650	-0.197	0.158	0.043	0.760	-0.188	0.178	-0.336	0.014*	-0.214	0.123
	12-month	-0.110	0.434	0.002	0.988	0.060	0.670	0.024	0.864	-0.403	0.003**	-0.193	0.167
CTAD	**Baseline**	-0.112	0.423	0.218	0.117	0.108	0.443	0.199	0.153	-0.087	0.536	0.136	0.330
	6-month	0.038	0.787	-0.159	0.255	0.037	0.793	-0.064	0.650	-0.250	0.071	-0.102	0.466
	12-month	0.066	0.636	-0.213	0.126	0.117	0.406	-0.157	0.263	-0.497	<0.001***	-0.319	0.021*
T1 tilt	**Baseline**	-0.216	0.120	0.004	0.976	-0.120	0.391	-0.138	0.324	-0.088	0.530	-0.196	0.160
	6-month	-0.228	0.101	-0.175	0.211	-0.193	0.166	-0.131	0.351	-0.261	0.059	-0.367	0.007**
	12-month	-0.085	0.544	0.054	0.702	0.090	0.523	0.087	0.536	-0.607	<0.001***	-0.229	0.099

*ATI: angle of trunk inclination; CSB: clinical shoulder balance; CHD: coracoid height difference; CA: clavicular angle; CTAD: clavicular tilt angle difference. *: p<0.05; **: p<0.01; ***: p<0.001.*

4.2.6 Correlations between changes of TAPS and spinal deformity, shoulder balance and compliance

Table 4.20 shows the correlations between changes of TAPS and changes of spinal deformity, shoulder balance and compliance. Changes of ATI degree and Cobb angle were significantly correlated with change of TAPS score in each Picture while no correlation was detected between the change of correction of Cobb angle and changes of TAPS scores. For the items in shoulder balance, only changes of CBS and T1 tilt were significantly correlated with change of TAPS score in each Picture. Although significant results were detected between change of CHD and Picture 3 (r-square=-0.273, $p<0.001$) as well as between change of CA and Picture 1 (r-square=-0.199, $p=0.012$) and 3 (r-square=-0.159, $p=0.046$), the correlations ranged between very low to low. In addition, compliance also showed low correlation with Picture 1 (r-square=-0.382, $p=0.005$).

Table 4.20 Correlations between changes of TAPS and spinal deformity, shoulder balance and compliance

	TAPS					
	Picture 1		Picture 2		Picture 3	
	r-square	p value	r-square	p value	r-square	p value
ATI degree	-0.395	<0.001***	-0.355	<0.001***	-0.407	<0.001***
Cobb angle	-0.440	<0.001***	-0.388	<0.001***	-0.431	<0.001***
Correction of Cobb angle	0.009	0.912	-0.004	0.958	0.028	0.724
CSB	-0.392	<0.001***	-0.226	0.004**	-0.362	<0.001***
CHD	-0.139	0.080	-0.093	0.244	-0.273	<0.001***
CA	-0.199	0.012*	-0.052	0.515	-0.158	0.046*
CTAD	-0.048	0.551	0.139	0.081	-0.021	0.794
T1 tilt	-0.303	<0.001***	-0.185	0.020*	-0.338	<0.001***
Compliance	0.382	0.005	0.104	0.459	0.208	0.134

*ATI: angle of trunk inclination; CSB: clinical shoulder balance; CHD: coracoid height difference; CA: clavicular angle; CTAD: clavicular tilt angle difference. *: p<0.05; **: p<0.01; ***: p<0.001.*

4.2.7 Correlations between changes of SRS-22 and spinal deformity, shoulder balance and compliance

Table 4.21 shows the correlations between changes of SRS-22 and changes of spinal deformity, shoulder balance and compliance. Changes of function showed low to very low correlations with changes of spinal deformity and shoulder balance except changes of correction of Cobb angle (r-square=-0.125, p=0.116) and compliance (r-square=0.084, p=0.551). Generally, changes of pain and mental health showed no correlations with changes of spinal deformity, shoulder balance and compliance. Nonetheless, changes of self-image, satisfaction and total score were significantly correlated with changes of spinal deformity, shoulder balance and compliance except correlations between change of self-image and change of correction of Cobb angle (r-square=-0.013, p=0.871), change of self-image and compliance (r-square=-0.104, p=0.456) as well as change of total score and change of correction of Cobb angle (r-square=0.039, p=0.623).

Table 4.21 Correlations between changes of SRS-22 and spinal deformity, shoulder balance and compliance

	SRS-22											
	Function		Pain		Self-image		Mental health		Satisfaction		Total score	
	r-square	p value	r-square	p value	r-square	p value	r-square	p value	r-square	p value	r-square	p value
ATI degree	-0.274	<0.001***	-0.163	0.040*	-0.383	<0.001***	-0.212	0.007**	-0.300	<0.001***	-0.422	<0.001***
Cobb angle	-0.165	0.038*	-0.095	0.234	-0.341	<0.001***	-0.098	0.220	-0.490	<0.001***	-0.379	<0.001***
Correction of Cobb angle	-0.125	0.116	-0.007	0.928	-0.013	0.871	-0.093	0.242	0.412	<0.001***	0.039	0.623
CSB	-0.252	0.001**	-0.189	0.017*	-0.487	<0.001***	-0.108	0.174	-0.232	0.003**	-0.424	<0.001***
CHD	-0.188	0.017*	-0.095	0.232	-0.312	<0.001***	-0.068	0.397	-0.179	0.024*	-0.281	<0.001***
CA	-0.265	0.001**	-0.041	0.604	-0.181	0.023*	-0.122	0.125	-0.327	<0.001***	-0.279	<0.001***
CTAD	-0.167	0.035*	-0.077	0.336	-0.176	0.026*	-0.074	0.356	-0.307	<0.001***	-0.239	0.002
T1 tilt	-0.282	<0.001***	-0.094	0.240	-0.269	0.001**	-0.159	0.046*	-0.359	<0.001***	-0.355	<0.001***
Compliance	0.084	0.551	0.091	0.518	-0.104	0.456	-0.082	0.559	0.771	<0.001***	0.339	0.013*

*ATI: angle of trunk inclination; CSB: clinical shoulder balance; CHD: coracoid height difference; CA: clavicular angle; CTAD: clavicular tilt angle difference. *: p<0.05; **: p<0.01; ***: p<0.001.*

4.2.8 Correlations between TAPS and SRS-22

Table 4.22 shows the correlations between TAPS and SRS-22 in each time point. No significant result was detected between changes of function, pain, self-image, mental health and TAPS in each Picture. Only satisfaction showed low to moderate correlations with Picture 1 in 12-month (r-square=0.506, $p<0.001$) as well as Picture 3 at baseline (r-square=-0.283, p=0.040) and 12-month (r-square=0.316, p=0.023). Additionally, total score was significantly correlated with Picture 1 in 12-month (r-square=0.352, p=0.011).

Table 4.22 Correlations between TAPS and SRS-22

		SRS-22											
		Function		Pain		Self-image		Mental health		Satisfaction		Total score	
		r-square	p value	r-square	p value	r-square	p value	r-square	p value	r-square	p value	r-square	p value
Picture 1	**Baseline**	0.099	0.479	-0.099	0.482	0.088	0.530	-0.022	0.876	-0.101	0.470	0.037	0.795
	6-month	0.011	0.937	0.112	0.423	0.208	0.134	0.107	0.444	0.049	0.728	0.158	0.259
	12-month	0.127	0.368	0.215	0.125	0.143	0.311	-0.115	0.415	0.506	<0.001***	0.352	0.011*
Picture 2	**Baseline**	-0.202	0.146	0.067	0.635	0.025	0.859	0.133	0.342	-0.233	0.094	-0.016	0.910
	6-month	-0.195	0.162	-0.179	0.199	-0.201	0.148	-0.159	0.256	0.047	0.737	-0.208	0.135
	12-month	0.125	0.377	-0.166	0.238	0.040	0.780	-0.226	0.106	0.190	0.178	0	1
Picture 3	**Baseline**	0.227	0.102	0.092	0.511	0.122	0.384	0.086	0.539	-0.283	0.040*	0.140	0.318
	6-month	0.026	0.852	0.007	0.958	0.167	0.232	0.108	0.440	0.151	0.279	0.165	0.236
	12-month	0	1	-0.079	0.578	-0.052	0.716	0.093	0.511	0.316	0.023*	0.162	0.250

**: p<0.05; **: p<0.01; ***: p<0.001.*

4.2.9 Correlations between changes of TAPS and SRS-22

Table 4.23 shows the correlations between changes of TAPS and changes of SRS-22 items. Changes of self-image and total score showed moderate to low correlations with changes of TAPS scores in each Picture while no significant result was detected between changes of pain, mental health and changes of TAPS scores in each Picture. In addition, changes of function and satisfaction were also significantly correlated with Picture 1 and 3.

Table 4.23 Correlations between changes of TAPS and SRS-22

	TAPS					
	Picture 1		Picture 2		Picture 3	
	r-square	p value	r-square	p value	r-square	p value
Function	0.187	0.018*	0.035	0.663	0.193	0.015*
Pain	0.115	0.150	0.036	0.650	0.101	0.205
Self-image	0.590	<0.001***	0.573	<0.001***	0.525	<0.001***
Mental health	0.092	0.247	-0.015	0.856	0.131	0.101
Satisfaction	0.222	0.005**	0.097	0.226	0.181	0.023*
Total score	0.491	<0.001***	0.421	<0.001***	0.459	<0.001***

**: p<0.05; **: p<0.01; ***: p<0.001.*

4.2.10 Correlations between changes of spinal deformity and changes of shoulder balance and compliance

Table 4.24 shows the correlations between changes of spinal deformity and changes of shoulder balance as well as compliance. Changes of items in shoulder balance were significantly correlated with changes of ATI degree and Cobb angle except the correlation between change of CTAD and change of ATI (r-square=0.081, p=0.313). Change of CTAD, the only item in shoulder balance, had low correlation with change of correction of Cobb angle (r-square=-0.169, p=0.033). Additionally, compliance had moderate to high correlations with changes of spinal deformity and shoulder balance except the correlation between compliance and change of CSB (r-square=-0.218, p=0.116).

Table 4.24 Correlations between changes of spinal deformity and changes of shoulder balance and compliance

	ATI degree		Cobb angle		Correction of Cobb angle		Compliance	
	r-square	p value	r-square	p value	r-square	p value	r-square	p value
Shoulder balance								
CSB	0.537	<0.001***	0.633	<0.001***	-0.081	0.310	-0.218	0.116
CHD	0.326	<0.001***	0.400	<0.001***	-0.083	0.298	-0.396	0.003**
CA	0.259	0.001**	0.402	<0.001***	-0.094	0.241	-0.510	<0.001***
CTAD	0.081	0.313	0.256	0.001**	-0.169	0.033*	-0.542	<0.001***
T1 tilt	0.559	<0.001***	0.617	<0.001***	-0.065	0.412	-0.573	<0.001***
Compliance	-0.423	0.002**	-0.658	<0.001***	0.895	<0.001***	/	/

*ATI: angle of trunk inclination; CSB: clinical shoulder balance; CHD: coracoid height difference; CA: clavicular angle; CTAD: clavicular tilt angle difference. *: p<0.05; **: p<0.01; ***: p<0.001.*

CHAPTER 5 DISCUSSION

In this section, the prevalence of AIS in the east part of China was elaborated and the insights behind the data were discussed. The results of the RCT regarding the effectiveness of orthotic intervention *versus* exercise on patients with AIS were also deliberated in terms of the correction of spinal curvature and body symmetry, and improvement of QoL. Finally, the study limitations and the recommendations for future studies would be presented.

5.1 The screening study

5.1.1 The current statue of scoliosis school screening programs

Routine screening of scoliosis is a controversial subject and screening efforts vary greatly around the world (Grivas et al., 2007a), with compulsory scoliosis school screening programs in some areas, voluntary scoliosis school screening programs in others, while some countries recommended against. Currently, some have legislated school screening, while national scoliosis school screening programs in Canada have been forbidden (Fletcher et al., 1979).

In 2008, the AAOS, the SRS, the POSNA, and the AAP (Richards et al., 2008) supported such screening, while in 1996, the USPSTF concluded that there was insufficient evidence to make a recommendation for, or against, screening of scoliosis (USPSTF, 1996). However, in 2004, the USPSTF changed their position and recommended against the routine screening of scoliosis (USPSTF, 2006). The AAOS, SRS, POSNA, and AAP concerned that this change in position by the USPSTF came in the absence of any significant change in the available literature, in the absence of

any change in position statements by the AAOS, SRS, POSNA, and AAP, and in the absence of any significant input from specialists who commonly care for scoliosis. The AAOS, SRS, POSNA, and AAP supported none of formal recommendations against scoliosis screening.

In 2010, the SRS determined that it would be worth exploring scoliosis screening from a multi-national perspective by creating an International Task Force. After a critical review of the available evidence (Beauséjour et al., 2013), the SRS International Task Force on scoliosis screening made several statements and recommendations: 1) scoliosis screening is recommended as valuable in technical efficacy, clinical, program and treatment effectiveness. The current literature provided insufficient evidence of cost effectiveness; 2) scoliosis screening should be aimed at identifying suspected cases who will be referred for diagnostic evaluation and confirmed, or ruled out; 3) the Scoliometer is currently the best tool available for scoliosis screening. There is moderate evidence to recommend referral with ATI degree above 4° and 7°, or greater; 4) there is moderate evidence that the use of scoliosis screening allows for early detection and referral of patients with AIS; 5) there is evidence that patients with scoliosis detected by screening are less likely to receive surgical treatment than those patients who did not have been screened; 6) prevalence, referral rates and PPVs of current tools used in the screening programs reach adequate values, so as to consider scoliosis a condition suitable for screening; 7) future work to determine minimum standards and targets (i.e. referral rates and PPVs) is needed for screening programs; 8) further investigation on cost-effectiveness of screening programs should be performed by comparing one group with scoliosis screening *versus* one without (Labelle et al., 2013).

Although the scoliosis school screening programs have been conducted in mainland China for several decades, due to the absence of legislation and the mandatory rules, the screening of scoliosis in mainland China was voluntary. One of the main reasons for the absence of nationwide screening is that the prevalence of the disease was too low to get the benefit from the scoliosis school screening programs, making it difficult to establish the likely impact and to be legislated. However, due to the benefits indicated by the SRS international Task Force on scoliosis screening, the Chinese Disabled People's Federation has been planning to launch the legislated nationwide scoliosis school screening. Wuxi City in Jiangsu Province was selected as one of the pilot cities. One of the major reasons, for setting scoliosis screening in the pilot cities was to fill the epidemiological blank of AIS since there is no large scale of scoliosis school screening conducted in the east part of China. It may also help to determine minimum standards and targets (i.e. referral rates and PPVs) and can serve as evidence to support the legislated nationwide scoliosis school screening programs.

Moreover, according to the systematic review and meta-analysis conducted by Zhang et al. (Zhang et al., 2015), the overall quality of screening studies conducted in mainland China was not high. Based on the summarized data, although more than 90% of studies defined the source of information and indicated the time period of screening, only around 60% of studies trained the evaluators before the screening. In addition, less than 30% of studies provided the information regarding patient exclusions, confounding assessment, participation rate and missing data. All of the above aspects were considered before the conduction of screening which may strength the reliability of the results from the current study.

5.1.2 Selection of tests at the school-based screening and hospital-based diagnosis phase

Several tests, scales or instruments, i.e. the physical examination, the TRACE scale, the FBT, the Scoliometer, the Moire topography and the ultrasound scanning, can be used for school-based screening. The major principles for the school-based screening are simple, noninvasive and time-effective.

In most cases, the surface deformity is observed by the parents. When the subjects visit the hospital, the physical examination is performed by the general clinicians. The spine alignment, shoulder asymmetries, scapula prominence, breast asymmetry, unequal waistline or arm distances, and lower limb length inequality are checked. However, it can only provide limited information and it cannot serve as the reference to make even rough diagnosis. Nonetheless, it is featured as a fast and simple examination which can be finished within a couple of minutes.

As compared to the qualitative physical examination, the TRACE scale has been recently proposed and validated as a semi-quantitative measurement (Zaina et al., 2009). The intra-rater repeatability was fair (three points out of twelve was the minimum change to be considered significant between two different evaluations for the same rater) while the inter-rater reliability was poor (four points out of twelve was the minimum change to be considered significant between two different raters). It requires neither expensive instruments nor prolonged evaluation sessions. However, based on our best knowledge, it has not been applied in any screening programs so that its PPV and negative predictive value (NPV) are unknown.

The simplest evaluation test in the clinical examination of patients with scoliosis is the FBT (Bunnell, 1984, 1993). The hump detected from the back and the

side indicated the pathognomic for scoliosis. Its PPV varies since it is proportional to the degree of curvature, the body composition of the patients (the hump is difficult to be detected in fat patients) and operators' experience. Therefore, the FBT was combined with the Scoliometer in most scoliosis school screening programs.

The Scoliometer measures the inclination of the hump detected in the FBT. It is an evaluation tool that has been proven highly useful. The Scoliometer measures the ATI and has high intra-rater and inter-rater reliabilities (the intra-rater reliability was 0.88 and the inter-rater reliability was 0.84 in the current study). It allows the determination of cut-off points above which a radiological examination is indicated. It has a sensitivity of about 100% and a specificity of about 47% when an ATI degree of 5° is chosen (Côté et al., 1998). When the ATI degree is set at 7°, the sensitivity decreases to 83%, however the specificity increases to 86% (De et al., 1998; Grosso et al., 2002; Huang, 1997). Although its detection of the hump through a quantitative recording is more sensitive as compared to the FBT, it is still impacted by the degree of curvature and the body composition of the patients (i.e. fat patients).

The Moire topography was applied in the screening program in Singapore in 1982. In general, the Moire topography is a simple method requiring a camera, a light source and a grating (Porto et al., 2010). The images are formed by the alternation of clear and dark fringes which provide a three-dimensional shape analysis of objects from a two-dimensional image analysis of the Moiré topograms obtained from the subjects' back allows verification of body asymmetries. and can be performed in a manner that is either predominantly qualitative or quantitative. However, it requires to assess the subjects in isolation by the same experienced operator with specific devices. Although it is a non-invasive technique with no radiation, its application is believed to be inconvenient in the scoliosis school screening program.

The ultrasound scanning is noninvasive and is believed to be the most promising examination to replace the X-ray examination in the future. It has been verified as a reliable and valid measurement of spinal curvature in the coronal plane (Wang et al., 2015). However, at this moment it is still time-consuming (at least 2min for scanning and 5min for reconstruction of the image) and requires specific devices.

Over the past several decades, different combinations of the above tests, scales and instruments were applied in several featured studies (Table 5.1). Their experience, challenges and successes were fully considered combined with the condition in Wuxi before the conduction of the current study. As a cross-sectional large scale screening program (around 80,000 students were screened), the tests should be simple, noninvasive and efficient. Therefore, after careful consideration of the advantages and disadvantages of the above tests, scales and instruments, the physical examination, the FBT combined with the Scoliometer were adopted in the current study.

For the hospital-based diagnosis, Cobb angle measured on the X-ray film is believed to be the golden standard with no doubt. Cobb angle measurements on the same radiographic film had an acceptable intra- and inter-rater reliability of 3-5° and 6-7°, respectively (Negrini et al., 1995). Other diagnostic methods are in application, for example, MRI (Malfair et al., 2010; Sucato, 2010), neurophysiological exams (Jones, 2006). Nevertheless, beyond their importance in the surgical setting, in the use for screening purposes, these techniques are not supported by the actual evidence, unless there are symptoms and signs of neurological compromise: only in these cases, in fact, a specific diagnosis is useful (Fernández et al., 2009).

Table 5.1 Featured scoliosis school screening programs conducted in mainland China

Author(s)	Year	Region	Latitude (°)	Study population	No. of AIS patients	Age	Prevalence (%)	Screening methods
Current study	2016	Wuxi, Jiangsu	31.57	79122	1,202	10-16	2.40	1. Adam`s forward bending test 2. Scoliometer evaluation 3. Whole spine X-ray examination
Fan et al.	2016	Guangzhou, Guangdong	23.13	99.695	5,125	10-16	0.97-8.80	
Yu et al.	2014	Guangzhou, Guangdong	23.13	23340	210	10-16	0.90	
Chen et al.	2010	Jinzhou, Liaoning	39.10	8670	38	10-16	0.44	
Du et al.	2010	Shunde, Guangdong	22.84	13247	94	10-16	0.71	
Dong et al.	2009	Nanchang, Jiangxi	28.68	9143	59	10-16	0.65	
Huang et al.	2011	Guangzhou, Guangdong	23.13	19528	141	10-16	0.72	1. Adam`s forward bending test 2. Whole spine X-ray examination
Zhou et al.	2008	Huian, Fujian	25.04	22574	170	10-16	0.75	
Zhang et al.	2003	Haikou, Hainan	20.03	5533	13	10-16	0.23	
Liu et al.	2011	Harbin, Heilongjiang	45.80	15797	299	10-16	1.89	1. Adam`s forward bending test 2. Moire topography 3. Whole spine X-ray examination
Liu et al.	2002	Guangzhou, Guangdong	23.13	68293	579	10-16	0.85	1. Adam`s forward bending test 2. Scoliometer evaluation 3. Moire topography 4. Whole spine X-ray examination

5.1.3 PPVs of FBT and the Scoliometer

At the school-based screening phase, it is believed that the FBT combined with the Scoliometer is a simple and fast method for identifying the presence of minor spinal deformity although its accuracy has been subjected to controversial debate (Côté et al., 1998). One of the major concerns of school-based screening is the over-referral to radiological examination when confirmed diagnosis needs to be made. Higher specificity, sensitivity, PPV and NPV are preferred, however, it was inevitable to have suboptimal accuracy due to the behavioral noncompliance of the examiners, individual differences of the subjects, even postural and diurnal changes. In addition, it was not ethical to refer screened-negative individuals for X-ray examination especially in a large-scale screening program. Therefore, the NPV is normally not possible to obtain in a scoliosis screening program since it needs to refer the screened-negatives to receive X-ray examination which has been previously documented as non-ethical.

The results reported in the literature were contradictory in terms of the intra- and inter-rater reliability values of the Scoliometer. In a recent study published by Coelho et al., all vertebral levels of the thoracic and lumbar spine were measured with the Scoliometer in the FBT. Excellent intra-rater reliability of 0.92 and very good inter-rater reliability of 0.89 were achieved. They concluded that regardless of the vertebral level and magnitude of the patients' ATI, the Scoliometer measurement is reliable (Coelho et al., 2013). The pilot study of the current study also achieved similar results.

However, from the school-based screening to hospital-based diagnosis, it is inevitable to predict the radiographic Cobb angle using noninvasive methods (the ATI degree in the current study) which is believed to have potential bias. Reports in the

literature are contradictory, with some authors proposing a strong correlation between the methods and other stating there is a poor correlation. These studies correlated the ATI degree with the Cobb angle. However, both values are determined in a subjective manner by the examiner. The low reliability of the corresponding prediction can lead to over-referral. The pilot study of the current study found a similar poor correlation between the ATI degree and Cobb angle and faced the same problem. The previous literature documented that the Scoliometer has a sensitivity of 100% and a specificity of 47% when the referral cut-off point was set at ATI degree of 5°, the sensitivity and specificity become much more balance when the ATI degree of 7° was set as the threshold. As a large-scale screening program, the ideal situation is to refer all the AIS patients for the final confirmation if possible. In this case, a higher sensitivity is preferred and the specificity becomes not such important. This is the main reason why the cut-off point was set at ATI degree of 5° in the current study.

Afterwards, the PPVs were calculated to show the accuracy of the Scoliometer. The PPV was often between 19.3% and 51.5% in previous studies (Fan et al., 2016; Glascoe, 2005; Huang, 1997; Suh et al., 2011; Wong et al., 2005; Zhang et al., 2015). A meta-analysis conducted by Fong et al. showed that the use of FBT alone resulted a higher referral rate as compared to use of FBT combined with the Scoliometer or Moire topography (7.2% *versus* 2.6%), and lower PPV for curves $\geqslant 10°$ (23.2% *versus* 38.0%) and $\geqslant 20°$ (3.5% *versus* 11.0%) (Fong et al., 2010). This further confirmed that it is essential to combine the FBT and the Scoliometer together in a scoliosis school screening program, it is helpful to reduce the referral rate and increase the PPV, in other words, to avoid radiological exposure for normal subjects. However, a recently published large population-based screening study using a three-stage design showed a PPV of 78.4% for diagnosis at a referral rate of 6.6% (Fan et al., 2016). This

indicates the screening effectiveness of AIS screening can be further improved with repeating the FBT and the Scoliometer assessment in those who were initially recognized as potential AIS patients. The PPV in the current study was 63.0% for diagnosis (Cobb angle of 10° or more). As compared to the findings of previous studies, the well-trained professionals who had experience from a pilot screening study, which included 11,024 primary school students, may have contributed to the high PPV for diagnosis in the current study (Zheng et al., 2016). It not only reduced the referral rate but also improved the PPV, and in turn saved medical resources and avoiding unnecessary radiological exposure. As shown in Table 4.4, the PPVs of Cobb angle above 24° were no longer as high as that of Cobb angle below 25°. In addition, large fluctuations were observed in both girls and boys with ATI degrees above 10°. These observations were consistent with which was reported by Fong et al. (Fong et al., 2010). In this case, it may be due to the limited sample size in either Cobb angle above 24° subgroups or ATI degree above 10° subgroups. However, the most important factor might be the accuracy of the Scoliometer. As reported by Pierre et al., the Scoliometer has a sensitivity of about 100% and a specificity of about 47% at an ATI degree of 5° (Côté et al., 1998), while its sensitivity decreases to 83% however the specificity increases to 86% when the ATI degree is set at 7° (De et al., 1998; Grosso et al., 2002; Huang, 1997). This indicated that the Scoliometer would become more reliable as ATI degree increased and the results of the current study for individuals with Cobb angles below 25° and ATI degrees below 11° meet this principle. However, this principle might not be applied for moderate and severe cases in the current study. It implied that the Scoliometer might not be the best choice for detecting moderate and severe AIS. Non-invasive and efficient technologies (for example, ultrasound scanning) could be considered in future scoliosis school

screening programs. Fan et al. increased the PPV from 64.8% to 78.4% by adding a rescreening session for individuals with ATI degree of 5° or more (Fan et al., 2016), indicating that the frequency of evaluation may also be critical in improving the accuracy at the school-based screening phase. In addition, the PPVs in the current study were calculated by dividing the number of students with Cobb angles of 10° or above by the number of students who participated in the hospital-based diagnosis stage. This may have become an overestimation as it seems plausible that students with apparent scoliotic curves may have been more likely to show up for clinical examination, in other words, slowly progressive curves, which may be already apparent enough for detection, are more likely to be detected by screening rather than highly progressive curves.

5.1.4 Overall AIS prevalence and prevalence by age and gender

Many scoliosis school screening programs have been performed in Mainland China, however, there are few reports on AIS prevalence from eastern China. As a medium-sized city, its representative can be reflected in terms of economy, humanity and life style in the east part of China. Most residents in this city are native Chinese.

In total, 79,122 (92%) out of 86,145 students participated in this study and all the primary and secondary schools in Wuxi City were enrolled. Since more than 90% of the students participated this program, the results may represent the situation in the east part of China. According to the literature, the prevalence of scoliosis in Mainland China was 1.02% (Zhang et al., 2015). The current study reported an overall AIS prevalence of 2.4% which was higher than the above pooled prevalence (Zhang et al., 2015). In addition, ten studies conducted in mainland China were found to have

comparable prevalence while the current study reported the second-high overall prevalence (see Table 5.1) (Chen et al., 2010; Dong et al., 2009; Du et al., 2010; Huang et al., 2011; Liu et al., 2002; Liu et al., 2011; Yu et al., 2014; Zhang et al., 2003; Zhou et al., 2009).

After a careful review of all the current literatures, it is believed that confounders, such as latitude, age, screening technologies, evaluation frequency and diagnostic criteria, may contribute to the variation of the overall prevalence in different regions.

Grivas et al. assumed that the different prevalence of scoliosis might be due to lifestyle differences across different geographical latitudes (Grivas et al., 2006). He concluded that the prevalence of scoliosis increased as the latitude was approaching the North Pole. There may be some outliers due to different reasons while the general trend of the prevalence presented in the studies conducted in mainland China matched this hypothesis (Table 5.1). The possible explanation might be the duration of sunlight decreases alone the increase of the latitude so that the bone density may decrease which may contribute to the development of this disease. For the age range, the pooled overall prevalence was estimated in ages 5-19 and the ranges varied across independent studies included in the meta-analysis. To the best of our knowledge, the prevalence of idiopathic scoliosis in patients aged 5-9 years and 17-19 years are relatively lower than that in adolescent patients aged 10-16 years. Therefore, it is reasonable to find the relatively lower pooled prevalence when a meta-analysis was conducted in the corresponding population (patients aged 5-19 years).

In terms of screening technologies, evaluation frequency and screening professionals, as shown in Table 5.1 most of the featured studies adopted the physical

examination and the FBT combined with the Scoliometer, while some combined physical examination with Morie topography instead of the FBT (Liu et al., 2002; Liu et al., 2011). In addition, referral criteria varied across different studies, Tian et al. adopted Cobb angles of 5° or more as the diagnostic threshold instead of 10° or more (Tian et al., 1997). Fan et al. repeated the screening procedure aiming at increasing the PPV and reducing the referral rate, while findings reported by Minghelli et al. were only based on the results of the Scoliometer (Minghelli et al., 2014). As a two-step screening study, participants in the current study were firstly screened in the schools and further diagnosed in the hospital by the team consisted of well-trained and experienced orthopaedic surgeons, rehabilitation physicians, therapists and nurses as compared to the screening only conducted by nurses or technicians (Yamamoto et al., 2015). The consensus achieved by the interdisciplinary team work may further avoid the unnecessary radiological exposure to the true healthy population. Therefore, it is believed that appropriate screening technologies, well-designed evaluation frequency and experienced screening professionals can contribute to a successful screening program. The results would be more trustable and can be integrated for inter-study comparison. Given the importance of various confounders, consensus procedure or guideline in AIS screening is needed for future studies.

It has been widely accepted that the prevalence rate of girls is higher than that of boys. One of the explanations can be the interactions between the production of leptin and development of scoliosis in girls. AIS in girls results from developmental disharmony between autonomic and somatic nervous systems and that it is expressed in the spine and trunk (Burwell et al., 2008). The theory states that the autonomic component of this double neuro-osseous theory for AIS pathogenesis in girls involves selectively increased sensitivity of the hypothalamus to circulating leptin, with

asymmetry as an adverse response; this asymmetry is routed bilaterally via the sympathetic nervous system to the growing axial skeleton, where it may initiate the scoliosis deformity. AIS patients have been shown to have muscle dysfunction and asymmetry in the paraspinal muscle (Shimode et al., 2003; Zoabli et al., 2007). It is unknown whether this abnormality was primary or secondary to the scoliotic curve. Therefore, another possible reason can be the imbalanced strength of paraspinal muscle alone the concave and convex sides of the spine could lead to higher chances of curve progression. Although this was also observed in boys, it is believed that the muscle strength is much weaker in girls compared to that in boys. The results of the current study confirmed this knowledge. However, it is interesting to note that a high peak prevalence was in 15-16yr female (4.10-4.69%) and 16yr male (3.50%) respectively, and the highest girls to boys ratio (2.36:1) was found in 13 year olds. The results were consistent with the findings of another large population-based AIS screening conducted in the Guangdong Province (Fan et al., 2016). Considering the observed high peak prevalence rate might be due to an accumulated effect along the development of the deformity, it is suggested to conduct the screening one or two years ahead of the age at which the high peak prevalence was observed. This indicated that the high-risk population in Mainland China might be different and the results could serve as reference and guidance for future screening studies in Mainland China.

5.1.5 Prevalence by BMI and gender

A few studies reported associations between BMI and prevalence of AIS. Fan et al. used 18kg/m^2 as the threshold for allocating patients to either an under- or overweight group and explored the prevalence across BMI subgroups. They found a significant

higher prevalence in students with BMI less than 18kg/m^2. Principally, this stratification is suitable for adult instead of adolescent. Therefore, in the current study the patients were allocated into four BMI subgroups based on the Age-and-sex growth charts developed by the U.S. Centers for Disease Control and Prevention (Gandhi et al., 2015). These charts were developed based on the results of a large-scale survey and was specifically for the adolescent. According to this evidence-based stratification, higher prevalence was found in the subgroups with lower BMI. The trend was consistent with the results reported by Fan et al. and Oded et al. (Fan et al., 2016; Oded et al., 2014). The latter concluded that the prevalence rate of spinal deformities was significantly greater among the underweight patients and increased BMI had a protective effect for developing spinal deformities based on a cross-sectional survey of 829,791 adolescents in Israel (Oded et al., 2014). One of the possible explanations might be the developmental disharmony between autonomic and somatic nervous systems in individuals with lower BMI, it may in turn launch selectively increased sensitivity of the hypothalamus to circulating leptin, with asymmetry as an adverse response (Burwell et al., 2008). In addition, thicker muscular tissues over the spine in the patients with higher BMI may have a protective effect since it is assumed that the muscles can strengthen the spine and provide self-generated corrective forces. It can also not be excluded that nutrition related factors are involved. In addition, girls had higher prevalence in each subgroup than that of boys, significant higher prevalence of girls was also observed in the normal weight and overweight subgroups. The mechanism behind this observation needs to be further clarified.

5.1.6 Prevalence by curve magnitude and gender, and curve distribution by age and gender

Approximately 10% of the diagnosed cases require non-operative management and 0.1-0.3% require surgical correction. As shown in Table 7, mild (Cobb angle of 11-24°) and moderate (Cobb angle of 25-40°) curves were also the most common types in the current study. For the patients in the subgroup of 10-24°, the condition is not such severe and normally the possibility of progression to a severe condition is low. While for the moderate cases, although the prevalence rate was not high, considering the large population, they should be prior to share the medical sources. The ratio of girls to boys increased with curvature magnitude indicating progress may be more frequently seen in females, which was consistent with the findings of previous studies (Lonstein, 2006; Parent et al., 2005). Figure 4.3 strengthened the above point of view again since it was observed that before 13 years old the girls had the lower average Cobb angle as compared to that of boys while inverse results were found after 13 years old. This can be explained by the theory that girls in mainland China always show delayed pubertal growth spurt. For the girls to boys ratio in the subgroup of Cobb angle above 40°, the results need to be taken caution since the sample size is not big enough.

5.1.7 Strength and limitations

To the best of our knowledge, this was the largest scoliosis school screening program ever conducted in the east part of China. It filled the epidemiological blank of AIS in this region and may serve as the reference for future studies.

Another strength of the current study was that the BMI and curve severity subgroups were classified according to the criteria developed by the U.S. Center for Disease Control, the SRS and the SOSORT respectively. This allows better data fusion and outcome comparison among different studies in the future.

In addition, two-step diagnostic studies always encounter attrition in the second step. In this case, students who were screened positive at the school-based screening phase might not show up at the hospital for X-ray examination. This could be related to students' and parents' limited knowledge about AIS and reluctance with regard to radiographic examinations. Potential AIS cases in non-respondents may cause bias with regard to the overall prevalence estimate and it cannot be avoided in any epidemiological studies. Therefore, one more innovation of the current study was the use of propensity scores to adjust for unit non-response. With this method, the prevalence was adjusted by predicting the potential positive cases in non-respondents. While this did not influence prevalence estimates much, therefore it was only shown with the weighted data.

One limitation of the current study is the experimental design. As a cross-sectional study, the longitudinal data cannot be provided, therefore the change of prevalence in the certain period is unknown. The follow-up screening is necessary in the future so that the effectiveness of screening and the scoliotic progression would be detected. Fortunately, the follow-up screening program is on the way and the data will be shared to the readers in the near future.

The other limitation of this study was the lack of radiographic data for a sample of screened negative individuals so that false negative rates could not be estimated. This cannot be avoided since referring screened negative individuals for X-ray examination was not ethical due to its invasive property. Compared to previous studies (De et al., 1998; Grosso et al., 2002; Huang, 1997), it was found a lower false positive rate using the Scoliometer although it is good enough at the school-based screening phase. The relatively great workload may be one of the reasons which restricted the time for examination and screening specificity. This may be addressed by introducing multiple screening instruments and increasing the number of professional staff at each screening time point in the future.

Additionally, in the current study the height was simply measured with a device which is widely used in the physical examination in China. However, it is noticed that the height might not be reliable in patients with AIS since it may be impaired by several confounders, i.e. tilted pelvis, twisted spine et al.. Therefore, in the follow-up screening projects, the arm span, which has been reported to be more reliable, will be used to substitute for height.

5.2 The intervention study

5.2.1 The current status of clinical trials in the scoliosis research field

To answer the clinical question “Is orthotic intervention or exercise effective in delaying the progression of or reducing the speed at which the curve progress?”, many studies were conducted in the past several decades. Nonetheless, consensus has not been achieved regarding whether orthotic intervention is the optimal option for mild

to moderate cases or whether exercise is effective in avoiding the need for orthotic treatment, surgery, or both.

The RCT is the strongest research design on the basis of which to draw valid conclusions regarding the effectiveness of interventions because, if well performed, it can minimize the risk of bias. The current evidence about orthotic intervention and exercise for AIS is of low to very low quality. According to the recently published two Cochrane reviews (Negrini et al., 2016; Romano et al., 2013), until now, apart from the current study only five RCTs have been successfully conducted, two comparing two types of braces (Lou et al., 2012; Wong et al., 2008), two comparing orthotic intervention *versus* observation (Coillard et al., 2014; Weinstein et al., 2014) and one comparing electrostimulation *versus* electrostimulation combined with exercise (Li, 2005). In addition, there were three more prospective controlled trials, two comparing orthotic intervention *versus* observation (Lusini et al., 2014; Nachemson et al., 1995) and one comparing two types of exercise treatment (Negrini et al., 2003). The methodological quality summary and the risk of bias graph for the featured studies alone with the current study were shown in Figure 4.5 and 4.6. All the studies included had different types of bias at different risk level. Therefore, the overall quality of evidence in favor of orthotic intervention, exercise or observation is from moderate to low quality.

Some of the above studies recruited participants with a range of pathology below the most frequent indications since in the classical range of 25° to 40° the implementation of RCTs is challenging. The RCT conducted by Weinstein et al. focused on 25° to 40°. Unfortunately, around 65% of subjects refused to participate and 21% of subjects and their parents rejected randomization. The final percentage of participants that could be allocated to the randomized arm was 10.6%. Because of the

low inclusion rate, the authors extended the inclusion criteria to include subjects with 20° (Weinstein et al., 2014). Bunge et al. also planned a RCT on the effectiveness of orthotic intervention *versus* observation in 2008, they were only able to enroll 4 patients after a period of 1.5 years, despite a good preparation and a pilot study showing good participation rates (Bunge et al., 2010a). The SRS, which consists mainly of orthopaedic surgeons, supported to plan an RCT (Weinstein et al., 2014); conversely, the conservative experts of the SOSORT rejected the possibility of performing an RCT (Negrini et al., 2012). Despite these professional positions, the strongest argument against the possibility of performing RCTs comes from the reality that most parents (70%–80% of cases) will not allow their children to be randomized so that it is difficult to collect a homogenous patient sample large enough to obtain adequate power of the study. This was the main reason for failure of the two best efforts performed in recent years (Bunge et al., 2010b; Weinstein et al., 2014). The current study faced similar problem during the subject enrollment. Considering the concept of acceptability of treatment together with efficacy and effectiveness, combination of recommendations of the two professional societies (the SRS and the SOSORT) and extension of the lower bounder of the SRS criteria were made. This action was learnt from Wong et al. (Wong et al., 2008) and Weinstein et al. (Weinstein et al., 2014) and it smoothed the enrollment procedure as it provided the chances for the patients who should have not been eligible to participate in. As compared to the Dutch and US trials, the potential reason of the relative low dropout rate (10% in the orthotic intervention group and 3% in the exercise group) of the current study can be that the two experimental groups were all provided with intervention. Instead of observation, patients are always willing to do something with their spinal deformity.

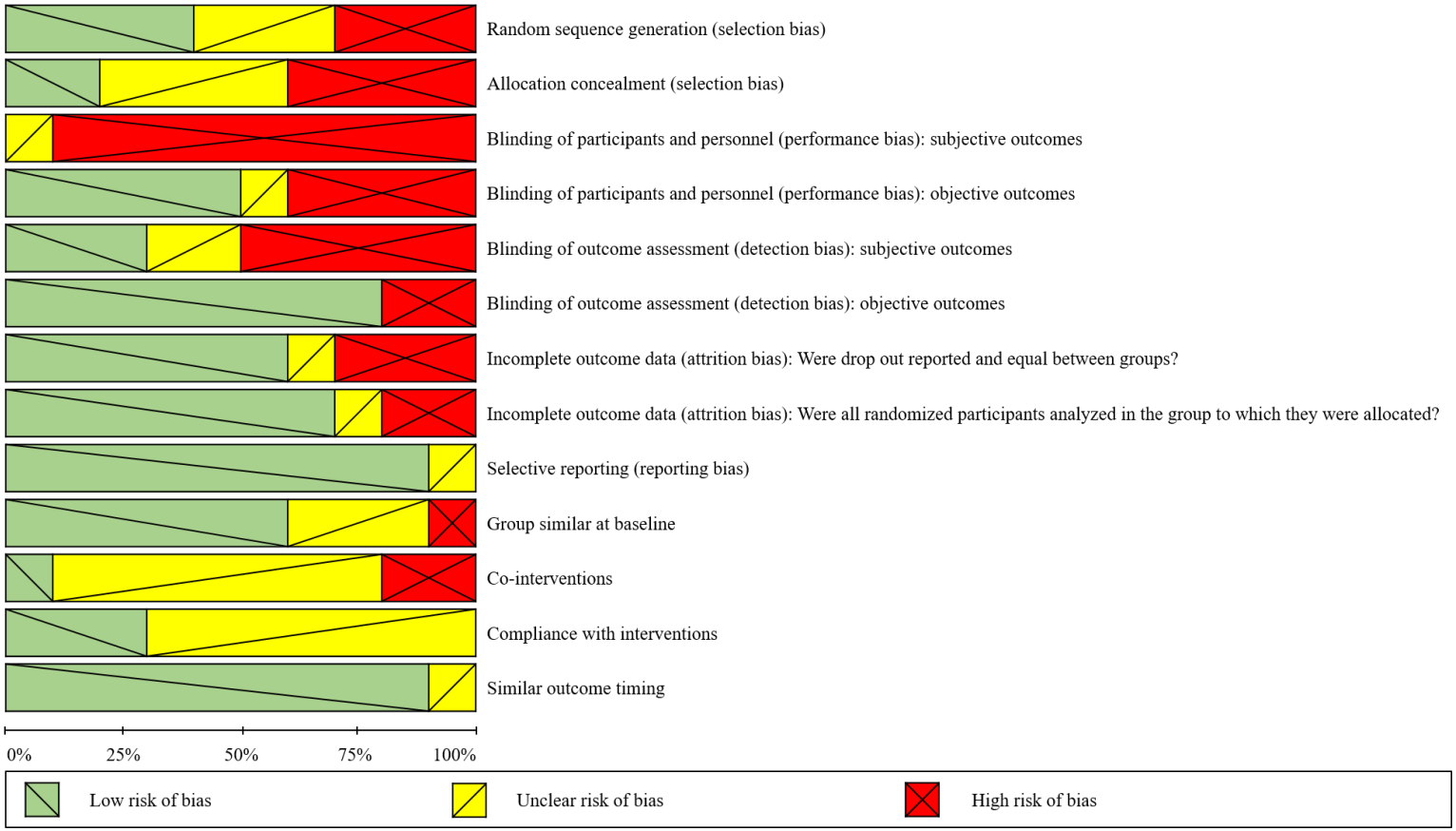
Although the RCT planned by Bunge et al. failed completely, the multicentered RCT conducted by Weinstein et al. and financed by the US Government has finally been changed from an RCT to a CCT. The main reason is that the ethical committee requested the study to be stopped because of the overwhelming success of orthotic intervention as compared to observation only in 2013. For this reason, it was possible to report the RCT data and the CCT data at the same time. Therefore, the probability to perform RCTs of orthotic intervention *versus* observation is low. Clinicians in this field will rely on the current low quality evidence for many years to come. Bunge et al. concluded, "it is harder to perform a RCT that abolishes or postpones a treatment than a RCT that adds a new treatment" (Bunge et al., 2010a). Nevertheless, RCTs comparing different types or designs of braces or different interventions have already been done, are being conducted and will presumably be performed in the near future.

Figure 5.5 Methodological quality summary: review authors' judgments about risk of bias items for the featured studies

The current study	Wan 2005	Negrini 2008	Wong 2008	Weinstein 2013	Nachemson 1995	Lusini 2013	Lou 2012	Coillard 2012	Bunge 2010	
+	?	-	?	+	-	-	?	+	+	Random sequence generation (selection bias)
+	?	-	?	?	-	-	?	+	?	Allocation concealment (selection bias)
-	-	-	-	-	-	-	?	-	-	Blinding of participants and personnel (performance bias): subjective outcomes
-	-	-	-	+	+	+	?	+	+	Blinding of participants and personnel (performance bias): objective outcomes
+	-	-	-	+	?	-	?	-	+	Blinding of outcome assessment (detection bias): subjective outcomes
+	-	-	+	+	+	+	+	+	+	Blinding of outcome assessment (detection bias): objective outcomes
+	+	+	+	+	-	-	+	-	?	Incomplete outcome data (attrition bias): Were drop out reported and equal between groups?
+	+	+	+	+	-	+	+	-	?	Incomplete outcome data (attrition bias): Were all randomized participants analyzed in the group to which they were allocated?
+	+	+	+	+	+	+	+	+	?	Selective reporting (reporting bias)
+	+	+	+	+	-	?	?	+	?	Group similar at baseline
?	?	+	?	?	?	-	?	?	-	Co-interventions
+	?	+	?	+	?	?	+	?	?	Compliance with interventions
+	+	+	+	+	+	?	+	+	+	Similar outcome timing

+: low risk of bias; ?: unclear risk of bias; -: high risk of bias.

Figure 5.6 Risk of bias graph: review authors' judgments about risk of bias items presented as percentages across all featured studies



5.2.2 The effectiveness of orthotic intervention and exercise on spinal curvature, QoL and body symmetry

For clinicians, the decision to prescribe non-operative management for patients with AIS is often not necessarily detached in terms of the psychosocial and aesthetical concerns. The SRS and the SOSORT recommended to "systematically report in clinical studies the primary patient-centered outcomes (i.e. aesthetics, disability, pain and QoL), and the secondary predictive outcomes (i.e. clinical, radiological and topographic data) of treatment approaches" (Negrini et al., 2015). Therefore, the goals of non-operative management of AIS can be summarized into two groups: morphological and functional (physical and psychological) aspects. The current study observed all the aspects as suggested by the two professional societies over the course of intervention.

5.2.2.1 Spinal curvature

As Weiss et al. documented that the clinical improvement comes along with a correction of spinal curvature (Weiss et al., 2007), the current findings confirmed this statement. Both interventions achieved significant improvement regarding the parameters of spinal curvature (ATI degree, Cobb angle and correction of Cobb angle) over the course of intervention. Results of inter-group comparison also showed that orthotic intervention was superior to capture correction in Cobb angle at the 12-month evaluation.

There is no doubt that Cobb angle was most frequently chosen as the primary outcome for various study designs. Till now, orthotic intervention has not fully proven

efficacy in halting the progressive nature of the deformity and reducing the need for surgery. Moreover, none of the retrieved studies on the effectiveness of exercise on spinal curvature in AIS was randomized and the controlled and uncontrolled studies retrieved failed to meet even basic methodological criteria. Consequently, it is impossible to draw any valid conclusion on the effectiveness of orthotic intervention and exercise. To the best of our knowledge, this is the first trial randomized participants into either the orthotic intervention group or the exercise group. Patients were followed-up for 12 months and were not considered until their bone maturity. Although the curve deterioration (5.88° in the orthotic intervention group and 2.24° in the exercise group on average) happened in both groups after 12 months of intervention, long-term effectiveness needs to be verified afterwards. In addition, as compared to the orthotic intervention group, the curve deterioration in the exercise group was not comparable to the measurement error (as high as 5°), this made the effectiveness of exercise on spinal curvature quite controversial. However, confidence and patience should be donated till the bone maturity. The orthotic intervention group showed significant better results than the exercise group in terms of Cobb angle at 12-month and correction of Cobb angle at 6-month and 12-month. One of the possible explanations might be the differences of the theoretical frameworks between the two interventions. Exercise can only determine behavioral and automatic changes of movement and posture through different motor control strategies (Bettany-Saltikov et al., 2014; Romano et al., 2013; Smania et al., 2008). This has been demonstrated to be driven more by automatic, feedforward schemes (Smania et al., 2008) and more effective than passive positioning in determining changes of spinal deformity (Stokes et al., 2004). This is one of the reasons for the exercise as a stand-alone intervention (Negrini, 2008; Negrini et al., 2011a). Nonetheless, according to the results of the

current study, the continuous passive correction, provided by the spinal orthoses by a 3-point system acting in multiple dimensions with the aim of curve hyper-/hypo-correction, elongation, unloading and derotation of the thorax, showed better effectiveness in a short-term treatment period (12 months). The orthotic intervention group was requested to wear the spinal orthoses 23 hours/day (at school, at home, in bed, etc.) except time of shower and sport activities while the patients in the exercise took part in a single session of 1.5 hours (learning the core content of the intervention sessions) every month and continued treatment once a week at the scoliosis clinic (40 minutes) plus one daily exercise at home (5-20 minutes) (Romano et al., 2015). No significant difference was detected between groups in terms of compliance (57.7±0.27% in the orthotic intervention group and 59.1±0.2% in the exercise group) and the compliance in the current study was similar to other studies (Lou et al., 2012; Wong et al., 2008). In this case, although several studies showed essential results indicating the effectiveness of the exercise treatment (the SEAS approach in the current study) in different phases of scoliosis treatment (Negrini et al., 2006a; Negrini et al., 2007a; Rivett et al., 2014; Romano et al., 2015), patients in the exercise group may have to put greater effort to achieve equivalent effectiveness as compared to those who in the orthotic intervention group.

5.2.2.2 Quality of life

QoL is another main point to be considered in the non-operative management of AIS. Although scoliosis is far from life-threatening, social and family -related factors might lead patients to develop QoL-related physical and mental issue (Tones et al., 2006). Recently, the rate at which AIS is corrected has been greatly improved with the

development of the theory of 3D correction either in orthotic intervention or exercise. Changes in healthcare models and constant advances in research have led to the realization that more attention should be paid to the QoL of patients with AIS and their perception of spinal deformity, instead of just focusing on correction of spinal deformity. In this perspective, the SRS and the SOSORT recommended to focus research on the primary patient-centered outcomes (such as aesthetics, disability, pain and QoL) of non-operative approaches.

It was interesting to find that the improvement of QoL was more significant in the exercise group. At all the three visits, the average scores of most subscales in the SRS-22 were significantly higher in the exercise group especially for the functional, mental health and total scores. The improvement can be due to the benefits of specific function-oriented exercise and education which was targeted at improving functional abilities. Although an orthotic device can provide continuously the correction of the spinal deformity, its stiffness and rigidity may impact the physical function and vitality. Nonetheless, the impact is very limited. Patient with AIS, even treated with orthotics, do not experience continual functional disability to the extent that they are unable to complete activities of daily living. In the current study the physical function improved in the orthotic intervention group during the course of intervention. Although the general QoL in the orthotic intervention group significantly improved, the status of mental health even became worse over the course of intervention. It can be explained by the theory that orthotic intervention is associated with high levels of stress and may negatively impact the QoL. Freidel et al. found a high prevalence of depressed mood in the patients with AIS under orthotic intervention (Freidel et al., 2002). In addition, orthotic intervention has been associated with negative body perception, reduced self-esteem and higher susceptibility to develop anxiety (FÄllstrÖm et al., 1986). The

patients with AIS were found to be more sensitive to the questions about their orthoses instead of their deformity (Kotwicki et al., 2007a). The initial diagnosis and treatment phase are a stressful experience for adolescents and their families, with feelings of isolation, denial, and distress reported by at least 40% of patients and their parents during the early stages of treatment (FÄllstrÖm et al., 1986; Gratz et al., 1984; MacLean Jr et al., 1989; Matsunaga et al., 1997). A treatment specific survey revealed that feelings of isolation or depression, and reduced participation in spare time activities or dating was reported by 25% to 43% of patients, regardless of type of treatment (Danielsson et al., 2001). The current findings also displayed a psychological impact in the first 6 months of orthotic intervention. However, no significant difference was observed at the 12-month evaluation. This result was consistent with the observation reported by Maclean et al. and can be explained by the reduced self-esteem over the course of intervention (MacLean Jr et al., 1989). The fluctuation of the psychological status also showed the patients' gradual adaption to the treatment. The situation was totally different in the exercise group. Both inter- and intra-group comparison demonstrated significant improvement of QoL in the exercise group. Generally, the physical function of patients with AIS will not be impaired by the disease. It was not surprised to observe the functional improvement as the exercise protocol applied in the current study is based on active self-correction principle (Romano et al., 2015). Due to its effects in increasing neuromotor control and stability of the spine (Herman et al., 1985; Machida, 1999; Nachemson et al., 1977), reducing biomechanical postural collapse (Duval-Beaupere et al., 1985), and increasing breathing function (Athanasopoulos et al., 1999; Weiss, 1991), exercise may have some potential advantages in improving patients' physical function. Scoliosis-specific exercise approach integrates the active self-correction into specifically designed

movements. As compared to orthotic intervention, it allows patients to move freely and can help to improve their physical conditions (i.e. strength and elasticity of certain muscles) as well as neuromotor ability (i.e. balance) (Bettany-Saltikov et al., 2014; Romano et al., 2013; Smania et al., 2008). Although patients with AIS undergoing treatment seem to experience poor psychosocial issues regardless of intervention types, the superior mental health in the exercise group can confirm the theory that the impact of the orthosis to the body image of the adolescent is the main contributory factor for stress production (Clayson et al., 1987). Overall, the synergistic effects of superior function and mental health contributed to the significant better QoL in the patients treated with exercise.

5.2.2.3 Body symmetry

Body image concerns are evident in adolescents with idiopathic scoliosis. Although research is limited, a disturbance in body symmetry pertaining to appearance among patients with AIS is an almost universal finding in studies that measure this variable. The onset of an appearance-related alternation during adolescence is thought to be of greater detriment to body symmetry than childhood or adulthood. Previous studies have documented that adolescents with idiopathic scoliosis are more likely to be dissatisfied with their appearance and fear that their bodies are developing abnormally than adolescents without scoliosis (Liskey-Fitzwater et al., 1993; Payne III et al., 1997). In the current study, although the orthotic intervention group achieved better outcome of shoulder balance, no significant result was detected on the subjective evaluation (TAPS) of body image between groups. The former further confirmed the efficacy of orthotic intervention on aesthetics (Negrini et al., 2012), while the latter

can be explained by the different perceptions of the patients on their own body image. It appears that body image during adolescence can be affected by the type of treatment. It was assumed that patients in the exercise group may be more confident on their body image due to their better mental health status. Furthermore, physical exercise has been proved to help to restore body satisfaction in adolescents with scoliosis (Dekel et al., 1996). On the other hand, orthotic intervention is generally associated with a poorer body image (Sapountzi-Krepia et al., 2001), the judgement in the orthotic intervention group can be biased due to the stress from the spinal orthoses. According to the current evidence, girls with idiopathic scoliosis seem to experience a poor body image due to feelings of unattractiveness, expressed by difficulty in finding clothes and dissatisfaction with appearance (Liskey-Fitzwater et al., 1993), while boys may be more distressed by perceived lack of physical health and strength (Payne III et al., 1997). Although the two interventions were proven to be effective on spinal curvature control and body image, significant differences were only observed between the baseline and the 12-month evaluation in the orthotic intervention group in terms of shoulder balance items. Therefore, orthotic intervention may not be replaced with exercise. Nonetheless, any treatment decision should be based on the patients' clinical condition as well as patients' preference.

Although the results in terms of TAPS evaluations did not differ significantly between the two experimental groups. Improvement of subjective body image was generally detected either in the view of patients, parents or doctors. It was interesting to document that at the 12-month evaluation subjective discrepancy was detected between doctors and patients ($z=-2$, $p=0.046$ for Picture 1 and $z=-2.828$, $p=0.005$ for Picture 3), and doctors and parents ($z=-2.449$, $p=0.014$ for Picture 3) in the exercise group. Despite the general improvement across the course of intervention, patients and

parents reported greater subjective body image than that of doctors at the third visit. Nonetheless, the scores provided by the doctors would be more objective according to their professional judgement, the improvement of body image maybe not such significant in the view of the doctors. On the other hand, the optimistic attitude of the patients and parents towards the improvement of body image may be good for their mental status and contribute to their better adherence to the interventions.

5.2.3 Correlations between spinal curvature, QoL and body symmetry

QoL is significantly affected by aesthetic sensation and one's appearance. Therefore, internal correction of a scoliosis (correction of spinal curvature) related external trunk deformity (body symmetry) is an important issue in non-operative management. The assessment of therapeutic outcomes may be based on subjective and objective visual assessment, on specially developed indices of visual evaluations or on parameters of surface topography assessment (Aulisa et al., 2011; Bago et al., 2010; Kotwicki et al., 2007b).

Clinical assessments as well as radiological measurements are the two basic examinations for evaluation of the deformity. The Cobb angle and the ATI are considered the most universal parameter to evaluate the curve magnitude. Shoulder balance can be objectively measured with radiological exam, while the trunk deformity can be evaluated with visual evaluation, namely the TAPS. They respectively reflect the internal and external deformity resulting from the spinal deformity. It seems logical that there exists some parallelism between the degree of intensity of clinical and of radiological parameters describing the deformity. The more

severe the internal deformity the more the external deformity is pronounced. The results of the current study confirmed this hypothesis. Significant correlations were detected between the internal deformity (spinal deformity reflected by Cobb angle and trunk deformity reflected by shoulder balance) and the external deformity (body image evaluated by the TAPS). The dynamic changes of corresponding parameters due to the intervention were also significantly correlated. As the previous literature documented, the efforts of some researchers who were seeking for internal parameters, which would perfectly correlate with the external deformity, have failed. Ono et al. presented results of radiographic exam and surface topography in 504 patients with idiopathic scoliosis and found the discrepancy between the Hump Sum and the Cobb angle (Ono, 1995). Grosso et al. found no correlation between Cobb angle and clinical parameters (ATR, hump height, distance of the spinous process from the plumb line) in a cohort of 116 patients with moderate scoliosis (Grosso et al., 2002). Goldberg et al. demonstrated significant but not complete correlation between Cobb angle and topography angle (Goldberg et al., 2001). The same team indicated the fact that Cobb angle and surface parameters are not measuring the same aspect of the deformity, by proposing a new surface topography measures quantify left-right asymmetry (Goldberg et al., 2005). The correlations were also not that strong in the current study. This may be due to that the Cobb angle signifies just the tilt of the two end vertebrae of the curve, projected on the surface parallel to the frontal plane of the trunk. According to Bunnell et al., “although there is a significant correlation between clinical deformity and radiological measurement, the standard deviation is high” (Bunnell, 2005). Age may also deviate the correlations as Grivas et al. documented that weak correlations were found in younger participants while stronger ones were found in older participants (Grivas et al., 2007b). Moreover, curve pattern also plays

important roles. In this study the groups presented a lightly higher proportion of single curve. Single curves usually cause more important external deformity than double curves since in double curves clinically the pattern is not very deforming for each curve balances the other. Correlations in future studies taking into consideration the same sex, age, type of scoliosis, Cobb degree and interventions would be more representative in this aspect.

In spite of an apparent consensus that Cobb angle cannot stand for surface deformity, the published results of brace treatment for progressive idiopathic scoliosis were most often based on the analysis of plane radiographs only, with special respect to the Cobb angle. However, external deformity is as important as internal deformity since in the view of the patients it has greater impact on the compliance of the interventions, the general health perception, self-estimation as well as on emotional and social functioning.

As documented previously, physical function is usually not impaired in adolescents with mild to moderate idiopathic scoliosis. The results of the current study were consistent with this observation. Although the functional items in SRS-22 were somehow significantly correlated to the deformity, the correlation coefficients were very low. Nonetheless, the psychological distress experienced by these patents is often attributed to the development of trunk deformity. These patients regularly suffer psychological issues, and when these issues appear, they are normally due to the cosmetic effect. This phenomenon was confirmed in the correlation analysis in the current study. Apart from the Cobb angle, patients with AIS and their families are more often concerned about their body image and this anxiety about aesthetics is also an important factor related to self-esteem. Correlation between self-esteem and mental health indicated that individuals with lower self-esteem had more mental health issues

than individuals with better self-esteem (Zhang et al., 2011). The less satisfaction with life and the lower self-esteem often have a serious emotional and psychological impact which can lead to deterioration in QoL. Although generally no significant correlation was detected between mental health and items representing deformity in this study, the total scores of SRS-22 and scores of satisfaction were significantly correlated with mental health. It has been found that patents with AIS show a greater propensity to develop feelings of dissatisfaction regarding the body image though the quantified psychological items were not sensitive enough to catch the variations of mental health. As a result, patents with AIS tend to lack self-confidence and have a sense of inferiority and even shame. This is a disturbing experience that forces patents to cope with stress, denial, fear, anger and shame. This lack of self-confidence can lead to a growing sense of pessimism and anxiety, resulting in a deterioration in social functioning and total psychological isolation. The lack of support from psychological professionals when receiving the "good news" that some interventions which may be helpful to the deformity and the minimal emotional support provided from the doctors and orthotists during follow-up visits, contributed to a situation of stress (Sapountzi-Krepia et al., 2006). Therefore, combine the scoliosis-specific non-operative interventions together with the psychological rehabilitation is important.

Previous literatures have documented the correlations between compliance and successful rate of orthotic intervention. No significant difference was detected between the prescription of 16-18 hours, 18-23 hours and night time treatment of orthotics (Dolan et al., 2007). On the contrary, it has been reported that the 23-hour regimens showed significant higher successful rate than others, while the difference between the 8 and 16-hour regimens was not significant (Rowe et al., 1997). The logistic regression analyses conducted by Negrini et al. presented a "dose-response"

curve in which the greater number of wearing time contributed to less progression (Negrini et al., 2012). The correlation results in the current study confirmed these findings. Significant higher compliance was correlated with lower Cobb degree (r-square=-0.658, $p<0.001$) and more correction of Cobb angle (r-square=0.895, $p<0.001$). Due to seldom patients would fully follow the prescription of 23 hours of brace wearing, the compliance of orthotic intervention in the current study was around 57.7% (total brace wearing time divided by prescribed brace wearing time), namely 12.8 hours/day on average. It has been showed that no progression in 82% of patients whom wore the brace more than 12 hours/day. As a result, dosage can be considered a potential major factor in explaining the results of orthotic intervention. In the past several decades, due to the difficulties in tracking the compliance of exercise and the quantification of the compliance, seldom results were underlined. Even if the patients declare that they would adhere to the interventions, the overstate of compliance is more severe in those who treated with exercise than orthotic intervention since nowadays different types sensor are embedded into the brace for tracking the absolute wearing time. In the current study, apart from the videos recorded by their parents for tracking the compliance of home session, their compliance of training at the Scoliosis Clinic was monitored by the corresponding therapists. These actions maximally avoided the overstate of compliance. It made the results more trustable and comparable to that of the orthotic intervention group.

Many studies have underlined compliance to interventions has been correlated to QoL and psychological issues (Birbaumer et al., 1994; Lindeman et al., 1999; MacLean Jr et al., 1989; Rivett et al., 2014; Rivett et al., 2009). Psychological distress among patients is of concern to doctors and orthopedists, as psychological distress can negatively affect the patient's adjustment to interventions via noncompliance. In this

study, no significant correlation was detected between compliance and mental health. Nonetheless, better compliance was significantly correlated to higher satisfaction score and total score in SRS-22. It is believed that better compliance can lead to better treatment outcomes and in turn improve the satisfaction of the treatment, the latter would positively affect the compliance and the general QoL.

5.2.4 Strength and limitations

For the first time, the effectiveness of orthotic intervention *versus* exercise was compared in a RCT. Although different designs have been adopted to evaluate the effectiveness of orthotic intervention *versus* exercise, RCT serves as level I evidence that has the most robust design against various biases and seldom suffered from confounding factors. Fortunately, significant results were found and this study may add certain insights to this research field. Specifically, it was proven that exercise was comparable with orthotic intervention while orthotic is still the most favored intervention. Furthermore, both the SRS and SOSORT criteria for research purpose were considered in the current study, this smoothed the enrollment procedure. The selection of the primary patient-centered outcomes and secondary predictive outcomes was also done according to the recommendations from the consensus paper published by the two professional societies (Negrini et al., 2015). This again may increase the possibilities of outcome comparison with other studies. Moreover, more reliable and objective strategies (embedded the thermo-force sensors into the spinal orthoses in the orthotic intervention group and combined video records with log-sheets together in the exercise group) were adopted in this trial to track the compliance in both groups as compared to the previous studies.

This report had 12-month follow-up period, thus, a long-term treatment effect till bone maturity could not be revealed. Indeed, long follow-up of adolescents until skeletal maturity would be desirable because progression is likely to occur during any time of adolescence. Fortunately, this study is on-going till the skeletal maturity of each patient and the data will be shared in the future. Additionally, since the sample size was calculated based on the primary outcome, the current study was able to report the clinically meaningful results in QoL but only statistically significant results in the secondary outcomes. With the development of modern social communication, it was difficult to avoid the communication between the patients in different intervention groups though efforts have been greatly donated to separate the patients in different groups into different training sessions. Patients in the orthotic intervention group were treated in the afternoon while those who in the exercise group were treated in the morning. Therefore, due to the study design as a RCT, treatment expectations were not addressed, and this confounding factor was only partially limited by telling the patients during enrollment that the efficacy of both treatments had not yet been established, and that both interventions might contribute to improving their deformity.

5.2.5 Recommendations for future studies

Screening of AIS in a specific region should be the beginning of AIS prevention. After screening, patients with AIS diagnosed in the screening projects should be referred to receive specific treatment, i.e. observation, exercise, orthotic or surgical treatment. Apart from that, longitudinal screening data were strongly suggested to collect, the effectiveness of the specific treatment can be partially reflected by the trend of the prevalence. Due to the lack of high level studies comparing the effectiveness of different interventions for AIS, efforts should be given to long-term

RCTs with high quality according to the recommendations published by the SRS and the SOSORT though the difficulties in performing RCTs have generally reached a consensus.

CHAPTER 6 CONCLUSIONS

This PhD project contained two main parts: a screening study which screened all the primary and secondary school students in Wuxi city, China; an intervention study which was designed as a RCT and compared the effectiveness of orthotic intervention *versus* exercise on the correction of spinal curvature and body symmetry, and improvement of QoL.

6.1 The major achievements of the screening study

- In this observational, cross-sectional study, a total number of 79,122 primary school (5th and 6th grades) and secondary school (7th to 9th grades) students aged 10-16 years were screened for AIS. To the best of our knowledge, it was the largest scoliosis school screening program ever conducted in the east part of China and filled the epidemiological blank of AIS in this region and may serve as the reference for future studies.
- Among the students who participated in the school-based screening, 2,687 (1,120 boys and 1,567 girls) were referred for radiography because of the detected ATI degree (5° or more) or other significant clinical signs.
- Eventually, 1,202 out of 1,911 students were diagnosed as AIS patients in the hospital-based diagnostic stage and the overall prevalence of AIS was around

2.4%. The overall prevalence of AIS in this region was slightly higher than the pooled prevalence (1.02% in mainland China) reported by a meta-analysis.

- The overall PPV for the Scoliometer was 63.0% for participants with Cobb angle of 10° or more, it decreased alone with the increase of the Cobb angle. This indicated that the Scoliometer might not be the best choice for detecting moderate and severe AIS.
- Girls and boys had AIS prevalence of 3.12% and 2.14%, respectively. Girls had 1.46 times higher AIS prevalence than boys.
- The decreasing trends of AIS prevalence were detected by the increase of BMI value.
- For the first time, the propensity scores were used for the adjustment of unit non-response. With this method, the prevalence was adjusted by predicting the potential positive cases in non-respondents.

6.2 The major achievements of the intervention study

- To the best of our knowledge, this was the first RCT study designed to answer the clinical question "Whether orthotic intervention and exercise are equally effective to the patients with mild to moderate AIS?".
- In this study, both orthotic intervention and exercise showed significant treatment effectiveness on patients with AIS.
- Orthotic intervention was superior to capture corrections in parameters of spinal deformity and aesthetics, while the QoL, especially in aspect of the functional and psychological status, was significantly better in the exercise group. It was proven that exercise was comparable with orthotic intervention while orthotic intervention

is still the most favored intervention. Follow-up studies are still necessary to further reveal the long-term effectiveness of orthotic intervention *versus* exercise.

- Significant correlations were detected between the internal deformity (spinal deformity reflected by Cobb angle and trunk deformity reflected by shoulder balance) and the external deformity (body image evaluated by the TAPS). The dynamic changes of corresponding parameters due to the intervention were also significantly correlated.
- Although generally no significant correlation was detected between mental health and items representing deformity in this study, the total scores of SRS-22 and scores of satisfaction were significantly correlated with mental health.
- In this study, significant higher compliance was correlated with lower Cobb degree and more correction of Cobb angle. Therefore, dosage can be considered a possible major factor in explaining some of the positive and negative results of interventions.
- No significant correlation was detected between compliance and mental health in this study. Nonetheless, better compliance was significantly correlated to higher satisfaction score and total score in SRS-22.
- Better compliance can lead to better treatment outcomes and in turn improve the satisfaction of the treatment, the latter would positively affect the compliance and the general QoL.

APPENDICES

Appendix A

English version of information sheet for the screening study

Information Sheet for the Screening Study

Study Title

Screening of adolescent idiopathic scoliosis in Wuxi City, China

Invitation Paragraph

We sincerely invite you to participate in this project. Before you decide to take part in this study it is important for you to understand why the research is being done and what it will involve. A member of the team can be contacted if there is anything that is not clear or if you would like more information. We would like you to take a few minutes to read this information sheet before making up your mind about whether or not you would like to help us with this study.

What is the purpose of the study?

This study seeks to explore the prevalence of adolescent idiopathic scoliosis (AIS) in Wuxi City, China. You have been invited to take part in the screening of AIS during the annual physical examination issued by the National Health and Family Planning Commission and Ministry of Education of the People`s Republic of China in primary and middle schools in Wuxi, China.

Do I have to take part?

Your participation is voluntary. We would like you to consent to participate in this study as we believe that you can make an important contribution to the research. If you do not wish to participate you do not have to do anything in response to this request. We are asking you to take part in the research because you are a stakeholder in this project and we believe you can provide important information to us that may be relevant to the evaluation that we are undertaking.

What will I do if I take part?

If you are happy to participate in the research we will ask you to read this information sheet, sign the consent form and return it to us.

Participants who are identified as potential AIS patients during the annual physical examination will be refer to the hospital to receive an X-ray examination which is used to clarify whether you are diagnosed as AIS patient or not.

You can withdraw at any time without giving a reason and there will be no adverse consequences if you do so.

What are the possible disadvantages and risk of taking part?

Whilst you may be referred to receive an X-ray examination which is used to clarify whether you are diagnosed as AIS patient or not. The X-ray exposure may be a concern for you, however, it should be highlighted that even you decided not to participate in this study, we still strongly suggest you receive an X-ray examination eliminating potential concerns.

What are the possible benefits of taking part?

Whilst there may be no personal benefits to your participation in this study, the information you provide can contribute to the future development of an efficient strategy for future screening in China.

Will my taking part in the study be kept confidential?

All information you provide to us will be kept confidential. Only members of the research team will have access to it. Under no circumstances will identifiable responses be provided to any other third party. Information emanating from the evaluation will only be made public in a completely unattributable format or at the aggregate level in order to ensure that no participant will be identified. We must however inform you that if you disclose information that may result in you or anyone else being put at risk of harm we may have to inform the appropriate authorities. If

this situation arises we will discuss all possible options for ourselves and you before deciding whether or not to take any action.

What will happen to the results of the research study?

All information provided by you will be stored anonymously on a computer with analysis of the information obtained undertaken by the research team based at the Hong Kong Polytechnic University. The results from this analysis will be available in one or more of the following sources; scientific papers in peer reviewed academic journals; presentations at national and international conferences; local seminars.

Who is organizing the research?

The project is funded by the Wuxi Science and Technology Program (WSTP), China (Grant number: ZD201408), the Wuxi Federation of Disabled Persons and the Wuxi Rehabilitation Hospital. An experienced medical team led by Dr. Man-Sang Wong (the Associate Head of Department of Biomedical Engineering, the Hong Kong Polytechnic University) and Prof. Chengqi He (the Associate Head of Institute for Disaster Management and Reconstruction in Sichuan University) will be responsible for the research design, data analysis and provide other technical and scientific support, while the screening will be conducted by a professional team from Wuxi Rehabilitation Hospital.

Any complaint or concern about any aspect of the way you have been dealt with during the course of the study will be addressed; please contact the Department

of Rehabilitation Medicine at Wuxi Rehabilitation Hospital at (Tel) 0510-8261 / (Email) 1505 @

Thank you for taking the time to read this Information Sheet.

Appendix B

English version of information sheet for the intervention study

Information Sheet for the Intervention Study

Study Title

Effectiveness of orthotic intervention *versus* exercise on the patients with adolescent idiopathic scoliosis: a randomized controlled trial study

Invitation Paragraph

We sincerely invite you to participate in this project. Before you decide to take part in this study it is important for you to understand why the research is being done and what it will involve. A member of the team can be contacted if there is anything that is not clear or if you would like more information. We would like you to take a few minutes to read this information sheet before making up your mind about whether or not you would like to help us with this study.

What is the purpose of the study?

This study seeks to investigate how physical deformity and psychological status are affected by different treatment options (orthotic intervention *vs.* exercise) and how

they impact compliance. This is important for clinical reasoning and decision making regarding trade-offs between different types of intervention.

Do I have to take part?

Your participation is voluntary. We would like you to consent to participate in this study as we believe that you can make an important contribution to the research. If you do not wish to participate you do not have to do anything in response to this request. We are asking you to take part in the research because you are a stakeholder in this project and we believe you can provide important information to us that may be relevant to the evaluation that we are undertaking.

What will I do if I take part?

If you are happy to participate in the research we will ask you to read this information sheet, sign the consent form and return it to us. When we receive this a member of the evaluation team will contact you to discuss your participation in the evaluation. At that point we can confirm your participation and make arrangements for you to meet one of the researchers.

Those who are eligible for the following criteria will be randomly assigned into two different intervention groups (the orthotic intervention group or exercise group): 1) AIS patients aged from 10 to 17; 2) Risser 0, 1, 2; 3) Cobb angle of 25-40°; 4) without associated musculoskeletal, neurological, or other conditions possibly responsible for the curvature; 6) no history of previous physical, orthotic or surgical

treatment; 7) physical and mental ability to adhere to orthotic intervention and exercise protocol.

Patients who are in the exercise group will learn how to perform a 3-dimensional self-mediated correction of their scoliosis, muscular stabilization of the corrected posture, and how to perform these postural correction strategies during activities of daily living. The patients will take part in a single session of 1.5 hours (learning the core content of the intervention sessions) every two to three months at the scoliosis clinic, in which they are evaluated by a therapist with expertise in scoliosis, learn their own personalized exercise protocol, and engage in a meeting for family counseling with regard to scoliosis. The patients continue treatment at the scoliosis clinic once a week (40 minutes) plus one daily exercise at home (5-20 minutes).

The trial is limited to the use of full-time, rigid TLSO. Participating physicians and orthotists will prescribe and fabricate the custom-made brace used during normal clinical practice. Braces are suggested to be worn 23 hours per day. An in-brace standing posteroanterior spine radiograph will be obtained within one month after brace delivery. Physicians and orthotists will follow-up the braced patient regularly, at least every 3 to 6 months.

Radiographic, clinical, self-repot, orthotic, and compliance data will be collected at each visit (normally every 5-7 months).

You can withdraw at any time without giving a reason and there will be no adverse consequences if you do so.

What are the possible disadvantages and risk of taking part?

The X-ray exposure may be a concern for you, however, it should be highlighted that even you decided not to participate in this study, we still strongly suggest you to receive an X-ray examination eliminating potential concerns.

Although the safety has been clarified when brace and exercise are utilized in routine AIS treatment, we would like to mention some potential adverse reactions i.e. skin irritation in orthotic intervention group or tiredness in exercise group. If this happens, a free medical care or consult will be provided. We will also be careful to check for your brace or exercise plan at each visit so that you can temporarily stop the treatment before it becomes a problem.

What are the possible benefits of taking part?

Whilst there may be no personal benefits to your participation in this study, the information you provide is important for clinical reasoning and decision making regarding trade-offs between different types of intervention.

Will my taking part in the study be kept confidential?

All information you provide to us will be kept confidential. Only members of the research team will have access to it. Under no circumstances will identifiable responses be provided to any other third party. Information emanating from the evaluation will only be made public in a completely unattributable format or at the aggregate level in order to ensure that no participant will be identified. We must

however inform you that if you disclose information that may result in you or anyone else being put at risk of harm we may have to inform the appropriate authorities. If this situation arises we will discuss all possible options for ourselves and you before deciding whether or not to take any action.

What will happen to the results of the research study?

All information provided by you will be stored anonymously on a computer with analysis of the information obtained undertaken by the research team based at Hong Kong Polytechnic University. The results from this analysis will be available in one or more of the following sources; scientific papers in peer reviewed academic journals; presentations at national and international conferences; local seminars.

Who is organizing the research?

The project is funded by the Wuxi Science and Technology Program (WSTP), China (Grant number: ZD201408), the Wuxi Federation of Disabled Persons and the Wuxi Rehabilitation Hospital. An experienced medical team led by Dr. Man-Sang Wong (the Associate Head of Department of Biomedical Engineering, the Hong Kong Polytechnic University) and Prof. Chengqi He (the Associate Head of Institute for Disaster Management and Reconstruction in Sichuan University) will be responsible for the research design, data analysis and provide other technical and scientific support, while the screening will be conducted by a professional team from Wuxi Rehabilitation Hospital.

Any complaint or concern about any aspect of the way you have been dealt with during the course of the study will be addressed; please contact the Department of Rehabilitation Medicine at Wuxi Rehabilitation Hospital at (Tel) 0510-8261 / (Email) 1505 @

Thank you for taking the time to read this Information Sheet.

Appendix C

English version of consent form of screening study

Consent Form for the Screening Study

Study Title

Screening of adolescent idiopathic scoliosis in Wuxi City, China

I, _____ (the participant`s or his/her legal guardian`s name) hereby have reviewed the information sheet and agree to participate in this trial.

I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.

I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences. If I exercise my right to withdraw and I don't want my data to be used, any data which have been collected from me will be destroyed.

I understand that I can withdraw from the study any personal data (i.e. data which identify me personally) at any time.

I understand that anonymized data (i.e. .data which do not identify me personally) cannot be withdrawn once they have been included in the study.

I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.

I consent to being a participant in the project

I consent to being audio and/or video recorded as part of the project

A copy of this consent form which contains the signatures of participant / legal guardian and primary investigator will be available on request.

Signature: Name of participant:	Date:
Signature: Name of legal guardian:	Date:
Signature: Name of principle investigator:	Date:

Appendix D

English version of consent form of intervention study

Consent Form for the Intervention Study

Study Title

Effectiveness of orthotic intervention *versus* exercise on the patients with adolescent idiopathic scoliosis: a randomized controlled trial study

I, _____ (the participant`s or his/her legal guardian`s name) hereby have reviewed the information sheet and agree to participate in this trial.

I confirm that I have read and understood the information sheet for the above project and the researcher has answered any queries to my satisfaction.

I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences. If I exercise my right to withdraw and I don't want my data to be used, any data which have been collected from me will be destroyed.

I understand that I can withdraw from the study any personal data (i.e. data which identify me personally) at any time.

I understand that anonymized data (i.e. .data which do not identify me personally) cannot be withdrawn once they have been included in the study.

I understand that any information recorded in the investigation will remain confidential and no information that identifies me will be made publicly available.

I consent to being a participant in the project

I consent to being audio and/or video recorded as part of the project

A copy of this consent form which contains the signatures of participant / legal guardian and primary investigator will be available on request.

Signature: Name of participant:	Date:
Signature: Name of legal guardian:	Date:
Signature: Name of principle investigator:	Date:

Appendix E

English version of the trunk appearance perception scale

The Trunk Appearance Perception Scale

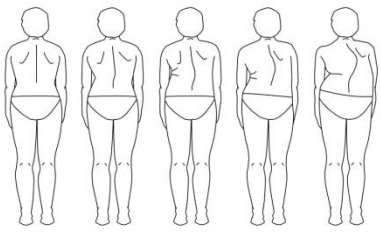
The TAPS includes three sets of figures that show the trunk from three viewpoints:

1) Picture 1: observing toward the back

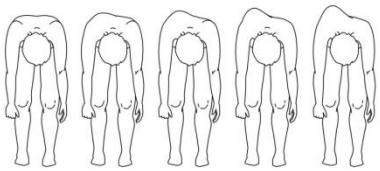
2) Picture 2: observing toward the head in the bending over position

3) Picture 3: observing toward the front.

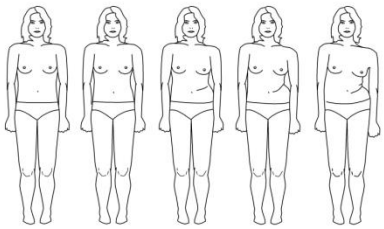
Each drawing is scored from 1 (greatest deformity) to 5 (smallest deformity) and mean scores (from patients, parents and doctors) are obtained by adding the scores for the 3 drawings and dividing by 3.



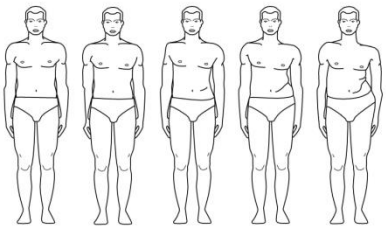
SET 1



SET 2



SET 3 (females)



SET 3 (males)

Appendix F

English version of SRS-22

SRS-22 Patient Questionnaire

Patient Name: _____ _____ _____ Date of Birth: ____ ____ ____
First MI Last Mo Day Yr

Today's Date: ____ ____ ____ Age: ____ ____
Mo Day Yr Yrs Mo

Medical Record #: _____

INSTRUCTIONS: WE ARE CAREFULLY EVALUATING THE CONDITION OF YOUR BACK AND IT IS IMPORTANT THAT YOU ANSWER EACH OF THESE QUESTIONS YOURSELF. PLEASE CIRCLE THE <u>ONE BEST ANSWER</u> TO EACH QUESTION.

1. Which one of the following best describes the amount of pain you have experienced during the past 6 months?

   None

   Mild

   Moderate

   Moderate to severe

   Severe

2. Which one of the following best describes the amount of pain you have experienced over the last month?

None

Mild

Moderate

Moderate to severe

Severe

3. During the past 6 months have you been a very nervous person?

   None of the time

   A little of the time

   Some of the time

   Most of the time

   All of the time

4. If you had to spend the rest of your life with your back shape as it is right now, how would you feel about it?

   Very happy

   Somewhat happy

   Neither happy nor unhappy

   Somewhat unhappy

   Very unhappy

5. What is your current level of activity?

   Bedridden

   Primarily no activity

   Light labor and light sports

   Moderate labor and moderate sports

Full activities without restriction

6. How do you look in clothes?

   Very good

   Good

   Fair

   Bad

   Very bad

7. In the past 6 months have you felt so down in the dumps that nothing could cheer you up?

   Very often

   Often

   Sometimes

   Rarely

   Never

8. Do you experience back pain when at rest?

   Very often

   Often

   Sometimes

   Rarely

   Never

9. What is your current level of work/school activity?

100% normal

75% normal

50% normal

25% normal

0% normal

10. Which of the following best describes the appearance of your trunk; defined as the human body except for the head and extremities?

Very good

Good

Fair

Poor

Very Poor

11. Which one of the following best describes your pain medication use for back pain?

None

Non-narcotics weekly or less (e.g., aspirin, Tylenol, Ibuprofen)

Non-narcotics daily

Narcotics weekly or less (e.g. Tylenol III, Lorcet, Percocet)

Narcotics daily

12. Does your back limit your ability to do things around the house?

Never

Rarely

Sometimes

Often

Very Often

13. Have you felt calm and peaceful during the past 6 months?

All of the time

Most of the time

Some of the time

A little of the time

None of the time

14. Do you feel that your back condition affects your personal relationships?

None

Slightly

Mildly

Moderately

Severely

15. Are you and/or your family experiencing financial difficulties because of your back?

Severely

Moderately

Mildly

Slightly

None

16. In the past 6 months have you felt down hearted and blue?

Never

Rarely

Sometimes

Often

Very often

17. In the last 3 months have you taken any days off of work, including household work, or school because of back pain?

0 days

1 day

2 days

3 days

4 or more days

18. Does your back condition limit your going out with friends/family?

Never

Rarely

Sometimes

Often

Very often

19. Do you feel attractive with your current back condition?

Yes, very

Yes, somewhat

Neither attractive nor unattractive

No, not very much

No, not at all

20. Have you been a happy person during the past 6 months?

None of the time

A little of the time

Some of the time

Most of the time

All of the time

21. Are you satisfied with the results of your back management?

Very satisfied

Satisfied

Neither satisfied nor unsatisfied

Unsatisfied

Very unsatisfied

22. Would you have the same management again if you had the same condition?

Definitely yes

Probably yes

Not sure

Probably not

Definitely not

Thank you for completing this questionnaire. Please comment if you wish.

REFERENCES

Akel, I, Pekmezci, M, Hayran, M, Genc, Y, Kocak, O, Derman, O, Erdoğan, I, & Yazici, M. Evaluation of shoulder balance in the normal adolescent population and its correlation with radiological parameters. *European Spine Journal, 2008; 17*(3): 348-54.

Antonia, Matamalas, Elisabetta, D'agata, Judith, Sanchez Raya, & Juan, Bago. Trunk appearance perception scale for physicians (TAPS-Phy) - a valid and reliable tool to rate trunk deformity in idiopathic scoliosis. *Scoliosis & Spinal Disorders, 2016; 11*(1): 24.

Ascani, E, Bartolozzi, P, Logroscino, Ca, Marchetti, Pg, Ponte, A, Savini, R, Travaglini, F, Binazzi, R, & Di Silvestre, M. Natural history of untreated idiopathic scoliosis after skeletal maturity. *Spine, 1986; 11*(8): 784-9.

Athanasopoulos, S, Paxinos, T, Tsafantakis, E, Zachariou, K, & Chatziconstantinou, S. The effect of aerobic training in girls with idiopathic scoliosis. *Scandinavian journal of medicine & science in sports, 1999; 9*(1): 36-40.

Aulisa, Angelo G, Guzzanti, Vincenzo, Falciglia, Francesco, Giordano, Marco, Marzetti, Emanuele, & Aulisa, Lorenzo. Lyon bracing in adolescent females with thoracic idiopathic scoliosis: a prospective

study based on SRS and SOSORT criteria. *BMC musculoskeletal disorders, 2015; 16*(1): 316.

Aulisa, Angelo G, Guzzanti, Vincenzo, Perisano, Carlo, Marzetti, Emanuele, Menghi, Amerigo, Giordano, Marco, & Aulisa, Lorenzo. Correlation Between Hump Dimensions And Curve Severity In Idiopathic Scoliosis Before And After Conservative Treatment. *Spine, 2011*.

Aulisa, Lorenzo, Papaleo, Pierangelo, Pola, Enrico, Angelini, Flavia, Aulisa, Angelo G, Tamburrelli, Francesco C, Pola, Paolo, & Logroscino, Carlo A. Association between IL-6 and MMP-3 gene polymorphisms and adolescent idiopathic scoliosis: a case-control study. *Spine, 2007; 32*(24): 2700-2.

Bagó, J, Pérez-Grueso, F. J., Les, E, Hernández, P, & Pellisé, F. Minimal important differences of the SRS-22 Patient Questionnaire following surgical treatment of idiopathic scoliosis. *European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 2009; 18*(12): 1898.

Bago, J., Sanchez-Raya, J., Perez-Grueso, F. J., & Climent, J. M. The Trunk Appearance Perception Scale (TAPS): a new tool to evaluate subjective impression of trunk deformity in patients with idiopathic scoliosis. *Scoliosis, 2010; 5*: 6. doi:10.1186/1748-7161-5-6

Beaton, D. E., Bombardier, C., Guillemin, F., & Ferraz, M. B. Guidelines for the process of cross-cultural adaptation of self-report measures. *Spine (Phila Pa 1976), 2000; 25*(24): 3186-91.

Beauchamp, M, Labelle, H, Grimard, G, Stanciu, C, Poitras, B, & Dansereau, J. Diurnal variation of Cobb angle measurement in adolescent idiopathic scoliosis. *Spine, 1993; 18*(12): 1581.

Beauséjour, Marie, Goulet, Lise, Parent, Stefan, Feldman, Debbie Ehrmann, Turgeon, Isabelle, Roy-Beaudry, Marjolaine, Sosa, Jose Felix, & Labelle, Hubert. The effectiveness of scoliosis screening programs: methods for systematic review and expert panel recommendations formulation. *Scoliosis, 2013; 8*(1): 12.

Berg, A. O. Screening for adolescent idiopathic scoliosis: a report from the United States Preventive Services Task Force. *J Am Board Fam Pract, 1993; 6*(5): 497-501.

Bettany-Saltikov, J, Parent, E, Romano, M, Villagrasa, M, & Negrini, S. Physiotherapeutic scoliosis-specific exercises for adolescents with idiopathic scoliosis. *European Journal of Physical & Rehabilitation Medicine, 2014; 50*(1): 111-21.

Bia, X, Marianna, & Ek. Conservative treatment of idiopathic scoliosis according to FITS concept: presentation of the method and preliminary, short term radiological and clinical results based on

SOSORT and SRS criteria. *Scoliosis,6,1(2011-11-28), 2011; 6*(1): 25.

Birbaumer, Niels, Flor, Herta, Cevey, Bernhard, Dworkin, Barry, & Miller, Neal E. Behavioral treatment of scoliosis and kyphosis. *Journal of psychosomatic research, 1994; 38*(6): 623-8.

Bohl, Daniel D, Telles, Connor J, Golinvaux, Nicholas S, Basques, Bryce A, Deluca, Peter A, & Grauer, Jonathan N. Effectiveness of Providence nighttime bracing in patients with adolescent idiopathic scoliosis. *Orthopedics, 2014; 37*(12): e1085-e90.

Bunge, E. M., Habbema, J. D., & De Koning, H. J. A randomised controlled trial on the effectiveness of bracing patients with idiopathic scoliosis: failure to include patients and lessons to be learnt. *European Spine Journal, 2010a; 19*(5): 747-53.

Bunge, Eveline M, Habbema, J Dik F, & De Koning, Harry J. A randomised controlled trial on the effectiveness of bracing patients with idiopathic scoliosis: failure to include patients and lessons to be learnt. *European Spine Journal, 2010b; 19*(5): 747-53.

Bunge, Eveline M, Koning, Harry J De, & Group, Andbrace Trial. Bracing Patients with Idiopathic Scoliosis: Design of the Dutch Randomized Controlled Treatment Trial. *Bmc Musculoskeletal Disorders, 2008; 9*(1): 1-7.

Bunnell, W. P. An objective criterion for scoliosis screening. *Journal of Bone & Joint Surgery American Volume, 1984; 66*(9): 1381.

Bunnell, W. P. Outcome of spinal screening. *Spine, 1993; 18*(12): 1572-80.

Bunnell, William P. Selective screening for scoliosis. *Clinical orthopaedics and related research, 2005; 434*: 40-5.

Burwell, Rg, Cole, Aa, Cook, Ta, Grivas, Tb, Kiel, Aw, Moulton, A, Thirlwall, As, Upadhyay, Ss, Webb, Jk, & Wemyss-Holden, Sa. Pathogenesis of idiopathic scoliosis. The Nottingham concept. *Acta orthopaedica belgica, 1992; 58*: 33-58.

Burwell, Rg, Dangerfield, Ph, Moulton, A, & Anderson, Si. Etiologic theories of idiopathic scoliosis: autonomic nervous system and the leptin-sympathetic nervous system concept for the pathogenesis of adolescent idiopathic scoliosis. *Studies in health technology and informatics, 2008; 140*: 197-207.

Chan, Siu Ling, Cheung, Kenneth Mc, Luk, Keith Dk, Wong, Kenneth Wh, & Man, Sang Wong. A correlation study between in-brace correction, compliance to spinal orthosis and health-related quality of life of patients with Adolescent Idiopathic Scoliosis. *Scoliosis,9,1(2014-02-22), 2014; 9*(1): 1-12.

Chen, Chongwen, Tong, Bin, Cong, Yi, Wang, Yufei, He, Zhigang, Chen, Zhiyong, Gao, Yuzhong, Zhang, Lu, & Cheng, Xianjiang.

Investigation of scoliosis among school children in Jinzhou of Liaoning. *Medical Innovation of China, 2010; 7*(8): 44-6. doi:10.3969/j.issn.1674-4985.2010.08.021

Clayson, David, Luz-Alterman, Steven, Cataletto, Mauro M, & Levine, David B. Long-term psychological sequelae of surgically versus nonsurgically treated scoliosis. *Spine, 1987; 12*(10): 983-6.

Cobb, Jr. Outline for the study of scoliosis. *Instructional Course Lectures, 1948; 5*: 261-75.

Coelho, Daniel M, Bonagamba, Guilherme H, & Oliveira, Anamaria S. Scoliometer measurements of patients with idiopathic scoliosis. *Brazilian journal of physical therapy, 2013; 17*(2): 179-84.

Coillard, C., Circo, A., & Rivard, C. A prospective randomized study of the natural history of idiopathic scoliosis versus treatment with the SpineCor brace. *European Journal of Physical & Rehabilitation Medicine, 2014; 50*(5): 479-87.

Coillard, Christine, Vachon, Valerie, Circo, Alin B, Beauséjour, Marie, & Rivard, Charles H. Effectiveness of the SpineCor brace based on the new standardized criteria proposed by the scoliosis research society for adolescent idiopathic scoliosis. *Journal of Pediatric Orthopaedics, 2007; 27*(4): 375-9.

Côté, P, & Cassidy, J. D. A Study of the Diagnostic Accuracy and Reliability of the Scoliometer and Adam's Forward Bend Test. *Spine, 1998; 23*(7): 796-802; discussion 3.

Danielsson, A. J., Hasserius, R, Ohlin, A, & Nachemson, A. L. A prospective study of brace treatment versus observation alone in adolescent idiopathic scoliosis: a follow-up mean of 16 years after maturity. *Spine, 2007; 32*(20): 2198-207.

Danielsson, A. J., Hasserius, R, Ohlin, A, & Nachemson, A. L. Health-related quality of life in untreated versus brace-treated patients with adolescent idiopathic scoliosis: a long-term follow-up. *Spine, 2010; 35*(2): 199.

Danielsson, A. J., Hasserius, R, Ohlin, A, & Nachemson, A. L. Body appearance and quality of life in adult patients with adolescent idiopathic scoliosis treated with a brace or under observation alone during adolescence. *Spine, 2012; 37*(9): 755-62.

Danielsson, Aina J, Romberg, Karin, & Nachemson, Alf L. Spinal range of motion, muscle endurance, and back pain and function at least 20 years after fusion or brace treatment for adolescent idiopathic scoliosis: a case-control study. *Spine, 2006; 31*(3): 275-83.

Danielsson, Aina J, Wiklund, Ingela, Pehrsson, Kerstin, & Nachemson, Alf L. Health-related quality of life in patients with adolescent idiopathic scoliosis: a matched follow-up at least 20 years after

treatment with brace or surgery. *European Spine Journal, 2001; 10*(4): 278-88.

De, Wilde L, Plasschaert, F, Cattoir, H, & Uyttendaele, D. Examination of the back using the Bunnell scoliometer in a Belgian school population around puberty. *Acta Orthopaedica Belgica, 1998; 64*(2): 136-43.

Dekel, Y, Tenenbaum, G, & Kudar, K. An exploratory study on the relationship between postural deformities and body-image and self-esteem in adolescents: the mediating role of physical activity. *International Journal of Sport Psychology, 1996; 27*(2): 183-96.

Dickson, R. A., Lawton, J. O., Archer, I. A., & Butt, W. P. The pathogenesis of idiopathic scoliosis. Biplanar spinal asymmetry. *Journal of Bone & Joint Surgery British Volume, 1984; 66*(1): 8-15.

Dobosiewicz, K, Durmala, J, & Kotwicki, T. Dobosiewicz method physiotherapy for idiopathic scoliosis. *Studies in Health Technology & Informatics, 2008; 135*: 228.

Dolan, Lori A, & Weinstein, Stuart L. Surgical rates after observation and bracing for adolescent idiopathic scoliosis: an evidence-based review. *Spine, 2007; 32*(19): S91-S100.

Dong, Zhangqing, Xiong, Long, Zhou, Jiangping, Tang, Xiaozheng, & Xiao, Qiang. Investigation of Scoliosis Among School Children in

Nanchang. *Acta Academiae Medicinae Jiangxi, 2009; 49*(2): 129-32. doi:10.3969/j.issn.1000-2294.2009.02.040

Donovan, J. L., Lane, J. A., Peters, T. J., Brindle, L, Salter, E, Gillatt, D, Powell, P, Bollina, P, Neal, D. E., & Hamdy, F. C. Development of a complex intervention improved randomization and informed consent in a randomized controlled trial. *Journal of Clinical Epidemiology, 2009; 62*(1): 29-36.

Du, Qingjun, Yin, Haidong, Huang, Mingguang, Zeng, Qiutao, Zhao, Hongbin, Lin, Yong, Jiang, Yuwen, & He, Jiaqiang. A survey on the incidence of idiopathic scoliosis for primary and secondary school students in Shunde District. *Lingnan Modern Clinics in Surgery, 2010; 10*(1): 52-4. doi:10.3969/j.issn.1009-976X.2010.01.021

Duval-Beaupere, G, Lespargot, A, & Grossiord, A. Flexibility of scoliosis: what does it mean? Is this terminology appropriate? *Spine, 1985; 10*(5): 428-32.

Dy, Fong, Km, Cheung, Yw, Wong, Yy, Wan, Cf, Lee, Tp, Lam, Jc, Cheng, Bk, Ng, & Kd, Luk. A population-based cohort study of 394,401 children followed for 10 years exhibits sustained effectiveness of scoliosis screening. *The Spine Journal, 2015; 15*(5): 825-33.

Fällström, Kerstin, Cochran, Thomas, & Nachemson, Alf. Long-term effects on personality development in patients with adolescent idiopathic scoliosis: influence of type of treatment. *Spine, 1986; 11*(7): 756-8.

Fan, Hengwei, Huang, Zifang, Wang, Qifei, Tan, Weiqing, Deng, Nali, Yu, Ping, & Yang, Junlin. Prevalence of Idiopathic Scoliosis in Chinese Schoolchildren: A Large, Population-Based Study. *Spine, 2016; 41*(3): 259-64.

Fernández, Alfredo Avellaneda, Guerrero, Alberto Isla, Martínez, Maravillas Izquierdo, Vázquez, María Eugenia Amado, Fernández, Javier Barrón, I Octavio, Ester Chesa, De La Cruz Labrado, Javier, Silva, Mercedes Escribano, García-Ramos, Rocío, & Ribes, Miguel García. Malformations of the craniocervical junction (Chiari type I and syringomyelia: classification, diagnosis and treatment). *BMC Musculoskeletal disorders, 2009; 10*(1): S1.

Fletcher, B, & Sackett, Dl. Canadian task force on the periodic health examination: the Periodic Health Examination. *CMAJ, 1979; 121*(1979): 1193-254.

Fong, Daniel Yee Tak, Lee, Chun Fan, Cheung, Kenneth Man Chee, Cheng, Jack Chun Yiu, Ng, Bobby Kin Wah, Lam, Tsz Ping, Mak, Kwok Hang, Yip, Paul Siu Fai, & Luk, Keith Dip Kei. A meta-

analysis of the clinical effectiveness of school scoliosis screening. *Spine, 2010; 35*(10): 1061-71.

Freidel, Klaus, Petermann, Franz, Reichel, Dagmar, Steiner, Angela, Warschburger, Petra, & Weiss, Hans R. Quality of life in women with idiopathic scoliosis. *Spine, 2002; 27*(4): E87-E91.

Fusco, C, Zaina, F, Atanasio, S, Romano, M, Negrini, A, & Negrini, S. Physical exercises in the treatment of adolescent idiopathic scoliosis: an updated systematic review. *Physiotherapy theory and practice, 2011; 27*(1): 80-114.

Gammon, Steven R, Mehlman, Charles T, Chan, Winston, Heifetz, Jonathan, Durrett, Gregory, & Wall, Eric J. A comparison of thoracolumbosacral orthoses and SpineCor treatment of adolescent idiopathic scoliosis patients using the Scoliosis Research Society standardized criteria. *Journal of Pediatric Orthopaedics, 2010; 30*(6): 531-8.

Gandhi, P. K., Revicki, D. A., & Huang, I. C. Adolescent body weight and health-related quality of life rated by adolescents and parents: the issue of measurement bias. *BMC Public Health, 2015; 15*: 1192. doi:10.1186/s12889-015-2533-4

Glascoe, Frances P. Standards for screening test construction. *J Public Relat Res, 2005; 6*: 185-207.

Goldberg, Caroline J, Kaliszer, Michael, Moore, David P, Fogarty, Esmond E, & Dowling, Frank E. Surface topography, Cobb angles, and cosmetic change in scoliosis. *Spine, 2001; 26*(4): E55-E63.

Goldberg, Cj, Grove, D, Moore, Dp, Fogarty, Ee, & Dowling, Fe. Surface topography and vectors: a new measure for the three dimensional quantification of scoliotic deformity. *Studies in health technology and informatics, 2005; 123*: 449-55.

Goldberg, Mark S, Mayo, Nancy E, Poitras, Benoît, Scott, Susan, & Hanley, James. The Ste-Justine Adolescent Idiopathic Scoliosis Cohort Study: Part II: Perception of Health, Self and Body Image, and Participation in Physical Activities. *Spine, 1994; 19*(14): 1562-72.

Gratz, Rene R, & Papalia-Finlay, Diane. Psychosocial adaptation to wearing the Milwaukee brace for scoliosis: a pilot study of adolescent females and their mothers. *Journal of Adolescent Health Care, 1984; 5*(4): 237-42.

Grivas, T. B., Wade, M. H., Negrini, S, O'brien, J. P., Maruyama, T, Hawes, M. C., Rigo, M, Weiss, H. R., Kotwicki, T, & Vasiliadis, E. S. SOSORT consensus paper: school screening for scoliosis. Where are we today? *Scoliosis, 2007a; 2*(1): 17.

Grivas, Theodoros B, Vasiliadis, Elias, Mouzakis, Vasilios, Mihas, Constantinos, & Koufopoulos, Georgios. Association between

adolescent idiopathic scoliosis prevalence and age at menarche in different geographic latitudes. *Scoliosis, 2006; 1*(1): 9.

Grivas, Theodoros B, Vasiliadis, Elias S, Mihas, Constantinos, & Savvidou, Olga. The effect of growth on the correlation between the spinal and rib cage deformity: implications on idiopathic scoliosis pathogenesis. *Scoliosis, 2007b; 2*(1): 11.

Grosso, C, Negrini, S, Boniolo, A, & Negrini, A. A. The validity of clinical examination in adolescent spinal deformities. *Studies in Health Technology & Informatics, 2002; 91*: 123.

Guo, Jing, Lam, Tsz Ping, Wong, Man Sang, Ng, Bobby Kin Wah, Lee, Kwong Man, Liu, King Lok, Hung, Lik Hang, Lau, Ajax Hong Yin, Sin, Sai Wing, & Kwok, Wing Kwan. A prospective randomized controlled study on the treatment outcome of SpineCor brace versus rigid brace for adolescent idiopathic scoliosis with follow-up according to the SRS standardized criteria. *European Spine Journal, 2014; 23*(12): 2650-7.

Han, Xiao, Liu, Zhen, Qiu, Yong, Sha, Shifu, Yan, Huang, Jin, Mengran, & Zhu, Zezhang. Clavicle Chest Cage Angle Difference. *Spine, 2016*: 1.

Hawes, Martha C. The use of exercises in the treatment of scoliosis: an evidence-based critical review of the literature. *Pediatric Rehabilitation, 2003; 6*(3-4): 171-82.

Herman, Richard, Mixon, James, Fisher, Anne, Maulucci, Ruth, & Stuyck, Joseph. Idiopathic Scoliosis and the Central Nervous System: A Motor Control Problem: The Harrington Lecture, 1983 Scoliosis Research Society. *Spine, 1985; 10*(1): 1-14.

Hodges, P. W. Core stability exercise in chronic low back pain. *Orthopedic Clinics of North America, 2003; 34*(2): 245-54.

Hong, J. Y., Suh, S. W., Yang, J. H., Park, S. Y., & Han, J. H. Reliability analysis of shoulder balance measures: comparison of the 4 available methods. *Spine, 2013; 38*(26): E1684.

Huang, Nanqi, Guo, Hengshan, Liu, Jin, Huang, Guangxin, Yang, Xiahui, Chen, Jing, & Su, Peiqiang. A survey on adolescent scoliosis in Guangzhou. *Chinese Journal of Epidemiology, 2011; 32*(2): 138-41. doi:10.3760/cma.j.issn.0254-6450.2011.02.008

Huang, S. C. Cut-off point of the Scoliometer in school scoliosis screening. *Spine, 1997; 22*(17): 1985.

Janicki, Joseph A, Poe-Kochert, Connie, Armstrong, Douglas G, & Thompson, George H. A comparison of the thoracolumbosacral orthoses and providence orthosis in the treatment of adolescent idiopathic scoliosis: results using the new SRS inclusion and assessment criteria for bracing studies. *Journal of Pediatric Orthopaedics, 2007; 27*(4): 369-74.

Jones, Sj. What is the evidence justifying non-invasive SEP and MEP monitoring during spinal surgery? *Supplements to Clinical neurophysiology, 2006; 59*: 305-10.

Kindsfater, Kirk, Lowe, Thomas, Lawellin, David, Weinstein, David, & Akmakjian, Jack. Levels of platelet calmodulin for the prediction of progression and severity of adolescent idiopathic scoliosis. *JBJS, 1994; 76*(8): 1186-92.

Korbel, K, Kozinoga, M, Stoliński, Ł, & Kotwicki, T. Scoliosis Research Society (SRS) Criteria and Society of Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) 2008 Guidelines in Non-Operative Treatment of Idiopathic Scoliosis. *Polish Orthopedics & Traumatology, 2014; 79*(14): 118.

Kotwicki, T, & Cheneau, J. Biomechanical action of a corrective brace on thoracic idiopathic scoliosis: Cheneau 2000 orthosis. *Disability & Rehabilitation Assistive Technology, 2008; 3*(3): 146.

Kotwicki, T., Kinel, E., Stryla, W., & Szulc, A. Estimation of the stress related to conservative scoliosis therapy: an analysis based on BSSQ questionnaires. *Scoliosis, 2007a; 2*(1): 1. doi:10.1186/1748-7161-2-1

Kotwicki, Tomasz, Kinel, Edyta, Stryla, Wanda, & Szulc, Andrzej. Discrepancy in clinical versus radiological parameters describing

deformity due to brace treatment for moderate idiopathic scoliosis. *Scoliosis, 2007b; 2*(1): 18.

Krakauer, J. W., & Mazzoni, P. Human sensorimotor learning: adaptation, skill, and beyond. *Curr Opin Neurobiol, 2011; 21*(4): 636-44. doi:10.1016/j.conb.2011.06.012

Kuroki, Hiroshi, Inomata, Naoki, Hamanaka, Hideaki, Higa, Kiyoshi, Chosa, Etsuo, & Tajima, Naoya. Efficacy of the Osaka Medical College (OMC) brace in the treatment of adolescent idiopathic scoliosis following Scoliosis Research Society brace studies criteria. *Scoliosis, 2015; 10*(1): 12.

Labelle, Hubert, Richards, Stephens B, De Kleuver, Marinus, Grivas, Theodoros B, Luk, Keith Dk, Wong, Hee Kit, Thometz, John, Beauséjour, Marie, Turgeon, Isabelle, & Fong, Daniel Yt. Screening for adolescent idiopathic scoliosis: an information statement by the scoliosis research society international task force. *Scoliosis, 2013; 8*(1): 17.

Li, M., Wang, C. F., Gu, S. X., He, S. S., Zhu, X. D., Zhao, Y. C., & Zhang, J. T. Adapted simplified Chinese (mainland) version of Scoliosis Research Society-22 questionnaire. *Spine, 2009; 34*(12): 1321.

Li, Wan. Results of exercise therapy in treatment of essentially S-shaped scoliosis patients: evaluations of Cobbs angle in the breast and lumbar segment. *Chinese J Clin Rehabil, 2005; 9*(34): 82-4.

Lindeman, Marjaana, & Behm, Kaisu. Cognitive strategies and self-esteem as predictors of brace-wear noncompliance in patients with idiopathic scoliosis and kyphosis. *Journal of Pediatric Orthopaedics, 1999; 19*(4): 493-9.

Liskey-Fitzwater, Natalie, Moore, Carolyn L, & Gurel, Lois M. Clothing importance and self-perception of female adolescents with and without scoliosis. *Clothing and Textiles Research Journal, 1993; 11*(3): 16-22.

Liu, Shangli, Li, Weiping, Li, Yuanjing, Li, Qing, Wang, Suwei, Chen, Zhongliang, Zhang, Guangbo, & He, Jiemin. A survey on adolescent scoliosis in Guangdong province. *Chinese Journal of Spine and Spinal Cord, 2002; 12*(1): 41-3.

Liu, Wei, Chen, Qinghe, Wang, Lun, Chao, Min, Qu, Jinliang, Lu, Miao, & Liu, Siyu. A general survey of the adolescent scoliosis in Harbin and an analysis of the result of the brace treatment. *Orthopedic Journal of China, 2011; 19*(15): 1244-7.

Lonstein, John E. Scoliosis: surgical versus nonsurgical treatment. *Clinical orthopaedics and related research, 2006; 443*: 248-59.

Lou, E., Hill, D., Raso, J., Donauer, A., Moreau, M., Mahood, J., & Hedden, D. Smart brace versus standard rigid brace for the treatment of scoliosis: a pilot study. *Stud Health Technol Inform, 2012; 176*: 338-41.

Luk, Keith Dk, Lee, Chun Fan, Cheung, Kenneth Mc, Cheng, Jack Cy, Ng, Bobby Kw, Lam, Tsz Ping, Mak, Kwok Hang, Yip, Paul Sf, & Fong, Daniel Yt. Clinical effectiveness of school screening for adolescent idiopathic scoliosis: a large population-based retrospective cohort study. *Spine, 2010; 35*(17): 1607-14.

Lusini, M, Donzelli, S, Minnella, S, Zaina, F, & Negrini, S. Brace treatment is effective in idiopathic scoliosis over 45°: an observational prospective cohort controlled study. *Spine Journal, 2014; 14*(9): 1951-6.

Lusini, M., Donzelli, S., Zaina, F., & Negrini, S. Brace treatment is effective in idiopathic scoliosis over 45°: a prospective controlled study. *Scoliosis, 2013; 8*(1): 1-.

Macdonald, David A., Moseley, G. Lorimer, & Hodges, Paul W. The lumbar multifidus: Does the evidence support clinical beliefs? *Manual Therapy, 2006; 11*(4): 254-63.

Machida, Masafumi. Cause of idiopathic scoliosis. *Spine, 1999; 24*(24): 2576.

Maclean Jr, William E, Green, Neil E, Pierre, Claudette B, & Ray, Diane C. Stress and coping with scoliosis: psychological effects on adolescents and their families. *Journal of Pediatric Orthopaedics, 1989; 9*(3): 257-61.

Malfair, David, Flemming, Anne K, Dvorak, Marcel F, Munk, Peter L, Vertinsky, Alexandra T, Heran, Manraj K, & Graeb, Doug A. Radiographic evaluation of scoliosis. *American Journal of Roentgenology, 2010; 194*(3_supplement): S8-S22.

Maruyama, T, Takeshita, K, & Kitagawa, T. Side-shift exercise and hitch exercise. *Studies in Health Technology & Informatics, 2008; 135*: 246-9.

Maruyama, Toru, Kobayashi, Yosuke, Miura, Makoto, & Nakao, Yusuke. Effectiveness of brace treatment for adolescent idiopathic scoliosis. *Scoliosis, 2015; 10*(2): S12.

Matamalas, A, Bagó, J, D'agata, E, & Pellisé, F. Does patient perception of shoulder balance correlate with clinical balance? *European Spine Journal, 2015*: 1-8.

Matsunaga, Shunji, Sakou, Takashi, & Nozoe, Shinichi. Psychological effects of brace therapy on patients with idiopathic scoliosis. *Journal of orthopaedic science, 1997; 2*(6): 391-5.

Mayo, Nancy E, Goldberg, Mark S, Poitras, Benoît, Scott, Susan, & Hanley, James. The Ste-Justine Adolescent Idiopathic Scoliosis Cohort Study: Part III: Back Pain. *Spine, 1994; 19*(14): 1573-81.

Minghelli, B., Nunes, C., & Oliveira, R. Prevalence of scoliosis in southern Portugal adolescents. *Pediatr Endocrinol Rev, 2014; 11*(4): 374-82.

Monticone, Marco, Ambrosini, Emilia, Cazzaniga, Daniele, Rocca, Barbara, & Ferrante, Simona. Active self-correction and task-oriented exercises reduce spinal deformity and improve quality of life in subjects with mild adolescent idiopathic scoliosis. Results of a randomised controlled trial. *European Spine Journal, 2014; 23*(6): 1204-14.

Nachemson, A. L., & Peterson, L. E. Effectiveness of treatment with a brace in girls who have adolescent idiopathic scoliosis. A prospective, controlled study based on data from the Brace Study of the Scoliosis Research Society. *Journal of Bone & Joint Surgery American Volume, 1995; 77*(6): 815-22.

Nachemson, Alf L, & Sahlstrand, Tage. Etiologic Factors in Adolescent Idiopathic Scoliosis. *Spine, 1977; 2*(3): 176-84.

National Center for Health Statistics. CDC Growth Charts: United States. Retrieved from http://www.cdc.gov/growthcharts/clinicalcharts.htm

Negrini, A, Negrini, S, Romano, M, Verzini, N, Parzini, S, & Monticone, M. A Blind Radiographic Controlled Study on the Efficacy of Active Self-Correction According to SEAS. 02. 3rd International Conference on Conservative Management of Spinal Deformities: 7–8 April 2006 2006. *2006a*.

Negrini, S. Bracing adolescent idiopathic scoliosis today. *Disability & Rehabilitation Assistive Technology, 2008; 3*(3): 107.

Negrini, S, Marchini, G, & Tessadri, F. Brace technology thematic series - The Sforzesco and Sibilla braces, and the SPoRT (Symmetric, Patient oriented, Rigid, Three-dimensional, active) concept. *Scoliosis, 2011a; 6*(1): 1-18.

Negrini, S, Marchini, G, & Tomaello, L. Efficacy of the Symmetric, Patient-oriented, Rigid, Three-Dimensional (SPoRT) concept of bracing for scoliosis: a pair-controlled retrospettive short-term study on the Sforzesco Brace. *3rd International SOSORT Meeting: 2006 April 07-08 2006; Poznan, Poland: SOSORT, 2006b*.

Negrini, S, Negrini, A, Romano, M, Verzini, N, Negrini, A, & Parzini, S. A controlled prospective study on the efficacy of SEAS.02 exercises in preparation to bracing for idiopathic scoliosis. *Studies in Health Technology & Informatics, 2006c; 123*(123): 519-22.

Negrini, S, Zaina, F, Romano, M, Negrini, A, & Parzini, S. Specific exercises reduce brace prescription in adolescent idiopathic

scoliosis: a prospective controlled cohort study with worst-case analysis. *Journal of Rehabilitation Medicine, 2008a; 40*(6): 451.

Negrini, S., Fusco, C., Minozzi, S., Atanasio, S., Zaina, F., & Romano, M. Exercises reduce the progression rate of adolescent idiopathic scoliosis: results of a comprehensive systematic review of the literature. *Disabil Rehabil, 2008b; 30*(10): 772-85. doi:10.1080/09638280801889568

Negrini, S., Minozzi, S., Bettany-Saltikov, J., Chockalingam, N., Grivas, T. B., Kotwicki, T., Maruyama, T., Romano, M., & Zaina, F. Braces for Idiopathic Scoliosis in Adolescents. *Spine (Phila Pa 1976), 2016; 41*(23): 1813-25. doi:10.1097/BRS.0000000000001887

Negrini, S., Minozzi, S., Bettany-Saltikov, J., Zaina, F., Chockalingam, N., Grivas, T. B., Kotwicki, T., Maruyama, T., Romano, M., & Vasiliadis, E. S. Braces for idiopathic scoliosis in adolescents. *Cochrane Database Syst Rev, 2010;* (1): CD006850. doi:10.1002/14651858.CD006850.pub2

Negrini, Stefano, Antonini, Guido, Carabalona, Roberta, & Minozzi, Silvia. Physical exercises as a treatment for adolescent idiopathic scoliosis. A systematic review. *Pediatric rehabilitation, 2003; 6*(3-4): 227-35.

Negrini, Stefano, Atanasio, Salvatore, Negrini, Alberto, Negrini, Alessandra, Negrini, Antonio, Negrini, Gabriella, Parzini, Silvana, Romano, Michele, Verzini, Nevia, & Zaina, Fabio. THE EVIDENCE BASED ISICO APPROACH TO SPINAL DEFORMITIES. *2007a*.

Negrini, Stefano, Aulisa, Angelo G, Aulisa, Lorenzo, Circo, Alin B, De Mauroy, Jean Claude, Durmala, Jacek, Grivas, Theodoros B, Knott, Patrick, Kotwicki, Tomasz, & Maruyama, Toru. 2011 SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis, 2012; 7*(1): 3.

Negrini, Stefano, Bettany-Saltikov, Josette, De Mauroy, Jean Claude, Durmala, Jacek, Grivas, Theodoros B, Knott, Patrick, Kotwicki, Tomasz, Maruyama, Toru, O'brien, Joseph P, & Parent, Eric. Letter to the Editor concerning:"Active self-correction and task-oriented exercises reduce spinal deformity and improve quality of life in subjects with mild adolescent idiopathic scoliosis. Results of a randomised controlled trial" by Monticone M, Ambrosini E, Cazzaniga D, Rocca B, Ferrante S (2014). Eur Spine J; DOI: 10.1007/s00586-014-3241-y. *European Spine Journal, 2014; 23*(10): 2218-20.

Negrini, Stefano, Hresko, Timothy M, O'brien, Joseph P, & Price, Nigel. Recommendations for research studies on treatment of idiopathic

scoliosis: Consensus 2014 between SOSORT and SRS non–operative management committee. *Scoliosis, 2015; 10*(1): 8.

Negrini, Stefano, Minozzi, Silvia, Bettany-Saltikov, Josette, Zaina, Fabio, Chockalingam, Nachiappan, Grivas, Theodoros B., Kotwicki, Tomasz, Maruyama, Toru, Romano, Michele, & Vasiliadis, Elias S. (2007b). *Braces for idiopathic scoliosis in adolescents*: John Wiley & Sons, Ltd.

Negrini, Stefano, Negrini, Alberto, Santambrogio, Giorgio C, & Sibilla, Paolo. Relation between static angles of the spine and a dynamic event like posture: approach to the problem. *Three Dimensional Analysis of Spinal Deformities. Volume, 1995; 1*.

Negrini, Stefano, Negrini, Alberto, Santambrogio, Giorgio C., & Sibilla, Paolo. Relation Between Static Angles of the Spine and a Dynamic Event Like Posture: Approach to the Problem.

Negrini, Stefano, Negrini, Francesco, Fusco, Claudia, & Zaina, Fabio. Idiopathic scoliosis patients with curves more than 45 Cobb degrees refusing surgery can be effectively treated through bracing with curve improvements. *The Spine Journal, 2011b; 11*(5): 369-80.

O'neill, Patrick J, Karol, Lori A, Shindle, Michael K, Elerson, Emily E, Brintzenhofeszoc, Karlynn M, Katz, Donald E, Farmer, Kevin W, & Sponseller, Paul D. Decreased orthotic effectiveness in

overweight patients with adolescent idiopathic scoliosis. *JBJS, 2005; 87*(5): 1069-74.

Oded, Hershkovich, Alon, Friedlander, Barak, Gordon, Harel, Arzi, Estela, Derazne, Dorit, Tzur, Ari, Shamiss, & Arnon, Afek. Association between body mass index, body height, and the prevalence of spinal deformities. *Spine J, 2014; 14*(8): 1581-7. doi:10.1016/j.spinee.2013.09.034

Ono, T. Trunk deformity in scoliosis studied by surface measurement. *Nihon Seikeigeka Gakkai zasshi, 1995; 69*(10): 915-26.

Ostelo, R. W., Van Tulder, M. W., Vlaeyen, J. W., Linton, S. J., Morley, S. J., & Assendelft, W. J. Behavioural treatment for chronic low-back pain. *Cochrane Database of Systematic Reviews, 2009; 1*(1): CD002014.

Parent, S, Newton, Po, & Wenger, Dr. Adolescent idiopathic scoliosis: etiology, anatomy, natural history, and bracing. *Instructional course lectures, 2005; 54*: 529-36.

Payne Iii, William K, Ogilvie, James W, Resnick, Michael D, Kane, Robert L, Transfeldt, Ensor E, & Blum, Robert W. Does scoliosis have a psychological impact and does gender make a difference? *Spine, 1997; 22*(12): 1380-4.

Pehrsson, Kerstin, Larsson, Sven, Oden, Anders, & Nachemson, Alf. Long-Term Follow-Up of Patients with Untreated Scoliosis A

Study of Mortality, Causes of Death, and Symptoms. *Spine, 1992; 17*(9): 1091-6.

Pineda, Sonia, Bago, Juan, Gilperez, Carmen, Climent, & M, Jose. Validity of the Walter Reed Visual Assessment Scale to measure subjective perception of spine deformity in patients with idiopathic scoliosis. *Scoliosis, 2006; 1*(1): 18.

Poitras, Benoît, Mayo, Nancy E, Goldberg, Mark S, Scott, Susan, & Hanley, James. The Ste-Justine Adolescent Idiopathic Scoliosis Cohort Study: Part IV: Surgical Correction and Back Pain. *Spine, 1994; 19*(14): 1582-8.

Porto, Flávia, Gurgel, Jonas Lírio, Russomano, Thais, & Farinatti, Paulo De Tarso Veras. Moiré topography: Characteristics and clinical application. *Gait & posture, 2010; 32*(3): 422-4.

Rahman, Tariq, Bowen, J Richard, Takemitsu, Masakazu, & Scott, Claude. The association between brace compliance and outcome for patients with idiopathic scoliosis. *Journal of Pediatric Orthopaedics, 2005; 25*(4): 420-2.

Ranganathan, R, & Newell, K. M. Changing up the routine: intervention-induced variability in motor learning. *Exercise & Sport Sciences Reviews, 2013; 41*(1): 64-70.

Reilly, Richard P, & Findley, Thomas W. Research in Physical Medicine and Rehabilitation: IV. Some Practical Designs in Applied

Research. *American journal of physical medicine & rehabilitation, 1989; 68*(4): 196-201.

Richards, B Stephens, & Vitale, Michael G. Screening for idiopathic scoliosis in adolescents: an information statement. *JBJS, 2008; 90*(1): 195-8.

Rigo, M, Quera-Salvá, G, Villagrasa, M, Ferrer, M, Casas, A, Corbella, C, Urrutia, A, Martínez, S, & Puigdevall, N. Scoliosis intensive out-patient rehabilitation based on Schroth method. *Studies in Health Technology & Informatics, 2008; 135*: 208.

Rivett, Lou Ann, Stewart, Aimee, & Potterton, Joanne. The effect of compliance to a Rigo System Cheneau brace and a specific exercise programme on idiopathic scoliosis curvature: a comparative study: SOSORT 2014 award winner. *Scoliosis and Spinal Disorders, 2014; 9*(1): 1-13.

Rivett, Louann, Rothberg, Alan, Stewart, Aimee, & Berkowitz, Rowan. The relationship between quality of life and compliance to a brace protocol in adolescents with idiopathic scoliosis: a comparative study. *BMC musculoskeletal disorders, 2009; 10*(1): 5.

Romano, M, Minozzi, S, Bettanysaltikov, J, Zaina, F, Chockalingam, N, Kotwicki, T, Maierhennes, A, & Negrini, S. Exercises for adolescent idiopathic scoliosis. *Cochrane Database Syst Rev, 2012; 38*(14): 883-93.

Romano, M, Minozzi, S, Zaina, F, Saltikov, J. B., Chockalingam, N, Kotwicki, T, Hennes, A. M., & Negrini, S. Exercises for adolescent idiopathic scoliosis: a Cochrane systematic review. *Spine, 2013; 38*(14): 883-93.

Romano, M, Negrini, A, Parzini, S, Tavernaro, M, Zaina, F, Donzelli, S, & Negrini, S. SEAS (Scientific Exercises Approach to Scoliosis): a modern and effective evidence based approach to physiotherapic specific scoliosis exercises. *Scoliosis and Spinal Disorders, 2015; 10*(1): 3.

Rowe, D. E., Bernstein, S. M., Riddick, M. F., Adler, F., Emans, J. B., & Gardner-Bonneau, D. A meta-analysis of the efficacy of non-operative treatments for idiopathic scoliosis. *J Bone Joint Surg Am, 1997; 79*(5): 664-74.

Sanchez, D. J., & Reber, P. J. Explicit pre-training instruction does not improve implicit perceptual-motor sequence learning. *Cognition, 2013; 126*(3): 341-51.

Sapountzi-Krepia, Despina, Psychogiou, Maria, Peterson, Darin, Zafiri, Vassiliki, Iordanopoulou, Eugenia, Michailidou, Fotini, & Christodoulou, Anastassios. The experience of brace treatment in children/adolescents with scoliosis. *Scoliosis, 2006; 1*(1): 8.

Sapountzi-Krepia, Despina S, Valavanis, John, Panteleakis, George P, Zangana, Dimitra T, Vlachojiannis, Pantelis C, & Sapkas, George S. Perceptions of body image, happiness and satisfaction in adolescents wearing a Boston brace for scoliosis treatment. *Journal of advanced nursing, 2001; 35*(5): 683-90.

Shimode, Masanori, Ryouji, Abe, & Kozo, Nakamura. Asymmetry of premotor time in the back muscles of adolescent idiopathic scoliosis. *Spine, 2003; 28*(22): 2535-9.

Smania, Nicola, Picelli, Alessandro, Romano, Michele, & Negrini, Stefano. Neurophysiological basis of rehabilitation of adolescent idiopathic scoliosis. *Disability & Rehabilitation, 2008; 30*(10): 763-71.

Stokes, I. A., Burwell, R. G., & Dangerfield, P. H. Biomechanical spinal growth modulation and progressive adolescent scoliosis--a test of the 'vicious cycle' pathogenetic hypothesis: summary of an electronic focus group debate of the IBSE. *Scoliosis, 2006; 1*(1): 16.

Stokes, I. A., & Gardnermorse, M. Muscle activation strategies and symmetry of spinal loading in the lumbar spine with scoliosis. *Spine, 2004; 29*(19): 2103-7.

Stokes, I. A., Spence, H, Aronsson, D. D., & Kilmer, N. Mechanical modulation of vertebral body growth. Implications for scoliosis progression. *Spine, 1996; 21*(10): 1162.

Stone, B, Beekman, C, Hall, V, Guess, V, & Brooks, Hl. The effect of an exercise program on change in curve in adolescents with minimal idiopathic scoliosis. A preliminary study. *Physical therapy, 1979; 59*(6): 759-63.

Sucato, Daniel J. Management of severe spinal deformity: scoliosis and kyphosis. *Spine, 2010; 35*(25): 2186-92.

Suh, Seung-Woo, Modi, Hitesh N, Yang, Jae-Hyuk, & Hong, Jae-Young. Idiopathic scoliosis in Korean schoolchildren: a prospective screening study of over 1 million children. *European spine journal, 2011; 20*(7): 1087-94.

Tam, Elisa Ms, Liu, Zhen, Lam, Tsz-Ping, Ting, Terry, Cheung, Gordon, Ng, Bobby Kw, Lee, Simon Km, Qiu, Yong, & Cheng, Jack Cy. Lower Muscle Mass and Body Fat in Adolescent Idiopathic Scoliosis Are Associated With Abnormal Leptin Bioavailability. *Spine, 2016; 41*(11): 940-6.

Tian, Jiwei, Wu, Xuequn, Zhao, Guangfu, Yan, Yong, Jia, Huaqing, & Ge, Jinghua. Prevalence of scoliosis in 7157 primary school students in Xuhui District, Shanghai City. *Chinese Journal of Pediatric Surgery, 1997; 18*(2): 115.

Tones, Megan, Moss, Nathan, & Polly Jr, David W. A review of quality of life and psychosocial issues in scoliosis. *Spine, 2006; 31*(26): 3027-38.

Uspstf. (1996). *Guide to clinical preventive services: report of the US Preventive Services Task Force*: Lippincott Williams & Wilkins.

Uspstf. (2006). *The guide to clinical preventive services: recommendations of the US Preventive Services Tack Force*: Lippincott Williams & Wilkins.

Uyttendaele, D, & Dangerfield, Ph. The influence of brace on quality of life of adolescents with idiopathic scoliosis. *Research Into Spinal Deformities 5, 2006; 5*: 352.

Uzümcügil, O, Atici, Y, Ozturkmen, Y, Yalcinkaya, M, & Caniklioglu, M. Evaluation of shoulder balance through growing rod intervention for early-onset scoliosis. *Journal of spinal disorders & techniques, 2012; 25*(7): 391-400.

Vasiliadis, Elias S, Grivas, Theodoros B, & Kaspiris, Angelos. Historical overview of spinal deformities in ancient Greece. *Scoliosis, 2009; 4*(1): 6.

Vives, Alejandra, Ferreccio, Catterina, & Marshall, Guillermo. A comparison of two methods to adjust for non-response bias: field substitution and weighting non-response adjusments based on response propensity. *Gaceta Sanitaria, 2009; 23*(4): 266-71.

Wang, Q, Li, M, Lou, Edmond Hm, & Wong, Ms. Reliability and validity study of clinical ultrasound imaging on lateral curvature of adolescent idiopathic scoliosis. *PloS one, 2015; 10*(8): e0135264.

Weigert, Karen Petra, Nygaard, Linda Marie, Christensen, Finn Bjarke, Hansen, Ebbe Stender, & Bünger, Cody. Outcome in adolescent idiopathic scoliosis after brace treatment and surgery assessed by means of the Scoliosis Research Society Instrument 24. *European Spine Journal, 2006; 15*(7): 1108-17.

Weinstein, S. L., Dolan, L. A., Wright, J. G., & Dobbs, M. B. Design of the Bracing in Adolescent Idiopathic Scoliosis Trial (BrAIST). *Spine, 2013; 38*(21): 1832.

Weinstein, S. L., Dolan, L. A., Wright, J. G., & Dobbs, M. B. Effects of bracing in adolescents with idiopathic scoliosis. *New England Journal of Medicine, 2014; 40*(1): 146–7.

Weinstein, Stuart L, Dolan, Lori A, Spratt, Kevin F, Peterson, Kirk K, Spoonamore, Mark J, & Ponseti, Ignacio V. Health and function of patients with untreated idiopathic scoliosis: a 50-year natural history study. *Jama, 2003; 289*(5): 559-67.

Weiss, Hans-Rudolf, & Weiss, Grita Maria. Brace treatment during pubertal growth spurt in girls with idiopathic scoliosis (IS): a prospective trial comparing two different concepts. *Pediatric Rehabilitation, 2005; 8*(3): 199-206.

Weiss, Hans-Rudolf, Weiss, Grita, & Schaar, Hans-Jürgen. Incidence of surgery in conservatively treated patients with scoliosis. *Pediatric Rehabilitation, 2003; 6*(2): 111-8.

Weiss, Hans-Rudolf, Werkmann, Mario, & Stephan, Carola. Brace related stress in scoliosis patients–Comparison of different concepts of bracing. *Scoliosis, 2007; 2*(1): 10.

Weiss, Hans Rudolf. The effect of an exercise program on vital capacity and rib mobility in patients with idiopathic scoliosis. *Spine, 1991; 16*(1): 88-93.

Weiss, Hans Rudolf. The method of Katharina Schroth - history, principles and current development. *Scoliosis and Spinal Disorders, 2011; 6*(1): 1-22.

Weiss, Hans Rudolf, Negrini, Stefano, Hawes, Martha C, Rigo, Manuel, Kotwicki, Tomasz, Grivas, Theodoros B, Maruyama, Toru, & Ofsosort, Members. Physical exercises in the treatment of idiopathic scoliosis at risk of brace treatment – SOSORT consensus paper 2005. *Scoliosis,1,1(2006-05-11), 2006; 1*(1): 6.

Wiemann, John M, Shah, Suken A, & Price, Charles T. Nighttime bracing versus observation for early adolescent idiopathic scoliosis. *Journal of pediatric orthopedics, 2014; 34*(6): 603.

Wong, Hee-Kit, Hui, James Hp, Rajan, Uma, & Chia, Hwee-Pin. Idiopathic scoliosis in Singapore schoolchildren: a prevalence

study 15 years into the screening program. *Spine, 2005; 30*(10): 1188-96.

Wong, M. S., Cheng, J. C., Lam, T. P., Ng, B. K., Sin, S. W., Lee-Shum, S. L., Chow, D. H., & Tam, S. Y. The effect of rigid versus flexible spinal orthosis on the clinical efficacy and acceptance of the patients with adolescent idiopathic scoliosis. *Spine, 2008; 33*(12): 1360.

Yamamoto, S., Shigematsu, H., Kadono, F., Tanaka, Y., Tatematsu, M., Okuda, A., Iwata, E., Koizumi, M., & Tanaka, Y. Adolescent Scoliosis Screening in Nara City Schools: A 23-Year Retrospective Cross-Sectional Study. *Asian Spine J, 2015; 9*(3): 407-15. doi:10.4184/asj.2015.9.3.407

Yawn, B. P. School-screening for scoliosis. A prospective epidemiological study in northwestern and central Greece. *Journal of Bone & Joint Surgery American Volume, 1998; 80*(8): 1498-503.

Yong Q, Liu Z, Sun Q, Et Al. Reliability and validity of chinese version of scoliosis research society-22(SRS-22)patient questionnaire. *Chinese Journal of Orthopaedics, 2008; 28*(6): 459-63.

Yrjönen, Timo, Ylikoski, Mauno, Schlenzka, Dietrich, Kinnunen, Riitta, & Poussa, Mikko. Effectiveness of the Providence nighttime bracing in adolescent idiopathic scoliosis: a comparative study of 36 female patients. *European Spine Journal, 2006; 15*(7): 1139-43.

Yu, Shenghua, Hu, Hansheng, Fan, Zhenbo, Qiu, Qinye, & Li, Yuanhui. An Investigation on the Prevalence Rate of Idiopathic Scoliosis for Primary and Secondary School Students in Guangzhou. *Clinical Medical & Engineering, 2014;* (10): 1359-60. doi:10.3969/j.issn.1674-4659.2014.10.1359

Zaborowska-Sapeta, K, Kowalski, I. M., Kotwicki, T, Protasiewicz-Fałdowska, H, & Kiebzak, W. Effectiveness of Chêneau brace treatment for idiopathic scoliosis: prospective study in 79 patients followed to skeletal maturity. *Scoliosis, 2011; 6*(1): 2.

Zaina, F, De Mauroy, J. C., Grivas, T, Hresko, M. T., Kotwizki, T, Maruyama, T, Price, N, Rigo, M, Stikeleather, L, & Wynne, J. Bracing for scoliosis in 2014: state of the art. *European Journal of Physical & Rehabilitation Medicine, 2014; 50*(1): 93-110.

Zaina, Fabio, De Mauroy, Jean Claude, Donzelli, Sabrina, & Negrini, Stefano. SOSORT Award Winner 2015: a multicentre study comparing the SPoRT and ART braces effectiveness according to the SOSORT-SRS recommendations. *Scoliosis, 2015; 10*(1): 23.

Zaina, Fabio, Negrini, Stefano, & Atanasio, Salvatore. TRACE (Trunk Aesthetic Clinical Evaluation), a routine clinical tool to evaluate aesthetics in scoliosis patients: development from the Aesthetic Index (AI) and repeatability. *Scoliosis, 2009; 4*(1): 3.

Zhang, Hongqi, Guo, Chaofeng, Tang, Mingxing, Liu, Shaohua, Li, Jinsong, Guo, Qiang, Chen, Lizhang, Zhu, Yong, & Zhao, Shushan. Prevalence of scoliosis among primary and middle school students in Mainland China: a systematic review and meta-analysis. *Spine, 2015; 40*(1): 41-9.

Zhang, Jingtao, Wang, Dayi, Chen, Ziqiang, Gao, Juan, Yu, Xiuchun, Sun, Haining, & Li, Ming. Decrease of self-concept in adolescent patients with mild to moderate scoliosis after conservative treatment. *Spine, 2011; 36*(15): E1004-E8.

Zhang, Shou, Jin, Xuhong, Guo, Xiang, Xing, Shi, Liang, Ning, Lin, Youren, & Chen, Ping. A Survey on Scoliosis in School-age Population in Hainan. *Hainan Medical Journal, 2003; 14*(12): 5-6. doi:10.3969/j.issn.1003-6350.2003.12.003

Zheng, Yu, Wu, Xiaojun, Dang, Yini, Yang, Yan, Reinhardt, Jan D, & Dang, Yingjie. Prevalence and determinants of idiopathic scoliosis in primary school children in Beitang district, Wuxi, China. *Journal of rehabilitation medicine, 2016; 48*(6): 547-53.

Zhou, Huiqing, Zhang, Jianxin, & Lin, Sishun. Epidemiological investigation of scoliosis among adolescents in Hui'an county, Fujian province. *Chinese Journal of Spine and Spinal Cord, 2009; 18*(11): 824-7. doi:10.3969/j.issn.1004-406X.2008.11.005

Zoabli, Gnahoua, Mathieu, Pierre A, & Aubin, Carl-Éric. Back muscles biometry in adolescent idiopathic scoliosis. *The Spine Journal, 2007; 7*(3): 338-44.