



The Open Orthopaedics Journal

Content list available at: <https://openorthopaedicsjournal.com>



REVIEW ARTICLE

Intervention *versus* Observation in Mild Idiopathic Scoliosis in Skeletally Immature Patients

Shu Yan NG¹, Ying Ling NG¹, Ka Ping Cheng¹, Wing Yan Chan¹ and Tsz Ki Ho^{1,*}

¹Spine Technology Ltd, Wanchai, Hong Kong

Abstract:

Introduction:

Observation is the treatment of choice for idiopathic scoliosis with Cobb angles between 15 degrees - 20 degrees in growing children. This passive approach does not address the anxiety of the patient and the stress of the parents. In this paper, we attempt to identify skeletally immature patients with mild scoliosis curvatures that are more at risk of progression and propose possible intervention for this group of subjects.

Methods:

The literature was searched in Pubmed, and additional references were searched manually in the literature.

Results:

Many studies have shown that low serum 25[OH]D level, bone mineral density (BMD), and body mass index (BMI) are related to the curve severity or progression of the curve.

We suggest that skeletally immature patients (< Risser 2) with mild curves be divided into two groups, *viz.* Group O (observation) with a lower risk of progression, and Group I (intervention) with a higher risk of curvature progression. We propose early intervention for the latter group.

It is suggested that pre-menarcheal, skeletally immature patients with mild idiopathic scoliosis, and low vitamin D, BMD, and BMI should be treated. Also, asymmetric foot biomechanics should be addressed, although nutrition and foot orthoses are regarded to have no role in the management of idiopathic scoliosis. The outcome of early intervention may be utterly different from late treatment when the curvature becomes more structural, and the patient more skeletally mature.

Conclusion:

Research is required to prove if the intervention is clinically indicated.

Keywords: Scoliosis, Foot orthosis, Exercise therapy, Observation, Spine, Early intervention.

Article History

Received: August 29, 2020

Revised: October 23, 2020

Accepted: October 26, 2020

1. INTRODUCTION

Idiopathic scoliosis is defined as a 3D spinal deformity, with lateral curvature of the spine ≥ 10 degrees with no identifiable causes. Treatment of the condition varies with the magnitude of curvatures and the remaining growth potential and includes observation, Physiotherapeutic Scoliosis Specific Exercises (PSSE), bracing, and surgery [1]. Of these, PSSE and bracing have the first level of evidence. Observation and surgery, although advocated as treatment, do not have a high level of evidence [1].

Observation has been stipulated as the treatment of choice for Juvenile Idiopathic Scoliosis (JIS) and Adolescent Idiopathic Scoliosis (AIS) with angles between 15 degrees - 20 degrees in growing children [2], as the trajectory of mild curvature is chaotic. Some curvatures progress, some remain stable, and some resolve [3, 4]. Patients are thus followed up regularly until the trajectory of curvatures development becomes clear [3]. Early intervention for mild scoliosis is generally regarded as over-treatment. When the Risser is 0 and 1, patients are usually followed up every three months [2, 5]. When the curves progress >5 degrees between visits or become > 20 degrees - 25degrees, PSSE and bracing are indicated [2, [5].

* Address correspondence to this author at Spine Technology Ltd, Rm 1101, 11/f Methodist House, 36 Hennessy Road, Wanchai, Hong Kong; Tel: 852-25229673; Fax: 852-25273618; E-mail: angelh@ezped.com

This passive approach does not address the patient's anxiety [6] and the stress of the parents, who worry about the progression of curvatures (Fig. 1). Once the curves progress, the non-surgical treatment prescribed will be much

More time-consuming and expensive. The high (40%) drop-out rate in the observation group in observation versus bracing studies [7] suggests that the parents may opt for active intervention instead of being observed for their children [8]. The clinicians may be seeing the condition from a different perspective from the parents.

The current study reviews the literature to see if it is possible to identify skeletally immature patients with mild scoliosis, who are more at risk of progression, and to propose intervention for this group of subjects.

2. MATERIALS AND METHODS

Papers were searched in PUBMED, using the Boolean search operators: ("Prognostic factors" OR "Risk of Progression" OR "Natural History") AND "adolescent idiopathic scoliosis" NOT "surgery." All the abstracts of the papers retrieved were reviewed. Non-English articles and those related to genetics, screening, cardio-pulmonary impact, long-term effects, and pathogenesis were excluded. The articles referenced in the reviewed literature during the search were

also examined to see if they are appropriate for inclusion in the discussion.

3. RESULTS

The search produced 32 articles. After the exclusion, only 18 papers were left. Additional related articles were manually searched from the reviewed articles and included when relevant.

Results revealed that some risk factors are associated with the progression of mild curvatures in skeletally immature patients. These include an initial Cobb angle severity >25 degrees, osteopenia, <13 years of age at diagnosis, premenarcheal, skeletal immaturity [9], low serum 25[OH]D level [10, 11], and low body mass index (BMI) [12, 13]. It is of interest to note that the serum level of 25[OH]D and BMD are inversely correlated to the Cobb angle [10]. Osteopenia [14] and body weight [15] have also been shown to be an independent and prognostic factor for the progression of curvatures in AIS patients.

For intervention, we could not find any studies that have investigated the effects of improving BMI, BMD, and vitamin D3 supplementation on scoliosis curvatures. Yet, custom foot orthoses were reported to improve mild curvatures in juvenile patients with curves below 25 degrees [16].

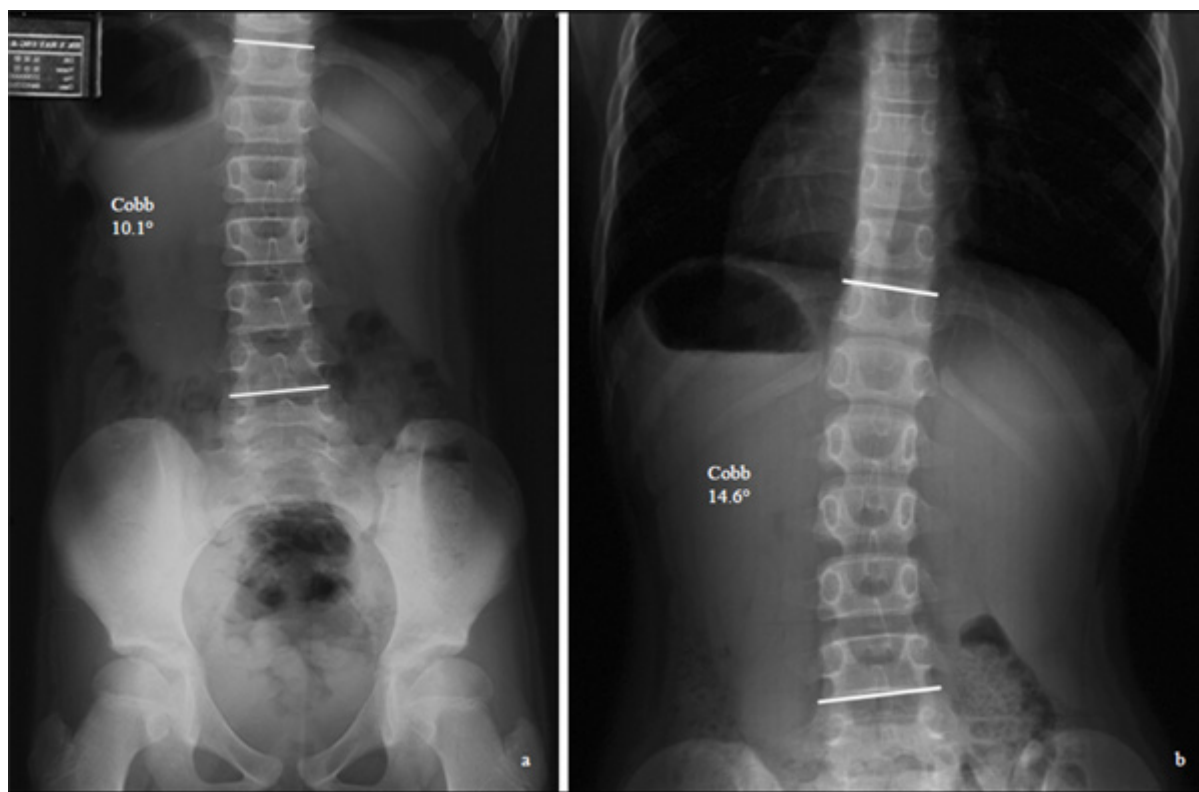


Fig. (1). A girl aged seven years suspected of suffering from mild lumbar scoliosis by her father, who is a Chinese medical practitioner, and was radiographed in February 2012. The X-ray showed that she was at Risser -0, with a Cobb angle of 10 degrees. A subsequent radiograph a year later in May 2013 showed an increase of Cobb angle to 14.6degrees, causing her father to worry. He sought active treatment for her daughter, although he is aware of the measurement errors and SOSORT guidelines.

4. DISCUSSION

4.1. Risk Factors of Curves Progression

There are, at present, no objective ways to know if a particular curvature would progress, despite that some risk factors for curvature progression have been reported (Table 1). Of the ten predictors of curvatures progression reported by Noshchenko *et al.* (2015) [9], the only relevant clinical predictors of progression for the present discussion would be residual growth potential, age <13 years, and osteopenia.

Many studies have shown that AIS patients have significantly lower 25[OH]D level than control subjects [10] [17]. Also, BMI is significantly lower in AIS patients than healthy controls [12, 13, 15]. Interestingly, serum 25[OH]D level [10], BMD [18], and BMI [15] were reported to be inversely related to the Cobb angle. Bodyweight was identified as an independent predictor of curve magnitude in male AIS patients [15]. Recently, Kim *et al.* (2020) reported that underweight is associated with scoliosis in Korean female adolescents [19].

Female gender is a risk factor for progression. The reported female to male ratio ranges from 1.5:1 to 3:1, and increases substantially with increasing age. The prevalence of curves with higher Cobb angles is significantly higher in girls than in boys, rising from 1.41:1 in curves from 10 degrees to 20 degrees to 7.2:1 in curves >40 degrees [20].

Different curve types progress differently. Of the different curve types, Lenke 1 curve (thoracic curve) is the most progressive. Zapata *et al.* (2019) followed the progression of mild curvatures (15 degrees -24 degrees) in patients, with Risser 0 and 1. Of the cohort of 302 consecutive patients, 24

(7.9%) cases progressed to >45 degrees. The Lenke 1 curve was the most common surgically treated type (58%), suggesting that of all the curve patterns, the main thoracic curve pattern is the most likely to progress [4].

4.1.1. Serum Vitamin D Level

Many studies have compared the serum 25[OD]D levels in AIS patients with age-matched healthy controls. They have reported that the serum 25[OD]D level of AIS patients is significantly lower than that of the controls (Table 2) [10, 11, 21]. Balioglu *et al.* (2017), in a retrospective study, evaluated the serum 25[OD]D level of AIS patients and age-matched controls. Results showed that the serum vitamin D level of AIS patients is significantly lower than that of controls [10]. Similar findings were reported by Gozdzińska *et al.* (2016) [11]. Balioglu *et al.* (2017) reported that the serum 25[OH]D level is negatively correlated with the Cobb angle ($p < 0.026$), yet Silva *et al.* (2017) found no relationship between the serum 25[OH]D level and the Cobb angle [10, 21].

4.1.2. Bone Mineral Density (BMD)

Adolescent idiopathic scoliosis patients have been found to have lower bone mineral density than healthy controls [22 - 26]. Osteopenia is a generalized phenomenon [23, 25, 26], involving not only the lumbar spine but also the radius and tibia. Lee *et al.* (2005) studied the BMD and curve magnitude in 919 AIS patients during the peri-pubertal growth period and reported that the BMD was inversely correlated to the curve magnitude [27]. Patients with lower bone mineral density generally had larger Cobb angle, whereas patients with normal BMD had smaller Cobb angles [27]. Subsequent studies by the same group supported the findings [18, 25, 10]. Osteopenia is a significant prognostic factor for curve progression [18].

Table 1. Possible risk factors of progression for skeletally immature patients with mild curvatures.

Gender - female
Curve type – thoracic major (Lenke 1 curve)
Risser -0 – 1
25[OH]D level – insufficiency or deficiency
Bone mineral density – osteopenic
Body mass index - underweight
Asymmetric foot biomechanics

Table 2. List of studies that have shown that the serum 25[OH]D level in AIS patients is significantly lowered than that of age- and sex-matched controls.

Study	Samples (n, age)	Ethnicity	Findings	Recommendation
Bagliou <i>et al.</i> 2016	229 AIS (14.7) vs 389 age-matched controls (13.9)	Turkish	Vit D level lower in AIS group vs., controls ($p=0.001$); negatively correlated w Cobb angle ($p < 0.026$)	Pts monitored for vitamin D sufficiency or deficiency
Gozdzińska <i>et al.</i> (2016)	50 premen (12.6) & 50 postmen (14.6) AIS girls vs 50 premen (11.9) & 50 postmen (13.6) controls	Polish	Premen Gp: 25[OH]D 23.5% lower in AIS pts ($p < 0.05$) than controls Postmen Gp: 25[OH]D 36.2% lower in AIS pts ($p < 0.000$) than controls	Vit D may be associated with scoliosis
Silva <i>et al.</i> (2017)	36 girls and 7 boys AIS (15.3)	Brazilian	97% AIS patients: 25[OH]D <30ng/mL insufficiency and deficiency	No relationship between vitamin D and Cobb angle

Study	Samples (n, age)	Ethnicity	Findings	Recommendation
Catan <i>et al.</i> (2020)	32 AIS girls vs. 32 gender and age-matched controls (14.75)	Romanian	25[OH]D level in AIS pts sig lowered than controls (p<0.0001)	

Abbreviations: Pts – patients, premen – premenarcheal, postmen – postmenarcheal, Gp – Group.

4.1.3. Body Mass Index (BMI)

Many studies have shown that the BMI of AIS patients is significantly less than that of age-matched healthy controls (Table 3) [12, 13, 15, 26, 28, 29]. Wang *et al.* (2012) reported that for AIS patients aged 15-17 years, with a mean Cobb angle of 30.4 degrees, 6.8% had BMI <5th percentile, whereas for the control group, only 3.4% had BMI <5th percentile [15]. Herschkovich *et al.* (2014) and Zheng *et al.* (2017) reported similar findings [30]. The prevalence of severe spinal deformities was 3-fold higher in the underweight group as compared with the overweight group [13].

4.1.4. Asymmetric Foot Biomechanics

There is a lack of studies on the relationship between asymmetric foot biomechanics and spinal curvatures. Yet, Bialek *et al.* (2015) and Lehnert-Schroth (2007) both advocated examination and exercising of the foot in the management of AIS patients [31, 32]. Lee *et al.* (2018)

evaluated 52 juvenile patients with a mean age of 79.5 months with excessive foot pronation and mild idiopathic scoliosis [16]. For those with the relaxed calcaneal stance phase angle difference (RCSPD) of >3 degrees between both feet, custom foot orthoses were prescribed. RCSP is the angle between the midline of the posterior calcaneus and the vertical line when the patient stands relaxed (Fig. 2). At 18 months post-intervention, in the group with the Cobb angle 10 degrees -19 degrees (n=20), the Cobb angle reduced from 17.29±1.8 degrees to 12.43±3.62 degrees. For the group with Cobb angle 20 degrees -24 degrees (n=9), the Cobb angle decreased from 21.62±1.54 degrees to 14.1±5.18 degrees. The improvement is most significant in patients < 6 years of age and a Cobb angle <25 degrees. The Cobb angle improved most at nine months post-intervention [16]. Improvement of Cobb angle, however, was not seen in patients with curvature ≥ 25 degrees. The mechanism involved is not understood; the asymmetric foot biomechanics may reduce the vertebral rotational instability, which often contributes to the progression of scoliosis [33].

Table 3. Studies on body mass index (BMI) in adolescent idiopathic scoliosis (AIS) patients.

Studies	Sample	Age	Cobb	Height Estimation	Findings
Qui <i>et al.</i> 2008 (retrospective controlled study)	613 AIS girls; vs. 449 healthy	12-16 (Chinese)	31°	Bjure's formula	Sig. lower in AIS girls
Wang <i>et al.</i> 2010 (Prospective controlled study)	290 skeletally mature AIS girls vs. 80 healthy controls	16-20 (Chinese)	20-40°; >40°	Arm span used, instead of body height	BMI sig lower in AIS girls with moderate and severe curves
Wang <i>et al.</i> 2012 (Retrospective controlled study)	332 AIS boys vs 356 age-matched controls	10.5-19.5 (Chinese)	30.4°	Bjure's formula	15-17 age; BMI sig lower in AIS boys
Oh <i>et al.</i> 2014 (Prospective randomized controlled study)	420 AIS pts vs. 409 healthy controls	19 (Korean)	23.2°	Bjure's formula	10-25° curve: BMI sig. lower than controls
Herschkovich <i>et al.</i> 2014 (Retrospective study)	59,039 male and 44,210 females	17 (Israeli)		Not reported	IS prevalence sig. higher in underweight males and females;
Wang <i>et al.</i> 2016 (Prospective case-control study)	47 AIS boys vs. 40 age and sex-matched healthy controls	12-20 (Chinese)	40-70°	Bjure's formula	Sig lower BMI in AIS vs. controls
Matusik <i>et al.</i> 2016 (Prospective study)	204 girls, 55 boys, with IS	14.21 (Polish)	10-39°; >40	Bjure's formula	BMI sig. higher in pts w severe curves than those w moderate curves
Kim <i>et al.</i> 2020	133M & 301F IS pts, vs. 8297M and 7681F	Korean		Not reported	BMI sig lower in IS pts (p<0.001)

Table 4. Proposed clinical examination List.

Scoliometer (ATR)
X-ray if the ATR >5o
BMI (kgs/m2)
BMD (QUS)
Serum 25[OH]D
Foot Assessment

Abbreviations: BMI – body mass index; BMD – Bone mineral density; QUS – quantitative ultrasound.



Fig. (2). Measurement of the relaxed calcaneal stance phase angle (RCSP) and the neutral calcaneal stance phase angle (NCSP). A bisector is drawn on the posterior aspect of the calcaneus. **a.** The patient stands erect. The angle between this line and the vertical line is the RCSP. **b.** With the subtalar joint placed in the neutral position, the angle between the bisector and the vertical line is the NCSP. The difference between the RCSP and NCSP represents the extent of excessive foot pronation or supination.

4.2. Clinical Implications

4.2.1. Clinical Examination

Generally, scoliosis screening is performed with a scoliometer, with a cut-off point between 5 degrees -7 degrees. It has to be noted that due to the presence of a rib cage, the angle of trunk rotation (ATR) is usually larger in a thoracic curve than in the thoracolumbar or lumbar curve, for a given curve magnitude. Depending on the outcome of the measurement, patients are either prescribed observation or be followed up by radiographic examination. When the Cobb angle is ≤ 20 degrees, observation is generally prescribed [1], and no further investigation will be performed.

Given the potential risk factors for curves progression, it is proposed that pre-menarcheal, skeletally immature patients with mild curvatures be also assessed for BMI [15], vitamin D level [10], and bone mineral density [14]. Also, the foot should be examined for bilateral differences in excessive pronation or supination (Table 4).

In assessing the BMI, the arm span of the patients can be used instead of the body height. Studies have shown that there is a high linear correlation between arm span and standing

height in healthy children and adolescents ($r^2=0.99$) [34]. The BMI is calculated as body weight in kilograms divided by the square of arm span [34]. When BMI $<5^{\text{th}}$ percentile, it is regarded as low. Kim *et al.* (2020) recently reported that using the World Health Organization BMI z score cut-off would under-estimate the prevalence of AIS [19]. They instead proposed to use the cut-off point of $<18.5\text{kg/m}^2$ as a criterion for defining mild underweight. The criterion may be used to screen early AIS cases [19].

Vitamin D levels can be assessed using blood samples and indirectly by quantitative ultrasonography (QUS) [35]. Yu *et al.* (2013) showed that QUS BMD could be an indicator of vitamin D status in young children [35].

Measurement of BMD may help identify patients with a higher risk of curves progression. QUS, which is devoid of radiation, may be used to evaluate the bone mineral status and bone fragility of growing children [36]. QUS measures the speed of sound (SOS) and broadband ultrasound attenuation (BUA) [37]. The speed of sound (SOS) measurements along the length of a long bone provide information not only on bone density but also on micro-architecture, cortical thickness, and bone elasticity [38, 39]. Readings from QUS cannot be used

interchangeably with DEXA results [40], as they do not measure identical properties of bone tissues [37].

Du *et al.* (2015) compared the SOS of QUS of AIS girls with healthy age- and sex-matched controls [41], and found that AIS patients had lower bone quality than the controls. In the AIS patients, 20.5% had a z score of SOS ≤ 2 , indicating low bone mineral content [41]. The difference was statistically significant for younger patients aged 10-14 ($p = .000$), but not for more skeletally mature patients aged 15 or above. Skeletally immature patients were more osteopenic [41]. The results supported the findings that QUS can be used as a screening tool to assess bone quality in children [41 - 44].

The feet should also be examined for asymmetric foot biomechanics. Lee *et al.* (2018) used a bilateral difference of RCSP of >3 degrees as a cut-off point. As accurate marking of the calcaneus is subjected to errors, we propose to use the difference between the RCSP and the neutral calcaneal stance phase (NCSP) instead (Fig. 2). NCSP is the angle subtended by the midline of the calcaneus and the vertical, with the subtalar joint in the neutral position. The difference between RCSP and NCSP represents the extent of excessive foot pronation or supination. A comparison of the difference bilaterally would reveal if asymmetric foot biomechanics is present.

4.2.2. Proposed Classification of Risk of Progression

4.2.2.1. In Skeletally Immature Patients with Mild Idiopathic Scoliosis

Given the identification of some prognostic factors in skeletally immature patients with mild curves, it may be time to re-think the observation strategy. It is suggested that premenarcheal, skeletally immature patients ($<$ Risser 2) with mild curves be divided into two groups. The observation group (Group O) has a lower risk of progression, and the intervention group (Group I) has a higher risk of progression. Group O may include patients with BMI $>18.5 \text{ kg/m}^2$, with normal serum

vitamin D ($>75 \text{ nmol/L}$), SOS BMD z score >-2 , and (RCSP-NCSP) difference <3 degrees bilaterally. Group I may include female patients with a thoracic curve, BMI $<18.5 \text{ kg/m}^2$, serum 25[OH]D $<75 \text{ nmol/L}$, SOS BMD z-score < -2 , and (RCSP-NCSP) difference >3 degrees bilaterally (Table 4).

4.2.2.2. Proposed Intervention

We are unable to find any studies evaluating the effects of improving serum 25[OH]D level, BMD, and BMI on the scoliosis curvatures. Yet, we opined to modify these risk factors in Group I patients, despite SOSORT held that nutrition and foot orthoses do not play any role in the management of idiopathic scoliosis [1]. The BMI, BMD, and foot biomechanics may act within a narrow window in the development of idiopathic scoliosis. Improving those factors beyond the early stages of curvature development when scoliosis becomes structural may not be helpful.

Early modification of risk factors may modify the course of the disease. Karski *et al.* (2019) showed that abstinence from weight-bearing and vitamin D3 supplementation straighten the tibial varum in infants below three years of age [45]. Yet, after the age of 3, similar treatments have no outcome, and patients require surgery for correction. Tibial varum or medial compartment arthrosis in adults would not respond to vitamin D3 supplementation, even in the presence of vitamin D insufficiency or deficiency. Similarly, interventions that may be effective in mild curvatures in skeletally immature patients may not be useful when the curvatures become more advanced.

For patients with low BMI, dietary advice is suggested (Fig. 3). Those with serum 25[OH]D level $<75 \text{ nmol/L}$ should increase their dietary intake of vitamin D to increase the BMD [46]. Cheng *et al.* (2005) showed that increase cheese intake increases cortical bone mass accrual [47], suggesting that dietary manipulation can improve the BMD in children. For young patients with mild spinal curvatures and asymmetric foot biomechanics, custom foot orthoses may be prescribed.

Table 5. Classification of skeletally immature patients with mild curvatures into the Group O, the observation group, and the Group I, the intervention group, using different risk parameters. RCSP – relaxed calcaneal stance phase, NCSP – neutral calcaneal stance phase.

Parameters	Group O	Group I
Gender	Male	Female
Risser	≥ 2	< 1
Serum 25[OH]D	$\geq 75 \text{ nmol/L}$	$< 75 \text{ nmol/L}$
Bone mineral density	SOS BMD z score $>- 2$	SOS BMD z score $\leq - 2$
Body mass index	$\geq 18.5 \text{ kg/m}^2$	$< 18.5 \text{ kg/m}^2$
(RCSP-NCSP)	$<3^\circ$	$\geq 3^\circ$

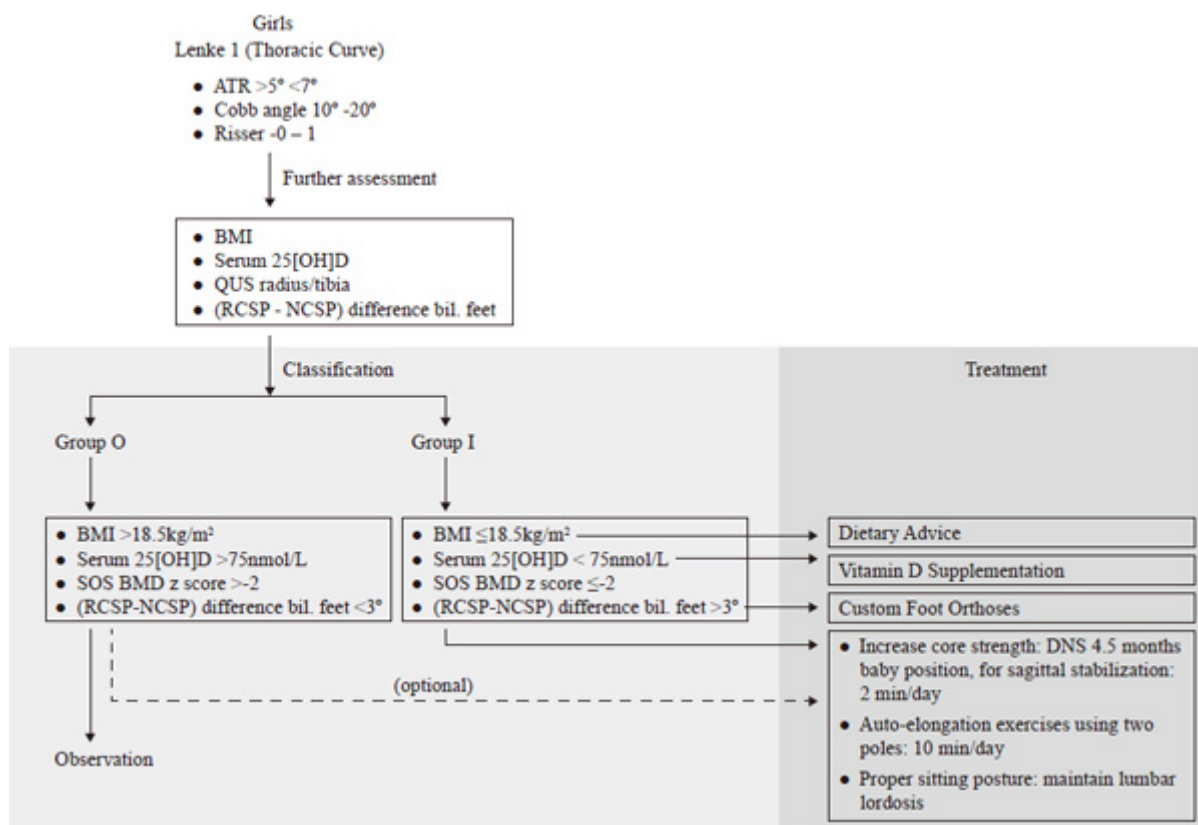


Fig. (3). The proposed intervention in Group I skeletally immature patients with mild curvature ≤ 20 degrees.

At-risk patients should learn simple PSSE exercises to stabilize the curvature. Simple dynamic neuromuscular stabilization (DNS) exercise, adopting a 4.5 months baby posture, may be prescribed for core strengthening [48]. The patient lies supine and flexes both hips and knees to 90

degrees, and uses the diaphragm for breathing (Fig. 4). This position is to be held for 1-2 minutes, and the exercise has to be performed 1-2 times daily. The exercise trains the brain and regulates the intra-abdominal pressure [48]. Concurrently, the child can perform the auto-elongation exercise using two poles (Fig. 5) [32].



Fig. (4). The exercise, adopting a 4.5-month-old baby posture, regulates the intra-abdominal pressure and stabilizes the spine sagittally.



Fig. (5). The exercise using two poles to auto-elongate the trunk. The patient uses the diaphragm to inhale. Meanwhile, he slowly wriggles the spine to extend the trunk. During exhalation, the patient tenses up all the muscles and forces the poles onto the floor.

Apart from simple exercises, the patient should adopt a proper sitting posture. Von Loon *et al.* (2009) have shown that forced lordosis in the thoracolumbar area would reduce the curve magnitude of a double major curve by >15% [49]. Whether the adoption of proper sitting posture would benefit other curve types has not been studied. Yet, the children should adopt corrective postures during daily activities (Fig. 6).

For Group I patients, active intervention is thus suggested (Fig. 7), particularly given the recent findings of a high progression rate (66%) in adolescents with curves 15 degrees – 19 degrees, and Risser 0-1. More importantly, perhaps, 7.8% of the patients progress to >45 degrees and only 3% of them have their curves resolved [4]. Lonstein and Carlson (1984) reported that resolution is more common in less mature patients with

curves <15 degrees [50]. These justify the need for early intervention in Group I patients. Also, the intervention is free of side effects. A daily dose of 400-800 IU, when indicated, is safe, particularly in the presence of vitamin D insufficiency and deficiency [51]. Further, a proper made custom foot orthoses would not cause any complications.

Whether these interventions have any impact on mild scoliosis curvatures in young patients with Risser -0 to 1 remains to be studied. However, the management would possibly help prevent some future morbidities that are associated with low BMI, low 25[OH]D, low BMD, and asymmetric foot biomechanics. In this perspective, the intervention is justified and should not be regarded as over-treatment.

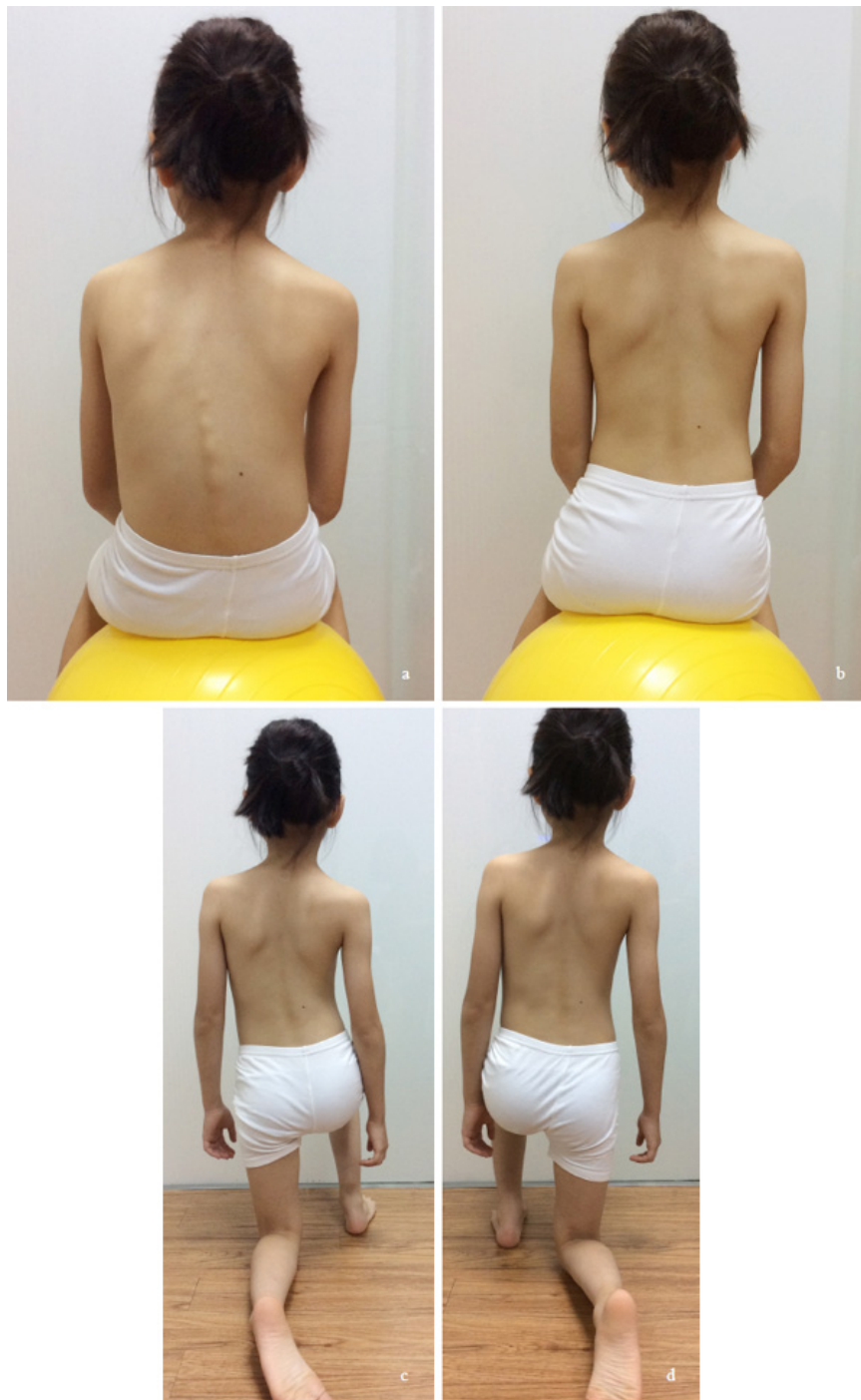


Fig. (6). The patient has to be instructed to maintain proper posture. **a.** the patient nine years of age sits with the back slouched. The left thoracic curve is evident. **b.** the patient attempts to sit straight with the lumbar in physiological lordosis. It is evident that the curve slightly reduces, despite mild compensation in the pelvis. **c.** kneeling with the right knee forward increases the left scoliosis curvature, whereas kneeling with the left knee forward **(d)** reduces the curvature.

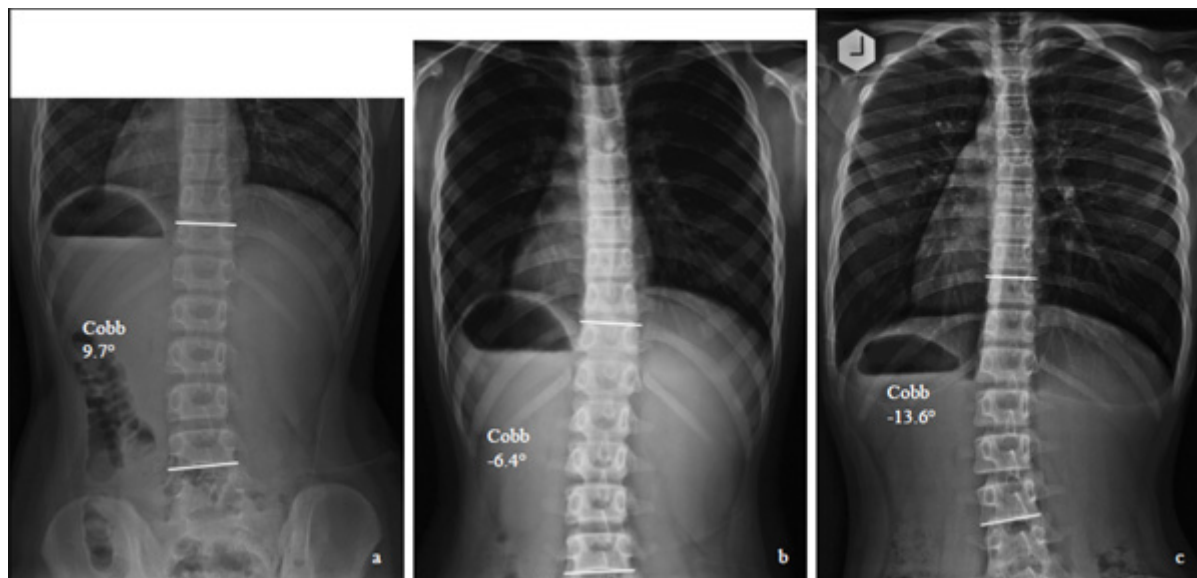


Fig. (7). The radiograph of the patient referred to in Fig. 1. After her father found that the curve progressed, her father instructed his daughter to perform the two poles exercises for about 10 minutes each day after dinner. Also, she was prescribed a pair of custom foot orthoses. After three months, in August 2013 (a), the Cobb angle was found to reduce to 9.7 degrees. Subsequent radiographs in June 2015 (b) and August 2016 (c), when the Risser stages were 0 and 3 respectively, showed that the Cobb angle remained stable, thus alleviating the worries of her father. Whether the curvature stabilized by itself or as a result of the intervention was, however, unknown.

5. LIMITATION AND FUTURE STUDIES

The above discussion is based on existing knowledge. There is, at present, no evidence to support the classification of mild scoliosis based on the risk of progression, and the effectiveness of the intervention in the management of mild scoliosis curvatures.

Studies are required to determine if the classification of skeletally immature patients with mild curvature measuring < 20 degrees, and Risser -0 and 1 into Group O and Group I, is reliable and clinically meaningful. Also, the cut-off points for each of the progression risk factors need to be determined.

The effectiveness of the proposed intervention on scoliosis requires studies and validation, although the management may reduce future morbidities associated with low serum 25[OH]D, BMD, and low BMI.

CONCLUSION

Instead of passive observation, the current paper proposes active intervention in pre-menarcheal, skeletally immature patients with Risser < 2 , Cobb angle ≤ 20 degrees, low BMI, 25[OH]D, BMD level, and with asymmetric foot biomechanics. Research is required to prove if the intervention is clinically useful or not in the management of skeletally immature patients with mild curvatures.

CONSENT FOR PUBLICATION

Informed consent was obtained from the patient for accompanying images.

FUNDING

No funding to declare.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

- [1] Negrini S, Donzelli S, Aulisa AG, *et al.* 2016 SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis Spinal Disord* 2018; 13(3): 3. [<http://dx.doi.org/10.1186/s13013-017-0145-8>] [PMID: 29435499]
- [2] Negrini S, Aulisa AG, Aulisa L, *et al.* 2011 SOSORT guidelines: Orthopaedic and Rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis* 2012; 7(1): 3. [<http://dx.doi.org/10.1186/1748-7161-7-3>] [PMID: 22264320]
- [3] de Mauroy JC. Idiopathic scoliosis and chaos. *Stud Health Technol Inform* 2008; 135: 53-7. [PMID: 18401080]
- [4] Zapata KA, Sucato DJ, Lee MC, Jo C-H. Skeletally immature patients with adolescent idiopathic scoliosis curves 15° - 24° are at high risk for progression. *Spine Deform* 2019; 7(6): 870-4. [<http://dx.doi.org/10.1016/j.jspd.2019.02.012>] [PMID: 31731996]
- [5] Burton MS. Diagnosis and treatment of adolescent idiopathic scoliosis. *Pediatr Ann* 2013; 42(11): 224-8. [<http://dx.doi.org/10.3928/00904481-20131022-09>] [PMID: 24168116]
- [6] Sanders AE, Andras LM, Iantorno SE, Hamilton A, Choi PD, Skaggs DL. Clinically significant psychological and emotional distress in 32% of adolescent idiopathic scoliosis patients. *Spine Deform* 2018; 6(4): 435-40. [<http://dx.doi.org/10.1016/j.jspd.2017.12.014>] [PMID: 29886916]
- [7] Coillard C, Circo AB, Rivard CH. A prospective randomized controlled trial of the natural history of idiopathic scoliosis versus treatment with the SpineCor brace. *Sosort Award 2011 winner. Eur J Phys Rehabil Med* 2014; 50(5): 479-87. [PMID: 25251736]
- [8] Weinstein SL, Dolan LA, Wright JG, Dobbs MB. Effects of bracing in adolescents with idiopathic scoliosis. *N Engl J Med* 2013; 369(16): 1512-21.

- [9] [\[http://dx.doi.org/10.1056/NEJMoa1307337\]](http://dx.doi.org/10.1056/NEJMoa1307337) [PMID: 24047455]
Noshchenko A, Hoffecker L, Lindley EM, *et al.* Predictors of spine deformity progression in adolescent idiopathic scoliosis: A systematic review with meta-analysis. *World J Orthop* 2015; 6(7): 537-58.
[\[http://dx.doi.org/10.5312/wjo.v6.i7.537\]](http://dx.doi.org/10.5312/wjo.v6.i7.537) [PMID: 26301183]
- [10] Balioglu MB, Aydin C, Kargin D, *et al.* Vitamin-D measurement in patients with adolescent idiopathic scoliosis. *J Pediatr Orthop B* 2017; 26(1): 48-52.
[\[http://dx.doi.org/10.1097/BPB.0000000000000320\]](http://dx.doi.org/10.1097/BPB.0000000000000320) [PMID: 27089048]
- [11] Goździalska A, Jaśkiewicz J, Knapik-Czajka M, *et al.* Association of calcium and phosphate balance, vitamin D, PTH, and calcitonin in patients with adolescent idiopathic scoliosis. *Spine* 2016; 41(8): 693-7.
[\[http://dx.doi.org/10.1097/BRS.0000000000001286\]](http://dx.doi.org/10.1097/BRS.0000000000001286) [PMID: 27064335]
- [12] Oh CH, Yoon SH, Park H-C, Park CO, Kim SY. A comparison of the somatometric measurements of adolescent males with and without idiopathic scoliosis. *J Spinal Disord Tech* 2014; 27(1): E26-31.
[\[http://dx.doi.org/10.1097/BSD.0b013e31828af710\]](http://dx.doi.org/10.1097/BSD.0b013e31828af710) [PMID: 23511644]
- [13] Hershkovich O, Friedlander A, Gordon B, *et al.* Association between body mass index, body height, and the prevalence of spinal deformities. *Spine J* 2014; 14(8): 1581-7.
[\[http://dx.doi.org/10.1016/j.spinee.2013.09.034\]](http://dx.doi.org/10.1016/j.spinee.2013.09.034) [PMID: 24332597]
- [14] Wang ZW, Hung VWY, Chen HX, *et al.* Bone mineral density as a prognostic factor for curve progression in adolescent idiopathic scoliosis: A longitudinal validation study. *Scoliosis* 2015; 10(Suppl. 1): O9.
[\[http://dx.doi.org/10.1186/1748-7161-10-S1-O9\]](http://dx.doi.org/10.1186/1748-7161-10-S1-O9)
- [15] Wei-Jun W, Xu S, Zhi-Wei W, Xu-Sheng Q, Zhen L, Yong Q. Abnormal anthropometric measurements and growth pattern in male adolescent idiopathic scoliosis. *Eur Spine J* 2012; 21(1): 77-83.
[\[http://dx.doi.org/10.1007/s00586-011-1960-x\]](http://dx.doi.org/10.1007/s00586-011-1960-x) [PMID: 21826498]
- [16] Lee JG, Yun YC, Jo WJ, Seog TY, Yoon Y-S. Correlation of radiographic and patient assessment of spine following correction of nonstructural component in juvenile idiopathic scoliosis. *Ann Rehabil Med* 2018; 42(6): 863-71.
[\[http://dx.doi.org/10.5535/arm.2018.42.6.863\]](http://dx.doi.org/10.5535/arm.2018.42.6.863) [PMID: 30613080]
- [17] Mayes T, Anadio JM, Sturm PF. Prevalence of vitamin d deficiency in pediatric patients with scoliosis preparing for spinal surgery. *Spine Deform* 2017; 5(6): 369-73.
[\[http://dx.doi.org/10.1016/j.jspd.2017.03.008\]](http://dx.doi.org/10.1016/j.jspd.2017.03.008) [PMID: 29050711]
- [18] Hung V W Y, Qin L, Cheung C S K, *et al.* 2005.
- [19] Kim S, Uhm J-Y, Chae D-H, Park Y. 2020.
- [20] Konieczny MR, Senyurt H, Krauspe R. Epidemiology of adolescent idiopathic scoliosis. *J Child Orthop* 2013; 7(1): 3-9.
[\[http://dx.doi.org/10.1007/s11832-012-0457-4\]](http://dx.doi.org/10.1007/s11832-012-0457-4) [PMID: 24432052]
- [21] Silva RTE, Fernandes RJR, Ono AHA, *et al.* Role of different hormones in the pathogenesis and severity of adolescent idiopathic scoliosis. *Acta Ortop Bras* 2017; 25(1): 15-7.
[\[http://dx.doi.org/10.1590/1413-785220172501168600\]](http://dx.doi.org/10.1590/1413-785220172501168600) [PMID: 28642644]
- [22] Cook SD, Harding AF, Morgan EL, *et al.* Trabecular bone mineral density in idiopathic scoliosis. *J Pediatr Orthop* 1987; 7(2): 168-74.
[\[http://dx.doi.org/10.1097/01241398-198703000-00011\]](http://dx.doi.org/10.1097/01241398-198703000-00011) [PMID: 3558800]
- [23] Cheng JCY, Guo X. Osteopenia in adolescent idiopathic scoliosis. A primary problem or secondary to the spinal deformity? *Spine* 1997; 22(15): 1716-21.
[\[http://dx.doi.org/10.1097/00007632-199708010-00006\]](http://dx.doi.org/10.1097/00007632-199708010-00006) [PMID: 9259781]
- [24] Cheng JCY, Qin L, Cheung CSK, *et al.* Generalized low areal and volumetric bone mineral density in adolescent idiopathic scoliosis. *J Bone Miner Res* 2000; 15(8): 1587-95.
[\[http://dx.doi.org/10.1359/jbmr.2000.15.8.1587\]](http://dx.doi.org/10.1359/jbmr.2000.15.8.1587) [PMID: 10934658]
- [25] Yip BHK, Yu FWP, Wang Z, *et al.* Prognostic value of bone mineral density on curve progression: A longitudinal cohort study of 513 girls with adolescent idiopathic scoliosis. *Sci Rep* 2016; 6: 39220.
[\[http://dx.doi.org/10.1038/srep39220\]](http://dx.doi.org/10.1038/srep39220) [PMID: 27991528]
- [26] Wang W, Wang Z, Zhu Z, Zhu F, Qiu Y. Body composition in males with adolescent idiopathic scoliosis: a case-control study with dual-energy X-ray absorptiometry. *BMC Musculoskelet Disord* 2016; 17: 107.
[\[http://dx.doi.org/10.1186/s12891-016-0968-0\]](http://dx.doi.org/10.1186/s12891-016-0968-0) [PMID: 26928006]
- [27] Lee WTK, Cheung CSK, Tse YK, *et al.* Association of osteopenia with curve severity in adolescent idiopathic scoliosis: a study of 919 girls. *Osteoporos Int* 2005; 16(12): 1924-32.
[\[http://dx.doi.org/10.1007/s00198-005-1964-7\]](http://dx.doi.org/10.1007/s00198-005-1964-7) [PMID: 16163440]
- [28] Qui Y, Qiu XS, Sun X, *et al.* Body mass index in girls with adolescent idiopathic scoliosis. *Zhonghua Wai Ke Za Zhi* 2008; 46(8): 588-91.
[PMID: 18844053]
- [29] Wang W-J, Hung VW-Y, Lam T-P, *et al.* The association of disproportionate skeletal growth and abnormal radius dimension ratio with curve severity in adolescent idiopathic scoliosis. *Eur Spine J* 2010; 19(5): 726-31.
[\[http://dx.doi.org/10.1007/s00586-009-1247-7\]](http://dx.doi.org/10.1007/s00586-009-1247-7) [PMID: 20047062]
- [30] Zheng Y, Dang Y, Yang Y, *et al.* 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 Deform* 2017; 5(6): 374-80.
[\[http://dx.doi.org/10.1016/j.jspd.2017.04.002\]](http://dx.doi.org/10.1016/j.jspd.2017.04.002) [PMID: 29050712]
- [31] Bialek M. Mild angle early onset idiopathic scoliosis children avoid progression under FITS method (Functional Individual Therapy of Scoliosis). *Medicine (Baltimore)* 2015; 94(20): e863.
[\[http://dx.doi.org/10.1097/MD.0000000000000863\]](http://dx.doi.org/10.1097/MD.0000000000000863) [PMID: 25997065]
- [32] Lehnert-Schroth C. Three-Dimensional Treatment for Scoliosis: Physiotherapeutic Method for Deformities of the Spine 2007.
- [33] Sarwark JF, Castelein RM, Maqsood A, Aubin CE. The biomechanics of induction in adolescent idiopathic scoliosis: Theoretical factors. *J Bone Joint Surg Am* 2019; 101(6)e22
[\[http://dx.doi.org/10.2106/JBJS.18.00846\]](http://dx.doi.org/10.2106/JBJS.18.00846) [PMID: 30893239]
- [34] Cheng JC, Leung SS, Lau J. Anthropometric measurements and body proportions among Chinese children. *Clin Orthop Relat Res* 1996; (323): 22-30.
[\[http://dx.doi.org/10.1097/00003086-199602000-00004\]](http://dx.doi.org/10.1097/00003086-199602000-00004) [PMID: 8625584]
- [35] Yu X, Zhang J, Yan C, Shen X. Relationships between serum 25-hydroxyvitamin D and quantitative ultrasound bone mineral density in 0-6 year old children. *Bone* 2013; 53(1): 306-10.
[\[http://dx.doi.org/10.1016/j.bone.2012.12.012\]](http://dx.doi.org/10.1016/j.bone.2012.12.012) [PMID: 23270750]
- [36] Omar A, Turan S, Bereket A. Reference data for bone speed of sound measurement by quantitative ultrasound in healthy children. *Arch Osteoporos* 2006; 1(1-2): 37-41.
[\[http://dx.doi.org/10.1007/s11657-006-0006-1\]](http://dx.doi.org/10.1007/s11657-006-0006-1)
- [37] Baroncelli GI. Quantitative ultrasound methods to assess bone mineral status in children: technical characteristics, performance, and clinical application. *Pediatr Res* 2008; 63(3): 220-8.
[\[http://dx.doi.org/10.1203/PDR.0b013e318163a286\]](http://dx.doi.org/10.1203/PDR.0b013e318163a286) [PMID: 18287958]
- [38] Hayman SR, Drake WM, Kendler DL, *et al.* North American male reference population for speed of sound in bone at multiple skeletal sites. *J Clin Densitom* 2002; 5(1): 63-71.
[\[http://dx.doi.org/10.1385/JCD:5:1:063\]](http://dx.doi.org/10.1385/JCD:5:1:063) [PMID: 11940730]
- [39] Zadik Z, Price D, Diamond G. Pediatric reference curves for multi-site quantitative ultrasound and its modulators. *Osteoporos Int* 2003; 14(10): 857-62.
[\[http://dx.doi.org/10.1007/s00198-003-1456-6\]](http://dx.doi.org/10.1007/s00198-003-1456-6) [PMID: 12915957]
- [40] Chong KH, Poh BK, Jamil NA, Kamaruddin NA, Deurenberg P. Radial quantitative ultrasound and dual energy x-ray absorptiometry: intermethod agreement for bone status assessment in children. *BioMed Res Int* 2015; 2015: 232876.
[\[http://dx.doi.org/10.1155/2015/232876\]](http://dx.doi.org/10.1155/2015/232876) [PMID: 25922831]
- [41] Du Q, Zhou X, Li JA, *et al.* Quantitative ultrasound measurements of bone quality in female adolescents with idiopathic scoliosis compared to normal controls. *J Manipulative Physiol Ther* 2015; 38(6): 434-41.
[\[http://dx.doi.org/10.1016/j.jmpt.2015.06.009\]](http://dx.doi.org/10.1016/j.jmpt.2015.06.009) [PMID: 26198594]
- [42] Lin JD, Chen JF, Chang HY, Ho C. Evaluation of bone mineral density by quantitative ultrasound of bone in 16,862 subjects during routine health examination. *Br J Radiol* 2001; 74(883): 602-6.
[\[http://dx.doi.org/10.1259/bjr.74.883.740602\]](http://dx.doi.org/10.1259/bjr.74.883.740602) [PMID: 11509395]
- [43] Miller PD, Njeh CF, Jankowski LG, Lenchik L. What are the standards by which bone mass measurement at peripheral skeletal sites should be used in the diagnosis of osteoporosis? *J Clin Densitom* 2002; 5(Suppl.): S39-45.
[\[http://dx.doi.org/10.1385/JCD:5:3S:S39\]](http://dx.doi.org/10.1385/JCD:5:3S:S39) [PMID: 12464710]
- [44] Zadik Z, Sinai T, Borondukov E, Zung A, Yaniv I, Reifen R. Longitudinal monitoring of bone accretion measured by quantitative multi-site ultrasound (QUS) of bones in patients with delayed puberty (a pilot study). *Osteoporos Int* 2005; 16(9): 1036-41.
[\[http://dx.doi.org/10.1007/s00198-004-1795-y\]](http://dx.doi.org/10.1007/s00198-004-1795-y) [PMID: 15616757]
- [45] Tomasz K, Jacek K, Marian D. "Syndrome of Contractures" According to Prof. Hans Mau; Problems of Shanks, Knees, Hips, Pelvis and Spine; Children, Adolescents, Adults, Diagnosis,

- Treatment. *Surg Sci* 2019; 10(01): 24-38.
[<http://dx.doi.org/10.4236/ss.2019.101004>]
- [46] Inoue T, Sugiyama T, Matsubara T, Kawai S, Furukawa S. Inverse correlation between the changes of lumbar bone mineral density and serum undercarboxylated osteocalcin after vitamin K2 (menatetrenone) treatment in children treated with glucocorticoid and alfacalcidol. *Endocr J* 2001; 48(1): 11-8.
[<http://dx.doi.org/10.1507/endocrj.48.11>] [PMID: 11403096]
- [47] Cheng S, Lyytikäinen A, Kröger H, *et al.* Effects of calcium, dairy product, and vitamin D supplementation on bone mass accrual and body composition in 10-12-y-old girls: a 2-y randomized trial. *Am J Clin Nutr* 2005; 82(5): 1115-26.
[<http://dx.doi.org/10.1093/ajcn/82.5.1115>] [PMID: 16280447]
- [48] Frank C, Kobesova A, Kolar P. Dynamic neuromuscular stabilization & sports rehabilitation. *Int J Sports Phys Ther* 2013; 8(1): 62-73.
[PMID: 23439921]
- [49] vanLoon PJ, Roukens M, Wever D. Brace treatment with progressive lordotic forces at the thoracolumbar junction in adolescent scoliosis and hyperkyphosis. *Scoliosis* 2009; 4(Suppl.): O47.
[<http://dx.doi.org/10.1186/1748-7161-4-S1-O47>]
- [50] Lonstein JE, Carlson JM. The prediction of curve progression in untreated idiopathic scoliosis during growth. *J Bone Joint Surg Am* 1984; 66(7): 1061-71.
[<http://dx.doi.org/10.2106/00004623-198466070-00013>] [PMID: 6480635]
- [51] Pela I. How much vitamin D for children? *Clin Cases Miner Bone Metab* 2012; 9(2): 112-7.
[PMID: 23087722]

© 2020 Yan NG *et al.*

This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International Public License (CC-BY 4.0), a copy of which is available at: <https://creativecommons.org/licenses/by/4.0/legalcode>. This license permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.