REVIEW
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School scoliosis screening, a program useful not only for the prevention of scoliosis. Part one: historical data, policies of administration, clinical and practical considerations, setting up a school scoliosis screening program and an effective protocol.

Theodoros B. Grivas

ABSTRACT

This report presents an introduction and brief historical data about the school scoliosis screening programs (SSS) and the universal policies for its administration. The clinical and practical considerations/topics for setting up and running the SSS programs for any SSS program examiner are described and analyzed. A protocol is proposed to implement a SSS program. The parameters of the proposed protocol are presented and analyzed, explaining why these specific parameters are included. This protocol may hopefully be used by other interested in SSS orthopaedic teams for the in-depth study of idiopathic scoliosis (IS).

KEYWORDS: School scoliosis screening - SSS, history, administration, clinical considerations, practical considerations, setting up SSS, protocol, anthropometry, Adam test

A. Introduction and brief historical data.

The currently implemented School Scoliosis Screening (SSS) programs aim to the prevention of idiopathic scoliosis (IS). The original and main aim of SSS is to identify most or all the individuals with *truncal asymmetry (TA)* and / or unrecognized IS at an early stage when a less invasive treatment is more effective, in other words it is prevention! The preventive examination for scoliosis in the general health assessment programs of youngsters and especially of school children started in Europe from the beginning of the 20th century. In Greece the school doctors were also assessing the children for scoliosis as well. There is evidence that these programs were implemented in many European countries and cities, also in Greece, and documented in a booklet named «Η ΣΚΟΛΙΩΣΙΣ», published in Athens 1915, written Dr Em. Lambadarios, and published by Thanos Tzavelas, (Fig. 1). The mentioned cities and countries were Hamburg, Lausanne, Par-

CORRESPONDING AUTHOR, GUARANTOR

Theodoros B. Grivas, MD PhD, Orthopaedic Surgeon.
Former head of the Traumatology and Orthopaedic Department of "Tzaneio" General Hospital of Piraeus, Piraeus, Greece.
Tel. +30-6944897585, Email: tgri69@otenet.gr; grivastb@gmail.com

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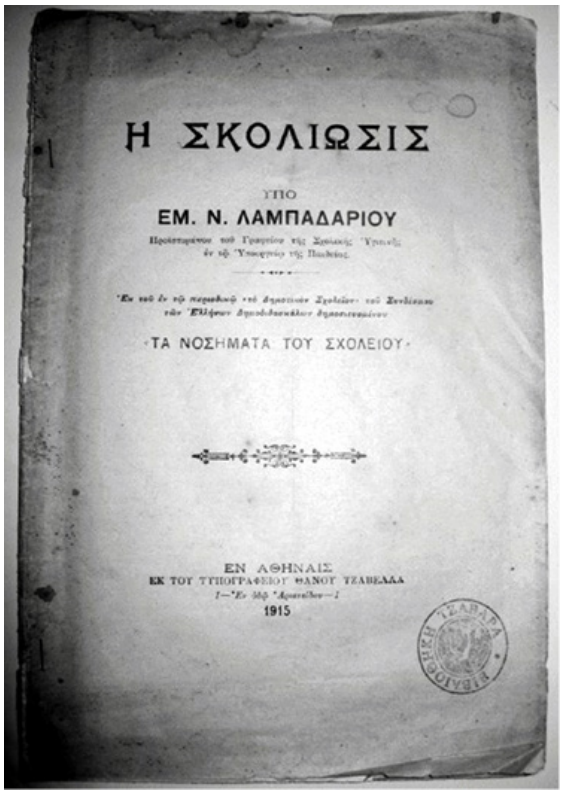
is, Athens, and Sweden.

Fifty years later, in 1963, SSS began in Aitken, a town in Minnesota, organized by Dr. Lonstein. Dr Lonstein stated that by the screening the benefits are great. The curves are detected when they are small, allowing progressive deformities to be detected early, promptly braced and deterioration prevented. The need for future surgical correction is thus decreased. The routine screening in Minnesota of school children for spine deformities has proved to be an effective method for the early detection of spine deformities. For the SSS programs Dr Lonstein stated that "The screening test is rapid and easy -"a 30-second investment for a lifetime of dividends", [1,2,3]. Dr. Dean MacEwen, was also involved in the early development of voluntary SSS programs by implementing them in schools in the state of Delaware in the 1960s, [4].

In 1975 Dr. Panagiotis Smyrnis organized and conducted the first SSS in Athens, Greece. In Attica 3494 children from 12-14 years of age were examined visually, conducting the Adam test. The percentage of clinically positive were found to be 10% and the percentage of radiologically positive of confirmed scoliosis for curves of 10 degrees or more, was 4.6% for girls and 1.1% for boys. This study also found that children with blond hair and blue eyes are more prone to scoliosis, compared to children with dark features. Dr Smyrnis noted that the bending test is still the most common, because it is simple and easy to use even for non-experts, but also a second check before any radiological examination is needed, and also in a calm environment. He stated that "it should be emphasized that apart from the size of the hump, its position in the spine has a clinical significance". Moreover, he recommended that the most critical age for mass screening is from 10-13 years old, when 85% of clinically significant IS appear, and it is observed usually 3:1 ratio between clinically and radiologically positive children, [5,54]. The results of this program were initially presented at the 3rd "N. Giannestra" Symposium in September 1975, and this program's outcomes publications followed, [55,56,57]. Consequently, similar SSS programs were implemented by interested by SSS orthopaedic teams in many Hellenic cities.


Η ΣΚΟΛΙΩΣΙΣ

ΥΠΟ

ΕΜ. Ν. ΛΑΜΠΑΔΑΡΙΟΥ

ΤΑ ΝΟΣΗΜΑΤΑ ΤΟΥ ΣΧΟΛΕΙΟΥ

ΕΝ ΑΘΗΝΑΙΣ

1915

Figure 1. [**ΕΜ. Ν. ΛΑΜΠΑΔΑΡΙΟΣ Η ΣΚΟΛΙΩΣΙΣ**. *ΤΑ ΝΟΣΗΜΑΤΑ ΤΟΥ ΣΧΟΛΕΙΟΥ. ΕΝ ΑΘΗΝΑΙΣ. Εκ του τυπογραφείου Θάνου Τζαβέλλα , Εν οδώ Αριστείδου 1, 1915.]*

The "Thriasio" and "Tzaneio" Hospital SSS program was conducted during 1996-2009 and 2009-2019 respectively. During this period the author of this report was servicing the Hellenic National Health System, and 24.223 children were examined. Further information on the history and reported outcomes of Hellenic SSS programs up to 2000, is provided in the book entitled: "School Screening in Greece", [5].

B. Policies of Administration of SSS programs.

The worldwide encouraging and adverse polices for implementation of SSS programs vary, [6,7]. The role of the US PREVENTIVE Services Task Force (USPSTF) has initially been negatived for years regarding the school screening implementation, [8,9]. Recently there is a universal tendency of a pro-SSS programs implementation, including the USPSTF as well. The USPSTF in its more recent report conclud-

ed that screening can detect adolescent idiopathic scoliosis, (AIS). Bracing and possibly exercise treatment can interrupt or slow progression of curvature in adolescence, [10]. Currently it seems that the pendulum swings back to scoliosis screening, [11].

For the set-up of our SSS program, the hospital administration applied to the Greek Ministry of Education for obtaining permission to examine the children in the school setting. The Ministry of Education sent a circular to Elementary and High Schools with its positive permission recommending the examination. The School Principal was provided with the educational material about our SSS program by a screening team member and the teachers distributed the consent letter, prepared by the SSS team, for the parents who were requested to sign for their children to be examined. In case of a scoliometric documented TA of the examinees, asymmetry indicating re-examination, the team prepared an invitation/referral letter of the SSS program for re-examination of the child or adolescent in the scoliosis clinic of the hospital. The examinees presented this letter to their parents.

The examination team usually consists of well-trained to implement SSS programs Orthopaedic doctors, Physiatrists, General Medicine doctors, Health visitors, Nurses, and Physiotherapists.

The financial information for the SSS programs, which must be used by the national decision-makers administrators, should be based on the studies of the direct cost of the program. The direct cost of a SSS program can be reduced to a minimum if it is well organized and carried out on a voluntary basis, [12].

Our training center for certified examiners for the SSS programs and our SSS program was legislated by the Hellenic State, see ΦΕΚ Αρ. Φύλλου *4168*, Τεύχος *B, 30/11/2017*, based on the "Special Training Center for the Implementation of the Student Screening Program for Scoliosis and Other Spinal Deformities".

C. Setting up SSS programs: Clinical and practical considerations

The training programs must include three trajectories. The first is the theoretical education on the spinal anatomy, physiology, pathology and treatment related to scoliosis and other spinal deformities. The second is the involvement in the performance of the SSS program. The third is the attendance of the scoliotic clinic in hospital, where the referred children are re-examined.

Before the involvement in any SSS program the examiners must be trained and certified in an official certification training center and must be familiarized into the following topics, [12].

1. How to obtain permission from the a) Administration of the Hospital, and b) the Ministry of Education to perform SSS.

2. How the groups of examiners are organized. The team includes orthopaedic surgeons, health visitors, physiotherapists, school nurses where available.

3. The instruments/forms on which the team must be appropriately trained for the implementation of the SSS.

4. Familiarization and training in confronting the behavioural issues of the children and adolescent age groups (children in primary and secondary education).

5. Methods for communicating with the School Administration, which is significant for the success of the SSS.

6. Management of the "materials" including the various forms to fill (protocol, consent and re-examination, at the scoliosis clinic, letters), and how to examine the children and use the relevant instruments, including the scoliometer, the body weight scale and the height measurement apparatus.

7. The decision making for the time and the screening frequency and performance, which is variable, depending on many parameters (e.g. how to schedule the screening in order to minimally disturb the educational program of the children).

8. Management of the data collection, its processing and analysis.

9. How children are monitored (those asymmetric children at risk of developing scoliosis or scoliotics), including referral to the outpatient clinic for re-assessment and the onset of early non-operative (conservative) treatment.

10. Increasing the community's awareness and

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insight into scoliosis by presenting and publishing data collected through SSS programs, [13].

Discussing the item 9 of the above list we note the following facts. The main burden of discontinuation of various school screening programs internationally was the phenomenon of over-referrals from SSS programs and of the ongoing controversy over its application. The over-referrals in the scoliosis clinics are mainly included in the *false positives* group, that is the children clinically diagnosed having a probable scoliosis due to existence of a hump, found conducting the Adam's test. This creates unjustified stress to the family and the child, but also unjustified transport expenditures for the visit to the scoliosis clinic and loss of the working day and wage for the parents. However, the real problem is the *false negative* cases, that is children who missed the opportunity for early diagnosis. This can be minimized by a certified skilled examination team which should always use the scoliometer, [14]. The amount of scoliometric TA by age for recommending re-examination, is discussed well along this report.

As far as the burden created by the *false positive* referrals is concerned, we note the following: It must be widely accepted that, with SSS programs, a chance is mainly given to the school-aged population to rule out those who will be at risk for developing scoliosis, rather than discover those who definitely have scoliosis, and it is easy to diagnose. This is especially true if there is a significant surface deformity justifying the central axis (that is the spinal) deformity. There is something else that must be highlighted and clearly understood. The SSS program aims at detection of surface deformity and/or the existing number of scoliosis cases; it does not aim at predicting which scoliotic curves will create deformity that will require some type of conservative or surgical treatment. The criteria used to predict deterioration of a small or moderate curve are unfortunately not related to SSS programs. All asymmetric children, therefore, who will be entitled to develop scoliosis, [15], will miss the opportunity to be picked up and will probably be discovered too late, when surgery will be the only treatment option. As expected, the outcome will be particularly worse in poor societies. Therefore, in explaining the role of school screening, it must also be clearly understood that its cost must be the direct cost of performance of the actual screening program and not the subsequent expenditures of follow-up, radiographs and other modalities described in the current literature, [12, 16].

Finally, the fact that the SSS programs were in some places discontinued was the result of a triumph of epidemiology over early diagnosis, and this in reality is a disaster, [6, 58]. Prevention must be a standard policy in civilized societies with medical systems caring about people's wellbeing and not about statistics, epidemiology or only cost. We always have to remember what the axiom in ancient Greece, the cradle of western civilization was. Ancient Greeks used to say that "metron of everything is man"; the measure, in other words, of appraising everything is only the human being, nothing else.

D. The Protocol.

In Table 1**,** the form for the study of school population of our used scoliosis screening protocol is presented. This SSS protocol is mostly original. A few commonly used parameters based on the existing peer-review literature are included, (mainly the scoliometer readings) and collection of other parameters based on our experience running our SSS program for twenty-five consecutive years.

In this SSS protocol form, initially the geographical region of the school is written and the date of the examination of each child. This information is useful because in the analysis of the results the place and the possible role of this geography on the prevalence of scoliosis is documented. It is reported that the prevalence of scoliosis depends to the geographical latitude, [17].

The date of the examination may be used not only for the documentation of the time of SSS implementation but also by using the documented date of birth, we can calculate the exact age of the examinee, a very important parameter for the study of IS.

D-a. The Personal Demographic Data are collected.

The surname and the name of the examinee, the father's and mother's name are written. In case that

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two children have the same name (synonymy), this information makes it possible to avoid mistakes and the use of the wrong data.

The home address of the examinee, (street, number, city and telephone number), provide a lot of convenience to the SSS team in case any communication with the family is necessary for referral and reexamination in the scoliosis clinic or for any other medical reason.

The school type and name (primary, high School, etc.) and the grade of the examinee is also useful information. The knowledge of the type of the school is very important. For example, in a specialized school for children suffering visual deficiency, the prevalence of scoliosis is quite different from that of children attending the ordinary public or private schools, [18].

D-b. The family demographic Basic Data are documented.

The birth place of the examinee and his/her date of birth (DoB), the father's and mother's birth place, age in years and profession are documented. All this information is offering very important data related to epigenetic factors affecting the prevalence of idiopathic scoliosis, [19,20,21,22,23].

D-c. Biological and somatometric data.

The following parameters are always measured and recorded as a mandatory part of the SSS program. The sex (male or female). It is well reported that the adolescent idiopathic scoliosis (AIS) affects mainly the females, (almost 80%), [24].

In girls we also document the exact age at menarche, (day, month, year). This information is very important because if an examined girl has truncal asymmetry, she is candidate or suspicious for developing scoliosis or she has already started developing scoliosis. The age of menarche is one of the parameters that dictate the treating physician how to tailor the proper management for her. Younger non-menarchial girls may develop progressive deformity while post-menarchial older girls have a reduced likelihood for progression. Additionally, a significant difference was found between menarche positive and menarche negative scoliotic girls in relation to the laterality of scoliotic curves: The former showed predominantly right sided primary curves while the latter had mainly left primary curves, [25].

The standing and sitting body height in cm is measured using the standard height measuring device. The assessment of standing body height and the stratification of this measurement by age in the examined children will allow us the appraisal of growth of the examinees and compare it with various internationally reported publications. This may provide some aetiological clues for the AIS. The sitting body height is one useful parameter, an indicator of spinal growth, [26, 27].

The measurement of body weight in Kg follows. It is reported in the literature that the scoliotic girls are slimmer with lower BMI and higher that the aged matched non-scoliotic children, [28, 29, 30, 31, 32].

The type of the gait, namely in-toeing, out-toeing, neutral type, is recognized by asking the examinee to walk. This information is looked-for, based on the knowledge that the scoliotics were found to have femoral anteversion asymmetry. Prochiantz 1986, studied the femora of 8 patients with idiopathic scoliosis using CT and concluded that a number of such cases originate in asymmetric femoral anteversion. Burwell et al 1988, using an ultrasound method to measure femoral anteversion, found that anteversion asymmetry was greater in school screening referrals and their siblings than in controls. A derivative also of femoral anteversion and its asymmetry (residual functional anteversion) was related to the Cobb angle of the lowest lateral spinal curves of 20° or more, [33, 34, 35, 36].

The eyes' color (dark, bright (green or blue), is documented as a non-mandatory note. Frequently AIS children have bright color eyes, [5]. However blue eyes may reveal syndromic scoliosis as at Waardenburg syndrome, which is characterized by the association of pigmentation abnormalities, including depigmented patches of the skin and hair, vivid blue eyes or heterochromia irides, and sensorineural hearing loss, [37, 38].

The handedness (right or left-hand dominance, or both) of the children is assessed. The hand preference of children is documented by just asking them which hand they prefer for everyday activities, es-

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pecially writing, eating, throwing an object or performing fine motor skills. For those children where hand preference for performing different types of manual tasks vary, hand preference is determined by the number of performed tasks by each hand. Thus, the examiners have a clear picture of each child's hand preference and no demonstration is needed. Each child is classified objectively as right or left-handed. The importance of this documentation is related to the role of brain hemisphere in relation to the laterality of the truncal asymmetry and the curve, [39].

Similarly, the hair color, (dark, bright -for example blond) is recorded. AIS seem to have brighter hair color, [5].

The arms' span in cm is measured and written in the form. In heathy adolescents, body height and arm span are similar. However, in AIS, arm span can be used as a substitute for falsely low body height due to spine curvature to calculate other parameters, e.g. pulmonary, [40].

Several reports have found a different anthropometric profile among patients with AIS when compared with age and gender matched control subjects. In a study with a large sample size, girls with AIS were considerably taller, leaner, and had longer arm spans than their peers; arm span and sitting height independently predicted curve severity. It was suggested that this is the result of an aberrant growth pattern related to the cause of AIS and its curve progression, [41, 42, 43, 44, 45].

The following parameters are optionally measured and recorded, depending of the manpower and the objectives of the SSS team's project.

The head diameter (frontal and sagittal in cm) is measured. In infantile idiopathic scoliosis it is reported that there is face asymmetry. A comprehensive evaluation should be performed to identify commonly associated conditions, such as plagiocephaly, congenital heart disease, inguinal hernia, and hip dysplasia, [46, 59].

Trans-acromial distance in cm, trans-iliac distance in cm, trans-trochanteric distance in cm, thoracic diameter (frontal in cm and anteroposterior in cm), also humerus forearm, hand, femur, tibial, and foot right and left in cm may be measured. These parameters are needed for the study of the body structure and asymmetries seen in AIS patients, [45, 59].

Any lumbar ATI scoliometer's increased reading by conducting the Adam's standing test, raises the suspicion of a leg length inequality (LLI). In case of LLI, it is useful to assess which bone/s of the leg, or one of the hemi-pelvises, or combination of some or all of them, are longer or shorter and responsible for the LLI. This can be achieved either by using a measuring tape and assessing the superior anterior iliac spine to medial malleolus distance bilaterally or by asking the placed on an examination bed examinee to bent his knees and observe the possible asymmetry at the levels of the knees. This LLI initially results in functional spinal deformity, which later during growth, if the LLI persists, remodels to structural spinal scoliosis and can be easily prevented by shoe elevations at an earlier stage, [47, 48].

The right and left trans-malleolar distance in cm, [59], and the length of right and left Achilles (short or normal) tendon are assessed, [59]. Observing from behind the erect examinee, in case of Achilles tendon shortening in one site, the examiner ascertains that the resting calcaneal stance position angle is increased resulting in valgus hindfoot. This increase shortens the affected foot's leg length, even slightly, disturbing the horizontality of the pelvis, also contributing to the lumbar spine curvature, [49, 59].

D-d. Truncal examination

The examiner may observe the erect child from behind and see if the body tilts to one side, if there is asymmetry in the shoulders, asymmetry in the space between the trunk and the upper limbs, or a not horizontal pelvis.

The next mandatory assessment, during SSS program implementation, is the examination for any truncal asymmetry by conducting the Adam's bending test in standing and sitting position using always a scoliometer. Smart-phones loaded with the proper software may be used as scoliometers as well, with acceptable validity and accuracy, [50, 51].

Trunk asymmetry is recorded for mid-thoracic (T4–T8), thoracolumbar (T12–L1) and lumbar (L2–L5) regions. For the standing forward bending posi-

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Table 1. The Protocol.

Protocol for the STUDY OF SCHOOL POPULATION

Region…….. Date of examination … / … / 2022…

A . Personal Data

Surname……Name……Father's name …… Mather's name ……

Address: street…… number…… City…… Telephon:……

School: **Primary** …… …Grade …… **High School** …… grade

B. Basic Data

Birth place of the examinee…… Date of birth ……. ……. …..

Birth place of Father…… Father's profession …… Father's age in years……

Birth place of Mather…… Mather's profession …… Mather's age in years ……

C. Biological and somatometric data

Sex: male , female. Menarche for females: month…… year……, Standing Height in cm…… Weight in Kg…… Gait in-toeing out-toeing neutral

Eyes' color: dark…., bright (green or blue)…., Sitting height cm…… Handedness: Right hand ……, Left hand…..

Hair color: dark…., bright (for example blond) arms' span in cm…… Head diameter: frontal in cm…… sagittal in cm……

Trans-acromial distance in cm….. , trans-iliac distance in cm…. , trans-trochanteric distance in cm…., **Thoracic diameter**: frontal in cm……, anteroposterior cm……

Bracket (humerus) length right in cm …., left in cm…., forearm lenght right in cm…., left in cm…., Hand length: right in cm…., left in cm….,

Femur Length: right in cm…., left in cm…., Tibial Length: right in cm…., left in cm…., Foot Length: right in cm…., left in cm….,

Trans-malleolar distance: Right in cm…., Left in cm….,

Length of Achilles tendon: Right: short…., normal…

Left: short…., normal…

D. Scoliosis

Clinical Radiological Hump (ATR) Scoliometer: Right Thoracic in °….., Thoraco-Lumbar in °….., Lumbar in °……

No scoliosis Left Thoracic in °….., Thoraco-Lumbar in °….., Lumbar in °……

Yes Scoliosis degrees from to **Type of scoliosis** **Comments**

Thoracic Left (Thl) ……. ……. ……. 1. Idiopathic ……

Thoracic Right (Thrt) ……. ……. ……. 2. Congenital ……

Thoraco-Lumbar Left (T-Ll) ……. ……. ……. 3. Paralytic ……

Thoraco-Lumbar Right (T-Lrt) ……. ……. ……. 4. Neurofibromatosis ……

Lumbar Left (Ll) ……. ……. ……. 5. Functional ……

Lumbar Right (Lrt) ……. ……. ……. 6. Due to Leg Length inequality: ……

Kyphosis……. ……. ……. ……

Lor ……. ……. ……. Are they aware that the child have scoliosis ? yes • no •

E. Clinical descriptions of the findings:

For example: developmental abnormalities, ect

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tion (StFBP) the examinee is asked to bend forward, looking down, keeping the feet 15 cm apart, knees braced back, shoulders loose and hands positioned in front of knees or shins with elbows straight and palms opposed. Any leg length inequality is not initially corrected. The side of the hump determines the laterality of trunk rotation. Trunk asymmetry (hump) to the right side is defined as right asymmetry and to the left is defined as left asymmetry in each of the three mentioned regions and recorded in degrees in the form, [39, 52]. For the sitting forward bending position, (SiFBP), the examinee is seated on a chair or stool (approximately 40 cm high) and is asked to bend forwards and place the head between the knees with the shoulders loose, elbows straight and hands positioned between knees. The scoliometer measurements are obtained successively at the same three areas of interest similarly to the standing forward bending position, [53].

After the Adam's StBFT, the Adam's SiBFT is carried out. Performing this test in sitting position, the pelvice becomes horizontal and the effect of any LLI on the truck is eliminated, therefore, any truncal changes in children with mild LLI are also reduced, [47].

This test is also useful in case of any truncal asymmetry at the lumbar level when performing the Adam's StBFT. Doing so, the real truncal/spinal asymmetry is revealed, because as it is reported, in healthy children, a physiological shortening of one leg (1–2 cm) is associated with a contralateral hump on the back in forward flexion not only at L3 but also at T12 and T8 vertebrae, [52].

The examined children with truncal asymmetry are referred to the scoliosis clinic of any legislated and specialized organization, (hospital, foundation, etc) for further evaluation. The SSS team, as it was noted before, has in advance prepared and printed a letter of invitation for re-assessment at the scoliotic clinic of the asymmetric children, which is handed to the headmaster of the school or the examined children to present to their families.

Growth has a significant effect in the correlation between the thoracic and the spinal deformity in girls with IS. Therefore, it should be taken into consideration when trying to assess the spinal deformity from surface measurements. It was reported that in IS during growth the rib cage deformity precedes the spinal deformity in the pathogenesis of idiopathic scoliosis, [15]. Therefore, our referral recommendation for re-examination at hospital is the following: if the child is less than 14 years of age and the scoliometer' s reading, (angle of trunk inclination / angle of trunk rotation (ATI / ATR)) is ≥ 6 degrees, as well as if the child is 14 or older than 14 years of age and the ATI/ATR is ≥ 5 degrees.

The referred children to the scoliosis clinic from the SSS programs are clinically and if indicated, radiographically examined. During the implementation of a SSS program, it is obvious that any other developmental abnormality is documented.

This described protocol has been used during the implementation of our SSS. The collected data were processed using the SPSS statically package. The outcome, except from the prevention and early management of IS, was the publications documenting numerous of the above parameters for the Hellenic school population, introducing the norms as well as a number of new concepts. Some of these studies are cited in this report and some other will be presented in a following article, where the results of our SSS program will be analyzed. The ultimate aim is not only the prevention and early management of IS, but its deeper study as well and a possible contribution to the knowledge of its aetiology, looking forward to an aetiological therapy of this condition in contrast to the symptomatic one, as it is today.

Abbreviations

ATI = angle of truncal inclination, ATR = angle of truncal rotation, AIS = Adolescent Idiopathic Scoliosis, BMI = body mass index, DRCS = double rib contour sign, IS = idiopathic scoliosis, IIS = Infantile Idiopathic Scoliosis, IVD = intervertebral discs, AIS = adolescent idiopathic scoliosis, LLI = Leg length inequality, LHS = leptin-hypothalamic-sympathetic, RI = Rib Index , RVA = Rib Vertebral Angle, RVAD = Rib Vertebral Angle Difference, StFBP test = forward bending position test, SiFBP = sitting forward bending position, SSS = School scoliosis screening , SE = standing erect, ST = surface topography, TA = trunk asymmetry, TR = thoracic ratio,

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4DF = 4D Formetric

Competing interests

The author declares that he has no competing interests.

Author's contribution

The author was responsible for organizing the SSS program, its protocol and the examination team, managed the administration of it, involved in the examination of children, the collection of all data, conceived and postulated the described concepts written in this report, implemented the literature search and drafted this manuscript.

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READY - MADE CITATION

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