Effectiveness of school scoliosis screening and the importance of this method in measures to reduce morbidity in an Italian territory

Angelo G. Aulisa[a], Marco Giordano[a], Vincenzo Guzzanti[a,b], Francesco Falciglia[a], Paolo Pizzetti[c] and Renato M. Toniolo[a]

Although several procedures for treating scoliosis have been developed, the most effective treatment is still based on early detection. For early diagnosis of idiopathic scoliosis, many authors have proposed methods of school screening; however, there is still no standardized screening program. The aim of this study was to evaluate a school screening method and the prevalence and distribution of scoliosis in Italian school children, aged 9–14 years, and to determine if the screening method can reduce morbidity in an Italian territory. The screening program consisted of three steps: the first step was a clinical examination carried out by the school physician and two specialists. In the second step, doubtful cases (presence of a hump between the two sides of the torso, in the thoracic or thoracolumbar region, measured using a hump meter) were evaluated by an orthopedic specialist and subsequently controlled every 6 months either clinically or by radiographic examination. The third step was the classification of the scoliosis and procedures for treatment. All patients were scheduled for a follow-up program and were evaluated during the subsequent 3 years. Statistical analyses were performed with GraphPad Prism 6. A total of 8995 children were screened for scoliosis. Of these, 487 showed clinical signs of scoliosis, and 181 were referred for anteroposterior radiographs because of a positive result on the forward-bending test (hump > 5 mm). No significant statistical difference was observed by the three clinical examiners. Of the 181 patients who were referred, 69 were radiographed, and the clinical diagnosis was confirmed in 94.2% of the cases. The prevalence of scoliosis (defined as a curve of ≥ 10°) was 0.76% (65 of 8995 children), and most of the curves (44; prevalence 67.69%) were small (< 20°). The overall ratio of boys to girls was 1 : 3.3, but varied according to the magnitude of the curve (1 : 3 for curves of <20°, 1 : 3.25 for curves of 20–29°, and 1 : 4 for curves of ≥ 30°). Double curves were the most common type identified, followed by thoracolumbar curves; specifically, of the 65 children who had a curve, 21 (32.30%) had a double curve, 18 (27.6%) had a thoracolumbar curve, 17 (26.1%) had a lumbar curve, and nine (13.84%) had a thoracic curve. In the following 3 years, only four patients were found to have curves more than 20° and none more than 30°. Our results show that the school screening program was accurate and repeatable. Moreover, screening children for scoliosis using a simple test appears to be an effective means of early detection. Above all, the screening process effectively decreased morbidity in the territory at a negligible cost. *J Pediatr Orthop B* 28:271–277 Copyright © 2019 Wolters Kluwer Health, Inc. All rights reserved.

Journal of Pediatric Orthopaedics B 2019, **28**:271–277

Keywords: hump, morbidity, school, scoliosis, screening

[a]U.O.C. of Orthopedics and Traumatology, Bambino Gesù Children's Hospital, Institute of Scientific Research, [b]University San Raffaele and [c]Private Practice, Rome, Italy

Correspondence to Angelo G. Aulisa, MD, U.O.C. of Orthopedics and Traumatology, Bambino Gesù Children's Hospital, Institute of Scientific Research, P.zza S. Onofrio 4 – 00165 Rome, Italy
Tel: +39 306 685 92313; fax: +39 066 859 2847;
e-mail: angelogabriele.aulisa@fastwebnet.it

Introduction

Scoliosis is a three-dimensional deformity of the spine characterized by a lateral curvature greater than 10° in the coronal plane [1].

Idiopathic scoliosis has no known cause and can be classified according to the age of onset into three forms: infantile (age of onset < 3 years), juvenile (age of onset 3–10 years), and adolescent form (age of onset > 10 years) [2]. Adolescent idiopathic form is the most common and occurs in ~2% of the adolescent population [3].

The ratio of girls to boys with small curves is equal, but increases to 1 : 8 for those requiring treatment [4,5].

Although several treatments have been developed, the most effective treatment is based on early detection. For this purpose, screening for scoliosis has been practiced widely for many years but remains a debatable topic. Scoliosis screening is mostly performed in schools and looks for spinal asymmetries.

The main method of school scoliosis screening is clinical examination in forward-bending position (Adam's test) and the use of a scoliometer or hump meter.

The optimal age for scoliosis screening is controversial [6–10].

Many advantages of scoliosis screening have been reported in the literature: reduced need for surgical treatment [11–16], early detection [11,17–19], as well as data on prevalence, etiology, and natural history [20–22], and the efficacy of earlier conservative treatment.

 DOI: 10.1097/BPB.0000000000000611

In the past, the usefulness of a scoliosis screening procedure had been questioned. Recent publications have stated that a correct conservative treatment can reduce the incidence and prevalence of scoliosis surgery [1,23–33], thus making early detection of scoliosis a key point for its treatment.

Actual objections to scoliosis screening are based on the doubtful cost-effectiveness [34,35], long-term radiographic damage [36,37], over-referral to the specialist [38,39], low sensitivity and specificity [40], poor correlation of clinical deformity, and radiographic abnormality [41].

The aim of this study is to reconsider the methodology of our screening procedures taking into account the new parameters expressed by recent literature on this topic [7,10,42] and to restate the capacity of a screening repeated over the years to affect morbidity in an Italian territory [43].

Patients and methods

The results of a screening for idiopathic scoliosis in the XIX District of Rome (190 846 citizens) were analyzed.

The screening was conducted on a population of 13 784 school children aged between 9 and 14 years (4202 boys, 4793 girls) who were students in the 4th and 5th years of primary school and lower secondary school. The screening took place over 3 years, and all patients were examined once a year.

For our screening program, we worked in collaboration with local school physicians previously instructed by an orthopedist on how to interpret certain fundamental signs correctly.

For this purpose, several meetings were held to define the modalities of the screening and to show clinical criteria to be used during the examination. In particular, the physician had to look for the following signs: asymmetry of pelvis, kyphosis–lordosis, asymmetry of the flanks, and presence of hump measured with a hump meter (Fig. 1) in a forward-bending position (Adams forward bend test).

The screening program consisted of three steps.

The first step was clinical examination by the school physician and two specialists. In the second, the cases concerned were evaluated by an orthopedic specialist who could prescribe clinical control every 6 months or radiographic examination. The last step was the classification of the scoliosis and treatment.

For the first step, the children were examined by the local school physician. We used 5 mm as a cutoff level for hump measurement, because from the literature and our experience, it seems that humps of less than 5 mm correspond to negligible curves that require clinical examination only after 6 months (40–52 months).

School physicians were asked to complete a questionnaire reporting the children's basic personal data (first and last names, birth date, etc.) and clinical findings identified during examination.

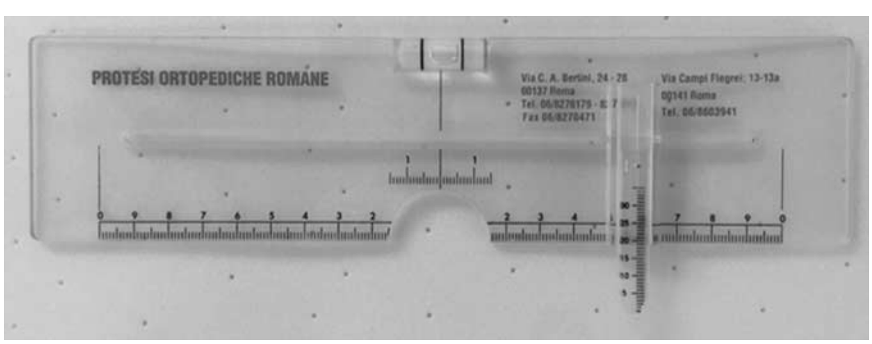
In particular, the questionnaire included three pictures: posteroanterior view in standing position, lateral view in standing position, and posteroanterior view regarding Adams forward bend test.

The outcome of the check-up was also reported on the questionnaire:

(1) Negative: patients were negative for scoliosis (or other spinal disease) at the time of the clinical examination.
(2) Advised to undergo clinical examination after 6 months: concerned all patients showing mild signs of scoliosis and therefore evaluated as 'at risk', but not advised to undergo radiological examinations. These patients were advised to undergo a clinical check-up after 6 months.
(3) Advised to undergo radiographic examination: patients presenting all the signs (mentioned later) were advised to undergo radiological examination as well as an additional clinical examination by the orthopedist on an ambulatory basis and accompanied by his/her parents.

During the second step, the clinician defined the scoliosis type and prescribed the most appropriate treatment.

Fig. 1



Hump meter.

Signs that the patient should undergo radiographic examination were as follows:

(1) Lumbar or thoracic hump larger than 5 mm.
(2) Hump smaller than 5 mm but in presence of lower limb asymmetry of more than 10 mm combined with a reduction of the contralateral flank.
(3) Declared spinal disease such as Scheuermann's disease, spondylolysis, and spondylolisthesis.

To test school physician reliability during the first step of our screening procedure, in the first year, children were divided into two groups: group A (5731 children) consisted of patients evaluated by the school physician, whereas group B consisted of patients directly evaluated by an orthopedist with expertise in spinal deformities.

Statistical analysis

Students with scoliosis were classified according to severity ($<20°$ and $\geq 20°$). A descriptive analysis was carried out before and after the screening in the school, or in the private orthopedic outpatient setting to determine the distribution at diagnosis of age and sex. Results were expressed as frequencies and/or percentages.

The difference in screening results between groups A (students seen by the local school physician) and B (students seen by the orthopedist) at baseline was assessed using the Pearson χ^2-test.

A P value less than 0.05 was considered statistically significant. Statistical analysis was performed with commercially available software [GraphPad Prism version 6 for Windows (GraphPad Software, San Diego, California USA)].

Ethical approval

This study was conducted with respect to the Helsinki Declaration, and all the participants (parents) gave their informed consent to allow the use of clinical data for research purposes.

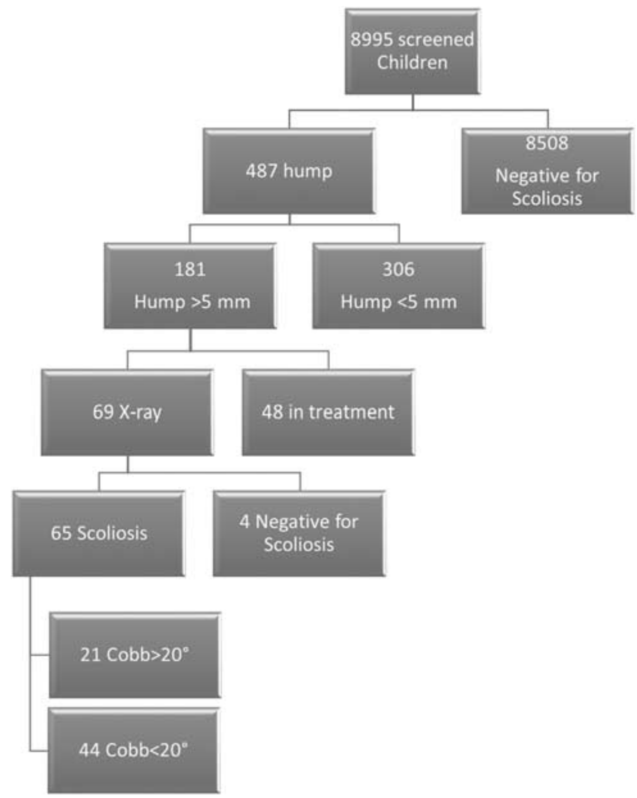
Results

At baseline, 9719 children from 32 different schools (18 elementary schools, and 14 junior high schools) were enrolled in the screening. Of these, 8995 (92.6%) were examined, as 22 (0.2%) refused the visit, and 702 (7.2%) were not present at school during examination sessions.

Of the 8238 children examined (91.6%), 576 (6.4%) were advised to undergo a further examination after 6 months, and only 181 (2%) were advised to undergo radiological examination (26.7% males and 73.3% females).

After the screening, 181 school children were advised to undergo radiological examination. Of these, 48 had already received a diagnosis of scoliosis and been treated by their specialist; 64 patients chose to be treated by an orthopedist they knew, and the other 69 decided to be treated in our clinic. Of the 69 patients treated by us, scoliosis was present in 65, comprising 15 (23%) males and 50 (77%) females. We also found four false-positive patients (Fig. 2).

Fig. 2



Flow diagram of the two different school-based scoliosis screening programs.

The relevance of the diagnosis of scoliosis in this screening campaign was 2.01% (181 of 8995). If we restrict the outcome to those patients who underwent radiography after the first examination, the sensitivity of this screening procedure is 94.2% (65 out of 69). Sensitivity rises to 96.58% (113 out of 117) if we also include patients already diagnosed and in treatment (48 children).

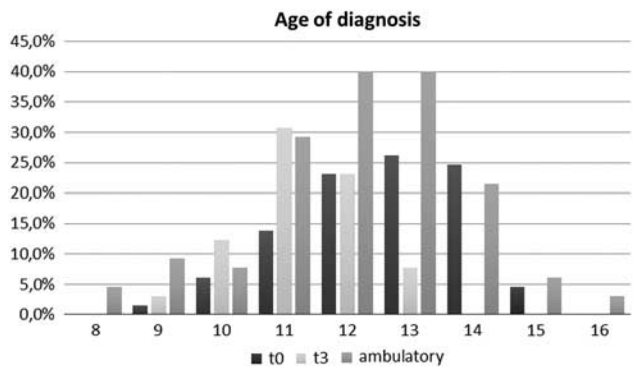
Specificity of the screening was 97.8%. Specificity is the most important characteristic of a screening test when diffusion of the disease is low; however, a reduction of sensitivity is possible.

The median age of scoliosis diagnosis differed among the three situations (Fig. 3): it is lower at the end of the screening (11 years) than at baseline (13 years), or in the ambulatory patients (12 years).

The prevalence of scoliosis, defined as a curve of 10° or more, was 0.76%, and most of the curves were small (Table 1 and Fig. 4).

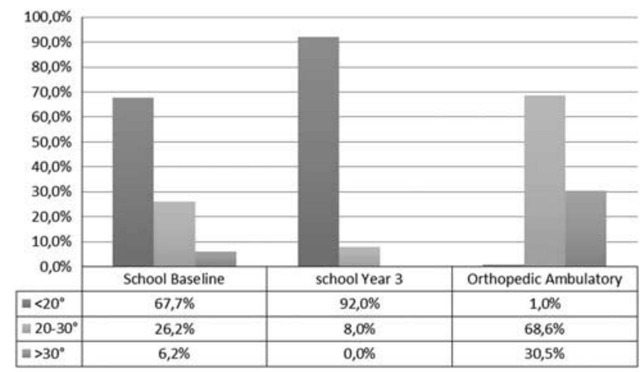
The overall ratio of boys to girls was 1 : 3.3 but varied according to the magnitude of the curve (1 : 3 for curves

Fig. 3



Age distribution (%) of the scoliosis diagnosis at baseline (t0 – black bar), at the end of the screening (t3 – light grey), and in an ambulatory setting (dark grey bar).

Fig. 4



Difference in the severity of the scoliosis between a school (at baseline and at the end of the screening) and a private orthopedic outpatient setting.

Table 1 Severity of the scoliosis for male and female children at baseline (t0), at the end of the screening (t3), and in an ambulatory setting

Severity (Cobb's degree)	< 20° [*n* (%)]	20°–30° [*n* (%)]	> 30° [*n* (%)]	Total [*n* (%)]
t0				
Female	33 (50.8)	13 (20.0)	4 (6.2)	50 (76.9)
Male	11 (16.9)	4 (6.2)	0 (0.0)	15 (23.1)
Total	44 (67.7)	17 (26.2)	4 (6.2)	65 (100.0)
t3				
Female	28 (56.0)	3 (6.0)	0 (0.0)	31 (62.0)
Male	18 (36.0)	1 (2.0)	0 (0.0)	19 (38.0)
Total	46 (92.0)	4 (8.0)	0 (0.0)	50 (100.0)
Ambulatory setting				
Female	1 (1.0)	68 (64.8)	31 (29.5)	100 (95.2)
Male	0 (0.0)	4 (3.8)	1 (1.0)	5 (4.8)
Total	1 (1.0)	72 (68.6)	32 (30.5)	105 (100.0)

of less than 20°, 1 : 3.25 for curves of 20°–29°, and 1 : 4 for curves of ≥ 30°). Double curves were the most common type identified, followed by thoracolumbar curves; specifically, of the 65 children who had a curve, 21 (32.30%) had a double curve, 18 (27.6%) had a thoracolumbar curve, 17 (26.1%) had a lumbar curve, and nine (13.84%) had a thoracic curve (Table 2).

Furthermore, the scoliosis severity at diagnosis was lower at the end of the screening than at baseline. However, children screened at school (both at baseline and at the end of the screening) show a lower severity than patients screened in a private orthopedic outpatient facility (Table 1 and Fig. 4).

In particular, in the following 3 years, we performed 52 radiographs, and 50 of them showed a scoliosis, but we found only four patients with curve greater than 20° and none with a curve greater than 30°. Regarding the type of curve, there were no double curves, and only one was thoracic.

Table 2 Distribution of scoliosis according to sex, type, and severity

	Female			Male			
	< 20°	20°–30°	> 30°	< 20°	20°–30°	> 30°	Total
Double curve	11	5	4	–	3	–	23
Thoracic	6	1	–	2	–	–	9
Thoracolumbar	7	4	–	5	1	–	17
Lumbar	9	3	–	4	–	–	16
Total	33	13	4	11	4	–	65

School physicians declared 94% of the examined pupils as 'negative', orthopedists declared 86% as 'negative'; the difference is statistically significant (P=0.001), also considering the large volume of our sample.

Discussion

In our screening campaign, the percentage of scoliosis diagnosis was 2.01% and was in line with the results reported in the literature.

Our screening program has some strong points, for instance, the chronological age being extended to the last two classes of primary school, the hump measurement that is an accurate sign, and a questionnaire that is easy to read and quickly completed.

Sensitivity and specificity of a two-step school scoliosis screening program proved to be optimal, and the results underline the several advantages that this procedure offers. In particular the 'two-step' procedure remarkably reduces the number of specialized medical examinations. Moreover, the 'two-step' procedure is easy to perform and reliable regarding diagnosis, but only if the school physicians performing the first screening are sufficiently expert enough.

There is no consensus concerning the optimal age for the screening. The American Academy of Orthopaedic Surgeons recommends that, for girls, the best time to screen is between 11 and 13 years of age. Boys need one control at 13 or 14 years of age. The American Academy of Paediatrics, however, advises a series of periodic examinations every 2 years from 10 to 16 years of age [26].

The Scoliosis Research Society suggests annual screening for all children between 10 and 14 years of age. Labelle *et al.* [7] states that girls should be screened two times at the age of 10 and 12 years instead of boys screened one time at 13 or 14 years of age.

Beauséjour *et al.* [10], contemplating while acknowledging that curve progression is relevant between 11 and 14 years of age, also examined students of 9–11 years of age to detect early stages of scoliosis.

Our study detected scoliosis in 44 pupils in the 9- to 11-year age group. For 14 of them, the scoliosis was at baseline and for the other 30 students was at t3. The latter group, considering their age, are those that are at higher risk of progression. Therefore, the advantage of extending screening procedures to the elementary school population is confirmed.

Regarding the hump, the American Academy of Paediatrics recommends screening for scoliosis via evaluation of the hump during Adams forward bend test. The Bunnel scoliometer and hump meter are the tools commonly used for this purpose. However, several studies are doubtful about the correlation between the clinical deformity (hump) and the curve severity evaluated by radiography [6–10,12,13]. Although a significant correlation between clinical signs and radiological measurement exists, the variability could be so high that a prevision of the entity of the curve obtained via clinical sign recollection only is not possible [41,44–51].

A longitudinal study has shown a significant correlation between hump dimensions and curve severity detected at both the beginning and the end of treatment. Similar results were obtained in subgroup analyses, except that no significant correlation was found at baseline between the hump dimension and curve severity in patients with lumbar curves [52].

The threshold to be used for detecting scoliosis requiring radiological examination is still under debate. According to Bunnel and Grivas, it is clearly impossible, using the scoliometer, to predict the scoliosis type accurately, particularly for younger children [41,46,53]. Labelle *et al.* [7] consider the scoliometer to be the best tool in terms of reliability and validity to evaluate trunk asymmetries. They recommend a threshold between 5° and 7° ($B°$) when using the scoliometer. According to Society on Scoliosis Orthopaedic and Rehabilitation Treatment, the threshold considered optimal for the majority of the physicians is 7° ($B°$). Furthermore, an angle of trunk rotation of 7° or more in right thoracic scoliosis, and an angle of trunk rotation of 6° or more in left thoracolumbar and lumbar scoliosis is considered a reliable criterion for identifying patients affected by a scoliosis of 25° (or more) Cobb's degree [38].

Conversely, the studies conducted with the hump meter have shown that a hump greater than 5 mm is significant for the diagnosis of scoliosis [43,50].

In this study, we have used a threshold of 5 mm with the hump meter. We consider this an effective threshold for identifying clinical deformity with low rate of false positives. In fact, in our study, we found only four false positives. To achieve a relevant validity of the screening, appropriate instruction of school physicians and a simple examination schedule are fundamental. This can reduce over-referral, false positives, and interobserver variability.

The positive effects of a screening program should be evaluated in subsequent years considering the number of patients with the disease and the severity of the disease.

According to Beauséjour *et al.* [10], a screening program is effective as it allows to detect younger patients and those with mild signs of scoliosis at the time of diagnosis, unlike other means of scoliosis diagnosis. Labelle *et al.* [7] observed that, even though the available literature showed studies without a control group, there is evidence of the ability of a screening campaign to detect patients with adolescent idiopathic scoliosis with subclinical conditions and to refer them for further control. Moreover, a screening correctly performed allows to identify younger cases and also those with a small Cobb's angle [7].

Beauséjour *et al.* [10] reports that it is feasible to compare the results of the screening with a control group that were not screened, to evaluate the effectiveness of the screening itself.

As control group, we have considered 105 patients who attended our clinic during the screening period. Patients of the control group were older and with a greater Cobb's angle than patients diagnosed by the screening program at baseline.

In subsequent years of screening, the number of cases of scoliosis diagnosed has diminished. Patients have been found to be younger and affected by a less severe disease than those diagnosed in the first year of screening.

Therefore, screening has been effective in the early identification of the disease, in patients without a diagnosis of scoliosis, and in those where the curve would have progressed over time.

The other strong point is the economic aspect. Financial costs of a screening can be direct and indirect. Direct costs are related to the carrying out of the screening, and indirect costs are related to the cure of the pathology screened.

For Beauséjour and colleagues, the financial cost should be given the same importance as the efficiency outcomes, that is, a general reduction of costs together with a general reduction of the pathology. Surgical treatment is much more expensive than conservative treatment, and early diagnosis could permit a considerable reduction of expense for the community.

Furthermore, earlier diagnosis and treatment permits to reduce the complications of a disease, the related cost of treatment, and the price for the community in terms of disability. In conclusion, the lower rate of surgery and back pain treatment (usually in adults with untreated adolescent idiopathic scoliosis) will save the government more than the 'price' of a screening process [10].

The cost of scoliosis screening should be calculated only on the first examination by a physician, the specialists' examination, and the radiological examination and not on the subsequent classification and treatment.

The more effective the screening programme is, the lower the indirect costs are [40]. Regarding costs, we agree with Bunnell and Grivas when they affirm that we should not look for the least expensive modality for screening, but for the one that, at equal cost, is the most effective in improving the quality of life of our patients.

Grivas *et al*. [38] showed that the indirect cost of a screening procedure can be minimal if it is well designed and carried out on a voluntary basis.

A 'two-step' screening procedure conducted at proper intervals can lower the costs for the National Health System (initial costs of production) as well as for local communities.

To minimize costs, for the first visit, we used school physicians or other health workers who had received prior instruction from an orthopedist. Sensitivity and specificity of the two-step screening were satisfactory. Specialists only evaluated suspected cases, and radiographic examinations were performed only when considered necessary. In cases of mild deformity (hump <5 mm), we preferred to re-evaluate patients after 6 months without performing radiographs to reduce costs and radiographic exposure.

The weak points are lack of health education, lack of information, and availability of basic operators.

Conclusion

This study demonstrates that the methodology used in our screening program has the requisite qualities advanced by recent scientific literature on the topic, is cost effective, is financially sustainable, and is able to reduce the morbidity of scoliosis in the territory.

Acknowledgements

A.G.A. participated in the conception, design and coordination of the study, acquisition of data, analysis and interpretation of data, drafting of the manuscript, and performed the statistical analysis; M.G., F.F., V.G., and R.M.T. helped to draft the manuscript; and P.P. participated in acquisition of data and helped to draft the manuscript. All authors read and approved the final manuscript.

Conflicts of interest

There are no conflicts of interest.

References

1 Negrini S, Aulisa AG, Aulisa L, Circo AB, Claude de Mauroy J, Durmala J, *et al*. 2011 SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis* 2012; **7**:3.
2 Altaf F, Gibson A, Dannawi Z, Noordeen H. Adolescent idiopathic scoliosis. *BMJ* 2013; **346**:f2508.
3 Leaver JM, Alvik A, Warren MD. Prescriptive screening for adolescent idiopathic scoliosis: a review of the evidence. *Int J Epidemiol* 1982; **11**:101–111.
4 Adobor RD, Riise RB, Sørensen R, Kibsgård TJ, Steen H, Brox JI. Scoliosis detection, patient characteristics, referral patterns and treatment in the absence of a screening program in Norway. *Scoliosis* 2012; **7**:18.
5 Bunnell WP. The natural history of idiopathic scoliosis before skeletal maturity. *Spine* 1986; **11**:773–776.
6 Rogala EJ, Drummond DS, Gurr J. Scoliosis: incidence and natural history. A prospective epidemiological study. *J Bone Joint Surg Am* 1978; **60**:173–176.
7 Labelle H, Richards SB, de Kleuver M, Grivas TB, Luk KDK, Wong HK, *et al*. Screening for adolescent idiopathic scoliosis: an information statement by the scoliosis research society international task force. *Scoliosis* 2013; **8**:17.
8 Adobor RD, Rimeslatten S, Steen H, Brox JI. School screening and point prevalence of adolescent idiopathic scoliosis in 4000 Norwegian children aged 12 years. *Scoliosis* 2011; **6**:23.
9 Grivas TB, Vasiliadis ES, O'brien JP. Suggestions for improvement of school screening for idiopathic scoliosis. *Stud Health Technol Inform* 2008; **140**:245–248.
10 Beauséjour M, Goulet L, Parent S, Feldman DE, Turgeon I, Roy-Beaudry M, *et al*. The effectiveness of scoliosis screening programs: methods for systematic review and expert panel recommendations formulation. *Scoliosis* 2013; **8**:12.
11 Sabirin J, Bakri R, Buang SN, Abdullah AT, Shapie A. School scoliosis screening programme-a systematic review. *Med J Malaysia* 2010; **65**:261–267.
12 Maruyama T, Kitagawa T, Takeshita K, Mochizuki K, Nakamura K. Conservative treatment for adolescent idiopathic scoliosis: can it reduce the incidence of surgical treatment? *Pediatr Rehabil* 2003; **6**:215–219.
13 Lonstein JE, Winter RB, Moe JH, Bianco AJ, Campbell RG, Norval MA. School screening for the early detection of spine deformities. Progress and pitfalls. *Minn Med* 1976; **59**:51–57.
14 Rigo M, Reiter C, Weiss HR. Effect of conservative management on the prevalence of surgery in patients with adolescent idiopathic scoliosis. *Pediatr Rehabil* 2003; **6**:209–214.
15 Weiss HR, Weiss G, Schaar HJ. Incidence of surgery in conservatively treated patients with scoliosis. *Pediatr Rehabil* 2003; **6**:111–118.
16 Kane WJ, Brown JC, Hensinger RN, Keller RB. Scoliosis and school screening for spinal deformity. *Am Fam Physician* 1978; **17**:123–127.
17 Bunge EM, Juttmann RE, de Koning HJ. Steering Committee of the NESCIO Group. Screening for scoliosis: do we have indications for effectiveness? *J Med Screen* 2006; **13**:29–33.
18 Fong DY, Lee CF, Cheung KM, Cheng JC, Ng BK, Lam TP, *et al*. A meta-analysis of the clinical effectiveness of school scoliosis screening. *Spine* 2010; **35**:1061–1071.
19 Torell G, Nordwall A, Nachemson A. The changing pattern of scoliosis treatment due to effective screening. *J Bone Joint Surg Am* 1981; **63**:337–341.
20 Ferris B, Edgar M, Leyshon A. Screening for scoliosis. *Acta Orthop Scand* 1988; **59**:417–418.
21 Grivas TB, Vasiliadis E, Savvidou OD, Triantafyllopoulos G. What a school screening program could contribute in clinical research of idiopathic scoliosis aetiology. *Disabil Rehabil* 2008; **30**:752–762.
22 Chowanska J, Kotwicki T, Rosadzinski K, Sliwinski Z. School screening for scoliosis: can surface topography replace examination with scoliometer? *Scoliosis* 2012; **7**:9.
23 Weinstein SL, Dolan LA, Wright JG, Dobbs MB. Effects of bracing in adolescents with idiopathic scoliosis. *N Engl J Med* 2013; **369**:1512–1521.
24 Negrini S, Atanasio S, Fusco C, Zaina F. Effectiveness of complete conservative treatment for adolescent idiopathic scoliosis (bracing and exercises) based on SOSORT management criteria: results according to the SRS criteria for bracing studies – SOSORT Award 2009 Winner. *Scoliosis* 2009; **4**:19.
25 Aulisa AG, Guzzanti V, Galli M, Perisano C, Falciglia F, Aulisa L. Treatment of thoraco-lumbar curves in adolescent females affected by idiopathic scoliosis with a progressive action short brace (PASB): assessment of results according to the SRS committee on bracing and nonoperative management standardization criteria. *Scoliosis* 2009; **4**:21.

26 Negrini S, Minozzi S, Bettany-Saltikov J, Zaina F, Chockalingam N, Grivas TB, *et al.* Braces for idiopathic scoliosis in adolescents. *Cochrane Database Syst Rev* 2015; **1**:CD006850.

27 Lange JE, Steen H, Gunderson R, Brox JI. Long-term results after Boston brace treatment in late-onset juvenile and adolescent idiopathic scoliosis. *Scoliosis* 2011; **6**:18.

28 Negrini S, Negrini F, Fusco C, Zaina F. Idiopathic scoliosis patients with curves more than 45 Cobb degrees refusing surgery can be effectively treated through bracing with curve improvements. *Spine J* 2011; **115**:369–380.

29 Lee CS, Hwang CJ, Kim DJ, Kim JH, Kim YT, Lee MY, *et al.* Effectiveness of the Charleston night-time bending brace in the treatment of adolescent idiopathic scoliosis. *J Pediatr Orthop* 2012; **32**:368–372.

30 Aulisa AG, Guzzanti V, Perisano C, Marzetti E, Falciglia F, Aulisa L. Treatment of lumbar curves in scoliotic adolescent females with progressive action short brace: a case series based on the Scoliosis Research Society Committee Criteria. *Spine* 2012; **37**:E786–E791.

31 Aulisa AG, Guzzanti V, Falciglia F, Giordano M, Marzetti E, Aulisa L. Lyon bracing in adolescent females with thoracic idiopathic scoliosis: a prospective study based on SRS and SOSORT criteria. *BMC Musculoskelet Disord* 2015; **16**:316.

32 Aulisa AG, Giordano M, Falciglia F, Marzetti E, Poscia A, Guzzanti V. Correlation between compliance and brace treatment in juvenile and adolescent idiopathic scoliosis: SOSORT 2014 award winner. *Scoliosis* 2014; **9**:6.

33 Donzelli S, Zaina F, Lusini M, Minnella S, Negrini S. In favour of the definition 'adolescents with idiopathic scoliosis': juvenile and adolescent idiopathic scoliosis braced after ten years of age, do not show different end results. SOSORT award winner 2014. *Scoliosis* 2014; **9**:7.

34 Ohtsuka Y, Yamagata M, Arai S, Kitahara H, Minami S. School screening for scoliosis by the Chiba University Medical School screening program. Results of 1.24 million students over an 8-year period. *Spine (Phila Pa 1976)* 1988; **13**:1251–1257.

35 Yawn BP, Yawn RA. The estimated cost of school scoliosis screening. *Spine* 2000; **25**:2387–2391.

36 Leone A, Aulisa A, Perisano C, Re T, Galli M. Advantages of a two-step procedure for school-based scoliosis screening. *Radiol Med (Torino)* 2010; **115**:238–245.

37 [No authors listed]. UNSCEAR 2000 published. United Nations Scientific Committee on the Effects of Atomic Radiation. *Health Phys* 2001; **80**:291.

38 Grivas TB, Wade MH, Negrini S, O'Brien JP, Maruyama T, Hawes MC, *et al.* SOSORT consensus paper: school screening for scoliosis. Where are we today? *Scoliosis* 2007; **2**:17.

39 Karachalios T, Sofianos J, Roidis N, Sapkas G, Korres D, Nikolopoulos K. Ten-year follow-up evaluation of a school screening program for scoliosis. Is the forward-bending test an accurate diagnostic criterion for the screening of scoliosis? *Spine* 1999; **24**:2318–2324.

40 Pruijs JE, Keessen W, van der Meer R, van Wieringen JC, Hageman MA. School screening for scoliosis: methodologic considerations. Part 1: external measurements. *Spine* 1992; **17**:431–436.

41 Bunnell WP. Selective screening for scoliosis. *Clin Orthop* 2005; **434**:40–45.

42 Grivas TB, Hresko MT, Labelle H, Price N, Kotwicki T, Maruyama T. The pendulum swings back to scoliosis screening: screening policies for early detection and treatment of idiopathic scoliosis – current concepts and recommendations. *Scoliosis* 2013; **8**:16.

43 Aulisa L, Bartolini F, Tamburrelli F, Valassina A. Early diagnosis of scoliosis: methodologic problem. *Arch Putti Chir Organi Mov* 1982; **32**:129–137.

44 Thulbourne T, Gillespie R. The rib hump in idiopathic scoliosis. Measurement, analysis and response to treatment. *J Bone Joint Surg Br* 1976; **58**:64–71.

45 Goldberg CJ, Kaliszer M, Moore DP, Fogarty EE, Dowling FE. Surface topography, Cobb angles, and cosmetic change in scoliosis. *Spine* 2001; **26**:E55–E63.

46 Grivas TB, Vasiliadis ES, Mihas C, Savvidou O. The effect of growth on the correlation between the spinal and rib cage deformity: implications on idiopathic scoliosis pathogenesis. *Scoliosis* 2007; **2**:11.

47 Burwell RG, James NJ, Johnson F, Webb JK, Wilson YG. Standardised trunk asymmetry scores. A study of back contour in healthy school children. *J Bone Joint Surg Br* 1983; **65**:452–463.

48 Korovessis PG, Stamatakis MV. Prediction of scoliotic Cobb angle with the use of the scoliometer. *Spine* 1996; **21**:1661–1666.

49 Theologis TN, Fairbank JC, Turner-Smith AR, Pantazopoulos T. Early detection of progression in adolescent idiopathic scoliosis by measurement of changes in back shape with the Integrated Shape Imaging System scanner. *Spine* 1997; **22**:1223–1227; discussion 1228.

50 Grosso C, Negrini S, Boniolo A, Negrini AA. The validity of clinical examination in adolescent spinal deformities. *Stud Health Technol Inform* 2002; **91**:123–125.

51 Sapkas G, Papagelopoulos PJ, Kateros K, Koundis GL, Boscainos PJ, Koukou UI, Katonis P. Prediction of Cobb angle in idiopathic adolescent scoliosis. *Clin Orthop* 2003; **411**:32–39.

52 Aulisa AG, Guzzanti V, Perisano C, Marzetti E, Menghi A, Giordano M, Aulisa L. Correlation between hump dimensions and curve severity in idiopathic scoliosis before and after conservative treatment. *Spine (Phila Pa 1976)* 2018; **43**:114–119.

53 Patias P, Grivas TB, Kaspiris A, Aggouris C, Drakoutos E. A review of the trunk surface metrics used as scoliosis and other deformities evaluation indices. *Scoliosis* 2010; **5**:12.