Journal of Back and Musculoskeletal Rehabilitation -1 (2020) 1–6 1
DOI 10.3233/BMR-200215
IOS Press

Adolescent idiopathic scoliosis screening: Could a school-based assessment protocol be useful for an early diagnosis?

Dalila Scaturro[a], Alessandro de Sire[b,c,*], Pietro Terrana[a], Claudio Costantino[d], Lorenza Lauricella[e], Claudia Emilia Sannasardo[a], Francesco Vitale[d] and Giulia Letizia Mauro[a]

[a]*Dipartimento di Discipline Chirurgiche, Oncologiche e Stomatologiche, Università degli Studi di Palermo, Palermo, Italy*

[b]*Physical and Rehabilitative Medicine, Department of Health Sciences, University of Eastern Piedmont, Novara, Italy*

[c]*Rehabilitation Unit, Mons. L. Novarese Hospital, Moncrivello, Vercelli, Italy*

[d]*Dipartimento di Promozione della Salute, Materno-Infantile, di Medicina Interna e Specialistica di Eccellenza "G. D'Alessandro", Università degli Studi di Palermo, Palermo, Italy*

[e]*Physical Medicine and Rehabilitation Unit, "P. Giaccone" University Hospital, Palermo, Italy*

Received 21 July 2020
Accepted 18 October 2020

Abstract.
BACKGROUND: Adolescent idiopathic scoliosis screening still needs a considerable implementation, particularly throughout a school-based assessment protocol.
OBJECTIVE: This study aims to evaluate the effectiveness of clinical examinations currently in use for the diagnosis of adolescent idiopathic scoliosis, through a survey carried out in secondary schools to standardize a screening protocol that could be generalized.
METHODS: In their classrooms, the adolescents underwent an idiopathic scoliosis screening through three examinations: Adam's test, axial trunk rotation (ATR) and plumb line. In case of single positivity to one of the three examinations, a column X-ray examination was recommended.
RESULTS: The sensitivity and diagnostic specificity of Adam's test or ATR were 56.3% and 92.7%, respectively. The positivity to at least one between ATR or plumb line showed that sensitivity was higher than specificity: 91.3% versus 80.8%; the positivity to at least one between Adams's test or plumb line showed a sensitivity of 95.2% and a specificity of 81.5%. Finally, the positivity to all three examinations showed an increase in specificity (99.7%).
CONCLUSIONS: Taken together, our findings show that this school-based screening protocol had a very high specificity in early diagnosis of adolescent idiopathic scoliosis.

Keywords: Scoliosis, spine deformities, adam's test, axial trunk rotation, plumb line

1. Background

Scoliosis is a complex structural deformity of the spinal column on the three planes of space. On the frontal plane a lateral bending movement occurs, as well as an alteration of the curves on the sagittal plane,

*Corresponding author: Alessandro de Sire, Physical and Rehabilitative Medicine, Department of Health Sciences, University of Eastern Piedmont, Viale Piazza D'Armi, 1 - 28100 Novara, Italy. Tel.: +39 3213734800; E-mail: alessandro.desire@gmail.com.

most often causing a curve inversion. On the axial plane a rotational movement still occurs [1–3].

Vertebral deformity, caused by scoliosis, can be defined as a sign of a complex syndrome with a multifactorial etiology [4,5]. Possible etiological factors such as female sex, familiarity, firstborn, genetic background, biomechanical or neurological disorders, aberrant hormones functioning such as growth hormone and melatonin, and body schema disorders are mentioned in several studies. Behind this etiological heterogeneity, clear scenarios of autosomal dominant or autosomal recessive transmission are described together with a multifactorial heredity background [4]. The prevalence of scoliosis varies from 0.47–5.2%, although a 2–3% occurrence of the disease is commonly accepted in the general population, with a female to male ratio of 4:1 [6].

Scoliosis might be classified as congenital and acquired scoliosis, which is classified into idiopathic acquired scoliosis (around 80% of cases) and scoliosis secondary to other causes (e.g. neurological diseases and connective systemic diseases). Idiopathic scoliosis is the definition for cases with an unknown cause, results from a combination of genetic and environmental risk factors [4].

Furthermore, scoliosis follows different classifications: i) based on age at diagnosis: infantile idiopathic scoliosis in children aged from 0 to 3 years; juvenile idiopathic scoliosis in subjects aged from 4 to 10 years; adolescent idiopathic scoliosis in those aged from 11 to 18 years; adult idiopathic scoliosis in people older than 18 years; ii) based on radiological criterion: mild with a Cobb's angle $< 15°$, mild-moderate 16–24°, moderate 25–34°, moderate-severe 35–44°, severe 45–59°, and very severe $> 60°$; iii) based on a topographic criterion of the siting of the curves: cervical (C6-C7), cervical-dorsal (C7-T1), dorsal (T1-T12), dorsal-lumbar (T12-L1); lumbar (L1-L5) [7]. According to the Society On Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) [8], a Cobb's angle $\geqslant 10°$ defines scoliosis and $>30°$ the probability of anatomical damage increases significantly.

Scoliosis can lead to a higher chance to develop back pain in adolescents with a resulting reduction of health-related quality of life (HRQoL) [9]; furthermore, it has been shown that scoliosis might cause an altered body image development with detrimental consequences on posture, coordination, and balance [10–12]. Moreover, in severe cases, scoliosis can cause cardio-pulmonary disability characterized by restrictive ventilatory syndrome, deformation of the thoracic cavity, compression of the lungs, and reduction of vital capacity [13]. Scoliosis should be diagnosed at an early stage in order to start a prompt and adequate treatment, avoiding respiratory, psychological, and social complications that could characterize this disease [12,14,15].

Among the several screening tests for adolescent idiopathic scoliosis, Adam's test, axial trunk rotation (ATR) and plumb line are the most used in common clinical practice. The Adam's test has shown to be more sensitive than the scoliometer (used for assessing ATR) and is still considered as the best non-invasive clinical test for screening scoliosis [16]. ATR has been recently investigated by Moalej et al. [17] for screening idiopathic scoliosis in a sample of 144 children (aged 7–12 years) from primary school. Lastly, plumb line is commonly used in the clinical practice and included in the latest Istituto Scientifico Italiano Colonna Vertebrale (ISICO) screening protocol [18].

However, to date, there is still no agreement on a proper and early detection of adolescent idiopathic scoliosis that still needs a considerable implementation, particularly throughout a school-based screening. Moreover, there is a lack of evidence on the most appropriate and reliable screening methods in terms of sensitivity and specificity. In this context, we sought to evaluate the usefulness of a specific assessment protocol, using clinical examinations currently used in the common clinical practice for the diagnosis of adolescent idiopathic scoliosis in secondary schools.

2. Methods

2.1. Participants

In this cross-sectional study, adolescents attending secondary schools in the Province of Palermo, Italy, were recruited under the supervision of the Rehabilitation and Epidemiology and Preventive Medicine Hospital Units, University of Palermo, Italy.

Inclusion criteria were: a) male and female adolescents; b) age from 11 to 14 years; c) subjects whose parents had signed their informed consent, after having received detailed information by the physicians. Exclusion criteria were: a) congenital scoliosis; b) scoliosis secondary to neuromuscular diseases and connective systemic disease; c) other postural disabilities (e.g. Scheuerman disease).

The study was approved by the Ethical Committee Palermo I of the University Hospital of Palermo (5/2019 of May 22th 2019) with the frame of rules specified by the Declaration of Helsinki and its subsequent amendments, and the principles of good clinical practice.

Fig. 1. School-based adolescent idiopathic scoliosis screening protocol (constituting of Adam's test, axial trunk rotation, and plumb line).

2.2. Idiopathic scoliosis screening protocol

All the adolescents underwent a specialist clinical examination by a 10-year experienced physiatrist in classrooms (as depicted in Fig. 1), undergoing: i) Adam's test; ii) ATR; iii) plumb line.

i) Adam's test: the patient should bend forward, with the head bent and lower limbs extended. This test is considered as positive when the asymmetry of the trunk appears [18].
ii) ATR: the patient should bend forward, with the head bent and lower limbs extended, and the physician measures the ATR through a scoliometer (Gima Professional Medical Products, Gima S.p.A., Gessate, Milan, Italy). In presence of more than 5 degrees, a column X-ray examination is recommended [19].
iii) plumb line: patient standing in a correct posture with a straight gaze, position the tangent line until it reaches the intergluteal fold to obtain a correct reference vertical for measurements. From the plumb line, once immobile, it is possible to calculate the distance up to the three reference points C7-D12-L3. The values considered normal for kyphosis are given by the sum of the arrow of C7 and L3 up to 90 mm and at L3 level up to 55 mm. Values above 90 mm and 55 mm should lead to a specialist investigation according to the latest ISICO screening protocol [18], however, there is no unanimous consensus.

The positivity to one of the three examinations, together with the clinical examination, indicated the execution of column X-ray examination to prescribe the most suitable treatment. This instrumental exam will allow the measurement of the Cobb's angle, measured by the angle between perpendicular lines erected from lines parallel to the superior endplate of the superior vertebra and the inferior endplate of the inferior vertebra of curvature, and Risser grade, an indirect measurement of skeletal maturity based on the ossification degree of the iliac apophysis by X-ray examination. Scoliosis is described as a curve with 10° or more and rotation of the vertebral body, according to the Scoliosis Research Society (SRS) and the International Scientific Society on Scoliosis SOSORT (Society On Scoliosis Orthopaedic and Rehabilitation Treatment). Patients with a confirmed diagnosis of radiographic scoliosis were then given an aesthetic evaluation through TRACE (Trunk Aesthetic Clinical Evaluation) developed by ISICO [20].

2.3. Statistical analysis

The parameters taken into consideration by our study for the evaluation of the effectiveness of the diagnostic examinations assessed (see Table 1 for further details) were: sensitivity = true positives/(true positives + false negatives); specificity = true negatives/(false positives + true negatives). Furthermore, we defined as a likelihood ratio (LR) the ratio between sensitivity and (1 – specificity). In short, LR+ is the ratio between the probability that a patient is positive and the probability that a healthy person is positive. In other words, in the case of a positive result, LR+ is times more likely that the subject is sick than healthy. On the other hand, LR- is considered as the ratio between the probability that a patient is negative and the probability that a healthy person is negative. In other words, in the case of a negative result, LR- is times more likely that the subject is ill than healthy. Further details are illustrated in Table 1.

3. Results

Of the 447 subjects recruited, 19 did not meet the eligibility criteria (10 had congenital scoliosis and nine had secondary scoliosis). Thus, we included 428 adolescents in the analysis, aged between 11 and 14 years (mean age = 11.9 years), including 228 males (53.3%)

Table 1
Sensitivity, specificity, predictive values and likelihood ratio (LR) of the scoliosis screening protocol

	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	LR+ (n)	LR- (n)
Adam's test	50.8	94.4	79.0	82.1	9.02	0.52
Axial trunk rotation	46.0	93.4	74.4	80.6	6.95	0.58
Plumb line	61.1	86.8	65.8	84.2	4.61	0.45
Adam's test or axial trunk rotation	56.3	92.7	76.3	83.6	7.74	0.47
Axial trunk rotation or plumb line	91.3	80.8	66.5	95.7	4.75	0.11
Adam's test or plumb line	95.2	81.5	68.2	97.6	5.14	0.06
Adam's test + axial trunk rotation	40.5	95.0	77.3	79.3	8.15	0.63
Axial trunk rotation + plumb line	15.9	99.3	90.9	73.9	23.97	0.85
Adam's test + plumb line	16.7	99.7	95.5	74.1	50.33	0.84
Positive to at least one examination	100.0	80.1	67.7	100.0	5.03	–
Positive to all three examinations	15.1	99.7	95.0	73.8	45.54	0.85

and 200 females (46.7%). Out of these 428 adolescents, 186 (43.5%) tested positive for at least one among Adam's test, ATR, and plumb line. Of these, 20 subjects (10.8%) were positive in all three examinations.

Thirteen subjects (7.0%) were positive only at Adam's test, 46 (24.7%) at both Adam's test and ATR, two subjects (1.1%) were positive to both Adam's test and plumb line, two at both ATR and plumb line examinations (1.1%), 93 subjects (50%) were positive at the plumb line only, and 10 (5.4%) were positive at inclinometer only. Associating the variables, a total of 81 adolescents (43.5%) were positive for Adam's test, 78 (41.9%) for the ATR, and 117 (62.9%) for the plumb line.

After the radiographic study, we observed that, among the 186 patients tested positive to at least one screening examination, 126 of them (66.7%) had a Cobb's angle greater than 10° and therefore considered affected by idiopathic scoliosis; moreover 46 (24.7%) adolescents had an angle greater than 8 and less than 10.

Analyzing and cross-referencing the data described above, we experienced that the Adam's test sensitivity and specificity were of 50.8% and 94.4%, respectively, with a positive predictive value of 79%, representing, among the three examinations performed, the one with the highest specificity, sensitivity, and positive predictive value. ATR showed a sensitivity of 46%, a specificity of 93.4%, and a positive predictive value of 74.4%. Finally, the plumb line showed the lowest results in terms of sensitivity (61.1%), specificity (86.8%), and positive predictive value (65.8%).

Then, we examined the sensitivity and diagnostic specificity of the group of positive subjects to at least one examination between Adam's test or ATR, respectively: 56.3% and 92.7%. On the other hand, the positivity to at least one examination between ATR or plumb line, sensitivity was higher than the specificity: 91.3% versus 80.8%. The same happened for the positivity to at least one examination between Adam's test or plumb line, which showed a sensitivity of 95.2% compared to a specificity of 81.5%. Finally, taking into consideration patients with positivity at the three examinations, there was a clear increase in specificity reaching 99.7% (see Table 1 for all these data).

4. Discussion

Our findings demonstrated the usefulness of a school-based screening program standardizing a protocol for the early diagnosis of adolescent idiopathic scoliosis. Individually performing the Adam's test, ATR, and plumb line could not be considered as sufficient tools aiming to detect potential scoliotic subjects due to the low sensitivity of each examination. Analyzing the high LR value of Adam's test and ATR, these examinations if administered individually might fail to intercept potential subjects with scoliosis. Hence, they can be singularly considered useful but not diagnostic. Conversely, the single plumb line is not indicated both in the diagnosing and screening process, having a lower sensitivity, specificity, and positive predictive value. Notably, the association between Adam's test/plumb line or ATR / plumb line significantly increases the sensitivity while maintaining high specificity. The high LR and a positive predictive value obtained from these combinations may suggest the use of both matches as a screening tool to perform early diagnosis of scoliosis.

In the United States, school screening for scoliosis has been a practice for years. In this context, the Scoliosis Research Society, the American Academy of Orthopedic Surgeons, and the American Academy of Pediatrics and the Pediatric Orthopedic Society of North America suggest that early detection of scoliosis upholds screening programs, however, there is no agree-

ment on the screening examination [21]. Dunn et al. recently reported that screening can detect juvenile idiopathic scoliosis [22] without indicating the best and most effective method.

In fact, in the literature, there is no clear agreement on the most effective screening examinations for adolescent idiopathic scoliosis. Our study has demonstrated the existence of a valid association set, constituting of Adam's test and plumb line, ATR, and plumb line, and that the execution of a single screening examination exposes to the risk of false negatives. Furthermore, the insertion of an easy and intuitive questionnaire for the identification of physical characteristics, habits, and attitudes allows us to identify new potential risk factors for the pathology and its evolution. It should be highlighted that early diagnosis of scoliosis might lead to less invasive conservative treatments [23,24] to avoid detrimental complications [13,25]. In this context, rehabilitation experts play a crucial role in this race against time to stop the disease evolution [12,26].

This study is not free from limitations. First, the study design did not consent to describe the main risk factors for developing idiopathic scoliosis. Second, there was an absence of data on the X-ray examinations for subjects screened in their follow-up evaluations. Third, the examinations had low specificity and sensitivity, individually. Lastly, taking into account that only subjects with ATR ranging from 0 to 3 degrees are commonly considered as healthy [27], it should be noted that there is still no agreement in the literature on people with ATR ranging from 3 to 5 degrees.

5. Conclusions

In conclusion, our findings show that a school-based screening protocol (a combination of Adam's test, ATR, and plumb line) had a very high specificity in the early diagnosis of adolescent idiopathic scoliosis. Future studies on screening of adolescent idiopathic scoliosis through other possible examinations are warranted to better detect this pathological condition to manage its treatment and avoid severe complications.

Conflict of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

References

[1] Stagnara P. Les déformations du rachis. Paris: Masson, 1985.
[2] Perdriolle R. La scoliose: son étudetridimensionnelle. Paris: Maloine, 1979.
[3] Selleri U, Negrini S La riabilitazione del paziente affetto da scoliosi idiopatica. Trattato di Medicina Riabilitativa, Medicina Fisica e Riabilitazione. Napoli: Idelson Gnocchi: 1123-47, 1999.
[4] Nachemson, Alf L., Sahlstrand, Tage, Md Etiologic Factors in Adolescent Idiopathic Scoliosis, Spine. 1977 Sep; 2(3): 176-184.
[5] Moen KY, Nachemson AL. Treatment of scoliosis. An historical perspective. Spine (PhilaPa 1976). 1999 Dec 15; 24(24): 2570-5. doi: 101097/00007632-199912150-00003.
[6] Konieczny MR, Senyurt H, Krauspe R. Epidemiology of adolescent idiopathic scoliosis. J Child Orthop. 2013 Feb; 7(1): 3-9. doi: 10.1007/s11832-012-0457-4.
[7] Konieczny MR, Senyurt H, Krauspe R. Epidemiology of adolescent idiopathic scoliosis. J Child Orthop. 2013 Feb; 7(1): 3-9. doi: 10.1007/s11832-012-0457-4.
[8] Negrini S, Donzelli S, Aulisa AG, Czaprowski D, Schreiber S, de Mauroy JC, et al. 2016 SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. Scoliosis Spinal Disord. 2018 Jan 10; 13: 3. doi: 10.1186/s13013-017-0145-8.
[9] Polastri M, Romano M. Lumbar scoliosis: Reducing lower back pain and improving function in adulthood. A case report with a 2-year follow-up. J Bodyw Mov Ther. 2017 Jan; 21(1): 81-85. doi: 10.1016/j.jbmt.2016.05.004.
[10] Fällström K, Cochran T, Nachemson A. Long-term effects on personality development in patients with adolescent idiopathic scoliosis. Influence of type of treatment. Spine (Phila Pa 1976), 1986 Sep; 11(7): 756-8. doi: 10.1097/00007632-198609000-00018.
[11] Schwieger T, Campo S, Weinstein SL, Dolan LA, Ashida S, Steuber KR. Body Image and Quality of Life and Brace Wear Adherence in Females With Adolescent Idiopathic Scoliosis. J Pediatr Orthop. 2017 Dec; 37(8): e519-e523. doi: 10.1097/BPO.0000000000000734.
[12] Yagci G, Ayhan C, Yakut Y. Effectiveness of basic body awareness therapy in adolescents with idiopathic scoliosis: A randomized controlled study. J Back Musculoskelet Rehabil. 2018; 31(4): 693-701. doi: 10.3233/BMR-170868.
[13] Johari J, Sharifudin MA, Ab Rahman A, Omar AS, Abdullah AT, Nor S, Lam WC, Yusof MI. Relationship between pulmonary function and degree of spinal deformity, location of apical vertebrae and age among adolescent idiopathic scoliosis patients. Singapore Med J. 2016 Jan; 57(1): 33-8. doi: 10.11622/smedj.2016009.
[14] Cheung JPY, Luk KD. Managing the Pediatric Spina: Growth Assessment. Asian Spine J. 2017 Oct; 11(5): 804. doi: 10.4184/asj.2017.11.5.804.
[15] Fusco C, Donzelli S, Lusini M, Salvatore M, Zaina F, Negrini S. Low rate of surgery in juvenile idiopathic scoliosis treated with a complete and tailored conservative approach: end-growth results from a retrospective cohort. Scoliosis. 2014 Aug 18; 9: 12. doi: 10.1186/1748-7161-9-12.
[16] Côté P, Kreitz BG, Cassidy JD, Dzus AK, Martel J. A study of the diagnostic accuracy and reliability of the Scoliometer and Adam's forward bend test. Spine (Phila Pa 1976). 1998 Apr 1; 23(7): 796-802; discussion 803. doi: 10.1097/00007632-199804010-00011.

[17] Moalej S, Asadabadi M, Hashemi R, Khedmat L, Tavacolizadeh R, Vahabi Z, Shariatpanahi G. Screening of scoliosis in school children in Tehran: The prevalence rate of idiopathic scoliosis. J Back Musculoskelet Rehabil. 2018; 31(4): 767-774. doi: 10.3233/BMR-171078.

[18] Protocollo Scientifico Screening ISICO Rev.10 [2018 Mar 3]. Available at: https//www.gss.it/gss/scoliosi2013/docs/Protocollo_Screening.pdf.

[19] Coelho DM, Bonagamba GH, Oliveira AS. Scoliometer measurements of patients with idiopathic scoliosis. Braz J Phys Ther. 2013 Mar-Apr; 17(2): 179-84. doi: 10.1590/S1413-35552012005000081.

[20] Zaina F, Negrini S, Atanasio S. TRACE (Trunk Aesthetic Clinical Evaluation), a routine clinical tool to evaluate aesthetics in scoliosis patients: development from the Aesthetic Index (AI) and repeatability. Scoliosis. 2009 Jan 20; 4: 3. doi: 10.1186/1748-7161-4-3.

[21] Horne JP, Flannery R, Usman S. Adolescent idiopathic scoliosis: diagnosis and management. Am Fam Physician. 2014 Feb 1; 89(3): 193-8.

[22] Dunn J, Henrikson NB, Morrison CC, Blasi PR, Nguyen M, Lin JS. Screening for Adolescent Idiopathic Scoliosis: Evidence Report and Systematic Review for the US Preventive Services Task Force. JAMA. 2018 Jan 9; 319(2): 173-187. doi: 10.1001/jama.2017.11669.

[23] Kavyani M, Nasiri E, Karimi MT, Fatoye F. The effect of spinal bracing on stability in patients with adolescent idiopathic scoliosis. J Back Musculoskelet Rehabil. 2020; 33(1): 139-143. doi: 10.3233/BMR-170908.

[24] Noh DK, You JS, Koh JH, Kim H, Kim D, Ko SM, Shin JY. Effects of novel corrective spinal technique on adolescent idiopathic scoliosis as assessed by radiographic imaging. J Back Musculoskelet Rehabil. 2014; 27(3): 331-8. doi: 10.3233/BMR-130452.

[25] Lippi L, de Sire A, Desilvestri M, Baricich A, Barbanera A, Cattalani A, Invernizzi M, Perrero L. Can scoliosis lead to spinal cord ischaemia? Early diagnosis and rehabilitation: a paradigmatic case report and literature review. J Back Musculoskelet Rehabil. 2020, In press.

[26] Levi D, Springer S, Parmet Y, Ovadia D, Ben-Sira D. Acute muscle stretching and the ability to maintain posture in females with adolescent idiopathic scoliosis. J Back Musculoskelet Rehabil. 2019; 32(4): 655-662. doi: 10.3233/BMR-181175.

[27] Linek P, Saulicz E, Wolny T, Myśliwiec A. Body Mass Normalization for Ultrasound Measurements of Adolescent Lateral Abdominal Muscle Thickness. J Ultrasound Med. 2017 Apr; 36(4): 775-782. doi: 10.7863/ultra.16.03086.