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Review

Screening for adolecent idiopathic scoliosis: A literature review

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BACKGROUND: Despite more than 60 years of screening for adolescent idiopathic scoliosis, it is still a controversial issue in the scientific literature. There are both opponents and supporters of the intervention, represented by government agencies, medical organizations, and individual researchers. Several countries have rejected national scoliosis screening, although some medical associations in these countries believe that screening based on the "Medical Home" model is feasible. By contrast, school-based scoliosis screening has been implemented nationally in a few countries. Given the lack of consensus on this issue, it is useful to systematize conflicting views on screening for adolescent idiopathic scoliosis.

AIM: This study aimed to review publications presenting information on the status of screening for juvenile idiopathic scoliosis to identify unresolved organizational issues.

MATERIALS AND METHODS: Data were searched in the open electronic scientific literature databases (eLIBRARY, PubMed, and Cochrane Library) using the following keywords and phrases: scoliosis screening; screening for adolescent idiopathic scoliosis (AIS); school screening for scoliosis; school scoliosis screening program. The depth of the search was 30 years.

RESULTS: Arguments "for" focus on the need for the early detection of AIS through screening in terms of the effectiveness of timely treatment, proven efficacy of conservative treatment of scoliosis, and reduction of surgical interventions among screened adolescents. The arguments "against" are related to the lack of a unified methodology for screening, high rate of false-positive and false-negative results, unproven effectiveness of screening in reducing the frequency of surgical interventions, economic efficiency, and psychological effect on adolescents and violation of their rights during the event.

CONCLUSIONS: Several organizational issues should be addressed with regard to screening. These include the training of staff who conducts the screening and development of a referral and follow-up system. The screening scheme and methods should be unified through the introduction of noninvasive screening methods to standardize the results and their subsequent uniform interpretation. The referral process for further examination should be standardized according to a defined protocol. The development of a special computer program to assist medical decision-making is relevant.

Keywords: scoliosis; screening; program; school screening; adolescent idiopathic scoliosis.

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Научный обзор

Скрининг на юношеский идиопатический сколиоз (обзор литературы)

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Обоснование. Несмотря на более чем шестидесятилетний период существования скрининга на юношеский идиопатический сколиоз, эта тема до сих пор вызывает споры в научной литературе. Существуют как противники, так и сторонники этого мероприятия в лице государственных структур, врачебных организаций и отдельных исследователей. Ряд стран отказались от национального скрининга на сколиоз, хотя отдельные врачебные объединения в этих же странах считают, что скрининг по модели «Медицинский дом» целесообразен. В противовес в целом ряде стран в национальных масштабах проводится школьный скрининг на сколиоз. В связи с отсутствием единого взгляда на данную проблему представляется целесообразным систематизировать разноречивые мнения по скринингу на юношеский идиопатический сколиоз.

Цель — проанализировать публикации, посвященные скринингу на юношеский идиопатический сколиоз, для определения круга нерешенных организационных вопросов.

Материалы и методы. Осуществлен поиск данных в открытых электронных базах научной литературы eLIBRARY, PubMed и Cochrane Library по ключевым словам и словосочетаниям: скрининг сколиоза, скрининг на юношеский идиопатический сколиоз, школьный скрининг на сколиоз, программа школьного скрининга на сколиоз [scoliosis screening; screening for adolescent idiopathic scoliosis (AIS); school screening for scoliosis; school scoliosis screening program]. Глубина поиска составила 30 лет.

Результаты. Аргументы «за» основаны на необходимости раннего выявления юношеского идиопатического сколиоза с учетом успешности своевременного лечения, доказанной эффективности консервативного лечения сколиоза и уменьшения количества хирургических вмешательств среди выявленных при скрининге подростков. Аргументы «против» связаны с отсутствием единой методики проведения скрининга, со значительной долей ложноположительных и ложноотрицательных результатов, недоказанностью эффективности скрининга с точки зрения снижения частоты хирургических вмешательств, экономической целесообразности, а также с психологическим воздействием на подростка и нарушением его прав при проведении мероприятия.

Заключение. Следует решить целый ряд организационных вопросов. К ним относятся подготовка кадров для осуществления скрининга, разработка системы направления на обследование и последующее наблюдение. Схема и методы проведения скрининга необходимо унифицировать посредством внедрения неинвазивных методов обследования с целью стандартизации получаемых результатов и их последующей единой интерпретации. Процесс направления на дальнейшее обследование также должен быть стандартизирован в соответствии с определенным протоколом. Актуальна разработка специальной компьютерной программы для помощи в принятии врачебных решений.

Ключевые слова: сколиоз; скрининг; программа; школьный скрининг; юношеский идиопатический сколиоз.

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ЭКО•ВЕКТОР

BACKGROUND

The prevention of the severe forms of adolescent idiopathic scoliosis (AIS), subject to surgical correction, is an important task of doctors involved in the treatment of spinal deformities. Early detection of scoliosis is relevant because if untreated, the disease progresses in the long term, and in some cases, surgery is ultimately required and disability occurs.

The development of screening for AIS was attributed to G.D. MacEwen, USA MD, who introduced this program to all Delaware schools in the 1960s [1]. A larger-scale scoliosis screening was started in 1963 in Aitken, a city with approximately 10,000 populations in Central Minnesota [2]. Since 1984, the American Academy of Orthopedic Surgeons (AAOS) and the Scoliosis Research Society (SRS) have approved the concept of schoolchildren screening for the early detection of scoliosis [3].

Although the history of AIS screening goes back >60 years, the controversy around it has not subsided until the present day. Even in the USA, the ancestor of scoliosis screening, there are different opinions on this matter. Thus, in 2004, the United States Preventive Services Task Force opposed periodic screening of adolescents without obvious symptoms of AIS, citing its low predictive value, the relatively small proportion of children with disease progression, and the probability of unreasonable treatment, including wearing a brace [4]. This position was also formulated in the latest statement of 2018 [5, 6]. However, in 2007, the AAOS, SRS, Pediatric Orthopedic Society of North America (POSNA), and the American Academy of Pediatrics (AAP) issued an information statement presenting the documented benefits of early detection and the efficiency of conservative treatment of AIS and therefore the feasibility of screening for AIS [7]. This position was also confirmed by SRS in 2013 [8] and by AAP in 2017 and 2019 [9].

In this regard, taking into account the problem of screening from the standpoint of various government agencies, medical organizations, and authors, we consider it appropriate to analyze publications related to screening for AIS.

The work aimed to analyze publications on screening for AIS to determine the range of unresolved organizational issues.

MATERIALS AND METHODS

Data were searched in the open electronic databases of scientific literature, namely, eLIBRARY, PubMed, and Cochrane Library, using the following keywords and phrases: scoliosis screening, screening for AIS, school screening for scoliosis, and school scoliosis screening program. The criteria for inclusion in the study were as follows: randomized controlled and controlled trials, systematic reviews, advisory, and informational and methodological materials from leading scientific societies on scoliosis. In total, 61 articles in Russian and English (full-text articles, documents, and abstracts of articles) containing information on screening for AIS were considered. Sources were mainly limited to those published in 1990–2021. Materials published before 1990 were included in the review if they contained underlying or historical data on screening for AIS not covered in later publications.

RESULTS

Primarily, 387 articles were selected by keywords, and a final list of 61 publications was identified according to the inclusion criteria. These included 12 retrospective controlled cohort studies, 10 prospective controlled cohort studies, 5 cross-sectional studies, 4 consensus studies, 2 case–control studies, 16 systematic reviews, and 1 description of single clinical cases. The remaining 11 publications were advisory (5) and informational (4) statements and methodological materials (2) on screening for AIS. The materials were grouped to search for answers to several questions:

- *Who recommends or does not recommend AIS screening? What are the main arguments against or for screening?*
- *What methods are used for screening? What are the values of the parameters the diagnostic radiography should be based on: the frequency of false-positive and false-negative results?*
- *What is the efficiency of screening in relation to the need for surgical treatment?*
- *Is screening for scoliosis economically feasible?*

DISCUSSION

Who recommends or does not recommend screening for AIS? What are the main arguments against or for screening? (Table 1)

This global problem [19, 20] concerns millions of people [21–23], but it is solved differently in different countries. In Bulgaria, Netherlands, Greece, India, Spain, Italy, China, Malaysia, Turkey, Singapore, Sweden, and Japan, screening examinations of schoolchildren for the early detection of pathology are conducted within the legislative framework on a national scale [24].

By contrast, the USA Preventive Service [5, 6], UK National Screening Committee [10, 11], and National Health and Medical Research Council of Australia [13] concluded that screening for scoliosis should not be national. Austria, Canada, France, Germany, Israel, Norway, Poland, and Spain adhere to the same principle for scoliosis [16]. The principle of non-national screening for scoliosis is also implemented in Russia. Russian scientific literature presents information on screening studies only on a regional scale [25–27].

Table 1. Summarized data on the question "scoliosis screening: recommended or not recommended?"

Scoliosis screening is *NOT RECOMMENDED* or *DISCONTINUED* (statement of the main argument)	
United States Preventive Services Task Force [5, 6]	If a service is offered, patients must understand the uncertainty concerning the balance of benefits and harms
United Kingdom of Great Britain, National Screening Committee, 2016 [10, 11]	There is little qualitative evidence on the efficiency of treatments for scoliosis, i.e., people with idiopathic scoliosis may receive unnecessary and ineffective treatment [12]
National Health and Medical Research Council, Australia, 2002 [13]	Insufficient randomized clinical trials demonstrating the efficiency of screening tests and conservative treatment
Canadian Task Force on Preventive Health Care, 1994 [14]	Insufficient evidence to decide definitively for or against
Screening for scoliosis is *RECOMMENDED* (formulation of the main argument)	
American Academy of Pediatrics, 2017 and 2019 [9]	Screening for scoliosis throughout adolescence at routine preventive examinations
Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT), 2016, published in 2018 [15]	Based on the 2007 SOSORT consensus document on screening [16], school programs are recommended
American Academy of Orthopedic Surgeons, Scoliosis Research Society, and Pediatric Orthopedic Society of North America, 2015 [7, 8]	Recommended for family doctors at home, Medical Home model
Scoliosis Research Society, 2013 [17]	Based on the consensus document and systematic review on screening by SRS, 2013 [18], school programs are recommended

In countries that do not have national requirements or standards for such screening, it may be approved at the state level and at the district, city, or individual school level [28]. Screening can be performed in the office of a pediatrician, chiropractor, or other health care worker, often not in school premises. A survey by Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) experts showed that screening studies are most often performed by school nurses (48.57%), physical therapists (28.57%), orthopedists (17.14%), and physical education teachers (11.42%) and less often by receptionist nurses, school doctors, and staff members of health centers [16].

In this regard, the experience of the Spine Society of Australia is interesting, which, with the support of the Royal Australian College of General Practitioners, developed the National Scoliosis Self-Detection Program. The website http://www.scoliosis-australia.org presents a special non-fiction booklet that can be read by adolescents aged 11–13 or their parents to suspect AIS and contact their family doctor. Moreover, the website organizes training on screening diagnostics of scoliosis for family doctors. A similar virtual office for patients has been created on the website of the British Scoliosis Society (http://www.britscoliosis.org.uk).

The authors who declare against screening, including school screening, raise the issue of its unethical nature and the vulnerability and fragility of adolescence [29, 30], more generally about the need to observe the rights of children when examining them [31]. In this aspect, the Medical Home model [7, 8] recommended by the SRS is considered the most preferred form of screening implemented by family doctors. Screening tests should be acceptable to the population, and treatments should be acceptable to the patients [32–34].

The supporters of screening for scoliosis assert that the early detection of scoliosis and timely prescription of conservative treatment reduces the frequency of surgical interventions and the severity of the scoliotic curve, which is confirmed by systematic reviews and retrospective and prospective clinical studies [2, 3, 16, 35, 36].

At what age children should be screened for scoliosis? (Table 2)

Although a systematic review by J.A. Deurloo and P.H. Verkerk [12] showed that the optimal age and frequency of screening for scoliosis is still unknown, Table 2 demonstrates that most experts insist that girls should be screened at age of 12 years and boys at age of 13 years.

What methods are used for screening? What are the values of the parameters the diagnostic radiography should be based on: frequency of false-positive and false-negative results? (Table 3)

Table 2. Recommended age for scoliosis screening

Society or author	Recommended age
American Academy of Orthopedic Surgeons, Scoliosis Research Society, Pediatric Orthopedic Society of North America, 2015 [7, 8]	Girls aged 10 and 12 years. Boys aged 13–14 years
American Academy of Pediatrics, 2017 and 2019 [9]	During scheduled doctor visits at the ages of 10, 12, 14, and 16 years
Society on Scoliosis Orthopedic and Rehabilitation Treatment, 2007 [16]	Girls aged 12 years Boys aged 13 years
J. Sabirin et al., 2010 [3]	Girls aged 12 years
T.B. Grivas et al., 2002 and 2006 [37, 38]	Girls living in northern countries should be screened at an older age range than girls living in the south

As shown in the table, inclinometry, which is the measurement of the maximum angle of the body rotation in an upright position and with a forward bend (angle of trunk rotation [ATR]) is apparently the simplest, fastest, most reliable, least expensive, and objective method to determine the trunk deformity, which is widely used in screening for AIS [3, 16, 17, 37, 40–47]. Moreover, several authors consider an angle of 5° to be the threshold value [41–43, 45–47]. In some works, an interval of 5°–7° is indicated [17, 40, 43]. In the SOSORT consensus study, which recommends conducting an examination using a scoliometer in the sitting position, not an upright position [16], and in the studies by J. Sabirin et al. [3], T.B. Grivas et al. [37], and I.S. Komang Agung et al. [43], an angle of 7° was adopted as a threshold value. Despite the low specificity, the Adams forward bend test [47], which was historically one of the first screening tests [1, 2], is still mentioned by researchers [43–46]. Some authors believe that with the increase in the number of screening tests, their sensitivity and specificity increase, and the proportion of false-positive and false-negative results decreases [44, 47].

The main controversy occurs over false-positive and false-negative screening results. These results are the basis of the main argument of the opponents of this event. According to W.P. Bunnell [48], although a significant correlation exists between clinical deformity and radiographic measurements, the standard deviation is so wide that predicting reliably the degree of curvature from surface topography in any patient is not possible. To rule out false-positive results, the author recommends repeated screening at school within 6–12 months instead of a referral for an X-ray examination.

The SOSORT report also noted that under typical screening conditions, 1–5 false-positive results are recorded for every detected curve >10°. Similarly, for each detected curve >20°, 3–24 false-positive results are obtained [16]. Canadian specialists M. Beausejour et al. [53] reported that 206 (42%) of 489 patients with suspected idiopathic scoliosis had no significant deformity (Cobb angle <10°), and the authors rated them as inappropriate referrals.

SOSORT believes that the school screening program is aimed at identifying superficial torso deformity rather than predicting which scoliotic curves will progress and may further lead to the need for conservative or surgical treatment [16].

According to the AAOS, SRS, POSNA, and AAP, diagnostic X-ray imaging of the spine in children, aimed at diagnosing scoliosis, should apply the "as low as reasonably achievable" principle to reduce the radiation dose [49].

In addition to the above screening tests for scoliosis, many devices and methods have been proposed, including molecular genetic tests based on DNA microarrays [50, 51]. However, the time and costs required to conduct these studies make them inappropriate for mass screening. As noted by H.R. Weiss [52], we should seek to replace school screening with costly gene screening methods. They are probably useful in predicting curve progression.

What is the efficiency of screening in relation to the need for surgical treatment?

Experts have different opinions regarding the efficiency of screening in relation to the need for surgical treatment. Among the studies that support screening, Torell et al. [54] evaluated the effect of an early detection and treatment program for idiopathic scoliosis in a population of 1.5 million people over 10 years. During this period, scoliosis >20° (measured by the Cobb method) was identified in 725 patients before they reached the age of 20 years. Although the treatment principles have basically remained the same, the proportion of patients requiring surgery has decreased annually. Malaysian scientists J. Sabirin et al. [3] also believed that the school screening program for scoliosis contributed to a reduction in the need for surgery. Moreover, the frequency of surgical intervention in patients detected by screening can be significantly reduced only through high-quality conservative treatment [55].

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Table 3. Information about screening tests, parameter values, and their sensitivity and specificity in chronological order

Authors	Screening tests (+) recommended by the authors, threshold values of parameters, and their sensitivity and specificity			
	Adams test	Inclinometry (scoliometer)	Plumb	Moiré topography
Armstrong, 1982 [39]	(+)			
Grossman, 1995 [40]		(+) 5°–7°		
De Wilde et al., 1998 [41]		(+) 5°; coefficient of variation — 10%		
Grivas et al., 2002 [37]		(+) 7°		
Grivas et al., 2007 [16]		(+) 7°; the study was conducted in a sitting position, not in the upright position		
Sabirin et al., 2010 [3]	(+)	(+) 7°		
Labelle et al., 2013 [17]		(+) 5°–7°		
Elshazly et al., 2014 [42]	(+)	(+) 5°		
Komang-Agung et al., 2018 [43]	(+)	(+) 5° Sensitivity, 95.6% Specificity, 18.5% (+) 7° Sensitivity, 78.26% Specificity, 88.88%		
Dunn et al., 2018 [44]	(+)	(+) When combining the Adams test with a scoliometer: sensitivity, 71.1%; specificity, 97.1%; false-positive results, 2.9%; false-negative results, 28.9%		(+) With a combination of all three tests: sensitivity, 93.8%; specificity, 99.2%; predictive value, 81.0%; false-positive results, 0.8%; false-negative results, 6.4%
Adamczewska et al., 2019 [45]		(+) 5°; the greatest value of the angle in the thoracic and thoracolumbar regions		
Yılmaz et al., 2020 [46]	(+)	(+) 5°		
Scaturro et al., 2021 [47]	(+) Specificity, 56.3%	(+) 5° Specificity, 92.7%	(+) When combining a plumb with the Adams test: specificity, 81.5%. With a combination of all three tests: specificity, 99.7%	

However, there are other opinions as well. Thus, Dutch doctors E.M. Bunge et al. [56] used the case–control principle to determine the efficiency of screening in reducing the need for surgical treatment. In operated patients identified during screening, who were diagnosed at the age of 10.8 ± 2.6 years, the Cobb angle of the scoliotic curve was 54° ± 8.2° before surgery and 30° ± 12.9° after surgery. The age of the remaining operated patients was 13.4 ± 1.7 years, and the Cobb angle of the scoliotic curve was 57° ± 11.7° before the surgery and 33° ± 10.2° after the surgery. Before the surgery, both groups used orthoses on the trunk for 2.5 years. Thus, the authors did not obtain convincing evidence to reduce the need for surgery by screening for idiopathic scoliosis. H. Labelle et al. [8] and J.A. Deurloo and P.H. Verkerk [12] shared the same opinion.

Is screening for scoliosis economically feasible?

Hong Kong scientists had fully estimated the expenditures for the scoliosis screening program in a large population-based study [59]. Screening costs (in 2005, USD) per student were $17.94, and expenditures for screening and diagnostic tests were $20.02. In addition, the cost of brace treatment until the age of 19 is $8,018, whereas surgery and follow-up until the same age is at least $27,538. These counts were comparable to those of a previous study by B.P. Yawn and R.A. Yawn [60]. However, it is not possible to conclude on the cost-effectiveness of screening from these data.

From the perspective of a public health and an international SRS panel, insufficient evidence supports a screening program for AIS, as it is unclear whether screening is cost effective [8]. Furthermore, the cost-effectiveness of the preventive program as a whole, not just a clinical examination of the back and tests, should be assessed [12, 28].

H. Labelle et al. [8] noted that a direct comparison of total screening costs is difficult because different researchers defined program costs, program costs + diagnostics, program costs + diagnostics + follow-up, and program costs + diagnostics + follow-up + treatment. Moreover, these costs must be analyzed based on performance indicators, that is, a decrease in overall costs, for example, due to the prevention of surgical intervention. The authors emphasize that further examination of the cost-effectiveness of screening programs by analyzing comparable conditions. In this regard, standardized special computer programs for making medical decisions [57], including smartphone applications [58], can be used.

On the contrary, J. Sabirin et al. [3] and S. Thilagaratnam [61] revealed evidence that a scoliosis screening program in schools was cost effective. This view is shared by SOSORT, which believes that if the event is well organized and conducted voluntarily, for example, in accordance with the model of the Greek school screening program Thriasio, then the direct costs of the screening program can be minimized [16].

CONCLUSION

The main arguments against screening programs are related to the apprehension of the negative psychological effect on the adolescent and the violation of children's rights during screening. Data on a significant proportion of false-positive and false-negative results and on the lack of data on cost-effectiveness are emphasized. However, in general, no studies have assessed the cost-effectiveness of not only screening but also the complex treatment of patients with AIS.

Despite the large number of pro-arguments, screening supporters do not deny that many organizational aspects of its implementation have not been resolved and standardized. Such aspects include training of personnel, development of a referral system for examination, and follow-up. The screening scheme and methods must be unified through the implementation of non-invasive examination methods to standardize the results obtained and their subsequent unified interpretation.

Taking into account international data, creating a national screening program as part of the national standard for the treatment of patients with AIS appears relevant. For the successful implementation of such a project, a centralized thorough collection of information about children who have undergone screening, patients in need of conservative treatment, and surgical intervention is necessary. In this regard, it is expedient to develop and subsequently use specialized computer programs to support medical decision-making.

ADDITIONAL INFORMATION

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