The smartphone as a tool to screen for scoliosis, applicable by everyone

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Abstract

Purpose (main purposes and research question) The purpose of this study is to assess the accuracy and precision of the smartphone with application and casing (Scolioscreen) compared to the Scoliometer.

Methods The Axial Trunk Rotation (ATR) was measured in adolescent scoliosis patients visiting the outpatient clinic while performing the Adam Forward Bending Test. The Scolioscreen measurements were performed by the orthopedic surgeon and a parent. They were compared to the measurement with the Scoliometer by the orthopedic surgeon, the gold standard. The accuracy was determined with the Pearson's correlation coefficient, and precision was determined by assessing the intra- and inter-variability with the intra-class correlation coefficient (ICC).

Results Fifty patients with adolescent idiopathic scoliosis (44 girls) were included with a mean age of 14.1 years and a mean Cobb angle of 38.5°. The accuracy of both the parents and orthopedic surgeon was excellent with a Pearson correlation coefficient of 0.92 and 0.97, respectively. All the ICC's, both intra- and inter-observer, were over 0.92 demonstrating excellent precision.

Conclusion This study confirms the accuracy and precision of the Scolioscreen when measuring the ATR on patients with AIS. Therefore, the Scoliometer can be replaced by the more easily available Scolioscreen which can be used by both physician and parents.

Keywords Scoliosis · Screening · Adolescent · Smartphone · Tool

Introduction

Abandoning school screening for scoliosis leads to later discovery of the deformity [1, 2] as scoliosis can develop without complaints and can remain unnoticed for a long period of time. Conservative treatment with a brace needs to be initiated before skeletal maturity in order to be able to prevent progression of the curve [3, 4]. If detected late and with a significant curve (> 50 Cobb angle), brace treatment is no longer an option and surgery is recommended to prevent progression in the future [5].

Consequently, it is important to find these patients at an earlier phase in order to be able to prevent surgery. An effective non-surgical treatment option for scoliosis is paramount

for reinstalling a screening program. The treatment options for early detected mild to moderate scoliosis are specific exercises and/or brace treatment to guide the remaining growth in order to prevent progression of the scoliosis [6]. The BRAIST study by Weinstein et al. proved the effectiveness of bracing as did other studies [3, 4].

In order to develop an efficient screening program, there are certain criteria that need to be met [7]. Among others, the target disease should be common, an effective treatment should be available, the screening should be cost effective, the burden of screening should be limited, and there needs to be a validated screening tool, which will be the focus of this study.

The Adam Forward Bending Test (AFBT William Adams 1865) combined with a Scoliometer measurement is the standard clinical test for detecting scoliosis [8]. A rib hump measured (or Axial Trunk Rotation ATR) 5° or higher corresponds to a Cobb angle of over 20° [9]. Scoliometers are not readily available and therefore not routinely used in

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screening. This led to suboptimal screening and eventually to abandoning screening altogether [10, 11].

Therefore, a new user-friendly tool was developed using a smartphone (Fig. 1). Most smartphones have an inclinometer and can therefore be used as a screening tool. Adding an application and a simple casing that will fit any smartphone below 155 mm result in the Scolioscreen (Spinologics, Montreal, Canada), an easily available (40–140 dollar cheaper) alternative for the current gold standard measurement device, the Scoliometer.

So far, several studies [12–17] showed that smartphones can be effectively used. Our mission is to set up a home screening program via patient empowerment; we want to examine its validity when used by parents compared to health-care physicians. With our systematic approach, we aim to expand scientific knowledge on the validity of this tool by an independent team.

The AFBT is a very simple test for the patient to perform, and measuring the rib hump can be compared to checking whether something is level (in this case the trunk). Hypothetically everyone, even non-trained individuals, should be able to measure the ATR. If parents will be able to perform the test, this will significantly reduce the health-care burden of scoliosis screening. Nevertheless, is this new tool valid for screening for scoliosis and can it be used by untrained people?

Therefore, the primary aim of this study was to assess the accuracy and precision of the Scolioscreen (smartphone with application and casing) compared to the gold standard, the Scoliometer. The secondary aim was to evaluate if one of the patients parents is able to perform the test with the same accuracy and precision.

Fig. 1 Smartphone with application and casing: the Scolioscreen

Fig. 2 Scolioscreen (Smartphone with application and casing, Spinologics, Montreal, Canada) and the Scoliometer (Mizuho OSI, Union city, USA)

Methods

Hypothesis

The Scolioscreen can replace the Scoliometer for measurement of the ATR even in untrained hands with good accuracy and precision.

Study design

The Scolioscreen was compared to the gold standard, the Scoliometer, when measuring the ATR in patients with AIS (Fig. 2). The Scolioscreen measurements were made using a tilt meter application (Clinometer + bubble level from plain-code TM) installed on an iPhone 6S, running on IOS 9.3, and a Nexus LG, running on android 6.01.

The protocol for subject recruitment and consent was approved by the Medical Ethical Committee at Erasmus medical Center (MEC-2015-426). Informed consent signed by the parents and/or patient was obtained.

Participants

Based on the Cosmin criteria and sample size calculation, we included 50 patients for this study, to have an adequate sample size for accuracy and precision assessment [18]. Consecutive patients with adolescent idiopathic scoliosis visiting the outpatient orthopedic clinic of the Sophia Children's Hospital, Erasmus MC, Rotterdam, were recruited between August 2015 and May 2016. All patients ≥ 10 years of age who were able to perform the Adam Forward Bending Test and had a Cobb angle $\geq 10^\circ$ were asked to participate in this study. Exclusion criteria were previous spinal surgery, other diseases affecting posture or trunk shape, a leg length discrepancy of > 2 cm, absence of parents during the appointment and brace treatment used by patients the night prior to the appointment.

Study procedures

The primary outcome parameter is the ATR measured in degrees in patients performing the AFBT. The Scolioscreen (smartphone with inclinometer application and casing) was

applied in the same manner as the Scoliometer would be applied. During a regular outpatient clinic, 5 ATR measurements were taken in the order determined by an electronic randomization system. One measurement was taken with the Scoliometer (Mizuho OSI, Union city, CA) by the orthopedic surgeon; this measurement is considered the gold standard measurement. During the same visit, two measurements with the Scolioscreen (smartphone and application and casing) were performed by the orthopedic surgeon and two by the patient's parent. In between all measurements, the patient was asked to re-perform the AFBT.

Measurements were performed blinded (screen turned away from observer), and results were collected by an independent researcher.

The parents were instructed how to use the smartphone by the orthopedic surgeon.

Patient characteristics

The following patient characteristics were reported: age, sex, weight, length, Risser score, Cobb angle and Nash Moe score. Patients underwent a standard outpatient procedure: history and physical examination by the orthopedic surgeon and a standing PA radiograph of the spine.

Statistical analysis

All statistical analyses were executed in SPSS statistics (IBM, Armonk, USA, version 21.0.0.1). Descriptive characteristics were tested for normality using the Shapiro–Wilk test and consequently noted as median with interquartile range (IQR) or mean with standard deviation (SD).

Required sample size was based on:

1. Sample size calculation with an expected ICC value 0.8 with 2 repeated measurements requiring 50 inclusions
2. The Cosmin criteria requiring 50–99 patients to meet a good study [19].

Accuracy of the smartphone was determined with the Pearson correlation coefficient from the mean Scolioscreen measurements vs the Scoliometer measurement, both performed by the orthopedic surgeon. Precision, in this study also the intra-observer reliability of the Scolioscreen measurement, was determined with the intra-class correlation coefficient (ICC) between the two measurements of the orthopedic surgeon.

Pearson correlation coefficient was used to determine the accuracy of Scolioscreen measurement by parents, mean Scolioscreen measurement parents vs Scoliometer measurement by the orthopedic surgeon. Precision again in this study also the intra-observer reliability of the Scolioscreen measurement by parents was determined with the intra-class

correlation coefficient between the two measurements. The inter-observer reliability was determined comparing the Scolioscreen measurements of the orthopedic surgeon to the Scolioscreen measurements of the parent.

The correlation between the Cobb angle, the Scoliometer measurement by the orthopedic surgeon, mean Scolioscreen measurement by the orthopedic surgeon was determined with the Pearson correlation coefficient.

Correlation coefficients had to be >0.8 in order to indicate a good association and >0.9 to indicate a very good association [19].

Results

Patient characteristics

In the population of this study, six boys and 44 girls were included, out of 91 eligible patients. The baseline characteristics are listed in Table 1.

Accuracy

The gold standard is the orthopedic surgeon using the Scoliometer measured a mean ATR of 12.5° (SD 4.9). When using the Scolioscreen, the value is 12.6° (SD 5.0) (Table 2).

Accuracy testing using measurements by the orthopedic surgeon with Scoliometer and Scolioscreen results in an excellent Pearson correlation coefficient of 0.97.

Table 1 Patient characteristics

	<i>n</i> = 50
Female, no (%)	44 (88)
Age, years	14.1 [1.9]
BMI, kg/m ²	19.9 [4.8]
Cobb angle, degrees	38.5 [14.7]
Risser score*, no (%)	
0	10 (20.4)
1	3 (6.1)
2	10 (20.4)
3	8 (16.3)
4	13 (26.5)
5	5 (10.2)
Nash Moe, no (%)	
0	6 (12.0)
1	14 (28.0)
2	27 (54.0)
3	3 (6.0)

Data reported as mean [standard deviation]

no number; BMI body mass index

*1 missing, Risser score could not be determined on X-ray

Table 2 Mean ATR measurements of different examiners

	ATR, degrees [SD]	Difference compared to Scoliometer*	Correlation coefficients
Scoliometer	12.5 [4.9]	NA	NA
<i>Scolioscreen</i>			
Orthopedic surgeon	12.6 [5.0]	−0.07	0.97
Parent	11.7 [4.8]	0.87	0.92

Values noted as mean (95% confidence interval)

ATR Axial Trunk Rotation

*Scoliometer measurement of orthopedic surgeon = gold standard

Table 3 Intra- and inter-observer ICC of the Scolioscreen

	Intra-observer	Inter-observer	SEM
Ortho- pedic surgeon	0.99 [0.98; 0.99]	Orthopedic sur- geon—parent 0.96 [0.90; 0.98]	0.23
Parent	0.93 [0.88; 0.96]		

Values noted as ICC [95%confidence interval]

ICC intraclass correlation; SEM standard error of measurement

Accuracy testing comparing the parent with Scolioscreen to the orthopedic surgeon with Scoliometer also has an excellent Pearson correlation coefficient of 0.92.

Precision

All the ICC's, both intra- and inter-observer, reached a value over 0.92 (Table 3). The standard error of measurement (SEM) between observers was 0.23°.

Secondary objectives

For the correlation between Cobb angle and ATR as assessed by the orthopedic surgeon, we found a Pearson correlation coefficient of 0.63 when using the Scoliometer and 0.60 when using the Scolioscreen.

Discussion

The aim of this study was to provide in an easy, better available and cheaper screening tool for IAS that can be used by patient's parents and is just as accurate and precise as the Scoliometer. We found that in the hands of the parents the smartphone with application and casing (Scolioscreen) is an accurate and precise tool when measuring the ATR in patients with AIS. This means that the Scolioscreen

measures the same values as the gold standard and can be used as an alternative for measuring the ATR.

Several other studies evaluated the use of smartphone's as screening tool for scoliosis.

Franko et al. [14] performed a validation study and found a good accuracy comparing the measurement of the Scoliometer to the smartphone (Pearson correlation coefficient 0.99). The two measurements were performed simultaneously; the iPhone with casing was at 180° of the Scoliometer during the measurement. In the test, both observers were blinded for the result of the other instrument. Our study uses consecutive measurements (with the patient re-performing the AFBT in between measurements) with the instrument turned away from the person performing the test. Possible changes in position of moving of the patient can explain the slightly lower accuracy in our study, but even with consecutive measurements accuracy remains high. So even with changes in position the Scolioscreen gives accurate measurements compared to the Scoliometer.

Izatt et al. [20] used plastic torso molds of patients performing the AFBT to eliminate the variability of patients fatigue or posture and found excellent intra- and inter-ICC value (ICC = 0.92–0.95) comparing Scoliometer to a smartphone with acrylic sleeve. Qiao et al. [12] had excellent reliability (ICC > 0.94) with a smartphone with application without casing. Balg et al. [16] also used a smartphone without casing and found excellent precision (ICC's > 0.9). Driscoll et al. [17] and Izatt et al. [20] advised not to use the smartphone without casing because of the difference in shape when compared to the Scoliometer. In larger curves, the spinous process will not impede the measurement by the smartphone, but in smaller curves, as you would expect in general population, the prominence of the spinous process could interfere with the smartphone measurements performed without casing. Consequently, smartphone measurements performed without casing might have a lower accuracy and precision. Therefore, we agree with Driscoll et al. and advise to use the smartphone with a casing.

Most studies used a specific smartphone with a single application [12, 14, 16, 17, 20] where in our study both android and IOS smartphones with two different inclination

applications were used with excellent accuracy and precision. This was also shown in a systematic review by Naziri et al. [13] where different available smartphone applications can be used effectively.

A moderate correlation (0.60) between the ATR and Cobb angle was found in the current study, whereas varying correlations ranging from 0.46 to 0.69 have been reported in the literature [21–23]. The trunk rotation is one component of the deformity caused by scoliosis; the Cobb angle measures another component. This explains why the correlation between the trunk rotation and the Cobb angle is only moderate.

Another major point of discussion in screening for scoliosis is the diagnostic value of the Scoliometer. The sensitivity varies from 0.62 to 1.0, depending on the choice of cutoff point when performing scoliosis screening. Generally, a cutoff point of 7°ATR is chosen, at which the sensitivity varies from 0.62 up to 0.86 and the specificity from 0.67 up to 0.75, leading to several false positive or false negative patients [22, 24, 25]. Yet the AFBT with ATR measurement is still the most accurate, precise and simple test to discover a scoliosis without using radiography [15]. Evaluating the diagnostic value of the screening test will be a focus of our future research.

Driscoll et al. [17] compared the Scoliometer to the smartphone with and without casing used by a surgeon a nurse and a parent and found excellent precision (all intra- and inter-observer ICC values of over 0.89) and accuracy (ICC's of 0.99, 0.95 and 0.91, respectively) when the casing was used. Our study confirms these data as it considers the parent as an examiner and demonstrates that a patients' parent can measure the ATR as accurate and precise as an orthopedic surgeon using a Scoliometer. Compared to Driscoll et al., we used different smartphones and different applications to make it more suitable for home screening. This empowers families to take part in their health care via self-assessment. Moreover, it would also significantly reduce the costs of scoliosis screening.

If we were to use the Scolioscreen for screening at home, the parents need to be well instructed.

Limitation of this study is the lack of a standardized protocol for performing the Adam Forward Bending Test. However, the introduced variability by lack of standardization was similar for the Scolioscreen and Scoliometer. Moreover, since the Adam Forward Bending Test is performed similarly as during the normal outpatient examination, the results of the current study are more applicable to the daily routine.

In this study, the parents performing the screening test were instructed and were parents from known scoliosis patients, so they are familiar with the AFBT and the Scoliometer measurement. For screening purpose, it will be crucial to have clear and simple instructions on how to perform the test in order to get reproducible results in all layers of

society. Exploring the possibilities of self-assessment for scoliosis and supplying parents with the information and tools necessary to be able to perform the self-assessment are the subject of our future research.

We will initiate a pilot study to evaluate the screening tool in the general population, and we will work on a multistep screening program to enhance the accuracy and precision of the screening method.

Conclusion

This study confirms the accuracy and precision of the Scolioscreen (smartphone with application and casing) when measuring the ATR on patients with AIS. Therefore, the Scoliometer can be replaced by the more easily available Scolioscreen which can be used by both physician and parents.

Authors' contribution JH, MR and HMW contributed to the study conception and design. Material preparation, data collection and analysis were performed by JH, MR and HMW. The first draft of the manuscript was written by HMW, and all authors revised consecutive versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and material The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request. Code availability See attached data statements.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Consent to participate Written informed consent was obtained from the participants and or parents/legal guardians.

Ethical approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of The Erasmus MC (Date 7/21/2015/No. MEC-2015-426).

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References

- Adobor RD, Riise RB, Sorensen R, Kibsgard TJ, Steen H, Brox JI (2012) Scoliosis detection, patient characteristics, referral patterns and treatment in the absence of a screening program in Norway. *Scoliosis* 7(1):18. <https://doi.org/10.1186/1748-7161-7-18>
- Ali Fazal M, Edgar M (2006) Detection of adolescent idiopathic scoliosis. *Acta Orthop Belg* 72(2):184–186
- Weinstein SL, Dolan LA, Wright JG, Dobbs MB (2013) Effects of bracing in adolescents with idiopathic scoliosis. *N Engl J Med* 369(16):1512–1521
- Negrini S, Minozzi S, Bettany-Saltikov J, Chockalingam N, Grivas TB, Kotwicki T, Maruyama T, Romano M, Zaina F (2015) Braces for idiopathic scoliosis in adolescents. *Cochrane Database Syst Rev*. <https://doi.org/10.1002/14651858.CD006850.pub3>
- Agabegi SS, Kazemi N, Sturm PF, Mehlman CT (2015) Natural history of adolescent idiopathic scoliosis in skeletally mature patients: a critical review. *J Am Acad Orthop Surg* 23(12):714–723
- Negrini S, Donzelli S, Aulisa AG, Czaprowski D, Schreiber S, de Mauroy JC, Diers H, Grivas TB, Knott P, Kotwicki T, Lebel A, Marti C, Maruyama T, O'Brien J, Price N, Parent E, Rigo M, Romano M, Stikeleather L, Wynne J, Zaina F (2018) 2016 SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis Spinal Disord* 13:3
- Andermann A, Blancquaert I, Beauchamp S, Dery V (2008) Revisiting Wilson and Jungner in the genomic age: a review of screening criteria over the past 40 years. *Bull World Health Organ* 86(4):317–319
- Labelle H, Richards SB, De Kleuver M, Grivas TB, Luk KD, Wong HK, Thometz J, Beausejour M, Turgeon I, Fong DY (2013) Screening for adolescent idiopathic scoliosis: an information statement by the scoliosis research society international task force. *Scoliosis* 8:17
- Bunnell WP (1984) An objective criterion for scoliosis screening. *J Bone Joint Surg Am* 66(9):1381–1387
- Bunge EM, Juttman RE, van Biezen FC, Creemers H, Hazebroek-Kampschreur AA, Luttmer BC, Wieggersma PA, de Koning HJ (2008) Netherlands Evaluation Study on Screening for Scoliosis G Estimating the effectiveness of screening for scoliosis: a case-control study. *Pediatrics* 121(1):9–14
- Deurloo JA, Verkerk PH (2015) To screen or not to screen for adolescent idiopathic scoliosis? A review of the literature. *Public Health* 129(9):1267–1272
- Qiao J, Xu L, Zhu Z, Zhu F, Liu Z, Qian B, Qiu Y (2014) Inter- and intraobserver reliability assessment of the axial trunk rotation: manual versus smartphone-aided measurement tools. *BMC Musculoskelet Disord* 15:343
- Naziri Q, Detolla J, Hayes W, Burekhovich S, Merola A, Akamanu C, Paulino CB (2018) A systematic review of all smart phone applications specifically aimed for use as a scoliosis screening tool. *J Long Term Eff Med Implants* 28(1):25–30
- Franko OI, Bray C, Newton PO (2012) Validation of a scoliosmeter smartphone app to assess scoliosis. *J Pediatr Orthop* 32(8):e72–e75
- Prowse A, Pope R, Gerdhem P, Abbott A (2016) Reliability and validity of inexpensive and easily administered anthropometric clinical evaluation methods of postural asymmetry measurement in adolescent idiopathic scoliosis: a systematic review. *Eur Spine J* 25(2):450–466
- Balg F, Juteau M, Theoret C, Svoltelis A, Grenier G (2014) Validity and reliability of the iPhone to measure rib hump in scoliosis. *J Pediatr Orthop* 34(8):774–779
- Driscoll M, Fortier-Tougas C, Labelle H, Parent S, Mac-Thiong JM (2014) Evaluation of an apparatus to be combined with a smartphone for the early detection of spinal deformities. *Scoliosis* 9:10
- Mokkink LB, Terwee CB, Patrick DL, Alonso J, Stratford PW, Knol DL, Bouter LM, de Vet HC (2010) The COSMIN checklist for assessing the methodological quality of studies on measurement properties of health status measurement instruments: an international Delphi study. *Qual Life Res* 19(4):539–549
- De Vet HCW, Terwee CB, Mokkink LB, Knol DL (2011) Measurement in medicine practical guides to biostatistics and epidemiology. Cambridge University Press, Cambridge
- Izatt MT, Bateman GR, Adam CJ (2012) Evaluation of the iPhone with an acrylic sleeve versus the Scoliosmeter for rib hump measurement in scoliosis. *Scoliosis* 7(1):14
- Sapkas G, Papagelopoulos PJ, Kateros K, Koundis GL, Boscainos PJ, Koukou UI, Katonis P (2003) Prediction of Cobb angle in idiopathic adolescent scoliosis. *Clin Orthop Relat Res* 411:32–39
- Amendt LE, Aulsebrook KL, Eybers JL, Wadsworth CT, Nielsen DH, Weinstein SL (1990) Validity and reliability testing of the Scoliosmeter. *Phys Ther* 70(2):108–117
- Pearsall DJ, Reid JG, Hedden DM (1992) Comparison of three noninvasive methods for measuring scoliosis. *Phys Ther* 72(9):648–657
- Coelho DM, Bonagamba GH, Oliveira AS (2013) Scoliosmeter measurements of patients with idiopathic scoliosis. *Braz J Phys Ther* 17(2):179–184. <https://doi.org/10.1590/S1413-35552012005000081>
- Bunnell WP (1993) Outcome of spinal screening. *Spine* 18(12):1572–1580

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