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EFFECTIVENESS OF PROPOSED RISK INDICATORS IN SCOLIOSIS CASE FINDING

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ABSTRACT

Study Design: This was a longitudinal-observational study, conducted in a local school.
Objective: To determine effectives of Normalized-Scoliosis-Risk Weightage (NSRW) and Cumulative-Scoliosis-Risk Weightage (CSRW) in scoliosis case finding.
Summary of Background Data: CSRW and NSRW were proposed to identify school-going children, who have a higher risk of acquiring scoliosis. Once identified, this high-risk population could be subjected to regular surveillance, thus easing burden from health-care teams. 169 students (55 boys; 114 girls) were studied; age range 5.75-9.73 *years* (mean ± standard deviation = 8.00 ± 0.60 *years*).
Methods: A mathematical model was proposed and tested to separate scoliosis-like conditions from true scoliosis. 'Differential-Spinal-Function Testing' (DSFT) was conducted, which consisted of four tests: visual (standing and sitting), forward bending (standing and sitting). Collected data were analyzed to decide effectiveness of NSRW and CSRW.
Results: Total cases studied were divided into three categories: students having (*i*) both NSRW and CSRW equal to or above threshold (98 cases), (*ii*) one indicator equal to or above threshold, the other indicator below threshold (41 cases) and (*iii*) both indicators below threshold (30 cases), making a total of 169 (= 98 + 41 + 30). Scoliosis was indicted in 56 students (57.14%) of 1st category, 10 students (24.39%) of 2nd category and 6 students (20.00%) of 3rd category.
Conclusions: If both indicators were equal to or above threshold, the student fell into the category of high risk, to be followed through till the end of growth period. When one of the indicators was equal to or above threshold and the other below threshold, the incumbent belonged to medium-risk category, to be followed through till the student reaches 16th birthday. If both indicators were below threshold, the student was classified as low-risk case. Such a youngster should be followed through till the individual reaches 11th birthday.

Keywords: Primary-school students, Normalized-Scoliosis-Risk Weightage (NSRW), Cumulative-Scoliosis-Risk Weightage (CSRW), Differential-Spinal-Function Testing (DSFT), Asr angle, degree-of-correction of spinal deformity, 3-D modeling of spinal column, scoliosis-like conditions, moiré fringe topography, dotted rasterstereography

LIST OF ABBREVIATIONS

CSRW: **C**umulative-**S**coliosis-**R**isk **W**eightage
DSFT: **D**ifferential-**S**pinal-**F**unction **T**esting
FBT: **F**orward-**B**ending **T**est
NGDS: **N**ational **G**rowth and **D**evelopmental **S**tandards for the Pakistani Children
NSRW: **N**ormalized-**S**coliosis-**R**isk **W**eightage
PN: **P**akistan **N**avy
SGPP: **S**ibling **G**rowth **P**ilot **P**roject — a subproject of the NGDS Pilot Project
V: **V**isual Examination

Units

cm: centimeter(s) • *kg*: kilogram(s)

INTRODUCTION

The original meaning of 'orthopedics' is straight (ortho) child (pedics), making scoliosis case finding a task of utmost importance. Scoliosis is defined as lateral curvatures and rotations of the spinal column. Recently, two indicators Normalized-Scoliosis-Risk Weightage (NSRW) and Cumulative-Scoliosis-Risk Weightage (CSRW) have been proposed to quantify risk of acquiring scoliosis and applied to data collected in a local school. In this paper,

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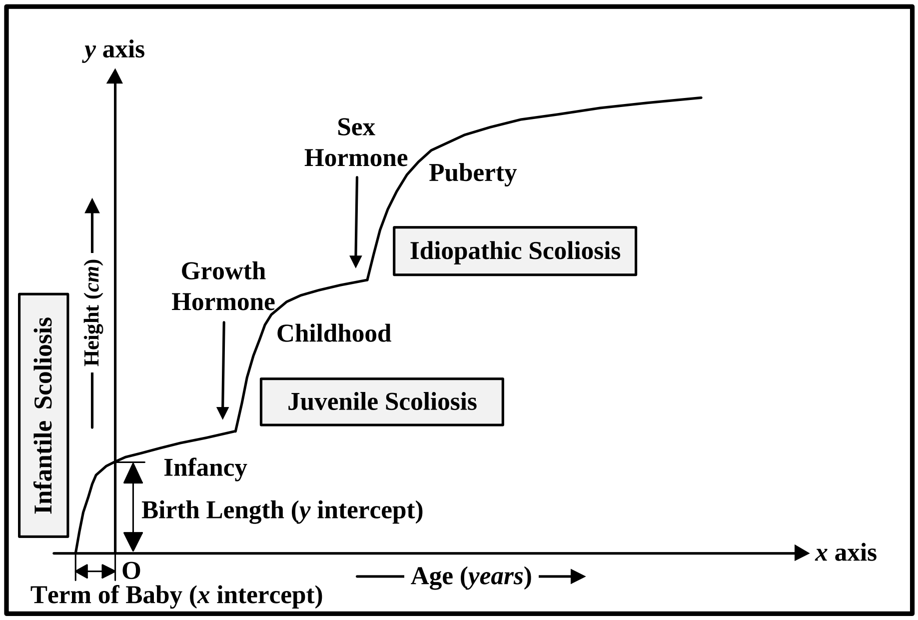

Fig. 1. ICP model of child growth and presence of scoliosis in different age ranges; progression of scoliosis is related to rate of height gain in various phases noting that periods of rapid growth are just after conception (for the first 2-3 *months*), start of childhood curve (around the age of 3-4 *years*) and start of puberty curve (around the age of 11-13 *years*).

collected data have been reanalyzed with an integrated approach to interpretation based on NSRW and CSRW to assign risk of scoliosis as high, medium or low, with appropriate surveillance strategies proposed.

TYPES OF SCOLIOSIS AND PHASES OF GROWTH OF A CHILD

According to ICP (Infancy-Childhood-Puberty) model (Karlberg, 1987), there are three periods of rapid growth, the first one just after conception for the first 2-3 *months*, the second one just after entering the childhood phase, after the release of growth hormone, around the age of 3 to 4 *years* and the third one just after entering puberty phase, after the release of sex hormone, around the age of 11-13 *years*. As shown in Figure 1, scoliosis, which starts during the first phase, is termed as 'infantile scoliosis' (conception/birth to 3 *years*). In a similar fashion, if the disease appears during the second phase, it is classified as 'juvenile scoliosis', whereas the one showing up during the third phase is recognized as 'idiopathic scoliosis' (An *et al.*, 2015). Lonstein (1994) used a similar classification infantile (birth to 3 *years*), juvenile (3 *years* to puberty) and adolescent or late-onset (after puberty).

Idiopathic scoliosis is the most common and has very grave concerns for the health of an individual (Gorsha *et al.*, 2017). Hence, it becomes very important to quantify the risk of scoliosis in under-10 children, so that the youngsters determined to have high, medium or low risk may be appropriately followed through (Luk *et al.*, 2010). This paper outlines a policy for the period of surveillance of such children turned adolescents so that there is a very low probability of missing a genuine curve at the same time optimizing health-care resources so that unnecessary screenings are not performed.

Because of lack of knowledge of etiology of adolescent idiopathic scoliosis, all treatment efforts are focused at prevention and correction of the early-onset scoliosis (Cunin, 2015; Horn, 2012; Weinstein *et al.*, 2008). Mid-early-onset scoliosis avoids progression under FITS (Functional Individual Therapy of Scoliosis) method (Bialek, 2015). Lebon *et al.* (2017) presented a 30-case multicenter study using magnetically controlled growing rod in early-onset scoliosis.

MONITORING THE SCOLIOSIS CURVE

Scoliosis, a potentially body-disfiguring condition, poses a real challenge for the health and the well being of primary-school students, in particular, girls. If undetected and allowed to reach an advanced stage, it may, severely, affect functionality of an adolescent (Saika *et al.*, 2002). Scoliosis should be identified through screening and case finding (Labelle *et al.*, 2013). The detected cases must be documented through photography, quantified through moiré

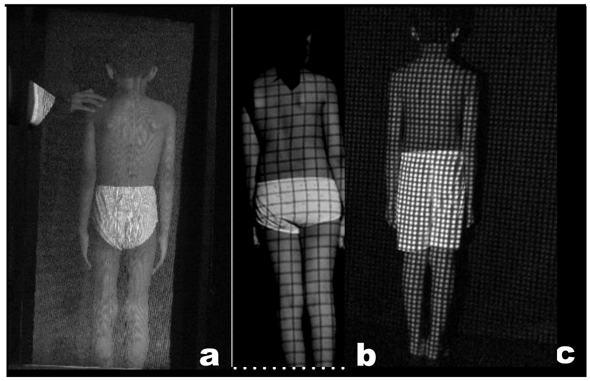

Fig. 2*a-c***.** Stereophotogrammetric techniques for analysis of back shape — (*a*) moiré fringe topography, (*b*) rasterstereography and (*c*) dotted-rasterstereography

fringe topography (Kamal *et al.*, 2013*c*; 2014*a* — Figure 2*a*), rasterstereography (Kamal *et al.*, 2013*a* — Figure 2*b*) and dotted-rasterstereography (Wasim *et al.*, 2013 — Figure 2*c*). These techniques are non-invasive and use non-ionizing radiation. Hence, they are safe for the body of a growing child. X rays should be obtained at the initial visit and again only when a change is indicated in moiré and raster patterns (Kamal and Lindseth, 1980). 3-D-spinal-column-surface analysis (height and curvature maps) was proposed 7-*year* ago by combining moiré fringe topography and rasterstereography with backscatter-X-ray-scanning technology, which has the potential to generate, not only, the outline, but also, the structure of spinal column using low-dose-X rays used in full-body scanning (Kamal, 2013*a*; *b*).

'Integrated-Trunk-Deformities-Screening System' was put forward in 1996 consisting of multiple-level screening of preteen youngsters (Kamal *et al.*, 1996). The checks placed at the top level were chosen on the basis of high sensitivity. The checks included at the bottom level were selected on the basis of high specificity (Kamal *et al.*, 2013*b*). A management strategy should be formulated by a team of orthopedic surgeons, which should include observation and follow up, exercises as well as brace treatment and, in severe cases, surgical correction (Nigrani *et al.*, 2015). A thorough neuro-orthopedic evaluation should be performed prior to deciding treatment options (Cottalorda *et al.*, 2012). During the last few years interest has increased in early-onset scoliosis (Tis *et al.*, 2012). At times, it appears in combination with other conditions (Persson-Bunke *et al.*, 2012).

Scoliosis is generally discovered through visual examination of back in the attention position and Adam's forward-bending test with the child barefoot and undressed except short underpants. For scoliosis case finding, the unclad student should be subjected to visual examinations and forward-bending tests (Linker, 2012; Kamal *et al.*, 2015*a*). Visual examinations may be supplemented by plumb line and engineering T (Figure 3*a*) as well as graph screen superimposed on photograph of back (Figure 3*b*). These tests generate a large number of false positives in primary-school students (Kamal *et al.*, 2013*b*). These students are then required to undergo X raying of spinal column to rule out or confirm scoliosis. X rays consist of ionizing radiations, which are harmful to the delicate bone marrow of the growing child. Hence, it becomes imperative that radiation techniques are used judiciously to minimize radiation burden (Cassar-Pullicino and Eisenstein, 2002).

Although Ferguson and Tideström methods have been reported in the literature, Scoliosis Research Society recommends working only with the Cobb method of quantifying the scoliotic curve. The first author introduced Asr

Fig. 3*a*, *b*. Visual examination using (*a*) plumb-line and engineering T as well as (*b*) graph screen superimposed on back photograph

angle in the context of 3-D modeling of the spinal column (Kamal, 1982*b*; 1983*a*; *b*). Asr Angle is defined through parallel transport in case of skewed lines, one of the lines is drawn normal to the plane tangent to the superior endplate of one vertebra above the fracture and another drawn normal to the plane tangent to the inferior endplate of the vertebra one level below the fracture.

RULING OUT SCOLIOSIS-LIKE CONDITIONS

In order to prevent over-treatment, it is necessary to rule out scoliosis-like conditions, which at times exhibit artificial scoliosis (Kamal *et al.*, 2013*d*). Examples are postural problems, leg-length inequality and hip weakness. In order to highlight these factors, two-level-differential-spinal-function testing (DSFT) was conducted (Figure 4). In the first level,

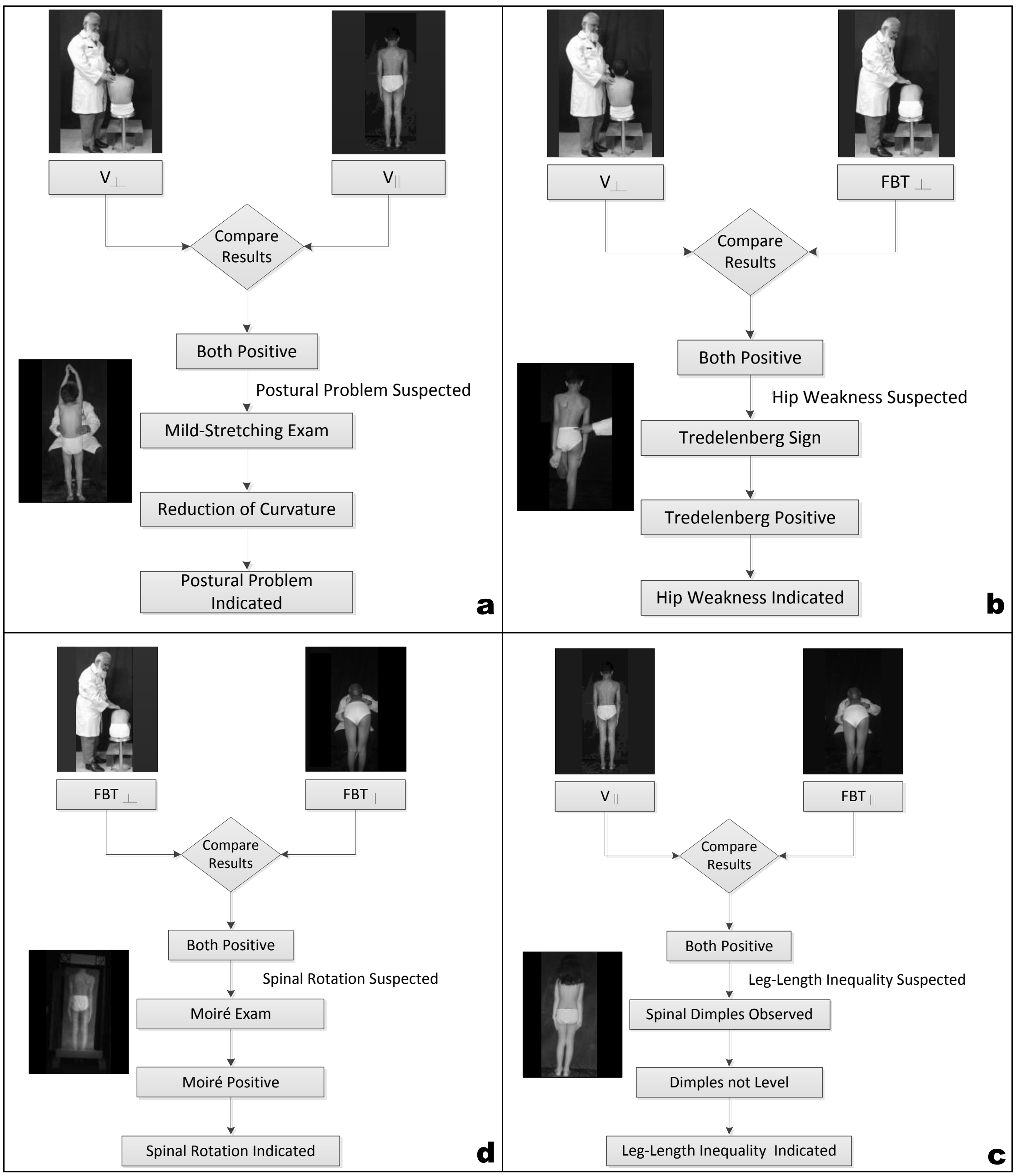

Fig. 4*a*-*d*. Flowchart for decision matrix used in DSFT, which may be used to plan for efficient detection and effective treatment of scoliosis — $V_{\parallel}$ ($V_{\perp}$) denotes visual examination performed, when the student was standing (sitting); $FBT_{\parallel}$ ($FBT_{\perp}$) represents forward-bending test conducted, when the pupil was standing (sitting)**:** (*a*) postural problem, (*b*) hip weakness and (*c*) leg-length inequality should be differentiated from (*d*) spinal rotations and lateral curvatures — curvature not reduced after mild stretching in (*a*)

Table 1. Severity of 'Degree-of-Correction of Spinal Deformity' and recommended treatment

Severity of Degree-of-Correction of Spinal Deformity	*Range of Degree of Correction of Spinal Deformity*	*Recommended Treatment*
Severe	0 - 33.33 %	Surgery
Intermediate	33.34 % - 66.66 %	To be decided by the orthopedic surgeon®
Mild	66.67 % - 100 %	Combination of exercises and brace

®The decision should depend on the location and the progression of scoliotic curve as well as the numerical value of 'Degree-of-Correction of Spinal Deformity' — how close the value is to 33.34% (inclination towards surgical treatment) or 66.66% (inclination towards a combination of exercises and brace)

two tests were performed and the results analyzed 'to suspect' a possible condition. In the second level, a third test was conducted 'to indicate' the suspected condition, equivalent to confirmatory test in chemical analysis (Kamal *et al.*, 2014*a*; 2015*a*; Sarwar, 2015).

MODELING OF SPINAL COLUMN

2-D models provide view in the frontal plane obtained from AP-X rays or moiré topographs of back, obtained with patient in attention position. Attempts were made to obtain Cobb angle from moiré topograph of back (El-Sayyad and Kamal, 1981; Kamal, 1982*a*).

One must realize that spinal column is a three-dimensional bone structure. AP-X-ray pictures are unable to generate a complete view. A full view is available by combining projections of spinal column in the sagittal and the frontal planes, generated from lateral and frontal X rays. In 1980s 3-D-static models were developed (Hierholzer and Lüxmann, 1982; Kamal, 1982*b*; 1983*a*; *b*). Natural curvatures of the spine, visible in lateral projection, were incorporated later (Kamal, 1996). 'Degree-of-Correction of Spinal Deformity' was introduced in terms of reduction in the angle of spinal curvature after guarded graduated passive correction by asking the patient to hang freely from a bar (Kamal, 1983*a*) and later redefined (Kamal, 1987) in terms of reduction in curvatures of the spinal column after guarded-graduated passive correction (Table 1).

More recently crystal-structure-based model of the human spinal column was proposed (Kamal *et al.*, 2012; 2014*b*). Spinal column, being a collection of vertebrae, was described in terms of positional coördinates of center-of-mass of each vertebra in the body-coördinate system (a coördinate system, which is fixed to the body). From the point-of-view of condensed-matter physics, this could be represented as 'form factor' used in crystallography. This could be enhanced by adding rotational and inter-vertebral-spacing information and the analysis would be similar to that of 'structure factor' used in solid-state physics to study structure of crystals.

Last year, cross-lattice structure-based model of the human spinal column was put forward (Kamal, 2019). In this model, the center-of-mass of each vertebra was expressed in terms of cross-lattice lengths in the cross-lattice-coördinate mesh. 'From factor' and 'structure factor' were defined accordingly for this model.

QUANTIFICATION OF RISK OF DEFORMITIES OF SPINAL COLUMN

There is a dire need to investigate the factors linked with scoliosis in school-going youngsters (Baroni *et al.*, 2015). Employing the power of mathematics, indicators were developed to specify scoliosis risk in prepubertal, peripubertal and pubertal children. Mathematical relationships defining prepubertal, peripubertal and pubertal as well as their association with approximate Tanner scores are given elsewhere (Kamal *et al.*, 2017*a*). These indicators go much deeper than asymmetry about the sagittal plane indicated by moiré fringe topography and could help decide at-risk children. Moiré technique is highly sensitive. Hence, it generates many false positives to be followed up, which overburdens resources of health care. This has the consequence of non-availability of essential medical surveillance to the population, which needs to be screened because of higher-risk of acquiring scoliosis.

7-*year* ago, CSRW (Cumulative-Scoliosis-Risk Weightage) was put forward (Kamal *et al.*, 2013*e*), which assigned a weight to each early-warning signal of scoliosis. These signals included history in family (scoliosis in either of the parents or any of the siblings enhances the risk), slot of age (3 *years* to less than 6.5 *years*; 6.5 *years* to less than 7.5 *years*; 7.5 *years* to less than 8.5 *years*; 8.5 *years* to less than 11 *years*), tallness (above $50^{th}/75^{th}/97^{th}$

Table 2. Weights assigned for computation of NSRW and CSRW[©]

Scoliosis-Risk Weightage		*A*[϶]	*B*[∈]	*C*[∃]
01. Family history		2.0	2.0	2.0
02. Age [3, 6.5)[⊃] *years*		0.5	0.5	0.5
03. Age [6.5, 7.5)[⊃] years		1.0	1.0	1.0
04. Age [7.5, 8.5)[⊃] *years*		1.5	1.5	1.5
05. Age [8.5, 11)[⊃] *years*		2.0	2.0	2.0
06. Tall (above 50^{P})[#]		1.0	1.5	2.0
07. Tall (above 75^{P})[#]		1.5	2.0	2.5
08. Tall (above 97^{P})[#]		2.0	2.5	3.0
09. Wasted (more than 10%)[$]		1.0	1.5	2.0
10. Wasted (more than 20%)[$]		1.5	2.0	2.5
11. Wasted (more than 30%)[$]		2.0	2.5	3.0
12. FBT_F (lumbar asymmetry)[Φ]	*clinical examination*[£]	1.0/1.5[⊂]	1.5/2.0[⊂]	2.0/2.5[⊂]
13.	*graph screen projected on FBT image*	1.0/1.5[⊂]	1.5/2.0[⊂]	2.0/2.5[⊂]
14. FBT_B (thoracic asymmetry)[ς]	*clinical examination*	1.0/1.5[⊂]	1.5/2.0[⊂]	2.0/2.5[⊂]
15.	*graph screen projected on FBT image*	1.0/1.5[⊂]	1.5/2.0[⊂]	2.0/2.5[⊂]
16. Shoulder drooping	*clinical examination*	0.5	1.0	1.5
17.	*graph screen projected on back image*	0.5	1.0	1.5
18. Uneven scapulae	*clinical examination*	0.5	1.0	1.5
19.	*graph screen projected on back image*	0.5	1.0	1.5
20. Midline of back C-shaped	*clinical examination*	0.5/1.0[¥]	1.0/1.5[¥]	1.5/2.0[¥]
21.	*graph screen projected on back image*	0.5/1.0[¥]	1.0/1.5[¥]	1.5/2.0[¥]
22. Midline of back S-shaped	*clinical examination*	1.0/1.5[¥]	1.5/2.0[¥]	2.0/2.5[¥]
23.	*graph screen projected on back image*	1.0/1.5[¥]	1.5/2.0[¥]	2.0/2.5[¥]
24. Non-equal body triangles	*clinical examination*	0.5	1.0	1.5
25.	*graph screen projected on back image*	0.5	1.0	1.5
26. Uneven spinal dimples	*clinical examination*	0.5	1.0	1.5
27.	*graph screen projected on back image*	0.5	1.0	1.5
28. Plumb-line non-alignment		1.0	1.5	2.0
29. Positive moiré	*back*	1.0	1.5	2.0
30.	*front*	0.5	1.0	1.5
31. Positive dotted-raster	*back*	1.0	1.5	2.0
32.	*front*	0.5	1.0	1.5
33. Limp		1.0	1.5	2.0
34. Spastic gait		0.5	1.0	1.5

[©] 01-11 are extrinsic factors — indirectly related to spinal deformity, whereas 12-34 are intrinsic factors — directly related (Cassar-Pullicino and Eisenstein, 2002)

[϶] Value applicable if the condition appears only during any single examination — 1st exam or 2nd exam or 3rd exam

[∈] Value applicable if the condition appears during any two examinations — (1st + 2nd) or (2nd + 3rd) or (1st + 3rd) or similar pairs if more than three examinations are available

[∃] Value applicable if the condition appears during any three of the checkups — (1st + 2nd + 3rd) or similar pairs if more than three checkups have been conducted.

[Φ] Forward-bending test, with the student facing the examiner

[£] A good-quality, stripped clinical examination no substitute for stereophotogrammetry, clinical photograph or projected grid on the body (Kotwicki, 2008)

[ς] Forward-bending test, with the student's back towards the examiner

[⊃] [*x*, *y*) means *x* (3 *years* in the first entry) included, but *y* (6.5 *years*) not — a 6.5-*year* old student, theefore, rated according to criterion 03.

[#] Superscript P denotes child's percentile, computed using box-interpolation technique described elsewhere (Kamal *et al.*, 2011)

[$] Determined by computing algebraic status, pertaining-to-mass (Kamal *et al.*, 2015*b*)

[⊂] Second value applicable, if asymmetries (front and back) on opposite sides

[¥] Second value applicable, if deformity not corrected upon asking the child to assume mild-stretching posture

Table 3. Threshold values of NSRW and CSRW, which should warrant DSFT

	NSRW	*CSRW*
After the First Checkup	25%	5.5
After the Second Checkup	30%	6.5
After the Third Checkup	35%[§]	7.5[§]

[§]Values applicable for the third and all the subsequent checkups

percentile), wasting implying lesser mass-for-height (more than 10/20/30 percent), positive forward-bending tests (indicating lumbar/thoracic asymmetry), non-alignment of plumb-line, positive indicators in visual examination of back (C or S shape of midline of back, shoulders drooping, scapulae uneven, body triangles unequal, spinal dimples uneven) and positive moiré (back and front), with the weightage increasing if the condition persisted for more than a single checkup (Table 2). Different tests to check spinal column are elaborated in detail in a previous publication (Kamal *et al.*, 2015*a*).

CSRW has the main drawback that if some test results are not at-hand on a given group of pupils (*e. g.*, history information), this index may not be compared with other pupils of the same grade. This presents the necessity to fine-tune this definition in order to account for the missing information. Such an enhancement should be able to accommodate additional information available by inclusion of further tests in later sessions, This way, the enhanced index may be compared for data collected in different years.

4-*year* ago, NSRW (Normalized-Scoliosis-Risk Weightage) was proposed (Kamal *et al.*, 2016*b*; Raza, 2016). The following expression could be used to compute NSRW, which was expressed as a percentage

$$NSRW = 100\frac{CSRW}{\sum score_{\max}}\,\%$$

where $score_{\max}$ represents the maximum value of score of a particular item (01-34), corresponding to a given checkup. Table 3 gives threshold values of NSRW and CSRW. The students crossing these thresholds should be subjected to DFST (Kamal *et al.*, 2013*d*; 2014*a*; 2015*a*). The question arises that with the introduction of NSRW, should CSRW be abandoned. Based on the analysis of data collected, the authors are of the opinion that both indictors should be computed and suitably combined to determine risk of acquiring scoliosis in still-growing youth.

SUBJECTS AND METHODS

The authors have tried to find cases of idiopathic scoliosis through a convenience sampling and examination of all students of a certain class, conducted as part of the NGDS Pilot Project https://ngds-ku.org — National Growth and Developmental Standards for the Pakistani Children. Descriptive statistics (qualitative and quantitative) of 169 students are presented in Table 4. This project is a longitudinal-observational study based on opt-in policy, being conducted since 1998 to date. Data, reported in this work, belong to a subset of data collected, during 2012-2014, on pupils, studying in a civilian school, who came from a middle-class locality of Karachi, Pakistan. Study protocols, designed after considering applicable human-right and ethical standards, were approved by 'Institutional Review Board' (Kamal *et al.*, 2016*a*). Inclusion criterion was that the pupils could be subjected to DSFT. One boy, with multiple musculoskeletal deformities, was unable to stand without help. His data were excluded at the processing stage.

The examinations were conducted with the pupils totally stripped except short underpants to facilitate proper spinal examination. In addition, their heights were measured by Vernier-scale method, using setsquares and wall-mounted engineering tape (least count 0.01 *cm*) and masses were recorded using modified-beam scale (least count 0.01 *kg*), step-by-step procedures described with labeled photographs, elsewhere (Kamal, 2017*b*).

Table 4. Descriptive statistics — qualitative and quantitative

Total number of children:	169 — boys 55 (32.54%); girls 114 (67.46%)
Mean age:	8.00 *years*
Standard deviation:	0.60 *years*
Median:	8.02 *years*
Mode:	8.29 *years*
Range:	(5.75-9.73) *years*

Table 5. High-, medium- and low-risk categories of scoliosis with recommendations for surveillance

Category	*Threshold values of NSRW and CSRW*	*No. of cases*	*Scoliosis indicated in*$^{\oplus}$	*Follow through*
High	Both indicators equal to or above threshold	98	56 (57.14%)$^{\otimes}$	Till growth ends
Medium	One of the indicators equal to or above threshold	41	10 (24.39%)	Till 16th birthday
Low	Both indicators below threshold	30	06 (20.00%)	Till 11th birthday

$^{\oplus}$Number of cases (percentage)

$^{\otimes}$Percentage is calculated using the recipe $100\left(\frac{56}{98}\right) = 57.14\%$

RESULTS AND DISCUSSION

In this paper we have presented data of 169 students — 55 boys, 114 girls. Scoliosis was indicated in 72 students (42.60%). Table 5 shows breakdown of cases, in which scoliosis was indicated. 98 students had both indicators equal to or above threshold; 41 had only one indicator equal to or above threshold; 30 had both indicators below threshold. The following factors seemed to contribute to the discovery of a large number of scoliosis indications in the reported study**:**

- Heavy school bags worn on one side.
- Unequal weight on feet due to faulty posture habits. High heels in girls might have contributed to bad body alignment.
- Inactivity in students due to heavy load of homework, Internet, in particular, use of social media, television, video and indoor games.
- Faulty posture because of furniture not according to size of students in school and in home; desks not according to sitting height, but too low (contributing to kyphosis) or too high (contributing to strain in neck muscles).
- Reduction of time spent outdoors, because of lack of courtyards in home (flat/apartment residence) as well as competing activities. This might have resulted in deprivation of sunshine to bare skin, which produces vitamin-D deficiency (weakening of spinal column)

RECOMMENDATIONS AND FUTURE DIRECTIONS

The authors recommend posture examinations for boys and girls in the age group 4-7 *years* (Kamal and El-Sayyad, 1981) and scoliosis-screening examinations for students in the age group 7-10 *years*, employing visual inspection, forward-bending test and moiré fringe topography, all of them from back, side and front (Kamal *et al.*, 2015*a*; 2016*b*). Students should be completely undressed except briefs or panties (spinal dimples exposed) and barefoot for these exams. CSRW and NSRW should be computed for each examinee. Further, sensitivity and specificity of each test included in DSFT should be determined (Kamal *et al.*, 2013*b*).

Based on the analysis of CSRW and NSRW scores, the screened population should be assigned to one of the risk groups, ‘low’ (both indicators below threshold), ‘medium’ (one indicator below threshold) and ‘high’ (both indicators equal to or above threshold). The authors recommend that low-risk students should be followed through till they are 11-*year* old, medium-risk to be kept under observation till they are 16-*year* old, whereas high-risk should be under surveillance till the end of their growth period (*i. e.*, till boys become 21-*year* old and girls become 19-*year* old). In addition**:**

- Parent and teacher awareness programs should be organized through discussion as well as guidance and counseling sessions, popular articles (Kamal, 1997*a*; *b*) and video series (Kamal, 2017*a*).
- Children should be exposed to fresh air and sunshine for 5 to 10 *minutes* daily to give them adequate doses of vitamin D. They should be minimally dressed for this activity so that their hands, thighs, legs, and most importantly, spinal column from external auditory meatus to hip joint, are exposed to sunshine (Kamal and Khan, 2018).
- At the end of each class, the students should stand up from their chairs and do light exercises stretching hands on top and sides, bending their bodies on each side and rotating their necks 90^{o} on the right and the left sides for 5-*minute* duration. Parents should, also, make sure that the same routine is followed at home during long periods of inactivity — exercises of 5-*minute* duration at the start of every hour (Kamal *et al.*, 2017*b*).
- Dedicated furniture should be made for the student at home. School furniture should have provision to adjust desk height according to sitting height of student.

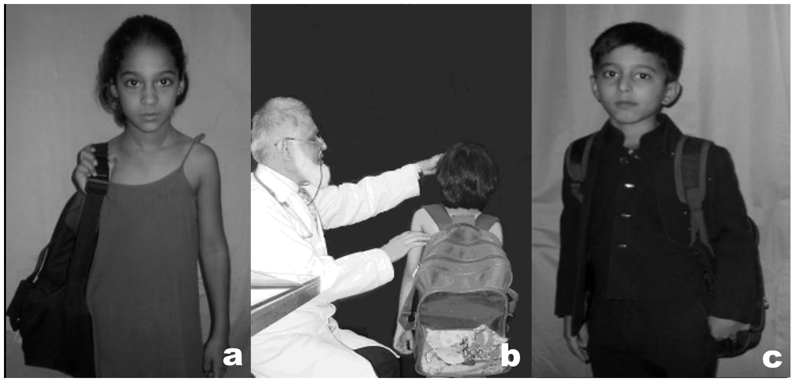

Fig. 5*a*-*c***.** (*a*) Incorrect and (*b*, *c*) correct ways of wearing school bag

- The students should be trained in good sitting and standing posture habits. Competitions should be held to promote better posture.
- Unnecessary books and copies should not be kept in school bags. A short-term solution is to store excess books and copies in lockers provided by school authorities. Upper limit on the weight of schoolbag should be set by legislation. Initial attempt towards achieving this goal is taken by the cabinet of Government of Khyber Pakhtunkhawa, Pakistan (Ashfaq, 2019). A long-term solution is to replace bulky school bags by a single monthly textbook cum workbook, keeping the contents up to the mark in line with the rapid explosion of knowledge (Kamal, 2015). This should, not only, free students' backs from heavy load of books and copies, but also, keep their interest and motivation alive by looking forward to new content every month.
- Parents should make sure that load in the school bags is symmetrically distributed on both sides.
- Bags should be worn on both shoulders (Kamal *et al.*, 1998). Bags with one strap should be banned on school premises (Figure 5).
- Prior to conducting screening of scoliosis, students may be introduced to physics (Kamal *et al.*, 1996; 1998) and mathematics (geometry) of scoliosis (Kurz *et al.*, 2015) at a level appropriate to their understanding.
- Remedial clinics should be arranged for students discovered to have faulty posture.

CONCLUSION

In brief, this was a longitudinal-observational study conducted in a local school, which determined effectives of NSRW and CSRW in scoliosis case finding. Total number of students examined was 169 (55 boys; 114 girls). On the basis of this study, these students were classified as high risk, medium risk and low risk.

More research is needed at the molecular level to determine the causes of idiopathic scoliosis. Scoliosis is a body disfiguring disease, which must be detected early through stripped visual, forward bending and moiré examinations, so that proper intervention is planned to prevent deforming the body of a youngster and affecting vital organs as well as produce a better body image. Classifying students into various risk categories should allow pediatric orthopedic surgeons allocate their time and resources efficiently and effectively in scoliosis case finding.

KEY POINTS

- There is need to identify population of school-going children at risk of acquiring scoliosis, so that school health teams could focus on these students for regular surveillance.
- In the absence of a scientifically validated criterion, resources are overburdened and the students requiring most attention often are neglected.
- The authors proposed earlier NSRW (Normalized-Scoliosis-Risk Weightage) and CSRW (Cumulative-Scoliosis-Risk Weightage) as risk indicators.
- Based on clinical examination and analysis of data collected on 55 boys and 114 girls, studying in a local school, the authors developed a mathematical model by combining thresholds of NSRW and CSRW to classify scoliosis risk as high, medium and low.
- It is recommended to monitor high-risk cases till the end of growth period, medium-risk till the student reaches 16^{th} birthday and low risk till the incumbent reaches 11^{th} birthday.

INFORMED CONSENT

Informed consent was obtained from parent(s) of each participating student for the school-based study (the NGDS Pilot Project) as well as parents for the family-centered study (Sibling Growth Pilot Project — SGPP). Details of the informed-consent process (as well as compliance with the ethical and the human-right protocols) are given elsewhere (Kamal *et al.*, 2016*a*). Forms are available on website of the NGDS Pilot Project**:**

Informed Consent Form**:** https://www.ngds-ku.org/ngds_folder/Protocols/NGDS_Form.pdf

SGPP Participation Form**:** https://www.ngds-ku.org/SGPP/SGPP_Form.pdf

CONFLICT OF INTEREST

The authors declare no conflict of interest. This Work contains no libelous or unlawful statements and does not infringe or violate the publicity or the privacy rights of any third party.

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DEDICATION

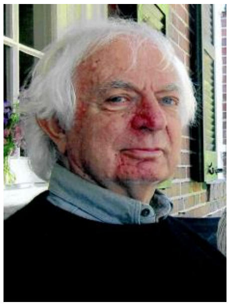
The first author (SAK) would like to dedicate this paper to his mentor and very loving teacher, Professor Dr. Don B. (Bernett) Lichtenberg (July 2, 1928 - October 18, 2017) of Indiana University, Bloomington, United States and his most revered master's essay (Kamal, 1986) supervisor, Professor Dr. J. (James) Calvin Walker (January 16, 1935 – January 15, 2016) of the Johns Hopkins University, Baltimore, Maryland, United States.

Don Lichtenberg earned a B. S. in physics from New York University in 1950, an M. S. and a Ph. D. both from University of Illinois, Urbana-Champaign in 1951 and 1955, respectively, studying high-energy and strange-particle physics. He completed his Ph. D. dissertation, entitled 'Pion production in proton-proton collisions', under the supervision and the guidance of Geoffrey F. Chew. SAK had the opportunity to read his famous book 'Unitary Symmetry and Elementary Particles' (1978). His other books include 'The Standard Model of Elementary Particles' (1991), 'Meson and Baryon Spectroscopy' (1965), 'The Universe and the Atom' (2007) and 'The Strongly Interacting Particles**:** An Introduction to Some Recent Developments' (1964). In addition, he edited the following books — 'Developments in the Quark Theory of Hadrons: A Reprint Collection' with S. Peter Rosen (1980) and 'Weak-Interaction Physics' (1977). SAK, also, had a chance to take a course on elementary particle physics from him, while a graduate student in Department of Physics, Indiana University, Bloomington. On June 1, 1981, Prof. Lichtenberg gave the following remarks regarding SAK's participation in the course**:**

> *Mr. Arif Kamal was a student in my course on the Theory of Elementary Particles during the spring semester 1981. This was an advanced graduate course, suitable for students working toward a Ph. D. on the subject of elementary particles. Mr. Kamal completed all the required work in more than satisfactory manner. He asked numerous questions in class and discussed the subject with me many time outside of class. He demonstrated great interest in the material, as well as a good knowledge of it. As part of the course work, I assigned each student a term paper, which would treat a topic in depth. Mr. Kamal was the only student in class to include originals work in his paper. While original part of the paper was highly speculative, it gave further evidence of Kamal's interest in going beyond the subject matter. It, also, showed that he is imaginative in thinking. I gave Mr. Kamal an A in the course. It was well deserved.*

He was listed in Marquis Who's Who in America. At the time his death, he was Professor Emeritus of Elementary Particle Physics (Theoretical) at Indiana University.

Cal Walker was born in Moorsville, North Carolina to James Clay Walker and Lois Brower. A 1952 graduate of China Grove High School, Walker received B. S. in with physics major from Harvard University in 1956 and elected to honor society Phi Beta Kappa. After graduation, he was awarded Henry W. Shaw traveling fellowship that gave him opportunity to spend time overseas. He completed his Ph. D. in nuclear physics from Princeton University in 1961. He was awarded Fulbright Fellowship in the early 1960s to go to Oxford University. He worked in Harwell Innovation and Science Campus in Oxfoerdshire and consulted at the Aberdeen Proving Ground. He came to Johns Hopkins in 1963 and stayed there till his retirement in 2001. For 6 years, he served as Chairman of Department of Physics and Astronomy. He made several notable contributions in Mössbauer spectroscopy. His best-known work, probably, was in the area of the magnetic



properties of ultra-thin iron (Fe) films. He was legendary for his love of flying, first of gliders and later of a variety of powered aircraft. He survived several serious glider crashes, and a few forced landings with the World War II vintage Taylorcraft that he had rebuilt with canvas and wood. Prof. Walker offered support and guidance to SAK to complete his studies at Baltimore. The first author acknowledged him in a paper, which came out of the master's essay (Kamal, 1990).

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