RESEARCH PAPER

Strings: Development and Validity of an Outcome Measure for Upper Limb Postural Deviations in Adolescents of India

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ABSTRACT

Background: Adolescents in India are increasingly experiencing upper limb postural deviations due to lifestyle changes, technological reliance, and limited ergonomic awareness. Despite this growing concern, standardized tools to assess and monitor these deviations are lacking. The Strings (Standardized Tool for Recording and Identifying Upper Limb Deviations and Guiding Solutions) outcome measure was developed to address this gap and provide a culturally relevant assessment tool.

Study Design: Cross-sectional methodological study focused on tool development and validation.

Methodology: Strings was developed through extensive literature review, expert consultations, and pilot testing to ensure relevance and comprehensiveness. The tool incorporates both objective measurements and subjective assessments, tailored to the anatomical and functional needs of adolescents. Validation was performed on a sample of 300 adolescents from diverse regions in India. Psychometric properties were assessed, including reliability (Cronbach's alpha) and validity through expert ratings and correlations with existing posture assessment tools.

Results: Strings demonstrated high reliability (Cronbach's alpha = 0.87) and strong validity. The tool showed high sensitivity and specificity in identifying upper limb postural deviations, confirming its utility as an effective assessment instrument.

Keywords: Posture, posture assessment, upper limb postural deviations, adolescents

How to cite this article: Singh J, Yogeshwar D, Garhpale A, Ahirwar N, Ghosliya PK, Pal K. Strings: Development and Validity of an Outcome Measure for Upper Limb Postural Deviations in Adolescents of India. Int J Drug Deliv Technol. 2026;16(19s): 350-355. DOI: 10.25258/ijddt.16.19s.41

Source of support: Nil.

Conflict of interest: None

Background-

The definition of good posture provided by Kendal et al. emphasizes the importance of muscular and skeletal balance in protecting the body's supporting structures from injury or deformity. Unlike some definitions that focus solely on static positioning, this definition acknowledges that good posture encompasses various body positions, including standing, lying, squatting, or stooping. It underscores the idea that optimal posture facilitates efficient muscle function and provides ideal positioning for internal organs[1]. The effects of postural changes on health are not exclusive to adults but also impact adolescents. Research increasingly highlights the significance of posture in pediatric health, with evidence pointing to associated risk factors. Poor posture in adolescents can have various consequences, including musculoskeletal issues, pain, reduced mobility, and potential long-term implications for overall health and well-being[2].

Positive or neutral spinal relationship is characterized by a vertical line between the center of gravity of each segment and the segment below it. This combination helps distribute force evenly across the spine, reducing stress and injury potential[3]. Postural control refers to the ability to engage muscles to balance and maintain the relationship between various body segments while seated[4]. Previous literature reported that maintaining a normal posture is indeed associated with minimizing strain on both active (muscles) and passive (ligaments) of spine. When the spine is in a neutral position, the

forces acting on it are distributed more evenly, reducing the likelihood of excessive stress on any particular structure. This can help decrease the risk of developing musculoskeletal pain symptoms related to poor posture[5, 6]. They may precipitate with various osteoligamentous and musculoskeletal symptoms resulting in muscle imbalance, pain, and fatigue which results in forward head and neck posture along with thoracic flexion with a reduction in lumbar curvatures[7]. In India, research on adolescent health issues, particularly postural deviations, is limited. There is a strong link between posture and overall health, with various factors contributing to poor posture, such as prolonged use of handheld devices like smartphones and laptops, as well as a lack of physical activity and increasingly sedentary lifestyles[8, 9, 10, 11].

If these factors are not addressed, the risks of symptom progression, relapse, and recurrence rise, potentially impacting overall quality of life. Several tools are available to assess postural deviations in adolescents, including the New York Posture Rating Chart (NYPRC), the Posture Screening and Assessment Tool (PSAT), the Adolescent Posture Assessment Scale (APAS), and Kendall's Postural Assessment. However, these tools have certain limitations—they can be costly, require specialized skills, are time-consuming, or only detect postural issues after they have developed. Currently, there is no tool designed to predict postural deformities early on, before they fully manifest. Most of these assessment tools cover only a limited range of components, questions, and domains, which highlights the need for a comprehensive tool tailored for the Indian population. Given that posture is essential for the health and well-being of adolescents, it is crucial to assess it at the right time. However, current assessment tools lack coverage of all necessary components that need attention. Therefore, this new outcome measure was developed specifically to evaluate posture in the adolescent population of India [12].

In reviewing the existing body of literature on upper limb postural deviations, a notable gap was identified in studies that provide comprehensive data on the incidence and prevalence of these deviations among adolescents populations, as well as the associated risk factors. While numerous studies acknowledge the presence of upper limb postural deviations, there remains a lack of robust, detailed analysis connecting these deviations with specific risk factors. This gap in research underscores the need for a more thorough investigation into the potential determinants of postural deviations, such as lifestyle factors, ergonomic influences, and genetic predispositions, which may contribute to the development and progression of these conditions in young individuals.

MATERIALS AND METHODS

I. Phases of outcome measure development- According to a systemic review conducted by Boateng et al. [13] in 2018, the outcome measure is developed and validate into 3 phases. First phase is Item development in which the domain and subdomain is developed. The second phase is Scale development in which all the extra components of scales will be removed and pre-required survey will be done to evaluate scale components and final version of scale will be developed. Third phase is Scale evaluation in which reliability and validity of scale will be assessed. These 3 steps were followed to develop and validate the present outcome measure. The detailed description is as follows.

1) Phase 1. Item development-

Step 1: identification of the domain(s) and item generation

(1) Domain identification - STRINGS of Upper limb postural deviations scale is consisting of 5 domains Forward Head Posture (FHP), Forward Shoulder Posture (FSP), Scapular Asymmetry, Lumbar lordosis (LL) and thoracic kyphosis (TK).

(2) Item Generation- There are two primary approaches for developing questions: deductive and inductive methods (Boateng et al. [13]). The deductive method involves identifying items through a literature review and evaluating existing scales, while the inductive method generates items based on responses from individuals during interviews. In the present study, several outcome measures were reviewed, including the New York Posture Rating Chart (NYPRC), the Posture Screening and Assessment Tool (PSAT), the Adolescent Posture Assessment Scale (APAS), and Kendall's Postural Assessment. Various search engines, such as Google Scholar, PubMed, Web of Science, and Scopus, were used for this review. Both deductive and inductive methods were employed to develop the outcome measure for the STRINGS Upper Limb Postural Deviations Scale. The items for the scale were chosen based on postural changes in adolescents caused by a sedentary lifestyle or prolonged poor posture. Each component includes questions specifically related to adolescent subjects, with a four-point grading system (1-4): 1 = Never (N), 2 = Somewhat Frequent (SF), 3 = Frequent (F), 4 = Always (A). The scale covers various aspects that may affect the subject, including Forward Shoulder Posture (FSP), Forward Head Posture (FHP), scapular asymmetry, lumbar lordosis, and thoracic kyphosis.

2) Step 2: Content validity- To evaluate the qualitative content validity the outcome measure was validated by eight physiotherapists with seven plus year of experience and who were engaged in clinical practice. After the validation final version of scale was developed with 5 domains and 20 items. For quantitative evaluation alpha Cronbach value and Intraclass

correlation coefficients (ICC) value was used to find out the content validity of STRINGS scale [13].

II. Phase 2

Scale development- The developed outcome measure was administered to 20 subjects to assess whether the participants understood all the questions and were able to answer them correctly. After collecting the responses from the participants, necessary modifications were made to the scale, and the final version was developed [13, 14]. The full process of scale development is illustrated in Fig. 1, and the finalized scale is included in Supplementary File 1.

II. Phase 3

Scale evaluation

1) Internal consistency- Internal consistency measures the strength of the relationships between the items and the appropriateness of scoring the items together in one scale. Cronbach's alpha was used to examine internal consistency. Inter-item correlations of 0.8 or more and item-to-total correlations of 0.2 or more were considered acceptable [13-15].

2) Test–retest reliability- Reliability was estimated using the reliability coefficients (ICC). To assess how consistent their scores across time. A value between 0.4 to 0.75 is considered as good reliability. More than 0.75 consider as excellent reliability [13-15].

3) Face validity and content validity- To assess face and content validity, the outcome measure was reviewed by experts with at least eight years of experience in the fields of Orthopedic, Neurology, Community, and Geriatric physiotherapy. The experts evaluated the measure based on language, wording, clarity, and ease of administration. Revisions were made iteratively until a 90% consensus was reached. For content validation, each expert rated each questionnaire item on a scale from 1 to 3, where 1 meant "rejected," 2 meant "accepted with modification," and 3 meant "accepted." This process continued until all items received a rating of 3 from all experts [15, 16].

4) Convergent validity and correlation analysis- Convergent validity assesses whether different methods measuring the same concept produce similar results. This involves estimating the relationship between scale scores and related constructs, often using a multi-trait multi-method matrix or Pearson's correlation coefficient; stronger correlation coefficients indicate greater support for convergent validity [13- 15]. It is used to establish the relationship between existing measures and newly developed scale scores. Scale scores can be correlated with existing measures, or Intraclass correlation coefficients (ICC) and the analysis of standard deviations of score differences can be applied.

5) Study setting and sampling- After receiving ethical approval from the institutional ethics committee, data collection was conducted in Jaipur. The study included 440 adolescents (ages 11-18), both male and female, who were able to communicate effectively and had intact cognitive function. Data was gathered from various subdivisions within the Jaipur district, using a convenient sampling method. The required sample size was calculated to be 422, based on Jaipur's population (approximately 450,000), with a 10% buffer for potential dropouts, resulting in a final sample size of 400. This calculation was done using EpiInfo software (version 7) with a 95% confidence interval, a 5% margin of error, and an expected frequency of 50%. The sample was then distributed among the subdivisions, and data was collected. Additionally, 100 participants were reserved for test-retest reliability. Consent was obtained from all participants who were willing to take part in the study.

6) Scale administration- The STRINGS scale is a patient-reported outcome measure. Before administering the scale, all participants received detailed instructions and consent was taken from all them. The purpose of the outcome measure and its grading system were thoroughly explained to each participant. When needed, the scale was translated into the local language by the individual assisting with its administration. The interviews were conducted face-to-face.

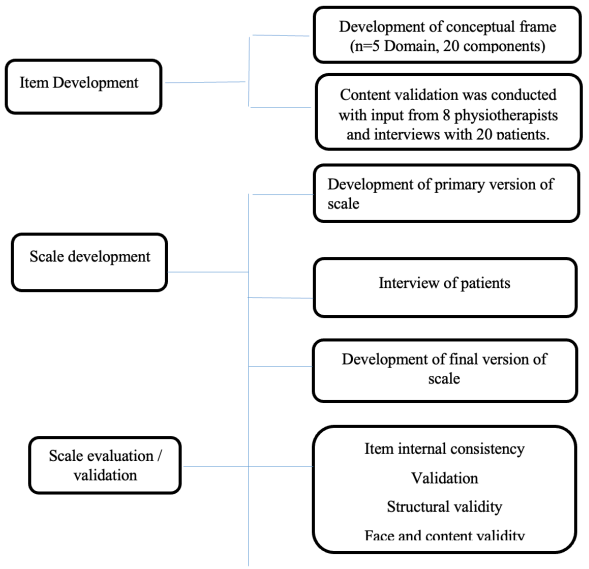

Fig. 1 development and Validation of STRINGS scale for upper limb postural deviations

RESULTS- Total 422 subjects participated in the study out of them 267 were males and 155 were females. All the subjects were 11- 18 years of age were included in the study.

Table 1, illustrates the parameters of upper limb postural evaluation with different tests Mean ± SD value for FHP was 64.28 ± 15.53, for FSP was 59.17 ± 14.55, for scapular asymmetry it was 60 ± 16, for lumbar

lordosis and thoracic kyphosis was 56.3 ± 12.08 and 60.41 ± 14.6 respectively.

Variables	Minimum	Maximum	Median (IQR)	Mean ± SD
Forward head posture (FHP)	25	100	62.5 (51.6-75)	64.28 ± 15.53
Forward shoulder posture (FSP)	25	93.75	62.5 (50-68.75)	59.17 ± 14.55
Scapular Asymmetry	25	100	58 (50-75)	60 ± 16
Lumbar Lordosis	30	95	55 (50-65)	56.3 ± 12.08
Thoracic Kyphosis	25	93.75	62.5 (50-68.75)	60.41 ± 14.6

Descriptive statistics of age and parameters of develop scale for upper limb postural evaluation

Table 2, illustrates the parameters of upper limb postural evaluation with different tests Mean ± SD value for FHP was 50.69 ± 1.48, for FSP was 3.09 ± 0.427, for scapular asymmetry it was 1.82 ± 0.135, for lumbar lordosis and thoracic kyphosis was 30.04 ± 5.61 and 26.92 ± 1.93 respectively.

Variables	Minimum	Maximum	Median (IQR)	Mean ± SD
Forward head posture (FHP)	48.03	52.93	51.12 (49.32-51.94)	50.69 ± 1.48
Forward shoulder posture (FSP)	2.54	3.91	3.05 (2.67-3.47)	3.09 ± 0.427
Scapular Asymmetry	1.5	1.99	1.85 (1.72-1.92)	1.82 ± 0.135
Lumbar Lordosis	22.47	40.14	28 (26.3-36.45)	30.4 ± 5.61
Thoracic Kyphosis	22.71	29.9	27.33 (25.34-28.61)	26.92 ± 1.93

Descriptive statistics of age and parameters of STRINGS for upper limb posture evaluation

Table 3 illustrates the correlation matrix for the admission scores on all the tests used. A Karl Pearson's rank correlation co-efficient are utilized throughout as the appropriate correlation co-efficient between all test used and STRINGS.

Variables	Corr (r)	t - test	P - Value	Significance
Forward head posture (FHP)	0.4136	9.311	0.00001	All are significant
Forward shoulder posture (FSP)	0.41 67	9.39 4	0.000 01	
Scapular Asymmetry	0.3976	8.880	0.00001	
Lumbar Lordosis	0.6721	18.601	0.00001	
Thoracic Kyphosis	0.6719	18.594	0.00001	

Association of develop scale and STRINGS scale for upper limb posture evaluation by using Karl Pearson's correlation coefficient statistics

Discussion- The findings from this study demonstrate the utility of STRINGS as a valuable tool for predicting postural deviations in adolescents at an early stage, before becoming an entity. By establishing cut-off values using STRINGS to predict impairment, the study highlights the importance of early intervention by physiotherapists. Specifically, when more than 50% of postural deviation is detected, it serves as a critical threshold indicating the need for individuals to seek assistance from physiotherapists. This emphasizes the proactive role that physiotherapy can play in addressing postural issues and preventing them from progressing further.

Postural assessment is essential for understanding and managing various musculoskeletal conditions. It can be conducted using instrumental techniques, which provide valuable insights into postural performance and strategies. However, these tools are often expensive, patented, or require specialized training, making them difficult to use in typical clinical settings and limiting their applicability for population-based studies [17].

The STRINGS scale addresses this gap by offering a practical and reliable tool for adolescents experiencing upper body pain. Significant correlations have been observed between STRINGS scores and measures such as the On Protractor mobile application, Pectoralis Minor Index (PMI), Lateral Scapular Slide Test (LSST), as well as kyphosis and lordosis indices [18]. A key advantage of the STRINGS scale is its dual focus on both patient-reported outcomes and therapist input, enhancing its sensitivity to detect changes, even in the acute stage or among otherwise healthy adolescents with subtle deficits that other scales may overlook [19]. Furthermore, by distinguishing between "back" and "neck" regions, the STRINGS scale reduces confusion in reporting and improves the accuracy, reliability, and validity of collected data.

Integrating questions on neck, shoulder, and back pain into posture assessment instruments provides a more comprehensive understanding of musculoskeletal issues in school-aged children. Such information can guide targeted interventions, promote ergonomic awareness, prevent pain, and improve overall musculoskeletal health in educational settings. In addition, the use of smartphone applications like Surgimap as a gold

standard for craniovertebral angle (CVA) measurement demonstrates the potential of mobile technologies in clinical assessment. Smartphones, equipped with accelerometers, gyroscopes, and magnetometers, facilitate accurate joint position and range of motion measurements, offering a cost-effective alternative to traditional photogrammetry [20–22]. Similarly, PMI, derived from Kendall and Sharman's work, offers a practical method to assess forward shoulder posture, despite being an indirect measure influenced by scapular positioning and soft tissue tension [23, 24]. Future studies should aim to validate and assess inter-rater reliability using standardized protocols.

The LSST has been debated for its reliability. Odom et al. reported inconsistencies in comparing scapular positions; however, their methodology involved a simple string measurement, which may have contributed to variability [26, 27]. Subsequent studies, such as T'Jonck et al., support continued refinement of LSST for clinical applicability [28]. Thoracic and lumbar curvature assessments using the Flexicurve method have demonstrated moderate to excellent intra-rater reliability and moderate inter-rater reliability in adolescents, especially when following standardized protocols with averaged measurements [29–31].

Overall, the STRINGS scale, supported by complementary tools like mobile applications, PMI, LSST, and Flexicurve, represents a significant advancement in postural assessment for adolescents, enabling comprehensive evaluation of musculoskeletal health. Limitations of this study include its focus exclusively on the Indian adolescent population and the consideration of cultural and ethnic factors specific to India. Future research should aim to validate the STRINGS scale and related assessment tools in adolescent populations from other countries to enhance generalizability and cross-cultural applicability.

Conclusion- The results showed high content validity and reliability of the scale. In addition, the findings showed confidence questions ranging from average to best for the most relevant multiple choice and binary items. From this, we can conclude that the STRINGS scale is a valid and accurate tool for the posture assessment of adolescent's people. It was considered while developing the outcome measure that all the necessary components will be covered in STRINGS scale so it can be easily used to assess posture. So, the study concludes that STRINGS scale is reliable and valid outcome measure which can be used for Indian adolescents' population to evaluate upper limb postural deviations.

Abbreviations-
NYPRC- New York Posture Rating Chart
PSAT- Posture Screening and Assessment Tool
APAS- Adolescents Posture Assessment Scale
FHP- Forward Head Posture
FSP- Forward Shoulder Posture
ICC- Intraclass Correlation Coefficients
CVA- Craniovertebral Angle
ROM- Range of Motion

Author contribution-

- Conception or design of the work; or the acquisition, analysis, or interpretation of data for the work: JS, DY
- Drafting the work or reviewing it critically for important intellectual content: PKG, AG
- Final approval of the version to be published: JS, NA
- Accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: PKG, DY

Acknowledgements
I would like to thank all coauthors for their work.
Funding- None
Conflict of interest
We do not have any conflict of interest.
Data availability statement
We confirm that the data supporting the findings of the study will be shared upon reasonable request.

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