Development and Validation of Prediction Equations for Spinal Curve Angles Based on Skin Surface Measurements

Tássia S. Furlanetto, MS, Eduardo B.C. de Oliveira, BPE, Cláudia T. Candotti, PhD, Adriane Vieira, PhD, Paula V. de Mesquita, MS, Isis J.R.L. Navarro, BS, and Jefferson F. Loss, PhD

Abstract

Objective: The purpose of this study was to develop, assess the reliability of, and validate prediction equations that estimate the sagittal curves of the spine from the skin surface.

Methods: Forty digital panoramic radiographs were used to develop the prediction equation, and 59 radiographs were used to assess reliability and validate the equations. For evaluation of the thoracic and lumbar curves, anatomical reference points were marked on the vertebral body, spinous process, and skin surface at the C6, C7, T2, T4, T6, T8, T10, T12, L2, L4, and S2 vertebrae. Three third-degree polynomials were obtained, estimated with the least squares method: inner curves from the centroid of the vertebral bodies and from the apex of the spinous processes and external curve from the skin surface. The magnitude of the curves of each region was estimated based on the angle between tangent lines at several vertebral levels. Prediction equations were obtained (simple linear regression) for the vertebral levels that had the best correlation between the inner and surface curves. The validation of the prediction equations was confirmed using Pearson's correlation (r), Student t test, and root mean square error. The reliability of the method was confirmed using the intraclass correlation coefficient, standard error of measurement, and minimal detectable change ($\alpha = 0.05$).

Results: The best correlations were obtained between the T4-T12 (thoracic) and T10-S2 (lumbar) levels ($r > 0.85$). For the intrarater and interrater reliability, the correlation was higher than 0.965 and higher than 0.896, respectively. There was a significant and strong correlation between estimated and actual values for the thoracic and lumbar curves, which was confirmed by the t-test results and by the root mean square error inferior to 1°.

Conclusion: Prediction equations can precisely and accurately estimate the angles of the internal sagittal curves of the spine from the skin surface. (J Manipulative Physiol Ther 2017;40:692-699)

Key Indexing terms: *Spinal Curvatures; Kyphosis; Lordosis; Spine*

Introduction

Maintaining the anteroposterior physiological curves of the spine is important for structural support, provides adequate protection to the spinal cord, and allows the mobility of the spinal segments.[1] These curves can be examined using the gold standard, the X-ray, or by noninvasive procedures, used as an option to avoid the problems that arise from exposure to radiation.[2-4] An example of a noninvasive tool for assessing posture is the Digital Image-based Postural Assessment software, which uses photogrammetry to measure changes in the spine.[5,6]

An important methodological difference in examining the spine using radiography and photogrammetry lies in the anatomical structures that are evaluated: The X-ray allows an internal evaluation, and photogrammetry allows assessment of the surface of the body. Although with X-rays the magnitude of the curves is calculated from the vertebral bodies,[7,8] photogrammetry identifies the spinous processes along the surface of the skin.[9]

The magnitude of the curves calculated from anatomical surface points is different from the magnitudes obtained from internal structures. Because the anatomical structures are closely related, a relationship is expected between the magnitudes calculated in different manners. Therefore, it is possible to obtain an accurate estimation of the internal curve using the external curve. Thus, this study aims to develop,

School of Physical Education, Physiotherapy and Dance, Federal University of the Rio Grande do Sul, Porto Alegre, RS, Brazil.

Corresponding author: Jefferson F. Loss, PhD, Rua Fernando Osório, 1887, Porto Alegre, RS, Brazil. Tel.: +55 51 3308 5822. (e-mail: *jefferson.loss@ufrgs.br*).

Paper submitted September 7, 2016; in revised form June 20, 2017; accepted June 20, 2017.

0161-4754

https://doi.org/10.1016/j.jmpt.2017.06.015

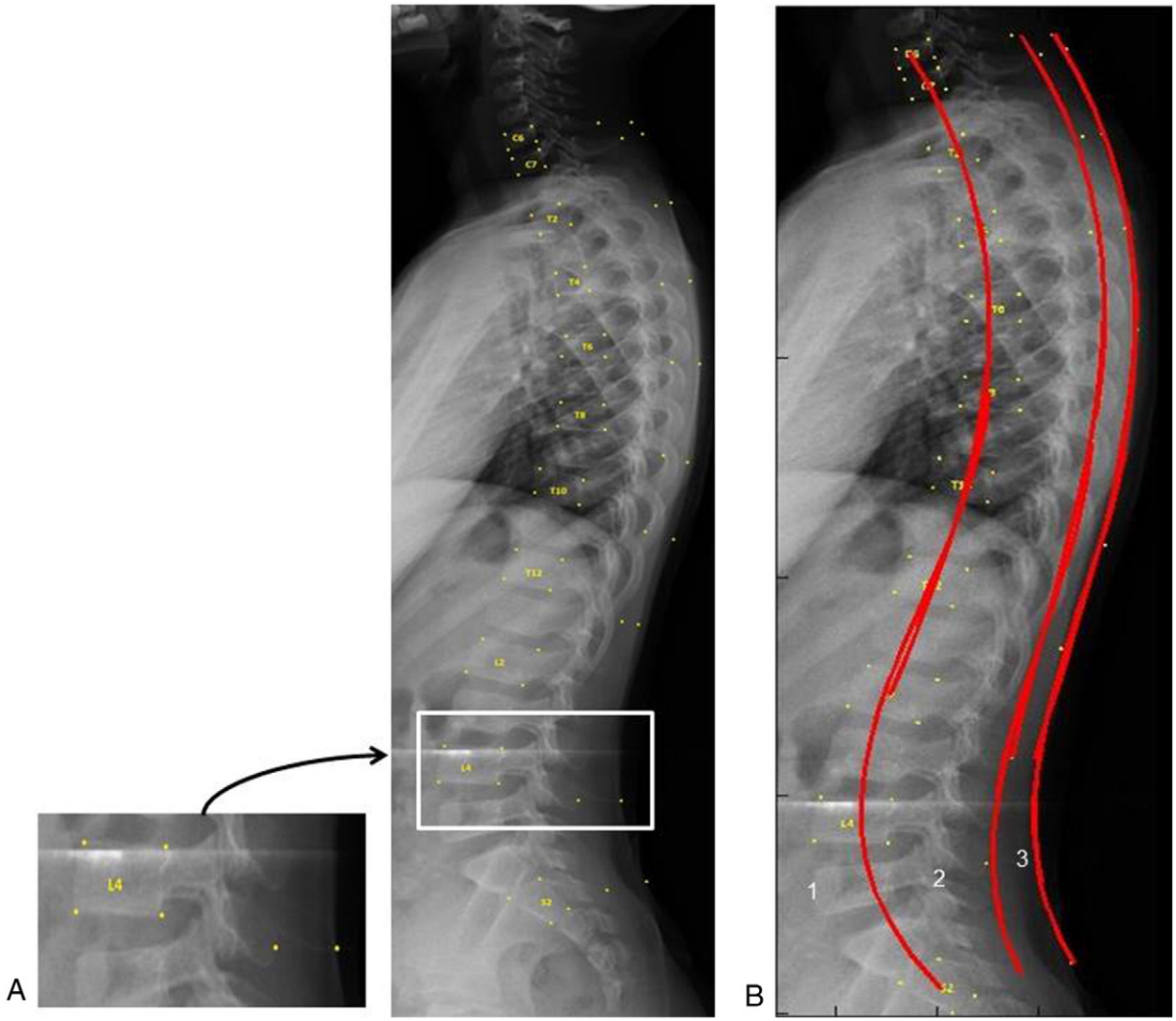

Fig 1. *(A) Anatomical points of reference marked on the radiographs. Detail: The 6 points marked on each vertebra. (B) Curves obtained for thoracic kyphosis and lumbar lordosis: 1 = inner curve from the centroid of the vertebral bodies; 2 = inner curve from the apex of the spinous processes; 3 = external curve from the skin surface.*

assess the reliability of, and validate a prediction equation to estimate the internal sagittal curves of the spine from the skin surface. With confirmation of its reliability and validity, it will be possible to use the prediction equation for qualifying noninvasive methods such as photogrammetry.

Methods

The objective of the study was reached with 99 panoramic digital radiographs with numerical scales related to children and young people aged between 6 and 18 years. Panoramic radiographs of the vertebral column were obtained from a database belonging to the Research Group. The use of a radiographic database, thus avoiding unnecessary exposure to radiation, is preferable for new studies. The radiographs were divided into 2 data sets: (1) 40 radiographs were used in the development of the prediction equations, and (2) 59 radiographs were used to validate the prediction equations. From this second sample set, 15 radiographs were randomly selected to assess the reliability of the method. All participants signed a free informed consent document, and the study was approved by the ethics committee of the Federal University of Rio Grande do Sul, Brazil, under No. 779.150.

Development of the Prediction Equations

With the use of GPower 3.1.7, the sample size was calculated based on *F* tests, assuming an effect size of 0.35,