Locating the Seventh Cervical Spinous Process: Development and Validation of a Multivariate Model Using Palpation and Personal Information

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Abstract

Objective: The aim of this study was to develop and validate a multivariate prediction model, guided by palpation and personal information, for locating the seventh cervical spinous process (C7SP).

Methods: A single-blinded, cross-sectional study at a primary to tertiary health care center was conducted for model development and temporal validation. One-hundred sixty participants were prospectively included for model development (n = 80) and time-split validation stages (n = 80). The C7SP was located using the thorax-rib static method (TRSM). Participants underwent chest radiography for assessment of the inner body structure located with TRSM and using radio-opaque markers placed over the skin. Age, sex, height, body mass, body mass index, and vertex-marker distance ($D_{V\text{-}M}$) were used to predict the distance from the C7SP to the vertex ($D_{V\text{-}C7}$). Multivariate linear regression modeling, limits of agreement plot, histogram of residues, receiver operating characteristic curves, and confusion tables were analyzed.

Results: The multivariate linear prediction model for $D_{V\text{-}C7}$ (in centimeters) was $D_{V\text{-}C7} = 0.986D_{V\text{-}M} + 0.018(\text{mass}) + 0.014(\text{age}) - 1.008$. Receiver operating characteristic curves had better discrimination of $D_{V\text{-}C7}$ (area under the curve = 0.661; 95% confidence interval = 0.541-0.782; $P = .015$) than $D_{V\text{-}M}$ (area under the curve = 0.480; 95% confidence interval = 0.345-0.614; $P = .761$), with respective cutoff points at 23.40 cm (sensitivity = 41%, specificity = 63%) and 24.75 cm (sensitivity = 69%, specificity = 52%). The C7SP was correctly located more often when using predicted $D_{V\text{-}C7}$ in the validation sample than when using the TRSM in the development sample: n = 53 (66%) vs n = 32 (40%), $P < .001$.

Conclusions: Better accuracy was obtained when locating the C7SP by use of a multivariate model that incorporates palpation and personal information. (J Manipulative Physiol Ther 2016;xx:1-9)

Key Indexing Terms: *Cervical Vertebrae; Palpation; Physical Examination; Diagnostic Errors; Physical Therapy Specialty; Rehabilitation*

Introduction

Health professionals apply palpation methods in expectation of accurate recognition of inner body structures before interventions such as physiotherapy,[1] anesthesiology,[2,3] osteopathy,[4] chiropractic,[5] acupuncture,[6] dentistry, and speech therapy.[7] Research fields such as biomechanics also depend on the accurate placement of skin markers over inner body structures.[8-10] Although the misrecognition of vertebral structures generally has few consequences, in some fields it can result in mild to severe health-related adverse events, particularly in the neck region.[11] The seventh cervical vertebra spinous process (C7SP) can be found by using palpation methods to identify the most prominent vertebrae[2,3] and by using the neck flexion-extension method.[1,3,12,13] Both methods are commonly used in the clinical setting, but their accuracy can be rather low, allegedly because potential factors (eg, anthropometric measures, variations caused by aging) are not considered objectively during palpation.[2,14] No current palpation method quantitatively accounts for the effect of personal information on palpation outcomes.

In the search for a more accurate palpation method to identify the C7SP, we proposed the thorax-rib static method (TRSM) in a companion study.[15] The thorax-rib static method has 2-fold

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greater accuracy than the flexion-extension method at any given level of anatomic detail. Nonetheless, TRSM's accuracy is still unsatisfactorily low; similarly, other palpation methods also lack the benefit of personalized information to guide palpation. Therefore, we argued that relevant predictors in addition to those obtained by palpation should be considered for a more accurate outcome.

In the health sciences, multivariate prediction models are statistical methods that combine predictors that used for diagnostic or prognostic purposes.[16] In the context of palpation, prediction models might help practitioners in making decisions by, for example, locating a given inner body structure, while considering multiple variables simultaneously. Thus, we hypothesized that combining palpation with personal information in a prediction model might yield greater accuracy than does palpation alone. Therefore, the aim of this study was to develop and validate a multivariate prediction model guided by personal information and TRSM for location of the C7SP.

Methods

Ethics

The Research Ethics Committee of Centro Universitário Augusto Motta approved this study protocol (CAAE 42535215.3.0000.523), which was designed in accordance with resolution 422/2012 from the National Health Council and with the Declaration of Helsinki. Participants were enrolled in this study after being informed about the study aims and receiving a critical appraisal of its potential risks and benefits. Each participant confirmed his or her understanding by signing an informed consent form.

Study Design and Sample Size

This study followed the Transparent Reporting of a Multivariate Prediction Model for Individual Prognosis or Diagnosis (TRIPOD) guidelines.[16] A single-blinded, cross-sectional study was conducted in 2 cohorts: model development (MD), conducted from June to August 2015 (cohort 1), and model validation (MV), conducted from August to October 2015 (cohort 2). Data collection in both stages employed a nonprobabilistic sampling scheme (convenience) at a primary to tertiary health care center (Radiology Diagnostic Department at Hospital Universitário Pedro Ernesto, UERJ, RJ, Brazil).

A minimum ratio of 10 events per variable (including the intercept) is required for MD.[17] Although formal sample size calculations for external MV studies are not mandatory,[18] a minimum estimated ratio of 7 events per predictor is thought necessary to attain a good prediction level ($R^2 = 0.70$).[19] A maximum of 6 predictors are considered here (see Predictors).

Participants

Participants were consecutively assessed for inclusion at both stages for MD and MV. For inclusion, participants required to be aged ≥18 years and to have received a prescription for a chest radiograph by an attending physician. Exclusion criteria included refusal to participate in the study after explanation of the study aims and procedures, insufficient clinical data acquired during the clinical interview, and low-quality radiographs for analysis.

Location of Seventh Cervical Spine Spinous Process Using Palpation

The TRSM was used to locate the C7SP as previously described.[15] Briefly, the examiner located the posterior arch of the first rib to depart from a vertical line from the mastoid process while the participant was standing; the T1 spinous process was located by following the posterior arch of the first rib; and the examiner moved his or her fingers to the next spinous process in the cephalic direction to locate the C7SP.

For MD in cohort 1, an elliptical radio-opaque marker (major axis = 15 mm; minor axis = 11 mm) was centered on the skin location identified as being above the C7SP using the TRSM and was fixed with hypoallergenic tape. This marker size was chosen (1) to better represent the shape and size of a thumb used for palpation; (2) to encompass the size of the extremity of the C7SP, ranging from 6 to 12 mm[20]; and (3) to minimize the chance of overlapping vertebral levels within the same marker, thus allowing a more precise analysis of the palpation method.

For MV in cohort 2, the skin location identified as being above the C7SP via the TRSM was marked with a dermographic pencil. In sequence, data from predictors were entered into an electronic worksheet to determine the adjusted location guided by the retained predictors. Finally, the same elliptical marker was positioned on the participant's skin with hypoallergenic adhesive tape at the adjusted location.

The same examiner (A.P.A.F.) performed all palpation procedures. This individual received a bachelor's degree in physiotherapy in 1991, obtained a diploma in osteopathy (DO) in 2002, and had 24 years of clinical experience in the manual therapy field. The examiner (A.P.A.F.) was blinded to the results of both stages for MD and MV because the radiologist provided no immediate feedback about the anatomic structure superimposed to the marker. Another examiner (L.C.P.) performed data collection and annotation.

Predictors: Measurement of Demographic Data

Predictors tested for MD comprised age, sex (male = 1, female = 0), height (in meters), body mass (in kilograms), body mass index (BMI, in meters per kilogram squared), and vertex-marker distance ($D_{V\text{-}M}$, in centimeters). Predictors retained for MV were assessed via the procedures described for MD.

Self-reported birthdate and sex were registered on the participant's case report form. Body height and mass were measured using a digital scale and stadiometer (model