Accuracy of Motion Palpation Flexion-Extension Test in Identifying the Seventh Cervical Spinal Process

Luciana C. Póvoa, PT, MSc,^{a,b,c,d} Ana P.A. Ferreira, PT, MSc,^{a,b,c,d} José F.C. Zanier, MD, PhD,^c and Julio G. Silva, PT, PhD^{d,e}

ABSTRACT

Objective: The aim of this study was to evaluate the accuracy of a motion palpation procedure, the flexion-extension test, in localizing the spinous process of the seventh cervical vertebra (C7).

Methods: We analyzed 101 adult participants with metal markers that permitted the identification of the C7 spinous process. This analysis occurred during a flexion-extension test and was confirmed by radiography. Data sample characteristics were analyzed by descriptive statistics, and the relationship between independent variables (weight, height, sex, age, and body mass index [BMI]) and dependent variables (coincidence between the most prominent vertebra and the stationary vertebra, as determined by the flexion-extension test) was determined via logistic regression.

Results: The sample population was 48.5% male with a mean age of 56.8 years (standard deviation, ± 14.9) and a mean BMI of 25.54 kg/m² (standard deviation, ± 5.5). In 54.5% of cases, the C7 spinous process was correctly identified by the flexion-extension test. The agreement between the flexion-extension test and radiography in accuracy of localization of the C7 spinous process was significant ($P = .021$), as was the correct localization of C7 ($P = .05$).

Conclusion: The localization of the C7 spinous process was more accurate in individuals with a BMI < 25 kg/m² and whose most prominent vertebra coincided with the stationary vertebra as determined by the flexion-extension test. (J Chiropr Med 2018;17:22-29)

Key Indexing Terms: *Palpation; Cervical Vertebrae; Motion*

INTRODUCTION

Motion palpation is used to determine the position of structures and localize vertebral levels. It is an important tool for the evaluation and treatment of musculoskeletal

disorders and for diagnostic and therapeutic procedures in other areas, such as orthopedic surgery and anesthesia.¹ Specifically, in the musculoskeletal area, knowledge of palpatory procedures can be considered an essential requirement for physical examination of vertebral structures.² According to Najm et al,³ the beneficial results of vertebral manipulative procedures are based on skillful and appropriate treatments, which, in turn, are based on accurate diagnoses that are dependent on accurate palpatory procedures. Within the framework of medicine, physiotherapy, nursing, and osteopathy, palpation training is fostered in the early period; to unify this information, a systematic teaching of palpatory anatomy should be established.

Methods to correctly identify vertebral levels by palpation have been described for the lumbar, thoracic, and cervical regions; however, none are satisfactorily reliable.⁴ In a systematic review, Cooperstein et al⁵ pointed out that anatomically incorrect landmark benchmarks would hinder the accurate identification of spinal sites of clinical interest, beyond what is to be expected as a result of examiner error and variation among patients, which lends some value to a systematic review of the literature addressing other commonly used spinal landmark rules.⁵

^a Rehabilitation Science Postgraduate Program, Human Analysis Movement Lab, Augusto Motta University Center, Rio de Janeiro, Brazil.

^b Brazilian Osteopathic Institute, Rio de Janeiro, Brazil.

^c Department of Radiology, Estado do Rio de Janeiro University, Rio de Janeiro, Brazil.

^d Human Analysis Movement Lab, Praça das Nações, Rio de Janeiro, Brazil

^e Department of Physical Therapy, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil.

Corresponding author: Julio G. Silva, PT, PhD, Human Analysis Movement Lab, Praça das Nações, no 34 – 3º andar, Bonsucesso, Rio de Janeiro, Brazil, CEP 21.041-021. Tel.: +55 21 3882 9797 R.1012.

(e-mail: jglsilva@yahoo.com.br, jgsilva@hucff.ufrrj.br).

1556-3707

Paper submitted April 5, 2017; in revised form November 18, 2017; accepted November 20, 2017.

© 2017 National University of Health Sciences.

<https://doi.org/10.1016/j.jcm.2017.11.005>

Compared with reliability studies, the accuracy of palpation has not received the same emphasis in the literature. This may be due to the difficulty of finding a gold standard to objectively measure the vertebral level being palpated and consequently the accuracy of this procedure.⁶ Despite the importance of motion palpation, information on the validity and reliability of palpatory methods is scarce in the literature.^{7,8}

In their systematic review, Stochkendahl et al⁹ found numerous criticisms of the methods for palpatory studies, mainly because of uncontrolled factors such as the inclusion of asymptomatic participants only, inexperienced observers, parallel testing, less conclusive definitions of positive findings and rating scales, and weak descriptions of the results; all of these factors drive the need to improve the quality of studies. In addition, the possible relationships between anthropometric variables, such as weight, height, body mass index (BMI), age, and sex, and the accuracy of localization of the C7 spinous process have not been well explored in the literature. Studies that have tried to analyze the relationship between BMI and sex have reported inconclusive results, only highlighting these factors as potential study limitations.^{4,10} In their last systematic review, Póvoa et al¹¹ identified few studies that evaluated the validity of manual palpatory procedures for examining bony landmarks of the cervical spine. They reported fair to good methodologic quality with poor external validity as a result of the sampling heterogeneity.

Based on these studies and the lack of rigorous methodologic research in palpation, there is a need to systematize palpation of the cervical spine. Investigation of the accuracy of the procedure and how anthropometric features (weight, height, BMI, and age) may affect outcomes is needed. Therefore, the objectives of this study were to (1) assess the accuracy of the motion palpation procedure (flexion-extension test) in locating the C7 spinous process; (2) determine the agreement between the localization of the most prominent vertebra and the localization of the stationary vertebra (C7) using the flexion-extension test; and (3) verify the possible agreement of the accuracy of the C7 spinous process localization with the independent variables of weight, height, sex, age and BMI and the dependent variables of agreement between the most prominent vertebra and the stationary vertebra, as determined by the flexion-extension test.

METHODS

This study used a convenience sample, with a total population selected consecutively. The structure of the study is shown in Figure 1.

Sample

The study analyzed 101 adult participants, outpatients and inpatients, who had received referral for chest-area

imaging at the radiology sector of the Pedro Ernesto University Hospital (HUPE) at the University of the State of Rio de Janeiro. Participants included individuals of both sexes, aged >18 years, who had a previous medical prescription for chest radiography.

Exclusion criteria for participants were previous surgery on the cervical spine; osteomyoarticular congenital malformation of the cervical region; intubation or use of devices or equipment that prevented palpation access; any adverse reaction to the tape used to set the marker reported by the participant; and failure of the radiography image to capture the marker (ring) used to circumscribe the desired spinous process. This work was approved by the Research Ethics Committee of HUPE/University of the State of Rio de Janeiro under number 501 745.

Procedures

Data on height, weight, age, and sex were recorded through participant self-reporting in an evaluation form. Participants went to the radiography examination room and were instructed to sit up straight without supporting their backs on their chairs and to keep their heads in a neutral position (looking forward, toward the horizon). At this time, the assessment was initiated and was always performed by the same evaluator.

1. The evaluator was at the left side of the patient to start the procedure of palpating the C7 spinous process. This approach identified the most prominent vertebra localization in the cervicothoracic region during passive flexion of the cervical spine. The examiner positioned the pulp of the middle finger of the dominant hand (right) on the desired vertebra and passively returned the volunteer's head to the neutral position.^{4,12}
2. With this previous localization of the most prominent vertebra localized in step 1, flexion-extension testing was performed to confirm the localization of C7. The evaluator kept his middle finger on the most prominent vertebra and placed his index finger on the spinous process of the overlying vertebra. With his other hand, the evaluator conducted an active-assisted extension of the cervical spine (the evaluator pushed the patient's head in a backward direction to provoke extension of the cervical spine). The purpose of this test was to identify the first vertebra that stays still while the aforementioned vertebra moves during the test. The rationale for this assumption is that the free C6 spinous process of the cervical spine is the last (lower cervical spinous process) vertebra to move during the test; therefore, the underlying vertebra, which is the first stationary vertebra, should be C7.⁴
3. Then the evaluator shifted his middle and index fingers in the cranial direction and repeated the

Fig 1. Study design.

flexion-extension test. This second stage was used to confirm the localization of the first stationary vertebra of the cervicothoracic group. This test assumes that the most prominent vertebra is the C7. To localize this structure, we performed a passive flexion of the cervical spine as described in the first step. With this localization (controlled by the index finger, supposedly C6, and middle finger, supposedly C7), the therapist performs the test, which consists of the active-assisted extension of the cervical spine. During extension, all of the cervical vertebrae will move forward, except C7. Therefore, if the previous localization is correct, the index finger will move forward (because it is C6) and the middle finger will not move (because it is C7, the stationary vertebra). This last step confirms this point by changing the position of the fingers so that the index finger will be positioned over C5 and the middle finger will be positioned over C6. Then the movement (active-assisted extension) will be performed again to check the previous information. It is expected now that the 2 fingers will move away. The vertebra that showed no

Fig 2. Marked position (ring).

motion in the flexion-extension test was considered to be C7, according to the description of Shin et al.⁴ At this point, the evaluator determined whether the most prominent vertebra was coincident with the stationary vertebra determined by the test.

After locating what was believed to be the spinous process of C7, the evaluator marked each volunteer's skin at that localization with a water-soluble pen and affixed a light metal ring (2 cm in diameter, which corresponds approximately to the diameter of the middle finger of an adult) with hypoallergenic and transparent tape (Fig 2).

We recorded information about the correspondence between the most prominent vertebra and the result of the flexion-extension test. In other words, we started with the most prominent vertebra (with passive flexion), but the ring was affixed on the place that the test (extension part) showed: the first vertebra without movement during the extension. Sometimes both localizations were the same (most prominent vertebra and the first vertebra that did not move during the extension). If this event occurred, the researcher registered that finding.

The test and placement of the marker on the C7 spinous process lasted approximately 15 minutes in total, from the reading and signing of the consent form to the final marking of the desired anatomic reference. After labeling, the patient was positioned facing radiography imaging equipment, with guidance given by the radiographer. Because the place of interest was the cervical spine, patients with referrals for imaging of the chest region were chosen because of the inclusion of the middle and lower cervical spine and ease of positioning (standing position), which would decrease any possible errors in localization as a result of patients' position changes.

The whole examination protocol was performed in accordance with the routine of the HUPE's radiology service. At the time of radiography, all participants

Fig 3. Location marker (ring) relative to the vertebral level in radiography.

performed a maximal inspiratory apnea of approximately 3 seconds and stopped on the radiologist's command. It should be emphasized that the palpation procedure was performed and the anthropometric data records were maintained by the evaluator, who has 22 years of clinical experience in manual therapy. Total percentage of palpation accuracy was expressed on a scale: 0% to 20% correct palpation = worst; 21% to 40% = poor; 41% to 60% = regular; 61% to 80% = good; and 81% to 100% = very good.

Instrumentation

The radiographic images were obtained from the HUPE radiology department using a Siemens MULTIX B (model and serial number 8440026 X1122: 4204 S20L) (Siemens, Munich, Germany). After the tests, radiographs were analyzed by a radiologist with more than 30 years of professional experience who was blinded to the data during collected the interview and to the palpation procedure performed. This analysis was used to determine the accuracy of the localization marker (ring) relative to the vertebral level. In the event of C7 localization error, the radiologist determined the vertebral level at which the loop was placed (Fig 3).

Data Analysis

A blinded evaluator compiled the results and conducted the statistical analysis of the data. The entire structure being contained within the marker (ring) was considered agreement. In this study, the independent variables of interest were sex, age, height, weight, and BMI, and the dependent variables of interest were agreement between the palpatory localization of the C7 spinous process (prominent vertebra) and the localization of the spinous process of the

stationary vertebra (presumably C7) through the flexion-extension test of the cervical area.

Independent variables were analyzed using descriptive statistics with central tendency values (mean and median) and dispersion (standard deviation). To allow analysis through binary logistic regression, age, weight, height, and BMI were classified by the median and divided into 2 groups greater than and less than this value. Thus, the categories were age category—1 group of ≤ 59 years and another of ≥ 60 years; height—1 group of up to ≤ 165 cm and the other ≥ 166 cm; participants were grouped by BMI as underweight and normal (≤ 24.99 kg/m²) or as overweight and obese (≥ 25 kg/m²). For the independent variable, the measurement bias of palpation (accuracy error) was divided into 2 groups: 1 over C6 (with inclusion of C6) and the other below T1 (with inclusion of T1).

RESULTS

Of the 127 individuals invited for the study, 26 were excluded because of changes in the positioning of the film that directly contributed to viewing limitations of the radiologic image and exclusion the region of interest, thus preventing an analysis of the cervical region.

The data characterizing the sample were analyzed using descriptive statistics with central tendency values (mean and median) and dispersion (standard deviation). According to the Kolmogorov-Smirnov test, the study population of 101 participants had a normal distribution, comprising 48.5% men ($n = 49$) and 51.5% women ($n = 52$), with an average age of 56.8 years (standard deviation [SD] ± 14.9). Regarding the anthropometric data, the average weight was 69.9 kg (SD ± 15.3), and the average height was 165 cm (SD ± 0.1). The body mass index was 25.59 kg/m² (SD ± 5.5), and the determination of overweight participants can be found in Table 1.

For the analysis of independent variables, binary logistic regression was performed to verify the correlation between localization of the C7 spinous process and the independent variables of weight, height, sex, BMI, and age; systematic

Table 1. Frequency of Measurement Biases in the Palpation of the C7 Spinal Process Out of a Total of 46

Bias Area	Frequency (n)	Percent
Above C5	6	13
C5	8	17.4
C6	28	60.9
T1	2	4.3
T2	2	4.3

Table 2. Logistic Regression Analysis: Category/Confirmed

Analysis	Exp (β)	95% CI	P
Age/radiograph confirmed	1.309	0.597-2.870	.501
BMI/radiograph confirmed	2.164	0.974-4.810	.05
Height/radiograph confirmed	0.690	0.314-1.516	.355
Sex/radiograph confirmed	1.052	0.480-2.303	.899
Prominent vertebrae and flexion-extension test/radiograph confirmed	0.373	0.161-0.861	.021

BMI, body mass index; CI, confidence interval.

error; and whether palpation was in agreement with the flexion-extension test and with the most prominent cervical vertebra, thus determining whether the most prominent vertebra is a good reference for C7 (tested by the flexion-extension test). The level of significance of the test was 95% ($P \leq .05$).

Regarding the frequency of accuracy, our data indicated a palpation accuracy of 54.5% success rate ($n = 55$) and an error of 45.5% ($n = 46$). The most prominent vertebra matched the location of the C7 spinous process (as determined by the flexion-extension test) in 35.6% ($n = 36$), and 65.4% ($n = 65$) did not coincide, as indicated by palpation with the flexion-extension test. Concerning the bias, the results are reported in Table 2.

Regarding the analysis of sex, age, weight, height, and BMI with the most prominent vertebra and flexion-extension test, our results indicated that increased BMI influenced the accuracy as well as the coincidence of the localization of the most prominent vertebra with the stationary vertebra (presumably C7) by the flexion-extension test. Concerning the independent variables of age, sex, and height, there was no influence, as shown in Table 3.

DISCUSSION

According to our results, the accuracy of the flexion-extension test for the localization of the spinous process of C7 confirmed by radiography was 54.5%. Our findings are consistent with the work of Robinson et al.¹³ In Robinson's work, the evaluators were more precise than accurate (there was agreement on the localization, but it was not in an accurate location) because the C7 localization was agreed upon in 12 of 18 participants evaluated, but the spinous process of C7 was correctly identified in only 8 patients. Also with regard to accuracy, Billis et al² achieved good repeatability among physical therapists in the spinal localization—that is, they were able to return to the same vertebral level during treatment sessions or during

Table 3. Logistic Regression Analysis: Category/Bias

Analysis	Exp (β)	95% CI	P
Age/measurement biases	1.545	0.424-5.633	.509
BMI/measurement biases	0.421	0.95-1.861	.254
Height/measurement biases	1.560	0.416-5.849	.510
Sex/measurement biases	1.778	0.486-6.5	.384
Prominent vertebrae and flexion-extension test/measurement biases	2.061	0.560-7.577	.276

BMI, body mass index; CI, confidence interval.

reevaluation of a level during the same session. However, the results indicated low reproducibility over all vertebral levels—in other words, they did not properly locate the desired level.

Gadotti and Magee¹⁴ studied 39 women and evaluated the capacity of a physical therapist to place markers on the surface of the skin along the spinal processes of C2, C4, C6, and C7, confirming the results by radiography. The total percentage of agreement of all assessed levels was 87.8%. However, the authors admitted that the high success rate in locating the cervical spinous processes may have been due to the use of 2 of the cervical spinous process identification methods, including counting from the occipital bone and the flexion-extension test. In the work of Shin et al,⁴ the goal was to compare the accuracy of 2 different methods of palpation used to identify the spinous process of C7 (most prominent vertebra and flexion-extension mobility test). The sample consisted of 48 participants in each group; C7 was correctly located in 37.5% of the control group (most prominent vertebra) and 77.1% of the group undergoing the flexion-extension test. Our results indicated a confirmation concordance of 54.5% between the supposed location of the C7 determined by the flexion-extension test and the confirmation on a radiograph image. We attributed the high accuracy of Shin et al⁴ to use of a single evaluator and to being nonblind to the results of fluoroscopy. In a similar investigation, Cooperstein et al¹⁵ analyzed the validity of C1 transverse process palpation compared with an imaging reference standard, and the stringent accuracy was 57.1%.

In this study, the biases of measurement were located at specific anatomic points: 13% above C5, 17.4% on C5, 60.9% on C6, 4.3% on T1, and 4.3% on T2. In the work that is most approximate to the bias frequency in our study, Shin et al⁴ identified the spinous process of C6 as the most prominent vertebra of the cervical spine in 47.9% of cases. However, this error took into account only the palpation of the most prominent vertebra from a static point of view, whereas in the present study we used the mobility test.

Our study population consisted of participants with an average age of 56.8 years ($SD \pm 14.9$), ranging from a

minimum of 23 to a maximum of 83 years. Other studies, such as that by Gadotti and Magee,¹³ had a younger population (mean 33 ± 3.8 years) and asymptomatic women. Our population was consecutive and included both symptomatic and asymptomatic individuals. This may explain the higher rate of hits in the study by Gadotti and Magee,¹³ who obtained an accuracy margin of 87.8% compared with our findings of only 54.5%. However, we believe our results to be correct and similar to those of their study because the mobility of the cervical segment is inversely proportional to age; that is, younger volunteers have more movement.¹⁶⁻¹⁸ According to Shin et al,⁴ the biomechanics of the cervical thoracic junction justify the use of the flexion-extension test for the correct localization of the C7 vertebra, which is considered a transitional vertebra of the mobile cervical spine to the rigid thoracic spine. During the extension, the lower anterior cervical disc space increases while the posterior space shortens; subsequently, the spinous processes move away together. The separation and the approach of the spinous processes during flexion and extension of the cervical spine occur only in the cervical spine and are not observed in the cervicothoracic junction. The approach of the spinous processes during extension leads to difficulties in palpation of C6, facilitating palpation of C7 and T1.

In the study by Simpson et al,¹⁶ the objective was to assess the segmental motion of the cervical spine (full range of motion) with radiography in flexion and extension and to determine the relationship with clinical variables. They analyzed 195 radiographs (133 women and 62 men) of symptomatic individuals aged 15 to 93 years. Age and sex were significantly negatively associated with the full range of motion of C2-C3, C3-C4, C4-C5, and C5-C6. The regression coefficient was 0.11, meaning that 0.11° of movement on each segment is lost per year of age. Considering the 5 levels of the cervical spine, there was an associated cervical spine movement decrease of 5° for each decade.

The objective of Yukawa et al¹⁸ was to establish standardized values for the full range of motion and changes related to aging in both women and men in each decade of life between the third and the eighth decades. They reported that, of 1230 asymptomatic volunteers who underwent imaging of the cervical spine (anteroposterior, lateral, flexion, and extension), the full range of motion decreased from the third through eighth decade of life (age range 67.7 ± 17 to 45 ± 12.5 years). Extension decreased more than flexion, particularly in women, and the lordotic alignment progressed with advancing age and was more pronounced in women than in men. Despite the suggested relationship between age and mobility of the cervical spine, it was not possible to verify in our study a statistically significant difference between corrected location of C7 and age using our data ($P = .501$).

Regarding weight, height, and BMI, the results suggested an influence of BMI on the accuracy of locating the

C7 spinous process. Body mass index had a negative association with the accuracy of localization of the spinous process of C7; that is, the greater the BMI, the less accurate the localization ($P = .05$). The average BMI of the study population was 25.59 kg/m^2 ($\text{SD} \pm 5.5$), with 50 individuals (49.5%) in the underweight and normal weight category and 51 individuals (50.5%) in the overweight and obese category. This finding may have great relevance because most studies did not identify a significant correlation between BMI and accuracy. This may have occurred because of the low number of overweight or obese volunteers included in the studies. Shin et al⁴ sampled individuals with a minimum weight of 38 kg and a maximum of 90 kg with BMI ranging from 15.8 to 31.2 kg/m^2 ; 67 individuals were in the BMI category $<25 \text{ kg/m}^2$ (normal/underweight), 26 were in the overweight category, and only 3 were identified as obese. In this study, there was no difference in accuracy between those with normal BMI and those with an overweight BMI, although it is important to note that only 27% of patients were in the overweight category and 3% in the obese category.

Robinson et al¹³ stated in their study that there was no significant difference in marking of the skin by manual therapists among distinct categories of BMI. However, this study also had a small number of obese volunteers (18%). Teoh et al,¹⁹ who compared the accuracy of 2 points of anatomic reference—the inferior angle of the scapula (10%) and more prominent vertebra (29%)—for identifying the spinous process of T7 reported an association between BMI and accuracy of localization starting from C7 for individuals with a BMI $<25 \text{ kg/m}^2$. For patients with a BMI $\geq 25 \text{ kg/m}^2$, both groups had low accuracy.

In our study, there was an interest in investigating the correlation between the localization of the most prominent vertebra and the localization point determined by the flexion-extension test and the accuracy of localization of the spinous process of C7. As a result, a concordance was identified in 36 participants (35.6%), and no agreement was reached in 65 participants (64.4%). This combination has yet to be tested in other studies. This result suggests that in this studied population, the most prominent vertebra is unreliable as a guide to the localization of the C7 spinous process. However, when the most prominent vertebra coincided with the location of the most prominent vertebra guided by the flexion-extension test, it allowed for greater accuracy.

Limitations

One limitation of our study was that the assessments were made by a single observer, and this limitation may have caused inaccuracy in locating the spinous process of C7. In addition, it should be noted that the anthropometric data were provided by the patients themselves. We follow research that indicated the possibility of using self-reported

weight and height information in similar populations (Brazilian, living in São Paulo) because this study presented values with high concordance and validity.²⁰

Another limitation was the use of the chest radiography to analyze the cervical spine region. Even though chest radiography could easily include the middle and lower cervical spine segments, there is a chance of not visualizing very well the cervical segments in special situations such as in participants with congenital abnormalities (eg, cervical rib and eighth cervical vertebra).

CONCLUSION

After analysis, flexion-extension test accuracy (confirmed by the radiography images) was identified in 54.5% of participants (n = 55). Regarding the association between the most prominent vertebra (static position) and C7 determined by the flexion-extension test (motion test), 65.4% (n = 65) did not coincide, and 35.6% (n = 36) were in agreement. To be more accurate, the localization of the most prominent vertebra should be at the same level as the localization of the stationary vertebra (C7) as determined by the flexion-extension test. We can suggest that the localization of the C7 spinous process is more accurate in individuals with a BMI ≤ 25 . Age, height, and sex did not influence motion palpation and C7 spinous process identification. However, there is need for further research on palpation procedures and aspects of the physical examination, in particular, the influence of mobility in cervical palpation segment and the localization of the most prominent vertebra process. In this way, we will have more tools to help systematize the palpation procedure.

FUNDING SOURCES AND CONFLICTS OF INTEREST

No funding sources or conflicts of interest were reported for this study.

CONTRIBUTORSHIP INFORMATION

Concept development (provided idea for the research): L.C.P., A.P.A.F., J.F.C.Z., J.G.S.

Design (planned the methods to generate the results): L.C.P., A.P.A.F., J.F.C.Z., J.G.S.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): L.C.P., A.P.A.F., J.F.C.Z., J.G.S.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): L.C.P., A.P.A.F., J.F.C.Z., J.G.S.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): L.C.P., A.P.A.F., J.F.C.Z., J.G.S.

Literature search (performed the literature search): L.C.P., A.P.A.F., J.F.C.Z., J.G.S.

Writing (responsible for writing a substantive part of the manuscript): L.C.P., A.P.A.F., J.F.C.Z., J.G.S.

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): L.C.P., A.P.A.F., J.F.C.Z., J.G.S.

Practical Application

- Localization of the C7 spinous process was more accurate when assessing nonobese individuals.

REFERENCES

1. Snider KT, Snider EJ, Degenhardt BF, Johnson JC, Kribs JW. Palpatory accuracy of lumbar spinous processes using multiple bony landmarks. *J Manip Physiol Ther.* 2011; 34(5):306-313.
2. Billis EV, Foster NE, Wright CC. Reproducibility and repeatability: errors of three groups of physiotherapists in locating spinal levels by palpation. *Man Ther.* 2003;8(4): 223-232.
3. Najm WI, Seffinger MA, Mishra SI, et al. Content validity of manual spinal palpation exams: a systematic review. *BMC Complement Altern Med.* 2003;3:1.
4. Shin S, Yoon D-M, Yoon KB. Identification of the correct cervical level by palpation of spinous processes. *Anesth Analg.* 2011;112(5):1232-1235.
5. Cooperstein R, Haneline M, Young M. The location of the inferior angle of the scapula in relation to the spine in the upright position: a systematic review of the literature and meta-analysis. *Chiropr Man Therap.* 2015;23:7.
6. Cooper K, Alexander L, Hancock E, Smith FW. The use of pMRI to validate the identification of palpated bony landmarks. *Man Ther.* 2013;18(4):289-293.
7. Stovall BA, Kumar S. Reliability of bony anatomic landmark asymmetry assessment in the lumbopelvic region: application to osteopathic medical education. *J Am Osteopath Assoc.* 2010;110(11):667-674.
8. Degenhardt BF, Johnson JC, Snider KT, Snider EJ. Maintenance and improvement of interobserver reliability of osteopathic palpation tests over a 4-month period. *J Am Osteopath Assoc.* 2010;110(10):579-586.
9. Stochkendahl MJ, Christensen HW, Hartvigsen J, et al. Manual examination of the spine: a systematic critical review of reproducibility. *J Manip Physiol Ther.* 2006;29(6): 475-485.
10. Kawchuk GN, Prasad N, Parent E, et al. Spinal landmark depth in relation to body mass index. *Man Ther.* 2011;16(4): 384-387.
11. Póvoa LC, Ferreira APA, Silva JG. Validation of palpation methods for evaluating anatomical bone landmarks of the cervical spine: a systematic review. *J Manip Physiol Ther.* 2015;38(4):302-310.
12. Tixa S. *Atlas de Anatomia Palpatória: do Pescoço, do Tronco e do Membro Superior*. Vol. 1. São Paulo, Brazil: Editora Manole; 2009.

13. Robinson R, Robinson HS, Bjørke G, Kvale A. Reliability and validity of a palpation technique for identifying the spinous processes of C7 and L5. *Man Ther.* 2009;14(4):409-414.
14. Gadotti IC, Magee D. Validity of surface marker placement on the cervical spine for craniocervical posture assessment. *Man Ther.* 2013;18(3):243-247.
15. Cooperstein R, Young M, Lew M. Validity of palpation of the C1 transverse process: comparison with a radiographic reference standard. *J Can Chiropr Assoc.* 2015;59(2):91-100.
16. Simpson AK, Biswas D, Emerson JW, Lawrence BD, Grauer JN. Quantifying the effects of age, gender, degeneration, and adjacent level degeneration on cervical spine range of motion using multivariate analyses. *Spine.* 2008;33(2):183-186.
17. Tommasi DG, Foppiani AC, Galante D, Lovecchio N, Sforza C. Active head and cervical range of motion: effect of age in healthy females. *Spine.* 2009;34(18):1910-1916.
18. Yukawa Y, Fumihiko Kato F, Suda K, Yamagata M, Ueta T. Age-related changes in osseous anatomy, alignment, and range of motion of the cervical spine. Part I: radiographic data from over 1,200 asymptomatic participants. *Eur Spine J.* 2012;21(8):1492-1498.
19. Teoh DA, Santosham KL, Lydell CC, Smith DF, Beriault MT. Surface anatomy as a guide to vertebral level for thoracic epidural placement. *Anesth Analg.* 2009;108(5):1705-1707.
20. Frutuoso MFP, Falsarella FA, Gambardella AMD. Validity of weight and height informed by adult women in the city of São Paulo. *Brazilian Soc Food Nutr.* 2011;36(1):127-136.