Clinical Measures Related to Forward Shoulder Posture: A Reliability and Correlational Study

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Abstract

Objectives: The purpose of this study was to examine the reliability of clinical measures related to forward shoulder posture (pectoralis minor index [PMI], scapular index [SI], abduction index [AI], acromion to the wall index [AWI] acromion to the treatment table index [ATI], and thoracic curvature [TC]), and to investigate the association (redundancy) among these measures.

Methods: Twenty-one asymptomatic participants participated in this study. Two physiotherapists were trained to perform the clinical measurements. Intraclass correlation coefficients ($ICC_{2,k}$) were calculated to assess intra- and interrater reliabilities. Pearson product moment correlation was used to investigate the existence of possible redundancy between the measures that showed high intra- and interrater reliabilities.

Results: The measures showed ICCs between 0.30 and 0.97. Five measures, PMI, SI, AWI, ATI, and TC, showed appropriate values for intrarater reliability (ICCs 0.77-0.94), and 3 measures, AWI, ATI, and TC, for interrater reliability (ICCs 0.82-0.85). Among measures that showed acceptable intra- and interrater reliability values, 2 measures were redundant, showing high association (AWI vs ATI) ($r = 0.80$, $P < .001$).

Conclusion: For PMI, SI, AWI, ATI, and TC measures, adequate values of intrarater reliability were observed. For AWI, ATI, and TC, adequate values of interrater reliability were found. Two pairs of measures were highly associated (PMI with SI; AWI with ATI), which indicates redundancy among them. Our results suggest that, when the same examiner performs the assessment, the combined use of the PMI, AWI, and TC measures allows a quick but comprehensive evaluation of the presence of forward shoulder posture. (J Manipulative Physiol Ther 2019;42:141-147)

Key Indexing Terms: *Shoulder; Posture; Clinical Decision-Making; Reproducibility of Results*

Introduction

Forward shoulder posture (FSP) is a commonly found postural deviation characterized by lateral translation, medial rotation, and anterior tilt of the scapula.[1] Muscle length changes in participants with FSP are thought to be associated with abnormal scapulohumeral rhythm, impingement of subacromial structures, glenohumeral instability, and rotator cuff tendinopathy and tears.[2] The identification of this postural deviation and its monitoring in response to specific treatment techniques is an integral part of the therapeutic approach to these dysfunctions. Several clinical measures are proposed to quantify FSP and its components directly, which are easily applicable in clinical practice.[3-10] Examples of such measures are pectoralis minor resting length,[4] scapular index (SI),[6] normalized measurement of scapular abduction,[7] thoracic curvature (TC),[8] acromion to the wall,[9] and acromion to the treatment table.[5]

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Clinical measures should be reliable to be used in clinical practice.[11] Appropriate intrarater reliability is necessary when the same examiner performs the measurements at different times, and appropriate interrater reliability is needed when different examiners perform the measures.[11,12] Some studies demonstrated good to excellent intrarater reliability of the pectoralis minor resting length,[13-16] whereas others showed good to excellent[14,16] and poor to moderate[15] interrater reliability. The normalized scapular abduction,[7] the acromion to the wall,[9] and the acromion to the treatment table[17,18] measures exhibited excellent or good intrarater reliability. The TC measure also demonstrated variations on intra- and interrater reliability, with some studies showing good intrarater reliability,[10,19,20] and others showing poor interrater reliability[21] or moderate intra- and interrater reliability.[22] Therefore, there is no consensus about the intra- and interrater reliabilities of most of the FSP-related measures, which hampers the selection of the method that should be used in clinical practice.

Forward shoulder posture has multiple components (ie, dimensions) that may be considered in a clinical evaluation,[6] such as postural changes[7,8] and muscle length.[13,14] The existing clinical measures were proposed to quantify specific dimensions of FSP.[4-8] To perform a comprehensive and time-efficient assessment, different FSP dimensions might be quantified, but redundant measures, informing about similar components, should be avoided. Borstad[6] showed poor or no association between some of these measures (ie, pectoralis minor length, SI, acromion to the treatment table, TC), which suggest that they do not share redundant information. However, the acromion to the wall and the normalized scapular abduction measures, which are commonly used,[5,9] were not investigated. On the other hand, because acromion to the wall and acromion to the treatment table measures quantify similar postural dimensions, it is expected that these measures are redundant. In addition, acromion to the wall and normalized scapular abduction may share information with the other FSP-related measures. The lack of consensus on the possible redundancy among these measures hinders the selection of the smallest number of measures necessary for a complete and time-efficient evaluation of FSP.

The objectives of the present study were to determine values of intra- and inter-rater reliabilities of 6 clinical measures related to FSP and to evaluate the association (ie, redundancy) among the measures with adequate reliability values. The results could guide the choice of the most appropriate group of measures for a reliable, comprehensive, and time-efficient clinical assessment of FSP.

Methods

Participants

A convenience sample of 21 healthy and asymptomatic undergraduate students, with no history of upper body orthopedic or neurologic impairments, participated in this study (4 men: 22 ± 0.71 years; 78.25 ± 8.83 kg 1.82 ± 0.12 m, and 17 women: 22 ± 1.41 years; 53 ± 2.88 kg; 1.61 ± 0.04 m). The sample size was estimated considering a moderate effect size for the association of the clinical measures ($r = 0.6$, $r^2 = 0.35$), with a significance level of 0.05 and statistical power of 0.80.[12] According to this estimation, 20 participants were needed. This study was approved by the Universidade Federal de Minas Gerais Ethics in Research Committee (protocol number: ETIC 574/08). Informed consent forms were obtained, and the rights of the participants were protected.

Procedures

The examiners of this study were physical therapists with more than 3 years of practice. Before the beginning of the data collection, the examiners were trained to perform the measures. The training process continued until both examiners felt confident in performing the tests. They agreed on the tests' procedures and instructions to be provided to the participants before the beginning of the study.

Initially, the participants were instructed about the procedures and signed an informed consent form. The participants wore clothes that allowed easy visualization of the shoulder and torso. Their heights were measured with a digital anthropometric scale. The participants were asked to keep their arms, shoulders, and neck relaxed while the examiner marked the anatomical structures related to the clinical measures. The right shoulder was chosen for standardization. The measurements were performed in a random order. The participants were evaluated in 3 different sessions. Data of the first and second sessions were collected by the same examiner and used to calculate the intrarater reliability. A second examiner conducted the third measurement session, whose data were compared with the data of the second session obtained by the first examiner, to calculate the interrater reliability. Intervals of 48 hours were given between each session. The measures used to test the association among assessments were the ones taken by the first examiner in the first session of data collection.

Clinical Measures

Except for the acromion to the treatment table measure, the FSP-related measures were taken with the participants standing with their torso, shoulders, and arms relaxed.

The pectoralis minor index (PMI) was determined by measuring, with a simple plastic metric tape, the distance from the coracoid process to the fourth intercostal space, close to the sternum, divided by the height of the participant, and then multiplied by 100 (Fig 1A).[4] Lower values of PMI indicate lower pectoralis minor length.[4]

The SI was calculated as the distance (also measured with the metric tape) from the center of the manubrium to the coracoid process, divided by the horizontal distance from the posterior aspect of the acromion to the spinal process at the same level, multiplied by 100 (Fig 1B).[6] This

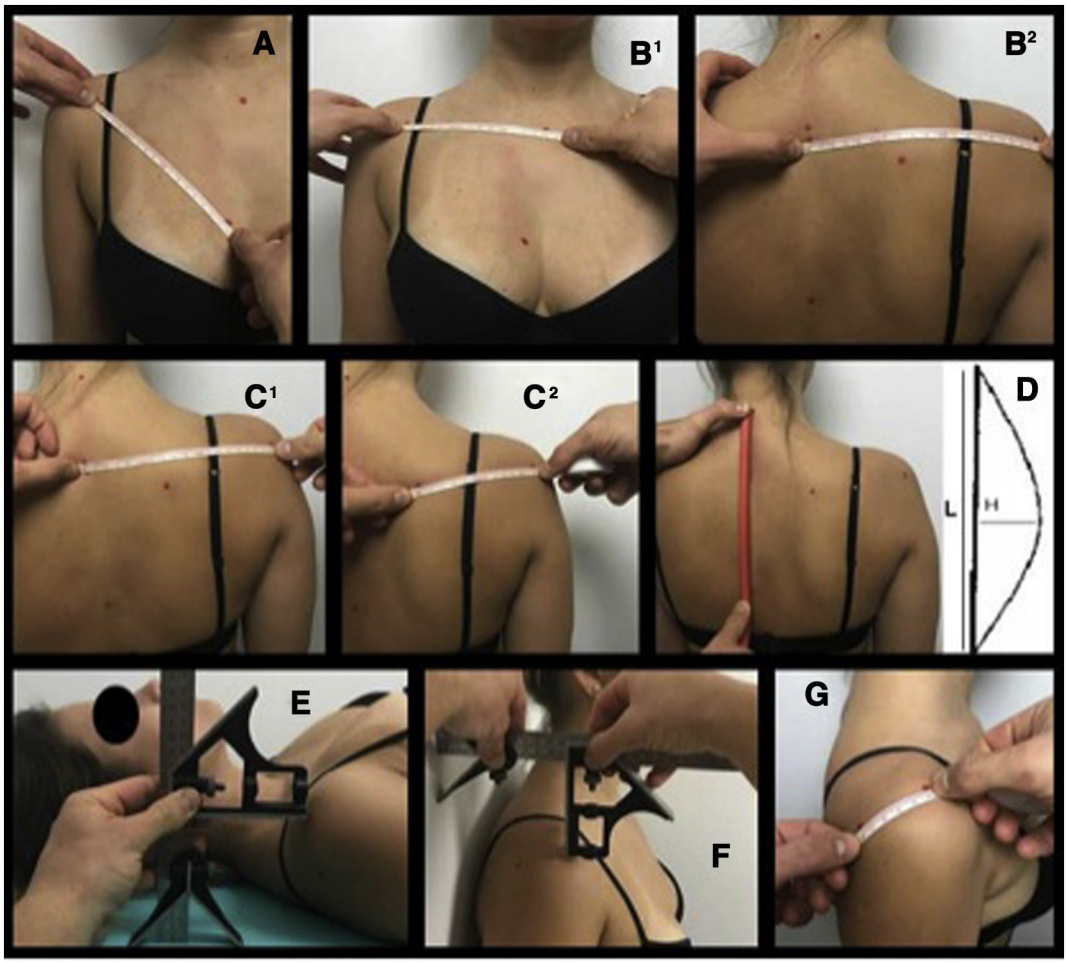

Fig 1. (*A) Pectoralis minor index: distance from the coracoid process to the right-side fourth intercostal space, close to the sternum. (B) Scapular index: (B[1]) distance from the center of the manubrium to the coracoid process. (B[2]) Horizontal distance from the posterior aspect of the acromion to the spinal process at the same level. (C) Abduction index: (C[1]) distance from the posterior aspect of the acromion to the spinal process of T3. (C[2]) Distance from the posterior aspect of the acromion to the root of the spine of the scapula. (D) Thoracic curvature: shape from the C7 spinal process to the spinal process of the vertebra at the same horizontal of the inferior angle of the scapula. The figure also shows how to determine the height (H) and the length (L) of the transcribed shape to calculate thoracic angle. (E) Acromion to the treatment table index (ATI): distance from the anterior aspect of the acromion to the treatment table, collected with the double square. (F) Acromion to the wall index (AWI): distance from the anterior aspect of the acromion to the wall, collected with the double square. (G) Acromion width: distance between the anterior to the posterior aspect of the acromion used for acromion to the treatment table and acromion to the wall normalization, resulting in ATI and AWI measures.*

measure is expected to inform about the position of the scapula.[6] Lower values of SI suggest greater lateral translation and medial rotation of the scapula.[6]

The abduction index (AI) was calculated as the distance from the posterior aspect of the acromion to the spinal process of T3, divided by the distance from the posterior aspect of the acromion to the root of the spine of the scapula (Fig 1C).[7] Measurements were performed with the metric tape. Greater values suggest greater lateral translation of the scapula.[7]

The thoracic curvature (TC) was measured by a flexible rule of 30 cm and was transcribed to a paper. The upper extremity of the rule was placed over the spinal process of C7 and the shape was collected from this point to the vertebra at the same horizontal height as the inferior angle of the scapula. After the transcription with a pencil, the height of the curve was traced with a metric rule. The following equation was used to calculate the $TC = 4 \times [\arctan (2 \times H / L)]$, where H is the height and L the length of the curve (Fig 1D).[8] The thoracic curvature was measured in degrees for each participant. Greater values determine lower concave curvature and consequently less thoracic kyphosis.[8]

The acromion to the treatment table was measured as the distance from the anterior aspect of the acromion to the table where participants were laid down (Fig 1E). This measure was divided by the acromion width (Fig 1G) for anthropometric normalization, resulting in the acromion to the treatment table index (ATI). A double square ruler was used to measure the distance from the acromion to the wall, and the acromion

Table 1. *Mean (Mean of Absolute Number or of Degrees) and SD of the 6 Clinical Measures Related to Forward Shoulder Posture on Each Day of Data Collection*

Measure	Main Examiner Session 1	Main Examiner Session 2	Second Examiner Session 3
PMI	9.78 (SD 0.59)	9.97 (SD 0.58)	9.32 (SD 0.89)
SI	66.81 (SD 5.71)	66.25 (SD 4.10)	64.49 (SD 5.76)
AI	1.50 (SD 0.07)	1.54 (SD 0.08)	1.56 (SD 0.09)
AWI	2.49 (SD 0.44)	2.38 (SD 0.36)	2.20 (SD 0.39)
ATI	2.30 (SD 0.42)	2.25 (SD 0.39)	2.09 (SD 0.39)
TC	32.13° (SD 9.56)	32.46° (SD 9.37)	34.78° (SD 9.90)

AI, abduction index; *ATI*, acromion to treatment table index; *AWI*, acromion to wall index; *PMI*, pectoralis minor index; *SD*, standard deviation; *SI*, scapular index; *TC*, thoracic curve.
All values are indexed and have no unit, except values for TC that are represented in degrees.

Table 2. *Values of Reliability (ICCs) and 95% CI of the 6 Clinical Measurements Related to FSP*

Measure	Intrarater ICC	95% CI	Interrater ICC	95% CI
PMI	0.90 [a]	0.69-0.96	0.37	-0.26-0.72
SI	0.77 [a]	0.43-0.91	0.72	0.32-0.88
AI	0.65	0.17-0.86	0.65	0.15-0.86
AWI	0.92 [a]	0.76-0.97	0.85 [a]	0.46-0.95
ATI	0.88 [a]	0.70-0.95	0.84 [a]	0.54-0.94
TC	0.94 [a]	0.87-0.98	0.82 [a]	0.60-0.93

AI, abduction index; *ATI*, acromion to treatment table index; *AWI*, acromion to wall index; *CI*, confidence interval; *ICC*, intraclass correlation coefficient; *PMI*, pectoralis minor index; *SI*, scapular index; *TC*, thoracic curve.
[a] ICC values above 0.75.

width was measured with a plastic metric tape. The ATI is based on a method proposed by Sahrmann[3] to evaluate FSP and estimates the pectoralis minor length in supine. Greater values indicate greater shoulder protraction.[3]

The acromion to the wall was measured with a double square ruler as the distance from the anterior aspect of the acromion to the wall (Fig 1F). This measure was also divided by the acromion width (Fig 1G) for anthropometric normalization, resulting in the acromion to the wall index (AWI). During this test, the participants were instructed to move backward until their buttocks or back touched the wall. These measurements are based on the method proposed by Peterson et al[9] to quantify shoulder protraction. Greater values indicate greater shoulder protraction.[9]

All measures, except TC, were carried out 3× in each session, and the mean was used for analysis. Thoracic curvature was measured once each measurement session.

Statistical Analysis

Intraclass correlation coefficients ($ICC_{2,1}$ for TC and $ICC_{2,3}$ for the others measures) were used to calculate the intra- and inter-rater reliabilities. Data normality was analyzed using Shapiro-Wilk tests. Pearson product moment correlation was used to determine the degree of association between the pairs of the measures that showed good to excellent intra- and interrater reliability (ICC >0.75).[11,12] Values above 0.75 indicate adequate reliability for clinical practice, and values between 0.60 and 0.75 correspond to moderate reliability.[12] The absolute reliability was determined by the standard error of measurement (SEM). In addition, minimal detectable differences (MDDs) were calculated ($SEM \times 1.96 \times \sqrt{2}$) to obtain the minimum difference between sessions that could be considered real changes (ie, above the measurement error) for treatment situations.[23] The level of significance was established at $P = .05$.

Table 3. *Matrix of Correlations (R Values) Between the 5 Clinical Measures That Showed Good Intrarater Reliability*

Measure	PMI	SI	AWI	ATI	TC
PMI	1.00	–	–	–	–
SI	.67[a]	1.00	–	–	–
AWI	-.37	-.51[a]	1.00	–	–
ATI	-.30	-.64[a]	.80[a]	1.00	–
TC	.14	.28	-.18	-.15	1.00

ATI, acromion to treatment table index; *AWI*, acromion to wall index; *PMI*, pectoralis minor index; *SI*, scapular index; *TC*, thoracic curve.
[a] Association values are statistically significant at $P < .05$.

Table 4. *Values of SEM and MDD of the 5 Clinical Measurements Related to Forward Shoulder Posture That Showed Good Intra-rater Reliability*

Measure	SEM	MDD
PMI	0.23	0.64
SI	3.07	8.5
AWI	0.14	0.38
ATI	0.19	0.53
TC	2.3°	6.4°

ATI, acromion to treatment table index; *AWI*, acromion to wall index; *MDD*, minimal detectable difference; *PMI*, pectoralis minor index; *SEM*, standard error measurement; *SI*, scapular index; *TC*, thoracic curve.

Results

Data of the 6 tests were normally distributed ($P > .05$). Descriptive data (mean and standard deviation) of the variables for both examiners are presented in Table 1.

The reliability analysis revealed ICC values varying from 0.62 to 0.97 for the intrarater reliability and from 0.30 to 0.84 for the interrater reliability.

Table 2 shows the intra- and interrater ICC values of all measures and their respective 95% CIs. Pearson correlations between measures that had good intrarater reliability are presented in Table 3. The pairs PMI vs SI, SI vs AWI, SI vs ATI, and ATI vs AWI showed significant associations (r = 0.67 [$P < .001$], r = -0.51 [$P = .020$], r = -0.64 [$P = .002$], and r = 0.80 [$P < .001$], respectively). The other correlations were nonsignificant ($P \geq .05$).

The SEM and MDD of the 5 measures that showed good intrarater reliability[12] are presented in Table 4.

Discussion

The results of the present study demonstrated adequate intrarater reliability for clinical practice,[12] for PMI, SI, AWI, ATI, and TC measures. However, when different examiners carried out these measures, only AWI, ATI, and TC showed adequate reliability values. Among those measures that demonstrated intrarater reliability, the analysis revealed positive associations between PMI and SI and between AWI and ATI, suggesting that each measurement pair quantify a similar dimension of shoulder posture. These results may help in guiding the selection of clinical measures to reliably identify the presence of FSP.

The PMI is a measure that has been already demonstrated to be valid[13] and reliable,[6,14-16] with cut points well established in the literature. Participants with PMI values below 7.42 have biomechanical alterations similar to those observed in patients with impingement syndrome.[4] Therefore, the PMI might be recommended instead of SI when defining the presence of FSP. However, the interrater ICC found for PMI was low (0.37), which restricts its clinical use when more than 1 examiner takes the measure. The poor interrater reliability values found for PMI can be explained by the greater difficult in the identification of the fourth intercostal space on female participants, which comprised the largest part of the sample (81%). The amount of soft tissue over this anatomical structure in women was a hampering factor reported by both examiners. Thus, SI, which had more appropriate interrater reliability, may be recommended for situations in which different examiners collect data.

Both AWI and ATI exhibited high reliability. These measures inform about alterations in the posterior–anterior displacement of the shoulder (shoulder protraction). High

positive association between both measures was observed, suggesting that they measure the same dimension of shoulder posture. Importantly, AWI had higher reliability values compared with ATI. During the ATI measurement, the evaluation table influenced the position of the thoracic spine and the scapula because the participant is in supine position during its execution.[18] In addition, standing position is of greater relevance for the presence of FSP. Thus, for FSP evaluation, the AWI measure seems the best choice when shoulder protraction is considered. In this study, normalization by the "acromion width" was carried out for AWI and ATI measures. This approach was not used in previous studies,[3,9,18] which failed to minimize anterior shoulder position according to the individuals' different anthropometric proportions.

The TC measure had high intra- and interrater reliability. Other studies, with different methods of collecting and calculating this curvature, also demonstrated good reliability of this method[6,8] and its validity.[10] The position of the thoracic spine seems to influence the positioning of the scapula on the ribcage and also its motion.[3,24] The results of the present study showed no association between TC and the other measures analyzed, which suggests that the TC evaluates a particular dimension of shoulder posture and could be used to complement other measures.

Considering the reliability values and associations among tests, we indicate, when there is a single examiner, the PMI, AWI, and TC measures as the group of measures for a complete and reproducible clinical evaluation of FSP. The combination of these tests should be able to quantify, in a comprehensive and objective way, the presence of altered shoulder posture. This procedure allows the assessment of postural changes owing to treatments that are intended to promote alignment corrections of shoulder, scapula, and thoracic spine. In clinical settings and research protocols that require the use of 2 or more examiners, PMI may be replaced by SI measure to guarantee adequate interrater reliability. An important advantage of the analyzed measures is the low cost, the availability of materials needed, and the time required to perform the procedures. The complete evaluation with the 6 measures required a maximum of 15 minutes per individual for each evaluator. For the suggested combination of measures (PMI, AWI, and TC), the total time spent was less than 10 minutes.

In addition to the psychometric properties evaluated, this study also calculated the MDD of the analyzed measures. These values could be used to assess the effects of interventions designed to modify shoulder, scapula, and thoracic spine postures. The calculated values are, for most part, acceptable, although these values could be as high as 23% of the mean values of the measures (eg, ATI). Also, the SEM values used to calculate the MDD for PMI and SI were higher than those observed in other studies that analyzed the same measures.[4,6] Nonetheless, the MDD values presented could be used as a reference to guide the process of evaluation and rehabilitation of musculoskeletal injuries related to FSP.

Limitations

Young participants, mostly women, with no history of upper body dysfunction composed the study sample. This fact may hinder the generalization of the results to older participants, men, or patients with shoulder problems and evident FSP. Studies on the psychometric properties of these measures in other populations are, thus, necessary for further conclusions, especially in individuals with pathological conditions related to postural changes. In addition, further research about the possible association of the evaluated measures with clinical shoulder conditions is still needed. Despite the limitations mentioned, adequate intrarater reliabilities, also found in other studies,[9,10,13,17] indicate that these measures could be employed in the design of preventive and rehabilitation programs for musculoskeletal disorders.

Conclusion

Five of the studied measures (PMI, SI, AWI, ATI, and TC) were considered adequate for clinical use when carried out by the same examiner. On the other hand, only 3 measures should be considered (AWI, ATI, and TC) when carried out by more than 1 examiner. In addition, 2 pairs of measures were highly associated, which indicates some level of redundancy among these measures. Taken together, our results suggest that, when the same examiner performs the assessment, the combined use of the PMI, AWI, and TC measures allows a quick but comprehensive evaluation of the presence of FSP. These measures should provide relevant information about changes in the posture of the upper body, especially shoulder, scapula, and thoracic spine.

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Contributorship Information

Concept development (provided idea for the research): S.T.F.
Design (planned the methods to generate the results): L. A.C.M.C., M.T.S., D.B.M.L., S.T.F.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): C.F.A., T.R.S., S.T.F.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): L. A.C.M.C., M.T.S., D.B.M.L.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): L.A.C. M.C., C.F.A., T.R.S., S.T.F.
Literature search (performed the literature search): L.A. C.M.C., C.F.A.
Writing (responsible for writing a substantive part of the manuscript): L.A.C.M.C., C.F.A., T.R.S., S.T.F.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): C.F.A., T.R.S., S.T.F.

Practical Applications

- This study evaluated MDD of various clinical measures related to FSP.
- Clinicians can use a group of measures (PMI, AWI, and TC) for reproducible clinical evaluation of the FSP.
- This study showed that some measures related to FSP seem to be redundant.

References

1. Ruivo RM, Pezarat-Correia P, Carita AI. Effects of a resistance and stretching training program on forward head and protracted shoulder posture in adolescents. *J Manipulative Physiol Ther.* 2017;40(1):1-10.
2. Ludewig PM, Reynolds JF. The association of scapular kinematics and glenohumeral joint pathologies. *J Orthop Sports Phys Ther.* 2009;39(2):90-104.
3. Sahrmann SA. *Diagnosis and Treatment of Movement Impairment Syndromes*. St. Louis, MO: Mosby; 2002.
4. Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. *J Orthop Sports Phys Ther.* 2005;35(4):227-238.
5. Kendall FP, McCreary EK, Provance PG. *Muscles: Testing and Function, with Posture and Pain*. 4th ed. Manole: São Paulo, Brazil; 1995.
6. Borstad JD. Resting position variables at the shoulder: evidence to support a posture-impairment association. *Phys Ther.* 2006;86(4):549-557.
7. Diveta J, Walker ML, Skibinski B. Relationship between performance of selected scapular muscles and scapular abduction in standing subjects. *Phys Ther.* 1990;70(8):470-479.
8. Greenfields B, Catlin PA, Coats PW, Green E, McDonald JJ, North C. Posture in patients with shoulder overuse injuries and healthy individuals. *J Orthop Sports Phys Ther.* 1995;21 (5):287-295.
9. Peterson DE, Blankenship KR, Robb JB, et al. Investigation of the validity and reliability of four objective techniques for measuring forward shoulder posture. *J Orthop Sports Phys Ther.* 1997;25(1):34-42.
10. Teixeira FA, Carvalho GA. Reliability and validity of thoracic kyphosis measurements using the flexicurve method. *Braz J Phys Ther.* 2007;11(3):173-177.
11. Gadotti IC, Vieira ER, Magee DJ. Importance and clarification of measurement properties in rehabilitation. *Braz J Phys Ther.* 2006;10(2):137-146.
12. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice*. 2nd ed. Upper Saddle River, NJ: Prentice-Hall; 2000.
13. Borstad JD. Measurement of pectoralis minor muscle length: validation and clinical application. *J Orthop Sports Phys Ther.* 2008;38(4):169-174.
14. Finley M, Goodstadt N, Soler D, Somerville K, Friedman Z, Ebaugh D. Reliability and validity of active and passive pectoralis minor muscle length measures. *Braz J Phys Ther.* 2017;21(3):212-218.
15. Struyf F, Meeus M, Fransen E, et al. Interrater and intrarater reliability of the pectoralis minor muscle length measurement in subjects with and without shoulder impingement symptoms. *Man Ther.* 2014;19(4):294-298.
16. Rosa DP, Borstad JD, Pires ED, Camargo PR. Reliability of measuring pectoralis minor muscle resting length in subjects with and without signs of shoulder impingement. *Braz J Phys Ther.* 2016;20(2):176-183.
17. Lewis JS, Valentine RE. The pectoralis minor length test: a study of the intrarater reliability and diagnostic accuracy in subjects with and without shoulder symptoms. *BMC Musculoskelet Disord.* 2007;8:64.
18. Weber C, Enzler M, Wieser K, Swanenburg J. Validation of the pectoralis minor length test: a novel approach. *Man Ther.* 2016;22:50-55.
19. Oliveira TS, Candotti CT, La Torre M, et al. Validity and reproducibility of the measurements obtained using the flexicurve instrument to evaluate the angles of thoracic and lumbar curvatures of the spine in the sagittal plane. *Rehabil Res Pract.* 2012;2012:186156.
20. Barrett E, Mccreesh K, Lewis J. Intrarater and interrater reliability of the flexicurve index, flexicurve angle, and manual inclinometer for the measurement of thoracic kyphosis. *Rehabil Res Pract.* 2013;2013:475870.
21. Azadinia F, Kamyab M, Behtash H, Ganjavian MS, Javaheri MRM. The validity and reliability of noninvasive methods for measuring kyphosis. *J Spinal Disord Tech.* 2014;27(6): E212-E218.
22. Sedrez JA, Candotti CT, Rosa MIZ, Medeiros FS, Marques MT, Loss JF. Test-retest, inter- and intra-rater reliability of the flexicurve for evaluation of the spine in children. *Braz J Phys Ther.* 2016;20(2):142-147.
23. Weir JO. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res.* 2005;19(1):231-240.
24. Kebaetse MS, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. *Arch Phys Med Rehabil.* 1999;80(5): 945-950.