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The influence of scapular orientation on the medial scapula corpus angle in snapping scapula syndrome

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Background: Snapping scapula syndrome (SSS) can result in crepitus and painful scapulae during motion and may be treated with bursectomy and/or superomedial angle resection. The medial scapula corpus angle (MSCA) measures blade curvature on a transverse plane below the suprascapular fossa and may indicate SSS, yet a large overlapping range in MSCA exists between patients with and without SSS. This study quantified the effects of 3-dimensional scapula orientation in the imaging field, and the resulting variability in scapula type and MSCA.

Methods: Computed tomography scans from 10 healthy controls (non-SSS) and 8 SSS patients were used to create 3-dimensional scapula models. The scapula type and MSCA were measured on a controlled reference imaging plane, and ones translated and rotated below the supraspinatus fossa to create 19 planes simulating variations due to scapulothoracic orientation. Planes translated and rotated above the reference plane also generated 13 modified MSCA planes to test areas modified during surgical resection. Statistical analyses compared the scapula type and MSCA between the reference and alternate planes within groups.

Results: Scapula type commonly changed and the MSCA varied up to 104° within a subject depending on the imaging plane, regardless of location below or above the reference plane. Numerous statistical differences were detected in MSCA between the reference plane and those translated and rotated below that plane in both non-SSS and SSS groups. Planes translated above the reference plane showed consistent statistical differences in MSCA to the reference plane, but only in the SSS group.

Discussion: Although scapula type and MSCA were previously shown to differentiate patients, the effect of viewing perspective was not considered. Differences in scapula orientation relative to the imaging plane dramatically varied the scapula type and MSCA, far exceeding differences between groups described previously. Herein, scapula type and MSCA often differed in planes translated above the reference plane, suggesting that scapular abnormalities contributing to SSS are largely at or close to the superomedial angle.

Conclusion: The MSCA as defined previously likely lacks the sensitivity and specificity to reliably be used as a clinical diagnostic tool for SSS. The blade showed consistent differences when translated above the reference plane; however, it was still highly variable. Sensitivity and specificity of planes above the reference plane should be investigated further as they may provide reliable differentiation of non-SSS and SSS patients.

Snapping scapula syndrome (SSS) is a relatively rare condition that presents with audible or palpable crepitus during shoulder abduction, as well as pain with overhead motion that can be debilitating.[6,25] The scapula forms a 3-layered pseudojoint with the thorax with several anatomically varying bursae, some of which are associated with SSS.[26] Predisposing anatomy such as curvature of

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the superomedial angle of the scapula <142° (average 144°)[1,14,15] or forward tilting of the scapula[4,13] have been implicated. Kinematic abnormalities including decreased scapula upward rotation and increased internal scapular rotation are also implicated. Masses including Luschka tubercle,[4] osteochondromas,[5] and other tumors[17] may play a role, as well as first rib abnormalities[27] or rib fractures.[24] Current treatment of SSS begins conservatively with nonsteroidal anti-inflammatory drugs, physical therapy, and steroid/anesthetic injections,[9,12] but can advance to open or arthroscopic bursectomy with or without superomedial angle resection.[12,18,19]

The SSS is currently diagnosed with both physical examination and clinical imaging. Shoulder range of motion, strength, and audible or palpable crepitus around the scapula are assessed.[13] Plain radiographs detect obvious osseous abnormalities; however, there is no consensus on when to obtain computed tomography (CT). Some groups suggest using 3-dimensional (3D) CT as the main imaging modality,[16] while others suggest CT is only indicated when bony abnormalities are present,[7] and still others suggest adopting a low threshold for obtaining CT based on suspicion of a bony mass causing symptoms.[6] Magnetic resonance imaging (MRI) is typically reserved to investigate soft tissue lesions, but can also be used to assess bony anatomy.[25] Ultrasound is not typically used for diagnosis, but rather for guiding injections.[25] Given the current reliance on inconsistent clinical symptoms and varying imaging guidance, a definitive radiologic diagnosis would be beneficial for identifying and treating SSS.

One measurement proposed to differentiate an SSS scapula is the medial scapula corpus angle (MSCA).[20] The MSCA quantifies curvature of the scapular blade, measured in the transverse plane of volumetric imaging at an index plane defined inferior to the spina scapula, one slice below the first sharply defined slice of the corpus. At this level, the scapula *type* is determined, and the angle of the anterior aspect of the scapula is measured from the medial border. Spiegl et al showed that all type 3 concave scapulae were found in individuals diagnosed with SSS.[20] Additionally, SSS patients were more likely to have positive MSCA, with an odds ratio of 8.4 and intraobserver and interobserver reliability >0.7 (as determined by intraclass correlation coefficients (ICCs)). However, there was a wide range of MSCA in both groups (e.g., −26° to +28° in non-SSS patients, −29° to +45° in SSS patients). Here, negative and positive values denote a scapula convex and concave towards the thorax, respectively. Although the previous study detected a statistically significant difference in MSCA between non-SSS and SSS patients, sensitivity and specificity during clinical use could be confounded by the large overlapping ranges.

In addition to anatomic variability of the scapula itself, the large overlapping ranges in MSCA may arise from uncontrolled scapulothoracic posture and/or the orientation of the patient in the supine imaging system. The MSCA is quantified on a single volumetric imaging slice, but radiographic measures taken from 2-dimensional imaging are susceptible to variability due to viewing perspective.[2,8,21,22] This confounding factor was not previously quantified for the MSCA in the setting of SSS. Therefore, the objective of the present study was to quantify the error in scapula *type* and MSCA due to changes in scapular orientation relative to the volumetric imaging field using 3D models generated from individuals in both non-SSS and SSS populations.

Methods

Deidentified CT scans of 10 healthy controls with no prior shoulder diagnoses (non-SSS) and 8 SSS patients were obtained during 2 institutional review board-approved studies (71782, 140177). The CT was preferred over the more common clinical MRI collected in SSS diagnostics to provide high-resolution 3D surfaces for analysis. For each CT scan, 3D reconstructions of the scapulae were created by segmenting the cortical boundaries of the bone (Mimics v24; Materialise, Plymouth, MI, USA). The 3D models were then reoriented into the scapular plane and a controlled reference imaging plane (ML: the line connecting points M and L) was generated (3-matic; Materialise, Plymouth, MI, USA) (Fig. 1). Using the ML plane, the scapula *type* was first classified as type 1 (straight), type 2 (S), or type 3 (concave) per Spiegl et al (Fig. 2).[20] Then, the MSCA was measured as the angle of the anterior surface of the scapula in the ML plane, with an angle opening away from the thorax designated as negative and an angle opening towards the thorax positive (Fig. 2, *B* and *C* respectively). The scapula classification and MSCA measurement on the reference ML plane was the baseline against which to compare type and MSCA on other imaging planes generated to simulate altered scapular orientations in the scanner field of view.

Per the prior study defining the MSCA, observers chose an index plane 1-2 image slices below reference plane 60% of the time, suggesting that when clinicians view the CT or MRI stacks they could be viewing a transverse plane 6 mm or more below the ML plane (based on an assumed 3-mm slice thickness).[20] Therefore, herein the ML plane was offset inferiorly in 3-mm increments to simulate up to 5 slices below the ML plane (ie, ML-3, ML-6, ML-9, ML-12, and ML-15). While not likely used clinically, the 9-15-mm planes were assessed to demonstrate the progression in type and MSCA measurement up to and beyond clinical use cases.

Given the inability to confirm the orientation of the scapula in the scanner field of view *a priori* during supine imaging, it is likely that clinicians are viewing a plane with a combination of scapulothoracic upward rotation (elevation) and anterior or posterior tilt (Fig. 3). Therefore, planes were then created to represent angulation of the scapula relative to the scanner bed, encompassing the typical variability in scapulothoracic posture.[3,10] These planes were created by pivoting the ML plane in 5° increments inferiorly about the medial (M-) or lateral (L-) end of the ML plane, simulating scapulothoracic upward and downward rotation, respectively (Fig. 4). Rotating inferiorly ensured that the viewing planes did not cross the supraspinatus fossa, which by definition is not visible in the planes used for MSCA measurement as defined previously.[20] Tilt planes were also created by rotating the sectioning plane about the line connecting ML in 5° increments, simulating scapulothoracic anterior (T−) and posterior (T+) tilt. Scapula type and MSCA measurements on these cross sections were then recorded. Together, the ML-, M-, L- and T+/− planes represent planes that could have been feasibly chosen using the method as defined by Spiegl et al.[20] The difference between the MSCA measured in the ML plane and the MSCA measured in each of the test planes was calculated (eg, Δ = ML plane MSCA—altered plane MSCA).

Although the MSCA measurements are by definition taken from viewing planes below the supraspinatus fossa, the superomedial angle has been implicated in the pathology of some SSS cases, and resection thereof can be a target for treatment. Therefore, for exploratory purposes, additional *modified* planes were constructed by translating the ML plane superiorly from the ML plane in 3-mm increments (ie, ML+3, ML+6, ML+9, ML+12, and ML+15), and rotating the ML plane superiorly about the M and L points (eg, M+, L+), respectively (Fig. 5). Although these modified planes would not have been used according to the definition of MSCA, as they cross the supraspinatus fossa, they were evaluated because they contain the region surrounding the superomedial angle. Once again, scapula type and MSCA measurements in these modified viewing planes were taken and the difference was calculated as above.

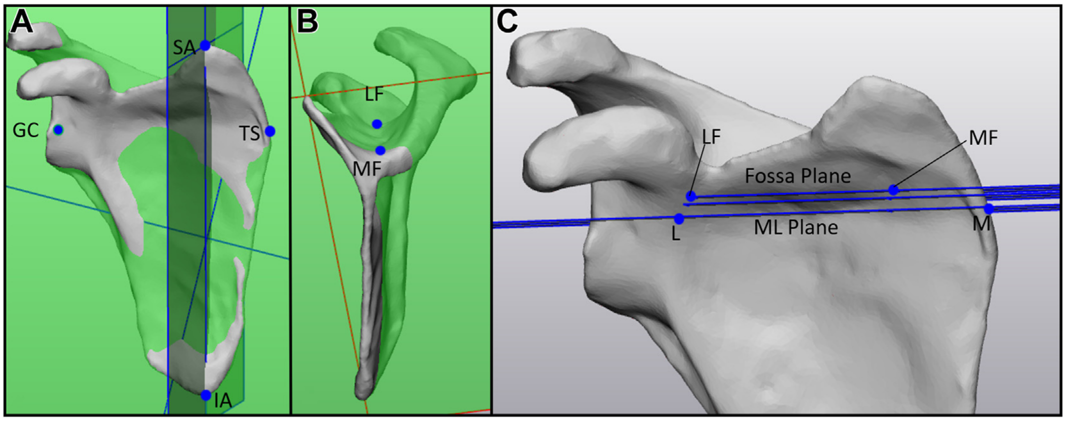

Figure 1 Creation of the controlled reference imaging plane (ML). (**A**) The most distal point of the inferior angle (*IA*), the center of the glenoid (*GC*), and the center of the trigonum of the scapula (*TS*) form the scapular plane. A plane perpendicular to the scapular plane passes through the IA and the most proximal point of the SA. (**B**) The MF is the most inferior intersection of this plane and the scapular plane, and the LF is the top of the glenoid vault at the origin of the scapular spine (**C**). The fossa plane is perpendicular to the scapular plane, passing through MF and LF. This plane was then translated down to the until the plane no longer covered any part of the fossa, and another 3 mm inferiorly along the scapular plane to create the reference measurement plane (ML). The M point was defined as the most medial point of the scapula along the ML plane, and the L point was defined as the point on the ML plane on the anterior aspect of the scapula at the base of the coracoid. *IA*, inferior angle; *LF*, lateral fossa point; *MF*, medial fossa point; *SA*, superior angle.

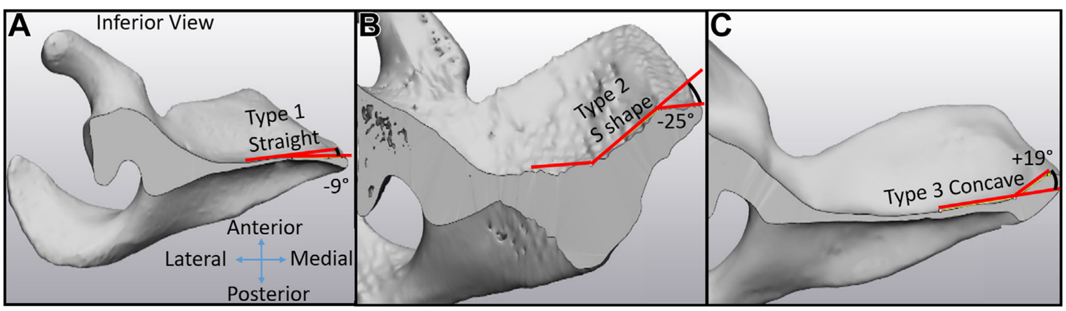

Figure 2 Scapula *types* as defined by Spiegl et al, with the shapes used to measure MSCA. (**A**) Type 1 (straight) scapula have no visually perceptible gross curvature. (**B**) Type 2 ‘S’ scapulae have multiple curvatures from medial to lateral. (**C**) Type 3 concave scapula angle continuously toward the thorax. For all types, the MSCA was measured as the last angulation on the anterior surface of the scapula at the medial border. *MSCA*, medial scapula corpus angle.

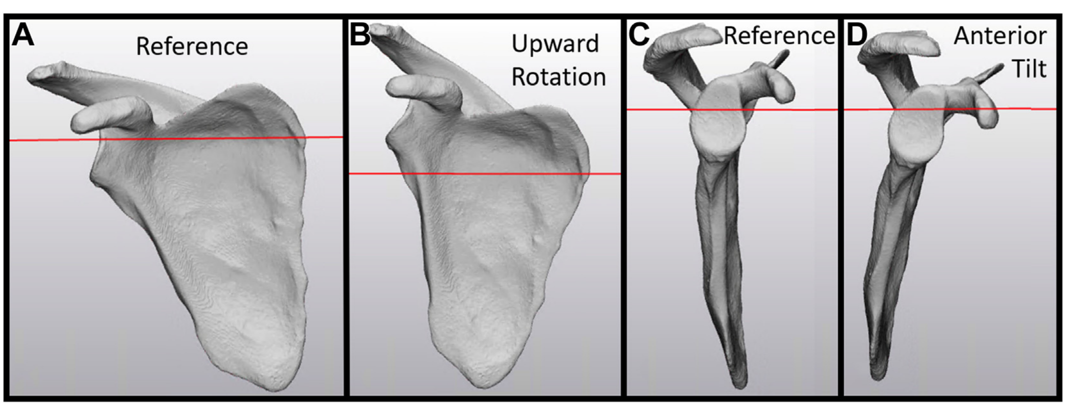

Figure 3 Scapulae in various degrees of elevation and tilt with the imaging plane in *red*. Anterior view of (**A**) the idealized ML plane compared to (**B**) 15° of scapulothoracic upward rotation (elevation). (**C**) Lateral view of idealized ML plane compared to (**D**) 15° of anterior tilt.

All images of the scapula cross sections were blinded and randomized before type and MSCA were determined. Nonparametric tests were used due to the non-normal distribution of the MSCA, thus medians with interquartile ranges are reported. Scapula type was evaluated with Chi-Squared tests comparing the type of each plane to the type of the reference ML plane. Wilcoxon tests were used to compare the MSCA in a given plane relative to the measurement in the reference ML plane within each group. Interobserver and intraobserver ICCs were calculated by examining a subset of 20 randomized imaging planes in each of 3 non-SSS and 3 SSS scapulae. Intraobserver ICCs were determined using a single observer at 2 time points 1 month apart. Interobserver ICCs were determined using 4 observers of different experience levels (Medical Student year 4, Resident

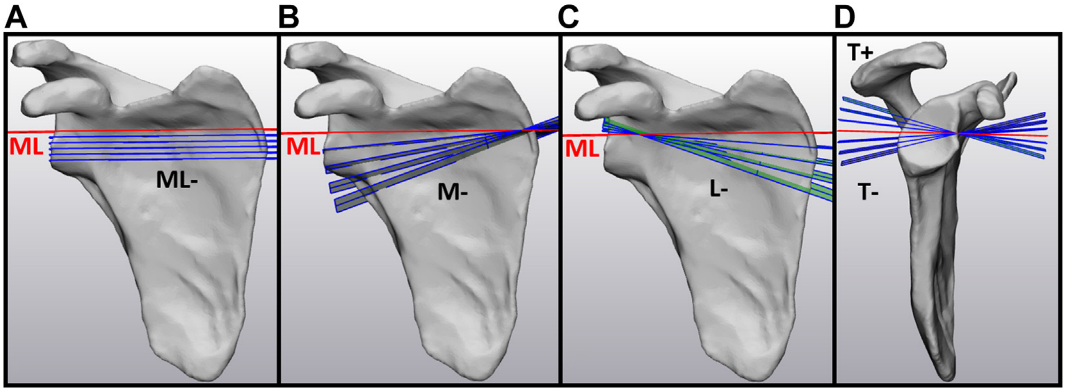

Figure 4 Alternate plane construction with the ML plane shown in *red*. (**A**) The ML- planes are translated below ML. (**B**) The M- planes are rotated inferiorly about M. (**C**) The L- planes are rotated inferiorly about L. (**D**) The T+ planes are tilted anteriorly and T- planes are tilted posteriorly about the axis ML.

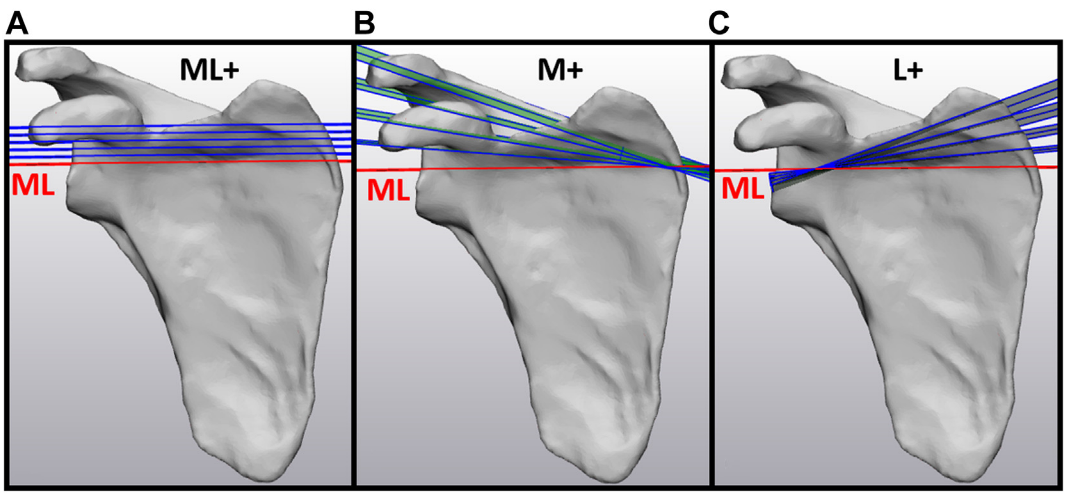

Figure 5 Modified MSCA plane construction with the ML plane shown in *red*. (**A**) The ML + planes are translated above ML. (**B**) The M+ planes are rotated superiorly about M. (**C**) The L+ planes are rotated superiorly about L. *MSCA*, medial scapula corpus angle.

Program year 2, PhD, MD) at a single time point. ICCs were evaluated as: <0.5 poor, 0.5-0.75 moderate, 0.7-0.9 good, and >0.9 excellent.[11] Statistical analyses were performed using STATA 16.0 (StataCorp, College Station, TX, USA). Statistical significance was set at $P \leq .050$.

Results

The age of the non-SSS group was 41 ± 12 years (mean ± standard deviation), and the age of the SSS group was 38 ± 19 years ($P = .698$). Models arose from 5 of 10 male and 5 of 8 male subjects in non-SSS and SSS groups, respectively ($P = .596$). All the non-SSS scapulae were right shoulders, while 5 of 8 of the SSS scapulae were right shoulders ($P = .011$).

When evaluating scapula type in non-SSS patients, in 8 of 20 planes the scapula type differed from the reference ML plane, and when evaluating scapula type in SSS patients, in 3 of 20 planes the scapula type differed from the reference ML plane ($P \leq .048$) (Fig. 6). Overall, non-SSS subjects were most likely to have type 3 scapulae (6 of 10 subjects) and SSS patients were equally likely to have type 2 or type 3 scapulae (3 of 8 subjects) regardless of the imaging plane.

In the planes below the reference ML plane (ie, −), the difference in MSCA measurement between the ML and ML- planes demonstrated angle variation of up to 52° in non-SSS and 83° in SSS patients (Fig. 7, *A*). The MSCA in the M-planes demonstrated angle variation from the ML plane of up to 52° in non-SSS and 81° in SSS patients (Fig. 7, *B*), whereas in L- planes it differed from the ML plane up to 104° for non-SSS and 37° for SSS patients and was almost entirely positive deviations (Fig. 7, *C*). The MSCA in the T+/− planes differed from the ML plane up to 45° for non-SSS and 63° for SSS patients (Fig. 7, *D*). There were no trends in the extent of variation by plane.

When evaluating the translated ML- imaging planes versus the ML plane, the MSCA only differed statistically in non-SSS subjects for the ML-9 ($P = .049$) and did not differ in SSS patients (Fig. 8, *A*). The MSCA did not differ in any M- plane from the ML plane for the non-SSS group, and only the M-20 plane differed from that in the ML plane for SSS subjects ($P = .039$) (Fig. 8, *B*). The MSCA differed in both groups in all L- planes compared to the ML plane ($P \leq .023$), except the L-20 plane for SSS patients ($P = .055$) (Fig. 8, *C*). None of the MSCA in T+/− planes statistically differed from the ML plane in either group ($P \geq .150$) (Fig. 8, *D*). There were no trends in the extent of variation by plane.

When the scapula types in modified planes above the reference ML plane (ie, +) were analyzed, in non-SSS patients the scapula type differed from the reference plane in 4 of 13 planes ($P \leq .048$) (Fig. 9). The MSCA in modified (ie, +) planes were also analyzed (Fig. 10). The difference between the MSCA in ML + planes and the

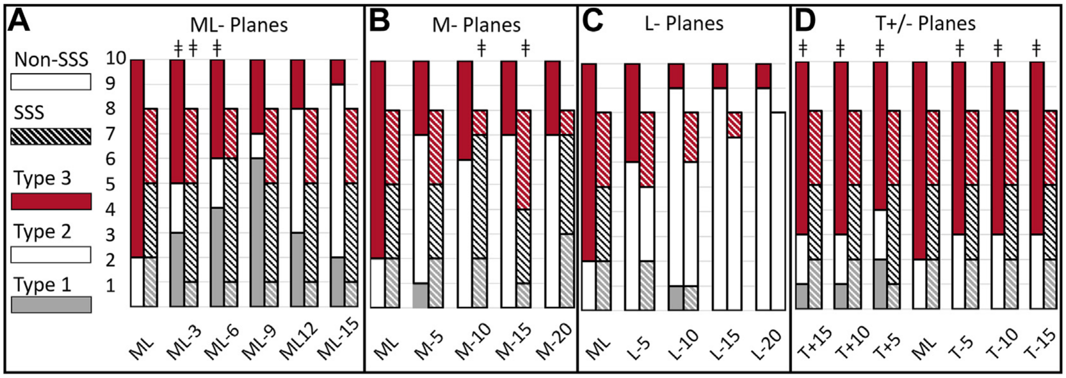

Figure 6 Scapula types in non-SSS (solid bars) and SSS (hatched bars) groups for ML-, M-, L- and T+/− planes. Each bar represents the number of subjects with a particular scapula type in the designated imaging plane. ‡ denotes a statistically significant difference in scapula type between a given plane and the ML plane within that group. *SSS*, snapping scapula syndrome.

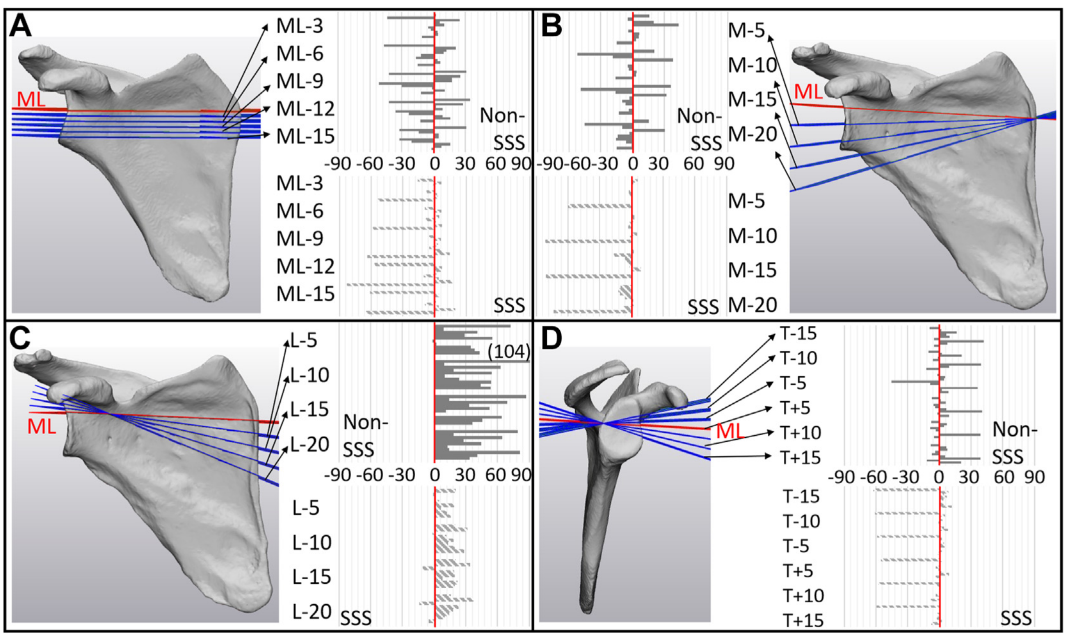

Figure 7 Difference (°) in MSCA between the reference ML plane and ML- (**A**), M- (**B**), L-(**C**), and T+/− (**D**) planes in non-SSS and SSS patients. Here each bar represents an individual subject (N = 10 for non-SSS, N = 8 for SSS patients) and bars are presented by subject in the same order for each figure. The *vertical red bar* denotes no difference (0°) in MSCA between the reference and altered planes. *MSCA*, medial scapula corpus angle; *SSS*, snapping scapula syndrome.

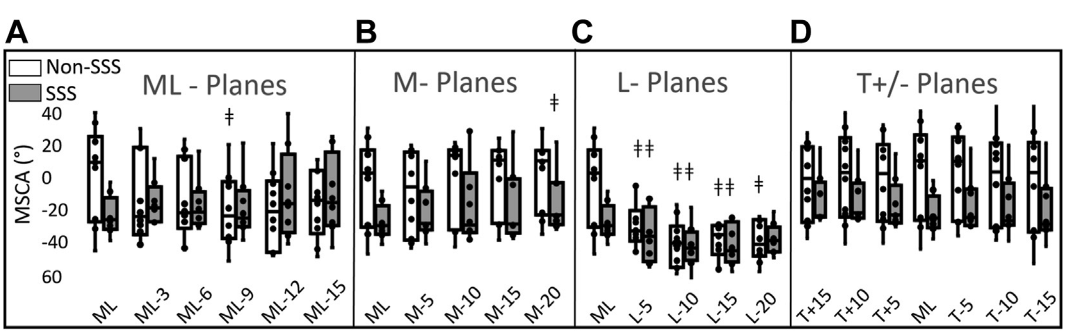

Figure 8 Box and whisker plot of MSCA in non-SSS (*white bars*) and SSS (*gray bars*) groups for ML-, M-, L- and T+/− planes. *Circles* represent individual MSCA measurements for a specific patient. Median is represented by a *horizontal line* in the box. The box represents the interquartile ranges. The whiskers represent the overall range. ‡ denotes a statistically significant difference in MSCA between a given plane and the ML plane within that group. *MSCA*, medial scapula corpus angle; *SSS*, snapping scapula syndrome.

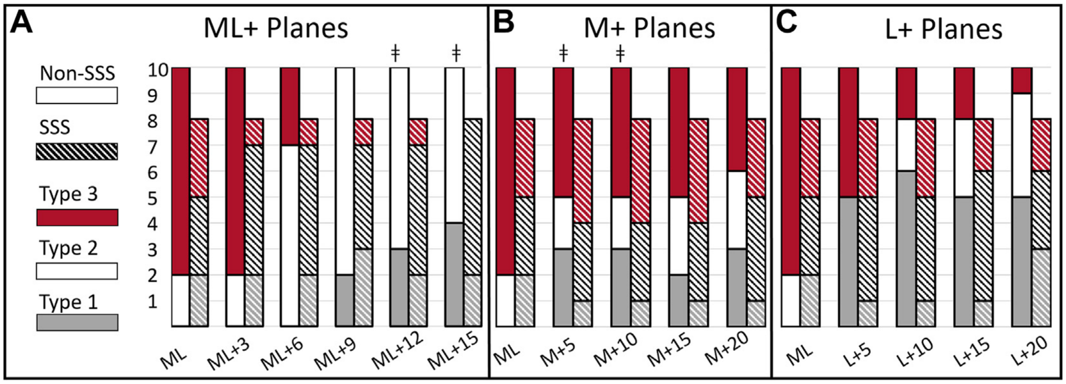

Figure 9 Scapula types in non-SSS (solid bars) and SSS (hatched bars) groups for modified ML+, M+ and L+ planes. Each bar represents the number of subjects with a particular scapula type in the designated imaging plane. ǂ denotes a statistically significant difference in scapula type between a given plane and the ML plane within that group. *SSS*, snapping scapula syndrome.

ML plane ranged up to 92° in non-SSS and 75° in SSS patients (Fig. 10, *A*). The difference between the MSCA in the ML plane and M+ planes ranged up to 45° in non-SSS and 69° in SSS patients (Fig. 10, *B*). Finally, the difference between MSCA measurements in the ML plane and L+ planes varied up to 72° in non-SSS and 78° in SSS patients from the ML plane (Fig. 10, *C*). There were no trends in the extent of variation by plane.

The MSCA did not differ in any ML + plane from the ML plane in non-SSS subjects. In the ML+6, ML+9, and ML+12 planes, the MSCA in SSS subjects differed from the ML plane ($P \leq .039$) (Fig. 11, *A*). The MSCA in M+ planes did not differ from that in the ML plane for either non-SSS or SSS patients ($P \geq .230$) (Fig. 11, *B*). The MSCA did not differ from the ML plane in any of the L+ planes in either non-SSS or SSS patients ($P \geq .109$) (Fig. 11, *C*).

Interrater and intrarater reliability as quantified by ICCs were 0.830 and 0.889 for scapula type and 0.954 and 0.643 for MSCA, respectively.

Discussion

This study quantified the inconsistency in scapula *type* and MSCA arising from variable scapular orientation in the imaging field of view by creating translated and rotated imaging planes relative to a controlled reference imaging plane (eg, ML). The differences in scapular type and MSCA between imaging planes in the same subject far surpassed previously reported differences between non-SSS and SSS patient groups, and exceeded the ranges described in the original manuscript that defined MSCA.[20] Even if the scapular orientation is controlled or corrected, as was done using the ML plane herein, large intersubject variability exists. Therefore, the MSCA as previously defined by Spiegl et al likely lacks the sensitivity and specificity to reliably be used as a clinical diagnostic tool for SSS. Interestingly, the modified MSCA measuring the scapular blade across the superior angle using translated ML planes (ie, ML+) appears to differentiate non-SSS from SSS groups, but is still subject to orientation errors like the MSCA below the supraspinatus fossa when rotating them (eg, M+, L+). Although this study was not powered to detect differences between non-SSS and SSS groups, this suggests that a corrected imaging slice when measured across the scapula superior to the supraspinatus fossa and parallel to ML may be a target for clinical use. The sensitivity and specificity of this technique requires more study.

Scapula *type* frequently changed depending on the imaging plane. In the original study using a single (uncontrolled) imaging slice/plane, there were no differences in scapula type between non-SSS and SSS patients and all type 3 scapulae belonged to patients with SSS.[20] However, in the present study all but 2 SSS patients had multiple planes with scapula types that deviated from that in the ML reference plane, and all but one non-SSS and 3 SSS patients had at least one imaging plane in which the scapula was a Type 3. Furthermore, across all the (−) planes, non-SSS patients were more likely to have type 3 scapulae. Thus, any association of scapula *type* to SSS is confounded by the imaging plane orientation, and many non-SSS subjects also had type 3 scapulae. This contradicts the prior findings and shows the importance of considering the 2-dimensional—3D perspectives of the measurements collected.[20]

The MSCA varied greatly within each subject solely based on the imaging plane. However, 5 of 20 planes for non-SSS and 4 of 20 planes for SSS differed from MSCA in the ML reference plane. More importantly, the MSCA of a single scapula often varied more depending on the viewing plane than non-SSS and SSS scapulae varied from each other within the same plane. Thus, the true significance of the difference in MSCA between non-SSS and SSS patients is uncertain if the scapular orientation is unknown or cannot be corrected for. Even if the scan is corrected into a consistent orientation, as in the ML plane used herein, the interquartile ranges of the MSCA as defined previously (ie., (−) planes) is likely to overlap (Fig. 8) such that distinguishing SSS from non-SSS scapula based solely on MSCA is unlikely. The scapula type in modified (+) planes yielded similar findings. Thus, regardless of if the scapula is analyzed as defined previously below the fossa or in the modified fashion above the ML plane, non-SSS and SSS patients do not appear to be distinguished using scapular type.

This study was not powered *a priori* to detect a difference between non-SSS and SSS subjects due to the small sample size of patients with adequate imaging for analysis. However, the scapula type and MSCA between non-SSS and SSS was compared to explore the differences seen between non-SSS and SSS in previous studies, as well as to identify potential new targets for distinguishing the populations. In particular, evaluating the scapula above the fossa as in the modified (+) planes analyzes the area targeted in superomedial angle resection. When MSCA was analyzed in the translated (+ML) planes, there were consistent statistically significant differences between non-SSS and SSS patients. Moreover, the interquartile ranges of these measurements began to deviate dramatically (Fig. 11). Interestingly, in contrast to the prior findings of Spiegl et al,[20] non-SSS patients were more likely to have positive MSCA, while SSS subjects were more likely to have smaller or negative MSCA. This variation from the prior findings is likely because in these planes the superior angle is evaluated as opposed

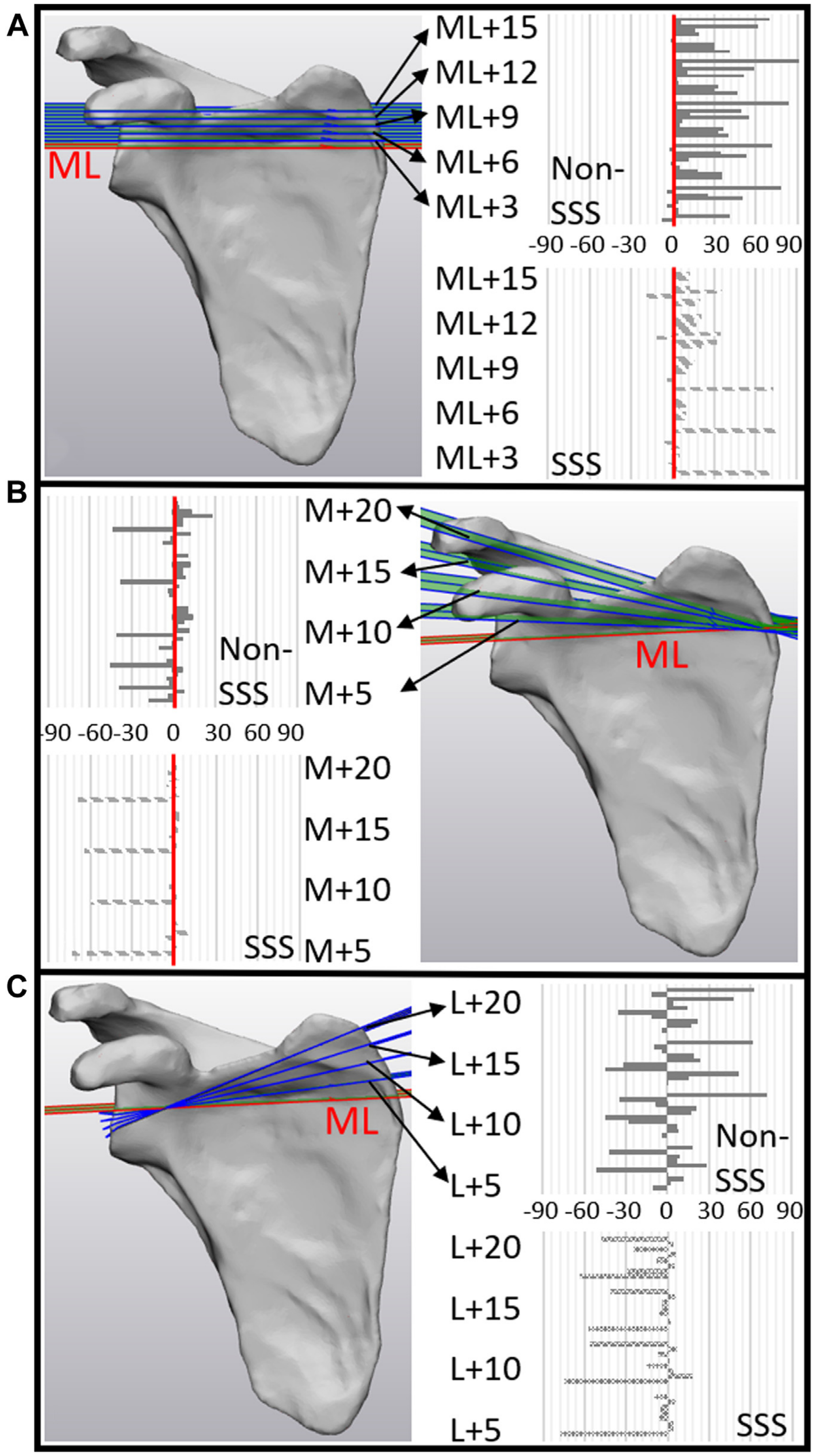

Figure 10 Difference (°) in MSCA between the reference ML plane and modified planes ML+ (**A**), M+ (**B**), L+ (**C**), in non-SSS and SSS patients. Here each bar represents an individual subject (N = 10 for non-SSS, N = 8 for SSS patients) and bars are presented by subject in the same order for each figure. The *vertical red bar* denotes no difference (0°) in MSCA between the reference and altered planes. *MSCA*, medial scapula corpus angle; *SSS*, snapping scapula syndrome.

to the area inferior to the scapular spine. Thus, the angle does not represent the same curvature in ML + planes as it does in the original description of MSCA, and could provide a new clinical target for SSS diagnosis.

The MSCA has been previously noted to be helpful to diagnose SSS but not useful in either predicting whether superomedial angle resection will resolve symptoms, or for presurgical planning.[23] This could be because the previously defined MSCA measures the

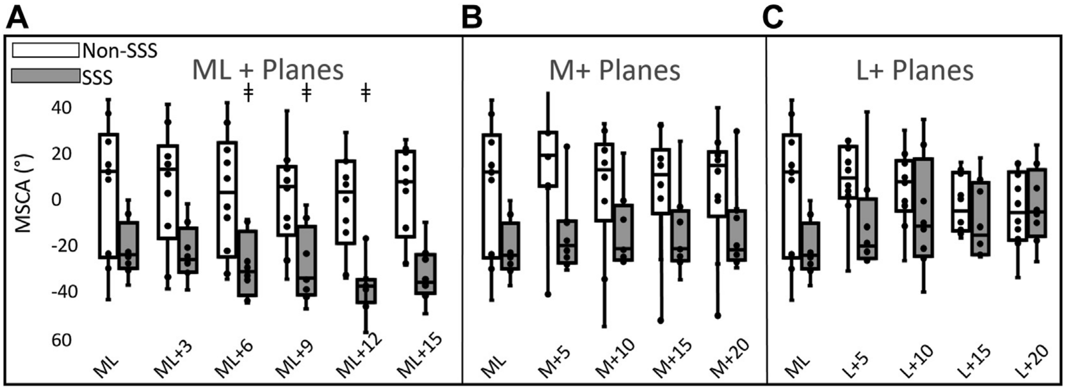

Figure 11 Box and whisker plot of MSCA in non-SSS (*white bars*) and SSS (*gray bars*) groups for modified ML+, M+ and L+ planes. *Circles* represent individual MSCA measurements for a specific patient. Median is represented by a *horizontal line* in the box. The box represents the interquartile ranges. The whiskers represent the overall ranges. ǂ denotes a statistically significant difference in MSCA between a given plane and the ML plane within that group. *MSCA*, medial scapula corpus angle; *SSS*, snapping scapula syndrome.

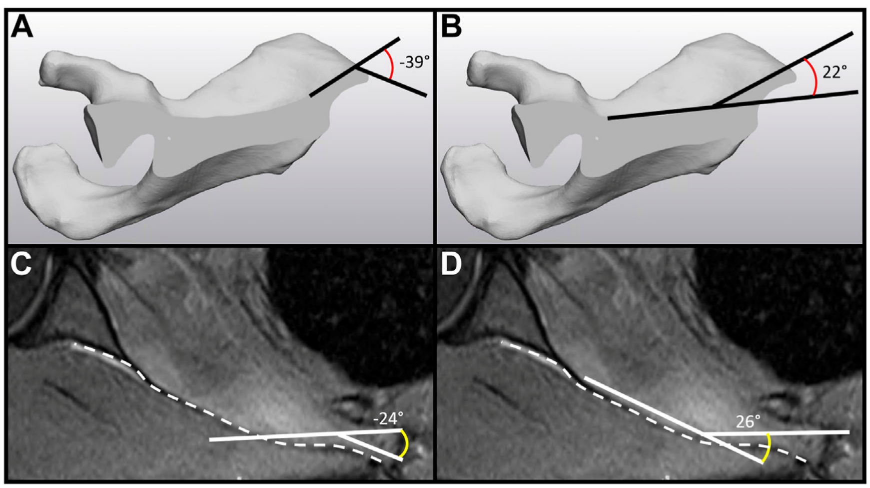

Figure 12 In this type 3 concave scapula taken from a segmented CT, measuring the angle of the medial protuberance gives a scapula with a negative MSCA (**A**). Measuring from the tip of the protuberance gives a positive MSCA (**B**). On a typical volumetric image, both measurements are viable. In this MRI of a type 3 concave scapula, the curvature of the scapula is shown in a *dashed line*, while the angle is shown in *yellow*. Measuring the angle from the medial edge of the protuberance gives a negative MSCA (**C**). Measuring from the prominent edge of the protuberance gives a positive MSCA (**D**). *CT*, computed tomography; *MRI*, magnetic resonance imaging; *MSCA*, medial scapula corpus angle.
Panes **C** and **D** were adapted from Spiegl et al,[20] with permission from Elsevier.

scapula inferior to the fossa with overlapping ranges of non-SSS and SSS patients, while the modified (+) MSCA addresses the scapula superior to the fossa, which is relevant to the superomedial angle resection treatment option. In the small population in the present study, the modified (+) MSCA demonstrated a difference with minimally overlapping interquartile ranges. In addition, this finding appears to be decoupled from scapula type, which was shown to be highly variable among the groups and imaging planes. Thus, further investigation above the fossa is warranted in more robust populations of non-SSS and SSS patients to determine the sensitivity and specificity of this measurement technique.

Regardless of the location and orientation of the imaging plane, there were still consistent issues in the process of quantifying scapula type and MSCA. ICCs were comparable to those in Spiegl et al[20] for interobserver agreement (0.95 vs. 0.80) and the intraobserver agreement (0.64 vs. 0.70). Part of this variability could stem from confusion as to where to calculate the MSCA. The clinician can choose to measure the angle of the protuberance at the medial edge of the scapula, or the angle from the most prominent edge of the protuberance (Fig. 12, *A* and *B*). In this example, the first measurement yields a -39° MSCA, while the second option yields a $+22^{\circ}$ MSCA. Either is a viable measurement per the original definition to measure "the costal surface of the medial scapula border". This issue is most easily seen in the high-resolution CT scans where the medial protuberance might be obvious as opposed to the low-resolution MRIs where it may not be (eg, Fig. 12, *C* and *D*). At the medial border where the scapula has multiple contours, 2 different measurements could be easily interchanged, leading to a measurement of -24° when taken from the medial edge, or $+26^{\circ}$ when taken from the most prominent edge of the protuberance. Another issue that arises with measurement technique is the choice of plane. As Spiegl et al noted, observers do not always choose the same index plane at the bottom of the fossa, and therefore there is a translational component affecting imaging plane selection. We modeled this with our ML- planes, and much like the other imaging planes, the wide-ranging results in these planes suggest that initial plane selection also leads to potentially different MSCA values.

There were several limitations to this study. First, there were relatively few subjects for analysis compared to previous studies of measuring scapula curvature in SSS because we required those with high-resolution CT imaging.[16,20] Thus, although there is an apparent statistically significant difference in MSCA in the modified

(+) planes above the fossa, the ability to differentiate between non-SSS and SSS in other planes was limited. However, due to the repeated measures study design within subject groups and the fidelity of the utilized CT imaging, the study was robust in classifying how scapula typing and MSCA were highly variable given orientation of the scapula to the imaging plane. To this end, the sensitivity and specificity of the modified (ML+) planes should be further investigated as it was the only measurement that consistently differentiated non-SSS from SSS scapulae in the present study. Indeed, the imaging plane is important regardless of the patient, as the entire cohort demonstrated wide-ranging MSCA measurements amongst a multitude of imaging planes. If this condition were indeed due to bony morphology alone and not concomitant kinematic abnormalities, a consistent imaging plane determined from the orientation between the scapula and the ribs, and then used to reorient the scapula in 3 dimensions might be applied to analyze the MSCA.

Conclusion

Although scapula type and MSCA were previously shown to differentiate patients, the effect of viewing perspective was not considered. Differences in scapula orientation relative to the imaging plane dramatically varied the scapula type and MSCA, far exceeding differences between groups described previously by Spiegl et al Herein, scapula type and MSCA often differed in planes translated above the reference plane, suggesting that scapular abnormalities contributing to SSS are largely at or close to the superomedial angle. The MSCA as previously defined by Spiegl et al likely lacks the sensitivity and specificity to reliably be used as a clinical diagnostic tool for SSS. The blade showed consistent differences when translated above the reference plane; however, it was still highly variable. Sensitivity and specificity of planes above the reference plane should be investigated further as they may provide reliable differentiation of non-SSS and SSS patients.

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References

1. Aggarwal A, Wahee P, Harjeet, Aggarwal AK, Sahni D. Variable osseous anatomy of costal surface of scapula and its implications in relation to snapping scapula syndrome. Surg Radiol Anat 2011;33:135-40. https://doi.org/10.1007/s00276-010-0723-4.
2. Chalmers PN, Suter T, Jacxsens M, Zhang Y, Zhang C, Tashjian RZ, et al. Influence of radiographic viewing perspective on glenoid inclination measurement. J Shoulder Elb Arthroplast 2019;3:2471549218824986. https://doi.org/10.1177/2471549218824986.
3. Culham E, Peat M. Functional anatomy of the shoulder complex. J Orthop Sports Phys Ther 1993;18:342-50.
4. Edelson JG. Variations in the anatomy of the scapula with reference to the snapping scapula. Clin Orthop Relat Res 1996:111-5.
5. Ermiş MN, Aykut US, Durakbaşa MO, Ozel MS, Bozkuş FS, Karakaş ES. Snapping scapula syndrome caused by subscapular osteochondroma. Eklem Hastalik Cerrahisi 2012;23:40-3.
6. Gaskill T, Millett PJ. Snapping scapula syndrome: diagnosis and management. J Am Acad Orthop Surg 2013;21:214-24. https://doi.org/10.5435/JAAOS-21-04-214.
7. de Haart M, van der Linden ES, de Vet HC, Arens H, Snoep G. The value of computed tomography in the diagnosis of grating scapula. Skeletal Radiol 1994;23:357-9.
8. Henninger HB, Suter T, Chalmers PN. Editorial commentary: is your critical shoulder angle accurate? Only if you can verify that you have the correct images. Arthroscopy 2021;37:447-9. https://doi.org/10.1016/j.arthro.2020.11.021.
9. Kibler WB, Sciascia A, Wilkes T. Scapular dyskinesis and its relation to shoulder injury. J Am Acad Orthop Surg 2012;20:364-72. https://doi.org/10.5435/JAAOS-20-06-364.
10. Kolz CW, Sulkar HJ, Aliaj K, Tashjian RZ, Chalmers PN, Qiu Y, et al. Age-related differences in humerothoracic, scapulothoracic, and glenohumeral kinematics during elevation and rotation motions. J Biomech 2021;117:110266. https://doi.org/10.1016/j.jbiomech.2021.110266.
11. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med 2016;15:155-63. https://doi.org/10.1016/j.jcm.2016.02.012.
12. Kuhn JE, Plancher KD, Hawkins RJ. Symptomatic scapulothoracic crepitus and bursitis. J Am Acad Orthop Surg 1998;6:267-73.
13. Lazar MA, Kwon YW, Rokito AS. Snapping scapula syndrome. J Bone Joint Surg Am 2009;91:2251-62. https://doi.org/10.2106/JBJS.H.01347.
14. Milch H. Snapping scapula. Clin Orthop 1961;20:139-50.
15. Milch H. Partial scapulectomy for snapping of the scapula. J Bone Joint Surg Am 1950;32-A:561-6.
16. Mozes G, Bickels J, Ovadia D, Dekel S. The use of three-dimensional computed tomography in evaluating snapping scapula syndrome. Orthopedics 1999;22:1029-33.
17. Parsons TA. The snapping scapula and subscapular exostoses. J Bone Joint Surg Br 1973;55:345-9.
18. Pavlik A, Ang K, Coghlan J, Bell S. Arthroscopic treatment of painful snapping of the scapula by using a new superior portal. Arthroscopy 2003;19:608-12. https://doi.org/10.1016/s0749-8063(03)00171-3.
19. Pearse EO, Bruguera J, Massoud SN, Sforza G, Copeland SA, Levy O. Arthroscopic management of the painful snapping scapula. Arthroscopy 2006;22:755-61. https://doi.org/10.1016/j.arthro.2006.04.079.
20. Spiegl UJ, Petri M, Smith SW, Ho CP, Millett PJ. Association between scapula bony morphology and snapping scapula syndrome. J Shoulder Elbow Surg 2015;24:1289-95. https://doi.org/10.1016/j.jse.2014.12.034.
21. Suter T, Henninger HB, Zhang Y, Wylie JD, Tashjian RZ. Comparison of measurements of the glenopolar angle in 3D CT reconstructions of the scapula and 2D plain radiographic views. Bone Joint J 2016;98-B:1510-6. https://doi.org/10.1302/0301-620X.98B11.37800.
22. Suter T, Krähenbühl N, Howell KC, Zhang Y, Henninger BH. Viewing perspective malrotation influences angular measurements on lateral radiographs of the scapula. J Shoulder Elbow Surg 2020;29:1030-9. https://doi.org/10.1016/j.jse.2019.09.022.
23. Tahal DS, Katthagen JC, Marchetti DC, Mikula JD, Montgomery SR, Brady A, et al. A cadaveric model evaluating the influence of bony anatomy and the effectiveness of partial scapulectomy on decompression of the scapulothoracic space in snapping scapula syndrome. Am J Sports Med 2017;45:1276-82. https://doi.org/10.1177/0363546516687755.
24. Takahara K, Uchiyama S, Nakagawa H, Kamimura M, Ohashi M, Miyasaka T. Snapping scapula syndrome due to malunion of rib fractures: a case report. J Shoulder Elbow Surg 2004;13:95-8. https://doi.org/10.1016/s1058-2746(03)00055-7.
25. Warth RJ, Spiegl UJ, Millett PJ. Scapulothoracic bursitis and snapping scapula syndrome: a critical review of current evidence. Am J Sports Med 2015;43:236-45. https://doi.org/10.1177/0363546514526373.
26. Williams GR Jr, Shakil M, Klimkiewicz J, Iannotti JP. Anatomy of the scapulothoracic articulation. Clin Orthop Relat Res 1999:237-46.
27. Wood VE, Verska JM. The snapping scapula in association with the thoracic outlet syndrome. Arch Surg 1989;124:1335-7.