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ORIGINAL ARTICLE

Assessment of scapulohumeral rhythm for scapular plane shoulder elevation using a modified digital inclinometer

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Abstract

AIM: To develop a better understanding of scapulohumeral rhythm during scapular plane shoulder elevation.

METHODS: Thirteen healthy, college-aged subjects participated in this study. Subjects were free from any upper extremity, neck or back pathology. A modified digital inclinometer was utilized to measure scapular upward rotation of the subject's dominant shoulder. Upward rotation was measured statically as subjects performed clinically relevant amounts of shoulder elevation in the scapular plane. Testing order was randomized by arm position. Scapular upward rotation was assessed over the entire arc of motion and over a series of increments. The percent contributions to shoulder elevation for the scapula and glenohumeral joint were calculated. Scapulohumeral rhythm was assessed and represented the ratio of glenohumeral motion to scapulothoracic motion (glenohumeral elevation: scapular upward rotation). A one-way ANOVA was used to compare scapular upward rotation between elevation increments.

RESULTS: Scapulohumeral rhythm for the entire arc of shoulder elevation was equal to a ratio of 2.34 :1 and ranged from 40.01:1 to 0.90:1 when assessed across the different increments of humeral elevation. Total scapular motion increased over the arc of shoulder elevation. The scapula contributed 2.53% of total motion for the first 30 degrees of shoulder elevation, between 20.87% and 37.53% for 30°-90° of shoulder elevation, and 52.73% for 90°-120° of shoulder elevation. Statistically significant differences in scapular upward rotation were identified across the shoulder elevation increments [$F_{(3,48)}$ = 12.63, P = 0.0001].

CONCLUSION: Clinically, we must recognize the usefulness of the inclinometer in documenting the variable nature of scapulohumeral rhythm in healthy and injured shoulders.

INTRODUCTION

Optimal function of the shoulder is reliant on the co-

ordinated movement of the scapula and the humerus[1]. Alterations in scapular position and control afforded by the scapula stabilizing muscles are believed to disrupt stability and function of the glenohumeral joint[1-3], thereby contributing to shoulder impingement, rotator cuff pathology and shoulder instability[4]. Given the role of the scapula in shoulder function, the ability to monitor the coordinated motion of the scapula and humerus, or scapulohumeral rhythm[5,6], may have clinical implications when dealing with overhead athletes and patients with shoulder pathologies.

Inman, Saunders and Abbott[7] were the first to measure scapulohumeral rhythm using radiography and suggested what became the widely accepted 2:1 ratio between glenohumeral elevation and scapulothoracic upward rotation (SUR). Since then imaging modalities (X-ray and magnetic resonance imaging)[8], cinematography[9], goniometry[10-12], and more recently 3-dimensional tracking systems[13-16] have been used to gain a better appreciation of shoulder kinematics. This evolution in kinematic assessment has resulted in new understandings of scapulohumeral rhythm in both healthy and injured populations. Some of the literature suggests the 2:1 ratio is not consistent across an entire arc of shoulder elevation[8-10,17,18] and that variability in this ratio may increase when considering the scapulohumeral rhythm exhibited by shoulder injured subjects[19,20].

Instrumentation accessibility has often precluded clinicians from being able to quantify glenohumeral and scapulothoracic joint contributions to scapulohumeral rhythm. Whether we consider exposure to electromagnetic radiation associated with radiography or the expense and time intensive nature of electromagnetic tracking systems, there are some limitations associated with quantifying the relative contributions of the glenohumeral and scapulothoracic joints to shoulder elevation in clinical settings. To enhance accessibility, Johnson *et al*[12] validated use of a digital inclinometer to quantify SUR, which has since been incorporated into a variety of clinically oriented research studies[21-27]. While many studies involving digital inclinometers have been successful in quantifying SUR, no studies involving digital inclinometers have attempted to examine scapulohumeral rhythm specifically. Although the aforementioned studies provide valuable information relative to scapulothoracic joint motion, return to activity following shoulder injury is dependent on function of both the scapulothoracic and the glenohumeral joint, and how both joints function together. The ability to utilize the inclinometer for quantifying scapulohumeral rhythm will provide clinicians with a means to monitor the often variable nature of scapulohumeral rhythm while also comparing the functional capacity of the shoulder to the established 2:1 scapulohumeral movement ratio. Therefore, the purpose of this study was to develop a better understanding of the coordinated movement of the scapula and humerus in order to enhance the evaluation and rehabilitation efforts of clinicians. We hypothesized that the coordinated movement of the scapula and humerus as measured by a digital inclinometer, would be different than the widely accepted 2:1 scapulohumeral rhythm ratio (glenohumeral: scapulothoracic motion) initially described by Inman[7]. Furthermore, we hypothesized that scapular contributions to incremental increases in glenohumeral elevation would not be consistent.

MATERIALS AND METHODS

Subjects
Thirteen healthy subjects (21.46 ± 1.13 years, 1.76 ± 0.11 meters, 76.18 ± 12.57 kg; 8 male, 5 female; 11 right, 2 left) were recruited to participate in this study. All subjects completed an informed consent document approved by the University's Institutional Review Board. Participants provided demographic data and completed a health history questionnaire. Subjects also underwent a brief physical examination, which involved measures of shoulder range of motion, strength normalized to body weight, and a subset of evaluative special tests to ensure a healthy dominant shoulder free of any current or previous upper extremity, neck or back injuries or conditions that would result in muscle weakness or reduced shoulder range of motion. The dominant shoulder was selected based upon which hand subjects chose to throw a ball with and sign their name.

Instrumentation
A digital inclinometer (Pro 360, Baseline®, Fabrication Enterprises, White Plains, NY) was used to assess scapular upward rotation during static humeral elevation trials. Using an electromagnetic tracking system, Johnson *et al*[12] validated use of the digital inclinometer to quantify SUR associated with varying amounts of humeral elevation ($r = 0.66$ to 0.89). A series of modifications were made to the inclinometer, consistent with the work of Johnson et al, to make it suitable for measuring SUR. Specially designed wooden locator rods were used with the inclinometer in order to appropriately align the inclinometer with the contours of the scapular spine. A custom made plate (Lexan, SABIC Innovative Plastics, Pittsfield, MA) was attached to the inclinometer, allowing for adjustable spacing of the rods (Figure 1A and B). Each locator rod was attached to the Lexan plate using hardware. A bubble level was also affixed to the inclinometer to maintain its position perpendicular orientation relative to the horizontal plane of the inclinometer[12]. With the modifications the inclinometer was aligned with the root of the spine of the scapula and the posterolateral corner of the acromion process[12].

A hand held dynamometer (ergoFET 300, Hogan Health Industries©, West Jordon, UT) was used to assess maximal strength during the initial screening process. Maximal strength tests for shoulder flexion, abduction, and internal and external rotation were performed according to the manual muscle testing guidelines presented by Hislop and Montgomery[28]. When applying the
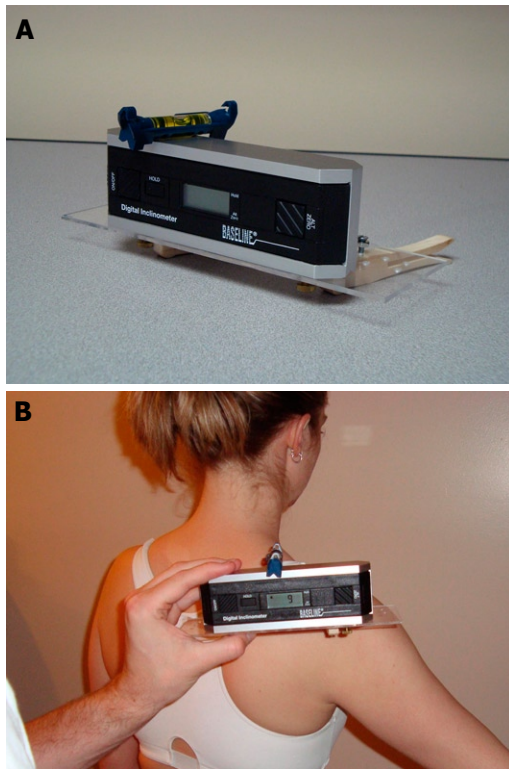
Figure 1 Modified digital inclinometer (A) and scapular upward rotation measurement (B).

Table 1 Humeral elevation increments, mean scapular upward rotation measures, and scapulohumeral rhythm ratios

Shoulder elevation increments	Mean scapular upward rotation ($\pm$ SD)	Scapulohumeral rhythm
0°-120°	35.95 (6.50)	2.34:1
0°-30°	0.73 (4.91)	40.05:1
30°-60°	10.99 (7.18)	1.73:1
60°-90°	8.45 (6.17)	2.55:1
90°-120°	15.78 (7.01)	0.90:1
0°-30°	0.73 (4.91)	40.05:1
30°-45°	5.69 (2.33)	1.64:1
45°-60°	5.29 (6.15)	1.83:1
60°-75°	3.15 (3.67)	3.76:1
75°-90°	5.29 (5.83)	1.83:1
90°-120°	15.78 (7.01)	0.09:1

For each shoulder elevation increment mean ± SD were calculated for scapular upward rotation. Scapular rotation was subtracted from each 15, 30, or 120 degree increment to determine glenohumeral contribution to shoulder elevation. Using the glenohumeral and scapular rotation values, scapulohumeral rhythm (glenohumeral:scapular) was calculated for each increment. SD represents standard deviation.

manual resistance for each test the hand held dynamometer was used in order to obtain force measures. Two trials were performed for each shoulder motion; means were calculated and were normalized to body weight.

Intervention

Subjects were seated on a plastic stool one arm's length from a stationary screen. Subjects were seated to minimize compensatory changes of the lower extremity and trunk, which could impact shoulder biomechanics. Subjects were asked to move their hands to selected points along the screen that corresponded to specific shoulder ranges of motion (rest, 30°, 45°, 60°, 75°, 90°, 120°) in the scapular plane. Shoulder ranges of motion were monitored with a digital inclinometer and hand placement was marked on the screen for each of the respective shoulder ranges of motion. The reliability and validity of our humeral elevation protocol was established previously in our laboratory using an electromagnetic tracking system. When performing humeral elevation in the scapular plane, our intra-session reliability ranged from $ICC_{(3,1)} = 0.935$ to $ICC_{(3,1)} = 0.947$, while scapular kinematic reliability ranged from $ICC_{(3,1)} = 0.964$ to $ICC_{(3,1)} = 0.999$. Similarly, we were able to report significant correlations between the electromagnetic tracking system and the digital inclinometer for shoulder elevation in the scapular plane with Pearson correlation coefficients ranging from 0.846 to 0.986. In addition to having used the inclinometer as part of a previous study to measure scapular upward rotation, intra-rater reliability for the primary investigator has been determined to be excellent when used to quantify scapular rotation [$ICC_{(3,1)} = 0.951$ to $ICC_{(3,1)} = 0.996$] with the inclinometer.

Testing order was randomized by arm position for each subject. Subjects began with their dominant hand at his/her side and were then asked to move their hand to a selected position and to hold that position while SUR was measured. Each trial lasted 10-15 s, and subjects were provided with 5-10 s rest in between each trial. For all inclinometer measures, the primary investigator relied on palpation to identify the position of the medial border and spine of the scapula and the posterolateral corner of the acromion. The primary investigator was responsible for all measures taken with the inclinometer. The inclinometer was repositioned each trial, and inclinometer values were confirmed and recorded by a laboratory assistant for each trial to eliminate investigator bias.

Statistical analysis

Means and standard deviations were calculated for the demographic data. Mean scapular rotation was calculated at 15 and 30 degree increments. Scapular motion was examined over several increments (Table 1).

Scapulohumeral rhythm was calculated using both the 15 degree and 30 degree increments by subtracting scapular rotation from shoulder elevation to determine glenohumeral joint contribution to shoulder elevation (Equation 1). The ratio of glenohumeral motion to scapular motion was then calculated to derive scapulohumeral rhythm (Equation 2).

(Eq. 1) Glenohumeral motion = (Total shoulder motion) - (scapular upward rotation)

(Eq. 2) Scapulohumeral rhythm = (Glenohumeral elevation)/(Scapular upward rotation)

Scapular contributions to shoulder elevation were calculated and percent contributions were calculated according to the aforementioned increment (Equation 3).
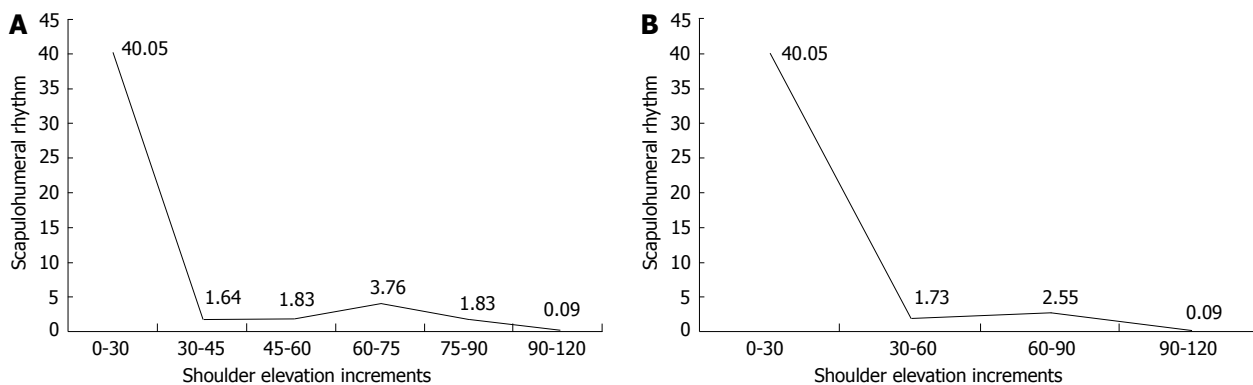
Figure 2 **Scapulohumeral rhythm for 15 shoulder elevation increments (A) and 30 degree shoulder elevation Increments (B).** Shoulder elevation increments represent degrees of shoulder elevation in the scapular plane. Values listed in the figure represents degrees of glenohumeral motion for every 1° of scapular upward rotation.

Table 2 Dominant shoulder range of motion and normalized strength			
	Active range of motion (± SD)	Passive range of motion (± SD)	Normalized strength (%) (± SD)
Flexion	175.86° (7.04°)	179.86° (0.53°)	19.29 (4.80)
Abduction	179.07° (1.86°)	180.00° (0.00°)	18.53 (3.90)
Internal rotation	52.43° (12.11°)	60.21° (13.72°)	17.25 (4.43)
External rotation	107.79° (7.78°)	129.14° (11.95°)	12.54 (3.37)

(Eq. 3)% Contribution $_{Scapula}$ = (Scapular rotation)/ (Total shoulder elevation).

Excel (Microsoft, Redmond, WA) and SPSS version 17.0 (IBM Corporation, Armonk, NY) were used for all statistical analyses. A one-way ANOVA was performed to compare mean SUR between 30 degree elevation increments. A Bonferroni *t*-test was used to address multiple comparisons between the elevation increments. An $\alpha = 0.05$ was set a priori.

RESULTS

Means and standard deviations for shoulder ranges of motion and strength are provided in Table 2. Ranges of shoulder motion and strength were within clinically acceptable normal limits and were representative of subjects reporting healthy shoulders.

The assessment of scapulohumeral rhythm across the entire arc of humeral elevation was very consistent with the 2:1 ratio defined by Inman. Scapulohumeral rhythm for the observed range represented a ratio of 2.34:1. However, when assessing scapulohumeral rhythm across the different increments of humeral elevation ratios ranged from 40.01:1 to 0.90:1. Following minimal contributions from the scapula during the first 30 degrees of humeral elevation mean scapulohumeral rhythm ratios when assessed over 15 and 30 degree increments ranged from 0.90:1 to 3.76:1 (Figure 2 A and B).

Total scapular motion increased over the arc of shoulder elevation. Contributions of the scapula to overall shoulder elevation were initially minimal when considering the first 30 degrees of shoulder elevation. These

contributions continued to increase by varying degrees over the course of shoulder elevation. However, these increases did not appear to occur in a linear fashion. Assessing the scapula's percent contributions to shoulder elevation across all subjects provided confirmation of this non-linear trend. Percent contributions of the scapula to shoulder elevation were substantially lower for the first 30 degrees of elevation, representing only 2.53% of the first 30 degrees of shoulder elevation. When examining 15° increments of shoulder elevation ranging from 30° to 90°, scapular rotation contributed between 20.87% and 37.53% to total shoulder motion. These contributions were not consistent across increments, and this trend continued when examining the increased scapular contributions percentage from 90° to 120° of elevation which reached 52.73% of total shoulder motion (Figure 3).

Statistically significant differences in scapular upward rotation were identified across the shoulder elevation increments [$F_{(3,48)}$ = 12.63, $P = 0.0001$]. The Boneferoni assessment revealed multiple significant differences between the 30 degree increments (Table 3). Differences in scapular rotation were not assessed for the 15 degree humeral elevation increments as this data was only obtained for a portion of the humeral elevation arc (30°-90°).

DISCUSSION

We were able to quantify the contributions of scapular upward rotation to shoulder elevation occurring in the scapular plane and we were able to provide evidence, using clinically available instrumentation, that scapulohumeral rhythm, as it relates to scapular upward rotation, does not conform entirely to the often accepted 2:1 ratio described by Inman[7]. While the overall ratio of 2.34:1 is in close agreement with the accepted norm, incremental observations of scapulohumeral rhythm were more consistent with recent observations, which are not entirely consistent with the 2:1 ratio[17,29,30]. We also observed increasingly more scapular upward rotation as the shoulder achieved greater amounts of elevation in the scapular plane, which is consistent with the scapula's role as it relates to optimizing function of the glenohumeral
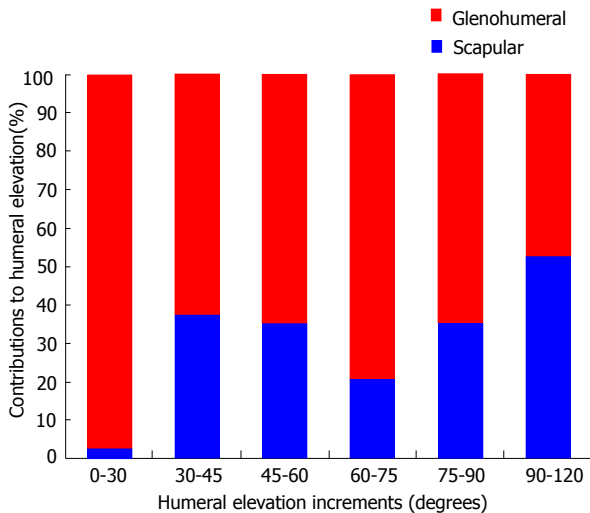
Figure 3 Glenohumeral and scapular upward rotation contributions to shoulder elevation.

Table 3 Multiple comparisons analyzing scapular upward rotation per 30 degree increments of shoulder elevation

Increment₁	Increment₂	Mean difference	Significance	95% confidence interval
0°-30°	30°-60° [1]	-10.26	0.001	-17.14; -3.37
	60°-90° [1]	-7.72	0.02	-14.60; -0.83
	90°-120° [1]	-15.05	≤ 0.001	-21.94; -8.17
30°-60°	0°-30° [1]	10.26	0.001	3.37; 17.14
	60°-90°	2.54	1	-4.35; 9.42
	90°-120°	-4.8	0.367	-11.68; 2.09
60°-90°	0°-30° [1]	7.72	0.02	0.83; 14.60
	30°-60°	-2.53	1	-9.42; 4.35
	90°-120° [1]	-7.33	0.031	-14.22; -0.45
90°-120°	0°-30° [1]	15.05	≤ 0.001	8.17; 21.94
	30°-60°	4.8	0.367	-2.09; 11.68
	60°-90° [1]	7.33	0.031	0.45; 14.22

One-way ANOVA revealed a statistically significant difference between 30 degree shoulder elevation increments for scapular rotation [$F_{(3,48)}$= 12.63, P ≤ 0.0001]. Bonferoni *t*-tests revealed statistically significant differences. [1]for scapular rotation between 30 degree elevation increments.

joint during overhead activity. Much like scapulohumeral rhythm, upward rotation contributions of the scapula to shoulder elevation varied across the arc of shoulder elevation, which is both consistent with previous reports[23,26,31] and provides support for use of the digital inclinometer in clinical settings to effectively monitor scapular motion as part of both injury evaluation and rehabilitation.

The scapulohumeral rhythm ratios we observed ranged from 40:1 to 0.90:1. Although our results relative to scapulohumeral rhythm across the entire range of motion are in fairly close agreement with the 2:1 ratio suggested by Inman *et al*[7], the 2:1 ratio is an average that does not represent the substantial variability observed throughout the range. The exceptionally high ratio obtained during the first 30 degrees of humeral elevation is consistent with the scapular setting phase that is often described when discussing shoulder kinematics and confirmed the observations of some investigators[8,10,17]. The observed ratio not only suggests that the scapula engages in a minimal amount of upward rotation, but rather that during the initial stages of shoulder elevation a period of downward rotation may be encountered. Borsa *et al*[26] reported a similar decline in upward rotation during the first 30° of shoulder elevation in the scapular plane. It is unclear what may have caused this downward rotation and while it is beyond the scope of our study it is plausible that weakness of the scapula stabilizing muscles may have contributed to the observed pattern. Following the setting phase, scapulohumeral rhythm approached the norms of scapulohumeral rhythm in a fashion consistent with what others have presented[17,29,30,32-34]. Scapulohumeral rhythm ratios between 30° and 90° ranged from 1.64:1 to 3.76:1; but none were equal to the clinically accepted 2:1 ratio. We then observed a decline in scapulohumeral rhythm (0.90:1) as subjects elevated their shoulders from 90° to 120° of elevation. This decline in scapulohumeral rhythm adds to the degree of hetero-

geneity in the literature as it relates to scapulohumeral rhythm at higher ranges of shoulder elevation[8-10,17,26,29-31]. However, our results are more consistent with those investigators that have indicated that scapulohumeral rhythm ranges between a 1:1 and 2:1 ratio[8-10,17,18,29,30,32-35]. Factors that could explain this observed shift include increases in inferior glenohumeral ligament tension[34], required positioning of the scapula to maintain function and stability of the glenohumeral joint, and maintenance of the subacromial space to avoid impingement[4].

We observed increases in total scapular upward rotation as the level of shoulder elevation increased; however, these increases varied considerably between observed increments. Over the arc of shoulder elevation the scapula encountered 35.95° of upward rotation, resulting in a scapulohumeral rhythm of 2.34:1. Consistent function of the shoulder complex relies on reliable patterns of scapular and glenohumeral motion during shoulder elevation and lowering to ensure optimal stability and mobility[29,31]. The relative increase in scapular upward rotation is similar to both what has been observed with electromagnetic tracking systems[17,29,31-34] and modified digital inclinometers[12,21-27]. Although we noted a relative overall increase in scapular upward rotation, we identified significant differences in scapular rotation between 30 degree shoulder elevation increments, which served to support our secondary hypothesis. The results of Witwer and Sauer[23] and Borsa *et al*[23,26,31] relative to scapular upward rotation and Borstad and Ludewig[33] specific to scapular tilting foreshadowed our findings with each noting differences or variability in scapular motion when comparing increments of shoulder elevation. The differences we observed between the 0°-30° increment and all other increments are logical given the limited degree to which the scapula moved during the setting phase. Given the often reported stability in scapulohumeral motion between 30° and 90° it is not surprising that differences were not noted between the 30°-60° and 60°-90°

increments. It is, however, interesting that the 90°-120° increment was not different when compared to all other increments in light of the scapulohumeral rhythm shift often observed when shoulder elevation occurs above 90°. One factor that may have contributed is the slightly higher relative variability in scapular rotation measures for the 30°-60° increment. This pattern in variability is not unlike what has been reported in other studies[23,26,31] and may have contributed to the lack of significant differences between the 30°-60° and 90°-120° increments. Ultimately, the pattern of scapular rotation we observed during shoulder elevation is similar to what clinicians might observe including (1) a scapular setting phase with little scapular rotation; (2) a relative but inconsistent increase in scapular contributions to shoulder elevation; followed finally by (3) increasingly more upward rotation of the scapula, which mirrors that of the humerus.

Contributions of the scapula to shoulder elevation reflected both inconsistencies in scapulohumeral rhythm and variable scapular upward rotation contributions to shoulder elevation. Again, the contributions of the scapula to shoulder elevation increments 0°-30° and 90°-120° were comparable to what has been reported in the literature, with the scapula contributing 2.53% and 52.73% of the total shoulder elevation, respectively. Examining the shoulder elevation arc incrementally from 30° to 90°, we noted fluctuations in percent scapular contributions to shoulder elevation, which mirrored the inconsistent patterns of scapulohumeral rhythm we observed. In order to be consistent with the 2:1 ratio scapular contributions needed to account for 33.33% of each increment while the glenohumeral joint accounted for the remaining 66.67%. The 15 degree increments 30°-45°, 45°-60° and the 75°-90° and the 30 degree increments (30°-60° and 60°-90°) approached but did not achieve these percent contributions. Reflecting on the scapular contributions across all increments of shoulder elevation, variability in scapular contributions are apparent, which suggests that while the 2:1 ratio may be easy to recall for clinical use, the 2:1 ratio does not accurately portray both scapular contributions and scapulohumeral rhythm observed during shoulder elevation in the scapular plane.

As healthcare and the focus on patient outcomes continue to evolve and our understanding of shoulder kinematics and shoulder pathologies changes as clinicians we must be prepared to add new measures to our clinical repertoires. A number of investigators have examined the contributions of the scapula to shoulder motion in pathologic shoulders using a variety of instruments[19,20,25,35-41], ultimately providing investigators and clinicians with a greater appreciation of scapular kinematics exhibited by various shoulder patient populations. While some have focused on scapulohumeral rhythm and changes in scapular upward rotation, many have expanded their efforts to consider the roles that the secondary scapular rotations (anterior-posterior tilt and medial-lateral tilt)[4] also have in shoulder function and shoulder pathologies. Much of our more recent under-

standings have come through the use of electromagnetic tracking systems, which are not always clinically viable options. Though visual inspection systems[42,43] may afford us the opportunity to globally identify scapular dysfunction, without the ability to quantify and fully appreciate these patterns in our patients the ability to deliver optimal care may be impacted. Our work and the recent work of others continues to support the clinical usefulness and applicability of the digital inclinometer for quantifying scapular kinematics. As our understanding of scapular kinematics continues to evolve and the needs for patient outcomes relative to these areas changes, the digital inclinometer will continue to provide an affordable and accessible means for quantifying shoulder and scapular kinematics.

Limitations
Even though we were able to demonstrate the clinical usefulness of the digital inclinometer for assessing scapulohumeral rhythm there were some areas of our study that may be viewed as weaknesses or that should be considered in future investigations. In our attempts to be more discriminate in our analysis of scapular kinematics we utilized 15 degree increments throughout the mid-range of the shoulder elevation arc. Unfortunately, we did not utilize this approach across the entire arc of elevation, focusing primarily on clinically relevant angles of shoulder elevation, thus limiting our ability to perform this detailed analysis throughout the observed motion. Future efforts should consider adding additional assessment increments and potentially extending the arc of shoulder elevation beyond 120°. Furthermore, it may have been useful to expand the study and include gender comparisons and bilateral comparison to ensure that the observed pattern occurred similarly in genders and in both the dominant and non-dominant shoulders. Future studies should also consider assessing scapula stabilizing strength at various points in the arc of shoulder elevation to determine if any relationships exist between scapular kinematics and stabilizing muscle strength. The roles of both generalized joint laxity and specifically shoulder ligament laxity should also be considered in future work in order to determine their respective impacts on scapulohumeral rhythm. Additionally, while we were able to call into question the widely accepted 2:1 ratio for scapulohumeral rhythm, greater attention should be directed at determining the clinical meaningfulness of this difference and the extent to which it may contribute to or the role it may have in perpetuating various shoulder pathologies.

In our efforts to gain a better appreciation of the coordinated movements of the scapula and humerus, while using a digital inclinometer we observed scapulohumeral rhythms that were not in total agreement with the widely accepted 2:1 ratio for shoulder elevation. Our observations were confirmed based upon percent contributions of the scapula to shoulder elevation and the significant differences in scapular contribution we noted when comparing shoulder elevation increments. Our findings

confirm the presence of a scapular setting phase early in the arc of shoulder elevation, followed by a period of relatively stable scapulohumeral rhythms which then continue to decline as the shoulder moves above 90° of elevation. While our results do not fully support the accepted 2:1 ratio, as investigators and clinicians we must recognize the usefulness of the inclinometer in documenting not only the variable nature of scapulohumeral rhythm in healthy shoulders but the likelihood of increasingly more variant scapulohumeral rhythm patterns exhibited in shoulder injured patients.

ACKNOWLEDGMENTS

COMMENTS

Background

The introduction of electromagnetic tracking systems has resulted in an evolution in kinematic assessment as it relates to the understanding of scapulohumeral rhythm in both healthy and injured populations. Electromagnetic tracking systems have improved our understanding of shoulder kinematics; however, instrumentation accessibility has often precluded clinicians from being able to quantify glenohumeral and scapulothoracic joint contributions to shoulder motion. Although, the validation of the digital inclinometer for assessing scapular upward rotation has made scapular kinematic assessment more accessible, no studies involving digital inclinometers have attempted to examine scapulohumeral rhythm specifically.

Research frontiers

The ability to utilize the inclinometer for quantifying scapulohumeral rhythm will provide clinicians with a means to monitor the often variable nature of scapulohumeral rhythm while also comparing the functional capacity of the shoulder to the established 2:1 scapulohumeral movement ratio.

Innovations and breakthroughs

Scapulohumeral rhythm for the entire arc of shoulder elevation was equal to a ratio of 2.34:1 and ranged from 40.01:1 to 0.90:1, which was not entirely consistent with the accepted scapulohumeral rhythm ratio. Although the scapula experienced variable upward rotation throughout the arc of shoulder elevation, our findings confirmed the presence of a scapular setting phase early in the arc of shoulder elevation, followed by a period of relatively stable scapulohumeral rhythms, which proceeded to decline as the shoulder moved above 90° of elevation.

Applications

The significance of the study is that investigators and clinicians should consider the usefulness of the inclinometer in documenting the variable nature of scapulohumeral rhythm in healthy shoulders and shoulder injured patients.

Terminology

Scapulohumeral rhythm: the coordinated motion of the scapula and humerus experienced during shoulder movement and motion that has been traditionally viewed as occurring at a ratio of 2:1 (2 degrees of humeral flexion/abduction to 1 degree of scapular upward rotation).

Peer review

A modified digital inclinometer was used to measure scapular upward rotation of the subject's dominant shoulder. The authors concluded that the scapulohumeral rhythms measured by a modified digital inclinometer were not consistent with the widely accepted 2:1 ratio for shoulder elevation. Future research should consider the role of hand dominance, gender, and ligamentous laxity as it relates to scapulohumeral rhythm.

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