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RELIABILITY AND VALIDITY OF INCLINOMETER MEASURES FOR ESTIMATING SCAPULAR AND CLAVICULAR ROTATIONS AS COMPARED TO A 3D ELECTROMAGNETIC TRACKING SYSTEM

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SUMMARY

This study compared measurements taken with a digital inclinometer with the ones taken with a 3-D electromagnetic tracking system to assess scapular and clavicular rotations in different positions of humeral elevation in the sagittal plane. Within-day and between-day reliability of the measurements with the inclinometer were also determined. Twenty-three subjects with and without history of shoulder pathology were recruited. A subset of 10 subjects was evaluated for between-day reliability. Five static positions were assessed: rest, 30°, 60°, 90° and 120° of humeral elevation. There was good to excellent intrarater reliability between repeated measurements for assessing clavicle elevation, scapular upward rotation and scapular tilt using the digital inclinometer in all testing positions of humeral elevation. There was moderate to excellent between-day reliability depending on the variable assessed when using the digital inclinometer. The inclinometer consistently measured decreased clavicular elevation compared to the electromagnetic system. For scapular upward rotation, the difference between both methods was less than 2° across all testing positions of humeral elevation. For scapular tilt, there was no significant interaction between method and arm position. The electromagnetic tracking system and the digital inclinometer are reliable devices for measuring clavicular elevation and scapular upward and tilt during humeral elevation in the sagittal plane. Further, the inclinometer can measure alterations in clavicular and scapular positions over time.

INTRODUCTION

Objective measurement of the scapular and clavicular positions are required in a clinical setting because it may help clinicians to evaluate a patient, to decide which exercises to prescribe and to measure possible changes that the exercises may create. Based on this goal, some studies assessed the position of the scapula and clavicle using simple clinical devices such as a tape measure [1-2], scoliometer [3], goniometer [4] and inclinometer [2,5-8]. The variability in reliability demonstrated in these studies is mainly due to differences in methodology. Scapular upward rotation is the most investigated and excellent reliability was demonstrated when using an inclinometer [5,6,8].

The purpose of this study was to compare measurements taken with a digital inclinometer to ones taken with a 3-D electromagnetic tracking system to assess scapular and clavicular rotations in different positions of humeral elevation in the sagittal plane under static conditions. It was also the aim of this study to determine within-day and between-day reliability of the measurements of scapular and clavicular motions using the digital inclinometer under static conditions.

METHODS

Twenty-three subjects (13 females, 10 males), 37.09 ± 13.57 years, with and without a history of shoulder pathology were recruited for this study. A subset of 10 subjects (6 females, 4 males) was evaluated for between day reliability using the digital inclinometer. All subjects had to present near normal range of motion for shoulder elevation (~150°) as measured by a digital inclinometer. This study was approved by the Ethics Committee of the University. Volunteers signed an informed consent agreement to participate in the study.

The clinical device used to assess static positions of the scapula and the clavicle was an Acumar™ digital inclinometer. For scapular upward rotation, the inclinometer was positioned on the scapular spine connecting the root of the spine to the posterolateral acromion. For scapular tilting, the inclinometer was positioned along the body of the scapula. To measure clavicular elevation the inclinometer was positioned along the clavicular long axis between the sternoclavicular joint and the acromioclavicular joint. The lines connecting the root of the spine to the posterolateral acromion, and the sternoclavicular joint to the acromioclavicular joint were achieved with the aid of a caliper. To prevent bias, the digital inclinometer was covered with adhesive tape, so the examiner was not able to see the values recorded on the instrument. A second examiner was responsible for reading the values and recording them. This ensured blinding of the first examiner and removed any subsequent bias.

Three-dimensional motion data were collected using the Flock of Birds® electromagnetic tracking device integrated with MotionMonitor™ software. The sensors were attached

to the sternum, to the middle portion of the clavicle, to the acromion of the scapula and to a thermoplastic cuff secured to the distal humerus to track humeral motion. Anatomical coordinate systems were established for each segment by palpating and digitizing anatomical landmarks as recommended per the International Society of Biomechanics. The 3-D measurements for clavicle and scapula were described with respect to a global reference, since the inclinometer measures in a gravitational rather than a trunk reference frame.

Five static arm positions were assessed: at rest, 30°, 60°, 90° and 120° of humeral elevation in the sagittal plane. Two measurements were taken using both devices at each static arm position. Clavicle motions at 120° of humerothoracic elevation were not considered for statistical analysis because surface sensor tracking is inaccurate at higher elevation angles [9].

Within and between-day reliability was determined by Intraclass Correlation Coefficients (ICCs) (Type 3,1), 95% confidence intervals of the ICCs and the standard error of measurement (SEM) for all scapular and clavicular rotational positions at each humerothoracic elevation tested. Between day reliability was determined on a sample of 10 subjects.

A two-way repeated measures ANOVA was used to test the main effects for method, or for any interactions of positions of humerothoracic angle and method. In case of significant interactions, the effect of method was analyzed by follow-up Tukey-Kramer´s test. A $P < 0.05$ was considered significant.

RESULTS AND DISCUSSION

There was good to excellent intrarater reliability between repeated measurements for assessing clavicle elevation (ICC values from 0.88 to 0.93), scapular upward rotation (ICC values from 0.86 to 0.95) and scapular tilt (ICC values from 0.78 to 0.94) using the digital inclinometer in all testing positions of humeral elevation. ICC values were higher at 60° and 30° of humeral elevation for assessing clavicle elevation and scapular upward rotation, respectively. However, ICC values were higher as humeral elevation increased when assessing scapular tilt. SEM values ranged from 1.42° to 3.18° when the inclinometer was used to assess clavicle and scapular positions.

There was moderate to excellent between-day reliability depending on the variable assessed when using the digital inclinometer. ICC values ranged from 0.58 to 0.92 when assessing clavicle elevation, from 0.50 to 0.92 when assessing scapular upward rotation, and from 0.79 to 0.90 when assessing scapular tilt. Although good to excellent reliability was shown in mostly all testing positions of humeral elevation, moderate reliability was presented for clavicle elevation at 90° of arm elevation and scapular upward rotation when the arm was at 120° of elevation. SEM values ranged from 1.57° to 5.68°

For clavicle elevation, there was significant interaction between method and arm position ($p<0.05$). The inclinometer consistently measured decreased clavicular elevation when compared to the electromagnetic system across all testing positions of humeral elevation. The maximum difference (7.7°) between both methods was observed in the rest position.

For scapular upward rotation, there was significant interaction between method and arm position ($p<0.05$). However, the difference between both methods was less than 2° across all testing positions of humeral elevation.

For scapular tilt, there was no significant interaction between method and arm position ($p>0.05$). The least (0.16°) and largest (2.75°) differences between both methods were observed with the arm at 90° of elevation and in the rest position, respectively.

This study identifies the intrarater and between-day reliability of using the digital inclinometer to assess clavicle elevation and scapular upward rotation in different positions of humeral elevation (rest, 30°, 60°, 90° and 120°) in the sagittal plane under static conditions. No previous studies were regarding measuring clavicle elevation and scapular tilt with an inclinometer. Different studies have shown good to excellent intrarater reliability to assess scapular upward rotation with an inclinometer [5,6,8]. However, there are differences in the upward rotation means among the studies that may be explained by the different populations assessed. Borsa et al. [6] demonstrated that the between-session repeatability of a digital inclinometer to assess scapular upward rotation was poor to excellent depending on humeral elevation angle.

Despite the mean difference between both methods (electromagnetic system and inclinometer), these findings can also suggest that the 2 methods may measure similar changes in clavicle elevation, scapular upward rotation and tilt during humeral elevation in the sagittal plane.

CONCLUSIONS

The electromagnetic tracking system and the digital inclinometer are reliable device for measuring clavicular elevation and scapular upward and tilt during humeral elevation in the sagittal plane. Further, the inclinometer can measure alterations in clavicular and scapular positions over time.

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