MEASURING SCAPULA MOVEMENT WITH DIGITAL IMAGE CORRELATION

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INTRODUCTION

Non-invasive motion analysis techniques to monitor shoulder function have been developed using passive retro-reflective markers [1]. Accurate measurement of the kinematics of the scapula is problematic due to the presence of overlying skin [2]. In this study Digital Image Correlation (D.I.C.) has been used to track the movement of an applied surface pattern on the scapula during arm elevation. D.I.C. is a non-contact method of providing three-dimensional shape and deformation of a surface area. Two high-resolution digital video cameras are used to capture simultaneous images of a surface area as it undergoes motion. Successive susbsets of each image are matched in the two camera views. Each subset acts as a marker with a distinctive pattern that can be identified in the image by the other camera. By measuring the level of skin movement over the scapula during arm elevation, it is possible to infer the errors associated with skin artifacts in standard motion capture systems.

METHODS

Five male subjects (22.5±1.5 years) with no previous history of shoulder pathology or instability were assessed. Speckled face paint was applied to the scapula and surrounding area (Fig. 1a). Each camera was focused on the pattern and the subject's exact position marked. The system was then calibrated using a series of images of a calibration target (Fig. 1b) in different orientations. Once calibration was complete, the subject was re-seated in the same position as earlier. Each subject was instructed to raise both arms at a self determined "slow" pace in the coronal plane, with their hands supinated. Multiple images of the speckled area were taken simultaneously by the two cameras of the stereo-system during elevation. The elevations were then repeated statically at increments of 20° of an external reference frame using a scapula locator [3] fitted with retro-reflective markers to measure scapulothoracic (ST) rotations. The scapula locator is considered to be the "gold standard" of non-invasive scapula tracking [2].

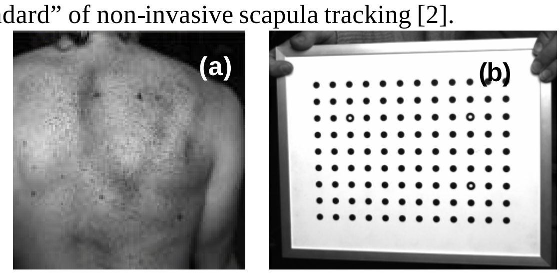

Fig. 1: (a) Speckled pattern applied to the skin over the scapula. (b) Calibration target for D.I.C. system.

RESULTS AND DISCUSSION

For each subject the area for analysis was manually selected from the initial rest image. All displacement analyses are with respect to this reference image. The correlation analysis was run using Vic-3D [4]. The shape, displacement and full-field strain of the region of interest were determined for each subject. The x and y axes are fitted by a least squares plane fit to the initial reference image. The z axis is perpendicular to the x-y plane pointing outwards. The z-displacement is shown in a 2D overlay plot in Fig. 2a and 2b and in 3D in Fig. 2c. The initial positions of the three scapula bony landmarks, the acromial angle (AA), the trigonum spinae (TS) and the angulus inferior (AI) were identified at the rest position (Fig. 2a) and were tracked throughout arm elevation (Fig. 2b).

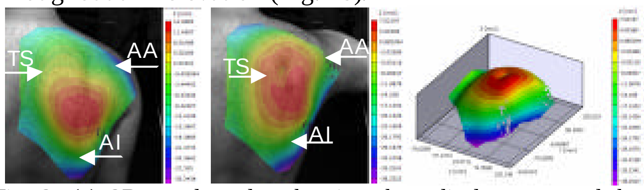

Fig. 2: (a) 2D overlay plot showing the z-displacement and the three scapula bony landmarks at rest, (b) 2D overlay plot showing the z-displacement and the three scapula bony landmarks at 90° arm elevation. AA is acromial angle, TS is trigonum spinae, AI is angulus inferior. (c) 3D plot showing the z-displacement at 90° arm elevation.

A multiple regression model was generated to compare the ST rotations measured with the scapula locator and the skin movement of the three scapula bony landmarks measured with D.I.C. and to determine the viability of predicting ST rotations by measuring skin movement.

Protraction:
4.918(TSx) - .785(TSy) + .972(TSz) – 1.739(AIx) + 3.978(AIy) -.775(AIz)

Lateral Rotation:
-.447(AAz) + .853(TSx) + .572(TSz) - .772(AIx) - .297(AIz)

Anterior (-)/ Posterior (+) Tilt:
2.246(AAx) + 1.528(AAy) + 1.701 (AAz) - .495(TSz)

AAx, AAy, AAz are displacements of the AA landmark in the x, y, z directions respectively, TSx, TSy, TSx are displacements of the TS landmark in the x, y, z directions respectively and AIx, AIy, AIz are displacements of the AI landmark in the x, y, z directions respectively. The strength of the correlations (protraction adjusted R^2=0.663, lateral rotation adjusted R^2=0.95, anterior/posterior tilt adjusted R^2=0.633) indicate that D.I.C. is potentially a very quick and accurate method of measuring scapula motion and accounting for errors due to skin artifacts in motion analysis of the upper limb. Further analysis will include correlation of the measured scapula rotations with the three-dimensional movement of the entire skin surface over the scapula.

REFERENCES

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