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Te Whare Wānanga o Tāmaki Makaurau

Quantifying Soft Tissue Artefacts on the Shoulder Complex Motion Using Biplanar Videoradiography

Ted Yeung[1] *Thor Besier[1,2]* *Joseph Crisco[3]* *Kumar Mithraratne[1]*

[1] Auckland Bioengineering Institute, University of Auckland, Auckland, New Zealand

[2] Department of Engineering Science, University of Auckland, Auckland, New Zealand

[3] Department of Orthopaedics, Warren Alpert Medical School of Brown University and Rhode Island Hospital, Providence, USA

Introduction

The shoulder complex consists of four skeletal bones with three articulations making it one of the most intricate joint systems in the human body.

This joint system is surrounded by a thick layer of soft tissue, which readily deforms during motion. Thus, tracking the motion of bony structures accurately using skin-mounted markers is difficult due to multiple bones with the complex shape and soft tissue artefacts as they violate rigid body assumptions. This problem is further complicated by the fact that the access to the palpable anatomical landmarks where markers can be placed is limited.

The aim of this study was to quantify soft tissue artefacts (STA) associated with the shoulder complex. The study employed two tracking modalities: (a) CT generated bone models and bi-planar videoradiography and (b) Conventional six-camera optical motion capture (OMC) system with skin-mounted reflective markers.

Experiment

Five male subjects (29.6 ± 7.8 yrs) with no history of shoulder injuries were selected for the study. In order to reconstruct the motion of the skeletal bones, subject specific bone models (polygonal mesh) were generated from computed tomography (CT) volume images.

This was then followed by standard OMC with skin-mounted markers and using X-Ray Reconstruction of Moving Morphology (XROMM) method (Brainerd et al.) for each task. Registration of the model and synchronisation of data from both system were carried out after data acquisition.

A six camera (Qualisys AB) motion capture system with passive infrared reflective markers were used as the OMC system (Figure 1). The subject was positioned on a backless desk chair between the image intensifier such that the shoulder was in view of the X-Ray Cameras. Both systems were sampled at 100Hz and synchronized. The distance between the X-ray source and image intensifier was about 100 cm ± 5 cm and the angle between the image intensifier is set to 70.2° ± 1.3° (Figure 2).

Each subject was asked to perform the following five tasks plus a neutral pose (Figure 4): neutral pose, scapula plane elevation, flexion/extension, shoulder shrug, internal/external rotation and downward throw.

Methodology

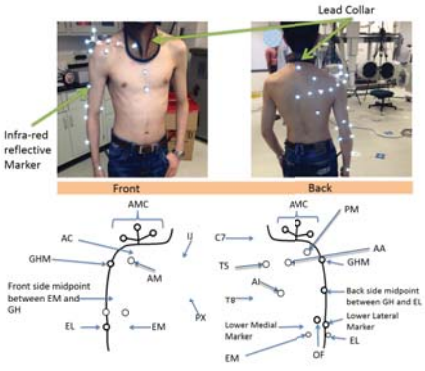

Figure 1: Marker Configuration

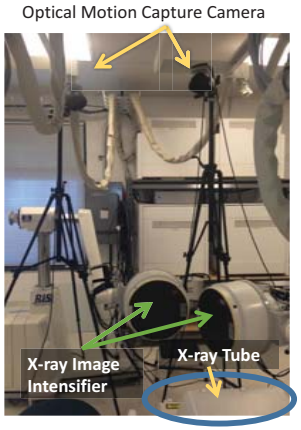

Figure 2: Experiment Setup

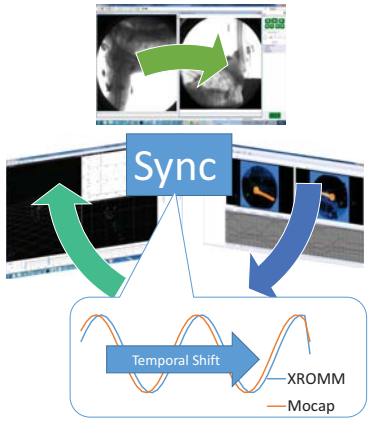

Figure 3: Workflow and synchronisation

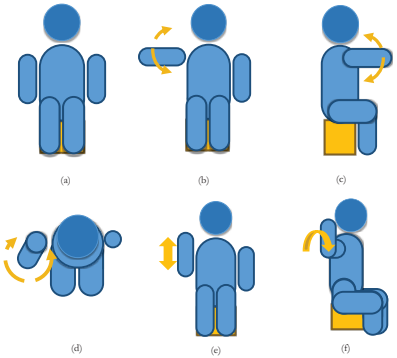

Figure 4 - Subject's Tasks: a) neutral pose, b) scapula plane elevation, c) flexion/extension, d) shoulder shrug, e) internal/external rotation and f) downward throw.

Results

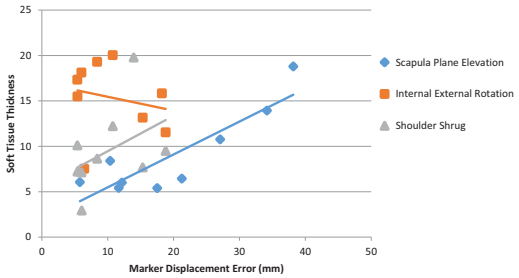

Figure 5: Soft tissue thickness Influence on Marker Displacement Error

Table 1: Average displacement errors (mm) for humerus and scapula with standard deviation in brackets

Humerus			
Subject	Scapular Plane Elevation	Internal/External Rotation	Shoulder Shrug
XSHD00001	8.7 (±4.3)	18.2 (±11.8)	4.4 (±2.3)
XSHD00002	27.2 (±8.6)	25.6 (±10.7)	10.5 (4.9)
XSHD00005	25.0 (±13.1)	15.7 (±5.3)	14.6 (±4.7)
Scapula			
Subject	Scapular Plane Elevation	Internal/External Rotation	Shoulder Shrug
XSHD00001	12.5 (±7.8)	6 (±3.3)	6.8 (±4.7)
XSHD00002	13.4 (±4.6)	10.2 (±4.6)	13 (±5.2)
XSHD00005	23.1 (±14.3)	7.1 (±2.0)	19.2 (±7.7)

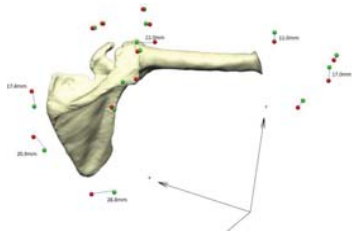

Figure 6: Error due to soft tissue artefacts for XSHD00001 at various marker locations of the humerus and scapula for scapula plane elevation. Green – actual position from XROMM: Red – position from motion capture system : Average error over the humerus and scapula are 8.7 ±4.3 mm and 12.5 ±7.8 mm respectively.

Table 2: Correlation between Soft Tissue and Soft Tissue Thickness of the scapula

Task	Scapula Plane Elevation	Internal External Rotation	Shoulder Shrug
Correlation	0.87	-0.21	0.42

Table 3: Soft Tissue Thickness (mm) covering the scapula

Subject	TS	AA	AI	AC
XSHD00001	15.32	6.06	6.44	5.42
XSHD00002	18.23	6.01	13.94	5.4
XSHD00005	21.9	8.4	18.8	10.77

Conclusion

The error between marker location from OMC and that predicted from XOMM is task dependent (Table 1). For example, scapula plane elevation showed a strong correlation between STT and displacement error (Figure 5, Table 2). These locations also represent muscle attachment sites and hence could have minimised tissue movements. Markers such as TS, AA and AMC located along the spine of the scapula showed low errors (see Figure 6). These locations also represent muscle attachment sites and hence could have reduced soft tissue movement.

In summary, our results also show that anatomical landmarks on the infraspinous fossa such as AI have high error, which indicates that the soft tissue at that particular location undergo significant deformation. In these cases, the landmarks will not be suitable for accurate capture of scapula motion.

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