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DEVELOPMENT OF A SUBJECT-SPECIFIC MUSCULOSKELETAL SHOULDER MODEL BASED ON INTRACORTICAL BONES PIN KINEMATICS TO EVALUATE SPORT AND DAILY LIFE ACTIVITIES

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INTRODUCTION

The reconstruction of shoulder kinematics from skin marker-based motion capture is known to be affected by significant error caused by soft tissue artifacts (STA) [1]. Inaccuracy in the shoulder kinematics limits certain applications of musculoskeletal models, especially those related to the scapulohumeral rhythm or the impingement due to the glenohumeral translation.

We were able to base this study on markers placed on intra-cortical bone pins obtained from a previous study [2], resulting in joint kinematics without the influence of STA. Such data are rare due to the invasiveness of pin implementation.

The objective of this study was to develop a subject-specific shoulder models for sport and daily life activity analysis using the kinematics data obtained from previous intracortical bone pin data collections. In addition, we constructed a second model, which is driven by skin markers exclusively. We compared resulting joint angles between both models. In this paper we aim to show preliminary results for one sport activity: throwing a ball and one daily life activity: reaching a back pocket.

METHODS

Experimental data

Both models represented one healthy male subject (177cm, 82kg). The intra-cortical bone pins were inserted on the humerus, on the scapula and on the clavicle. In addition, 26 skin markers were attached to the thorax, clavicle, scapula and humerus. The subject performed full range-of-motion movements, six activities of daily living, and five sports activities, which gives in total 20 trials. A full description of the experimental data collection is presented in the study of Dal Maso, et al [2].

Model development

A large-scale musculoskeletal shoulder model was previously developed using the AnyBody Modelling System (AnyBody Technology, Aalborg, DK). The model contains sternoclavicular (3-dof), acromioclavicular (3-dof) and glenohumeral (3-dof) joints. The pelvis segment was rigidly connected to the thorax. Left clavicle, humerus and scapula segments were morphed to match a subject-specific geometry using reconstructed CT-scans. As CT-scans of the humerus bone were incomplete distally, skin markers located on epicondyles were used to scale the humerus length. In the pin-based model, the position and the orientation of clavicle, scapula and humerus segments were determined from markers located on intra-cortical bone pins using inverse kinematics. Four markers were located on the pin attached to the clavicle, four on the scapula pin and five on the humerus pin. These markers were manually selected on the reconstructed pins from CT-scans, and their position on the model was found using registration transformation, determined from the bone morphing process. This operation allowed accurate identification of pin markers' position without the need for optimization. In the skin marker-based model, we used skin markers exclusively. Six markers were used to drive the clavicle segment, eight - the scapula and five - the humerus. The position of these markers were optimized during a standing trial together with fixed pin markers (Fig. 1). Six skin markers were located on the thorax segment in both models. No markers were placed on hand, ulna and radius segments to avoid STA that would derive from these markers. Instead, elbow and wrist joints were locked in an extended position. In the weighted least-squares optimization problem used to reconstruct the model kinematics, the weight of 10 was set for pins markers while the weight of 1 was set for skin markers [3]. We calculated the root mean square deviation (RMSD) of joint angles between both models for simulations of two movements: reaching a back pocket and throwing a ball.

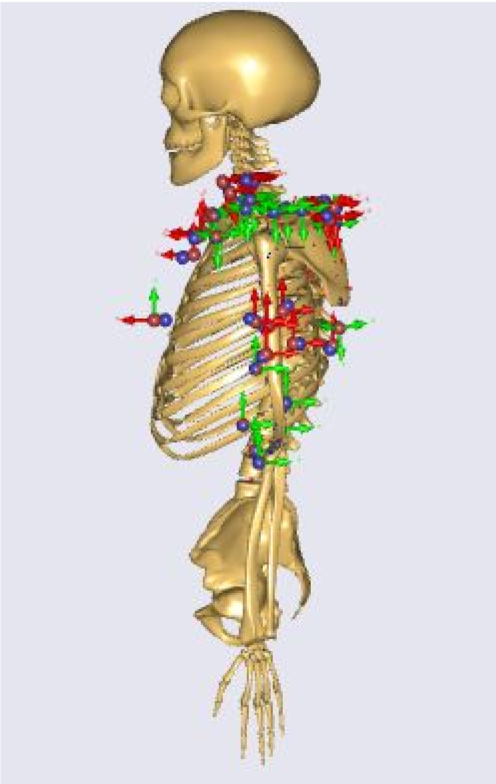

Fig 1: The model of the left shoulder during standing position with full set of markers. Red arrows show directions in which the markers position was locked while the green ones show direction in which the markers position was optimized.

RESULTS AND DISCUSSION

RMSDs of each joint angle are shown in Table 1. Mean RMSD of joint angles was higher for throwing a ball than for reaching a back pocket (9.24° vs 6.98°). The lowest RMSD in reaching a back pocket trial was observed for the glenohumeral abduction (1.73°) while the highest for the glenohumeral external rotation (15.73°). In throwing a ball trial for the sternoclavicular elevation (2.33°) and for the acromioclavicular medial rotation (19.80°) respectively. The glenohumeral abduction angles for throwing a ball and reaching a back pocket movements are shown on the Fig. 2.

Resulting kinematics and kinetics data from the pin-marker driven model will be used in further studies on the scapulohumeral rhythm, the scapulothoracic connection modelling and the joint stability determined by the glenohumeral translation.

Table 1. RMSDs [deg] between pin marker-driven model and skin marker-driven model for each joint angle.

	Pocket reaching	**Ball throw**
ACMedRot	13.12	19.80
ACPostTilt	10.81	11.91
ACProtraction	2.20	3.50
SCAxialRot	9.55	8.39
SCElevation	3.84	16.50
SCProtraction	2.51	4.31
GHAbduction	1.73	2.33
GHFlexion	3.30	3.82
GHExtRot	6.98	12.65

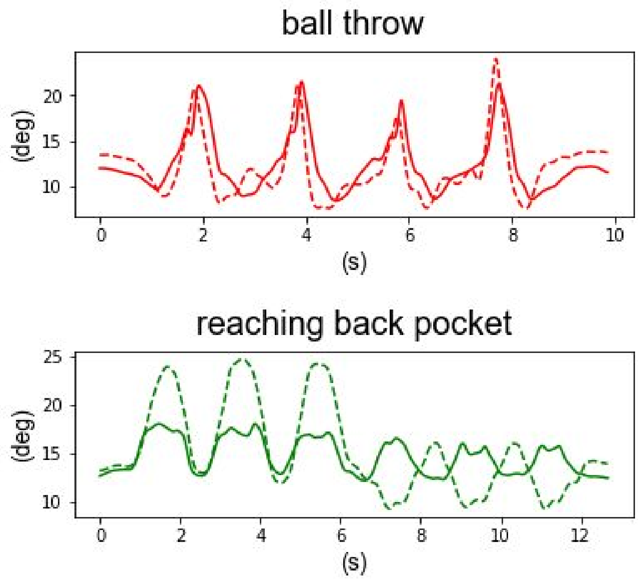

Fig 2: The glenohumeral abduction joint angles calculated by pin marker-driven model (solid line) and skin marker-driven model (dash line) for 1) throwing a ball and 2) reaching a back pocket movements.

CONCLUSIONS

We presented a framework to develop a subject-specific intra-cortical bones pin driven musculoskeletal model of the shoulder. Additionally, we compared a resulting join angles from this model with a model that is driven by skin markers exclusively. The pin marker-driven model has an advantage over skin marker-driven models because it is not affected by the STA, and therefore presents several options for investigation of detailed shoulder kinematics. The presented model is still under development.

REFERENCES

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