AN OPEN-SOURCE SUBJECT-SPECIFIC MUSCULOSKELETAL SHOULDER MODEL

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INTRODUCTION

Professionals that are interested in human movement, like biomechanics scientists and physiotherapists, have seen an increase in the tool capabilities that can help them analyze a wide spectrum of human movement characteristics. Along with the actual technological development, the existence of projects that result in open-source platforms for modelling, simulating and analyzing the neuromusculoskeletal system [1], is a real contribute for those to whom the interpretation of human movement is a daily challenge. In order that a musculoskeletal model might correctly describe and predict a subject biomechanical behaviour, it should be as scaled as possible to the subject anatomical specificities. A simple proportional scaling of a biomechanical model would probably lead to misrepresentation of a subject specific reality, in the geometric shape of the segments, as in the attachment locations of their muscles. This misrepresentation may contribute to an inaccuracy of the calculation of force and moment-generating capacities of a muscle. The aim of this work was to develop a shoulder model that could be scalable to any given subject.

METHODS

A musculoskeletal shoulder model was created using OpenSim software system [1]. This model includes a graphical representation of the thorax, clavicle, scapula, humerus, radius and ulna. The model has five joints (sternoclavicular, acromioclavicular, scapulothoracic, glenohumeral and elbow), sixteen muscle-tendon actuators and four sets of ligaments (coraco-clavicular, costo-clavicular, sterno-clavicular and gleno-humeral). The scapulothoracic joint is defined by a gliding plane on the surface of an ellipsoid that is fitted to the thorax dimensions of the subject. The scapula moves on the surface of this ellipsoid with 3 degrees of freedom. All joint axes, local coordinate systems definitions and kinematics descriptions are made according to [2]. For landmarks, joint rotation centers, muscle and ligament attachment locations, the base dataset of seven cadavers (known as the VU-study 1988-1996) provided by the Dutch shoulder group web page (www.fbw.vu.nl/research/Lijn_A4/shoulder/overview.htm) was used [3]. In order to scale the model to a specific subject two steps are required: a dimensional scaling; and the scaling of the muscle and ligament attachment locations. The first is computed by scale factors that are obtained by comparing distances between markers on the model and experimental marker positions of the subject. The second step is accomplished using a linear transformation method that allows the scaling of a muscle and ligament attachment locations dataset to any given subject [4]. The model is able to compute, both kinematics and dynamic analysis. To address the repercussions of this scaling procedure on the model calculations, teres minor (TMi) moment arms was estimated at 30º and 60º of glenohumeral elevation in the scapular plane, with 0º axial rotation.

RESULTS AND DISCUSSION

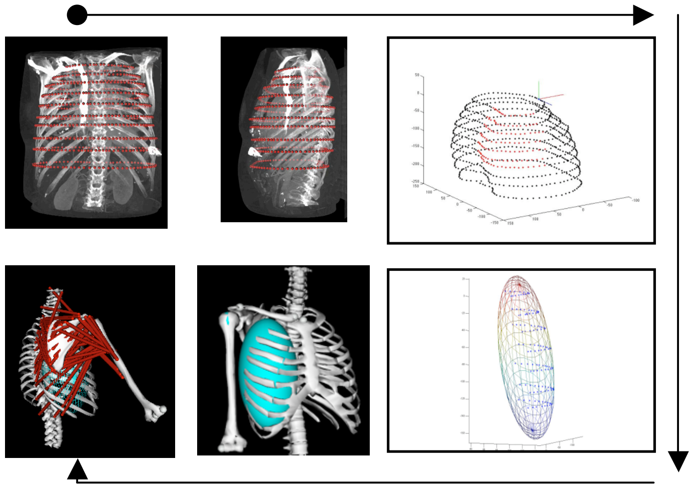

Figure 1: Shoulder model (without radius and ulna) using image data to scale the thorax dimensions as an example.

With this work we were able to produce a musculoskeletal shoulder model that is completely scalable, both in segment dimensions, as in the location of the muscle and ligament attachment locations. This procedure relies on a fully automated process that has as input the coordinates of the palpable landmarks and experimental markers used during the kinematics recordings according to [2], and as output the scaled model. After applying the scaling procedure the resulting moment arms of TMi were seen to be inside the interval of the moment arms found in the literature. This model will be freely available as soon as its validation will allow it.

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