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Tracking the scapula motion through multibody kinematics optimisation to study manual wheelchair propulsion

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KEYWORDS Shoulder; kinematic chain; scapulothoracic; wheelchair; sequential kinematics

1. Introduction

Propelling a manual wheelchair (MWC) is a strenuous form of locomotion for the musculoskeletal system resulting in 30 to 70 % of the MWC users suffering from musculoskeletal disorders, particularly at the shoulder complex. Consequently, studying its biomechanics with non-invasive techniques is a major concern. Studying its kinematic is the first step for further analysis. Yet, this is a challenging task because soft tissue artefact (STA) especially occurs over the scapula. Sequential kinematics of the scapula can be assessed by means of a scapula locator (SCL) placed on the scapula in several static poses. Using this technique, some authors showed that scapula exhibited a non-negligible motion during MWC propulsion (Koontz et al. 2004). However, this technique is difficult to use to follow continuous motion at real velocity. Nonetheless, multiple calibration methods (de Groot and Brand 2001), have been used in the scapula plane but they were not suitable for the study of MWC where the motion can occur in the three planes. Other authors reported the use of a technical cluster composed of three markers placed on the acromion or on the scapula spine. This technique seemed to be efficient for tracking the scapula orientation but failed for the translation in segmental optimisation, resulting in acromio-clavicular dislocation (Naaim et al. 2017). To avoid this phenomenon, some authors recommend the use of multibody kinematic optimisation (MKO) (Duprey et al. 2016), giving a key role to the kinematic chain model. Different models have been proposed for the shoulder complex joints, i.e. sternoclavicular (SC), scapulohumeral (ST), acromioclavicular (AC) and glenohumeral (GH) joints. But, none of these models were validated for the study of MWC propulsion.

The aim of the study was to evaluate the relevance of using a spinal marker cluster to track the scapula position through different kinematic chains with MKO to study manual wheelchair propulsion.

2. Methods

2.1. Experimental data

Ten able-bodied subjects were recruited for two or three motion capture sessions resulting in 23 data sets. Reflective markers were placed on the upper limbs and torso, and their 3D locations were recorded at 100 Hz using a 13-cameras optoelectronic motion capture system (Vicon System, © Oxford Metrics Inc., UK). Specifically, a marker cluster was placed on the scapula spine. Each data-set was composed of 4 sequential kinematics acquisitions corresponding to: beginning of the push phase (BPP), hand at top of the handrim (HTH), end of push phase (EPP), and another acquisition with an arm elevation at 30° in the scapula plane (EVS). During each acquisition, an experimenter placed a SCL based on three palpated anatomical landmarks: Angulus Acromialis (AA), Trigonum Scapulae and Margo Medialis.

2.2. Musculoskeletal models

Three 3D linked-segment models of the upper limbs were used and their respective degrees of freedom (DoF) are reported in Table 1. The models included hand, forearm bones, humerus, clavicle, scapula and thorax.

The first model was derived from Holzbaur’s model geometries (Holzbaur et al. 2005) with free clavicles and scapulae. The second model was adapted also from the Holzbaur’s model, which presented a regression motion equation allowing the scapula to move with respect to the humerus orientation. The third one was derived from the generic scapulothoracic joint model where the scapula can glide along a contact ellipsoid (Seth et al. 2016).

These models, which shared the same initial geometry and markers placement, were scaled to each subject anthropology with the algorithm implemented in the OpenSim software (Delp et al. 2007), and the location of the AC
4. Conclusions

The musculoskeletal models with an ellipsoid joint appear to be more efficient to track the scapula motion with a spinal cluster through MKO to study MWC propulsion. However, further research for the personalisation of the kinematic chain remains to be performed.

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