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Measurement of scapular dyskinesis using wireless inertial and magnetic sensors: Importance of scapula calibration

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ABSTRACT

Measurement of 3D scapular kinematics is meaningful in patients with shoulder pathologies showing scapular dyskinesis. This study evaluates the effect of single and double anatomical calibration (0° and 120°) with a scapula locator compared to standard calibration (using sensor alignment with the spina scapulae and static upright posture, ISEO-protocol) on 3D scapular kinematics measured with an inertial and magnetic measurement system (IMMS).

Ten patients with scapular dyskinesis performed humeral anteflexion and abduction movements while 3D scapular kinematics were measured using IMMS sensors. The sensor on the scapula was anatomically calibrated (i) according to the ISEO-protocol, (ii) using single scapula locator calibration (0°) and (iii) double scapula locator calibration (0° and 120°). For calibration, the scapula locator (with IMMS) was positioned on the scapula, while holding the humerus at several anteflexion and abduction postures.

Single and double calibration resulted in a significant increase of scapular anterior tilt (14–30°) with respect to the skin-fixed sensor (ISEO). Protraction angles were not significantly different. During anteflexion, double calibration did not show a significant increase in lateral rotation compared to single calibration. During abduction of $>90°$, double calibration showed 10–14° increased lateral rotation with respect to single calibration, although this was not significant ($P>0.06$).

Calibration with a scapula locator when applying IMMS is necessary, because measures of scapular anterior tilt are grossly underestimated with the ISEO-protocol. For shoulder movements that exceed 90° elevation, a double calibration prevents small but relevant underestimation of lateral rotation angles of the scapula.

1. Introduction

Measurement of 3D scapular kinematics is particularly meaningful in patients with shoulder pathologies showing scapular dyskinesis (Kibler et al., 2009; Kibler and Sciascia, 2010; Ludewig and Reynolds, 2009; McClure et al., 2009; Tate et al., 2009; van den Noort et al., 2014). Scapular dyskinesis is defined as a posterior displacement of the scapular medial border and/or inferior angle away from the thorax (winging) or a dysrhythmia of the scapular motion, such as premature or excessive elevation or protraction during arm elevation, a rapid medial rotation during arm lowering, or a non-smooth motion during arm elevation or lowering (McClure et al., 2009). Such alterations have been observed in e.g. shoulder instability, rotator cuff injury and impingement syndrome (De Baets et al., 2013; Lukasiewicz et al., 1999; McClure et al., 2006; Roren et al., 2013; Struyf et al., 2011; Warner et al., 1992).

Wireless sensors of an inertial and magnetic measurement system (IMMS) are suitable to conveniently measure the 3D kinematics of the scapula. A few studies evaluated the intra- and inter-observer reliability and precision of such a system in healthy subjects (Cutti et al., 2008; Parel et al., 2014, 2012; van den Noort et al., 2014). Technical dynamic accuracy of IMMS sensors used in the latter study is reported to be around 2° (Xsens Technologies B. V., 2011). Standard errors of measurement (SEM) of IMMS in scapular kinematic measurement were found to be within 5° for both intra-and inter-observer data of medio/lateral rotation, anterior/posterior tilt and for intra-observer data of scapular re/protraction (van den Noort et al., 2014). Inter-observer data of re/

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