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Short communication

Accuracy and repeatability of joint angles measured using a single camera markerless motion capture system

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ABSTRACT

Markerless motion capture systems have developed in an effort to evaluate human movement in a natural setting. However, the accuracy and reliability of these systems remain understudied. Therefore, the goals of this study were to quantify the accuracy and repeatability of joint angles using a single camera markerless motion capture system and to compare the markerless system performance with that of a marker-based system. A jig was placed in multiple static postures with marker trajectories collected using a ten camera motion analysis system. Depth and color image data were simultaneously collected from a single Microsoft Kinect camera, which was subsequently used to calculate virtual marker trajectories. A digital inclinometer provided a measure of ground-truth for sagittal and frontal plane joint angles. Joint angles were calculated with marker data from both motion capture systems using successive body-fixed rotations. The sagittal and frontal plane joint angles calculated from the marker-based and markerless system agreed with inclinometer measurements by $< 0.5^\circ$. The systems agreed with each other by $< 0.5^\circ$ for sagittal and frontal plane joint angles and $< 2^\circ$ for transverse plane rotation. Both systems showed a coefficient of reliability $< 0.5^\circ$ for all angles. These results illustrate the feasibility of a single camera markerless motion capture system to accurately measure lower extremity kinematics and provide a first step in using this technology to discern clinically relevant differences in the joint kinematics of patient populations.

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1. Introduction

The use of marker-based motion capture technology has grown exponentially in both its use as a research tool and for clinical assessments, as evidenced by its widespread utilization (e.g. McGinley et al., 2009). However, there are a number of limitations inherent in the way that data are collected that preclude its use in some settings and environments. For instance, because of the need to use an array of cameras, marker-based motion capture is difficult to perform in settings such as a patient's home, on the sports field, or in public. One potential solution that has been suggested is to use a markerless motion capture system (Mundermann et al., 2006).

Markerless motion capture technology has shown promise to assess both gait and postural control (Clark et al., 2012, 2013; Corazza et al., 2006; Mentiplay et al., 2013; Stone and Skubic, 2011). The accuracy of marker-based systems has been analyzed

(Holden et al., 1997; Kiran et al., 2010; Miranda et al., 2013; Richards, 1999) whereas the accuracy of markerless motion capture techniques has not been studied as extensively. The accuracy of markerless systems has been assessed using marker-based measures as ground-truth (Clark et al., 2012, 2013; Mentiplay et al., 2013; Mundermann et al., 2005; Steele et al., 2009; Stone and Skubic, 2011). While providing important insights between the two systems, these studies do not provide information into whether the markerless systems were more or less accurate than the marker-based system. Other ground-truth measures have been used: a virtual walking model for lower-extremity kinematics (Corazza et al., 2006) and a landmark identification method for hand kinematics (Metcalf et al., 2013). However, an assessment of the accuracy of a single camera markerless motion capture system with a ground-truth measure and how this compares to traditional marker-based motion capture to measure lower extremity kinematics still remains understudied.

Repeatability of marker-based systems has also been extensively studied (Ferber et al., 2002; Leardini et al., 2007; McGinley et al., 2009; Miller et al., 2002; Schwartz et al., 2004; Vander Linden et al., 1992). By comparison there are few reports on markerless motion capture repeatability (Clark et al., 2012;

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