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The reliability and criterion validity of 2D video assessment of single leg squat and hop landing

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ABSTRACT

The objective was to assess the intra-tester, within and between day reliability of measurement of hip adduction (HADD) and frontal plane projection angles (FPPA) during single leg squat (SLS) and single leg landing (SLL) using 2D video and the validity of these measurements against those found during 3D motion capture. 15 healthy subjects had their SLS and SLL assessed using 3D motion capture and video analysis. Inter-tester reliability for both SLS and SLL when measuring FPPA and HADD show excellent correlations ($ICC_{2,1}$ 0.97–0.99). Within and between day assessment of SLS and SLL showed good to excellent correlations for both variables ($ICC_{3,1}$ 0.72–91). 2D FPPA measures were found to have good correlation with knee abduction angle in 3-D ($r = 0.79$, $p = 0.008$) during SLS, and also to knee abduction moment ($r = 0.65$, $p = 0.009$). 2D HADD showed very good correlation with 3D HADD during SLS ($r = 0.81$, $p = 0.001$), and a good correlation during SLL ($r = 0.62$, $p = 0.013$). All other associations were weak ($r < 0.4$). This study suggests that 2D video kinematics have a reasonable association to what is being measured with 3D motion capture.

1. Introduction

Three dimensional (3D) motion analysis has been used extensively to assess kinematic and kinetic variables during lower limb motion. It has been regarded as the 'gold standard' for the assessment of potentially high risk manoeuvres related to a variety of knee injuries (McLean et al., 2005). Although 3D motion capture is considered the gold standard for kinematic and kinetic analysis, it is frequently not used in the clinical environment or for pre-participation screening, possibly due to the time required to acquire and analyse the data, large cost of equipment, and the training needed to effectively use it. In the place of 3D motion capture, 2-dimensional (2D) video motion analysis has been used to quantify hip and knee kinematics (Munro et al., 2012). 2D motion capture though has an inherent limitation as it cannot measure kinematics that occurs in planes not perpendicular to the camera without potential for perspective error. As such, 2D motion capture may not be suitable for performance assessment of any motion that is not purely uniplanar such as the knee valgus motion at the knee, which in reality is a movement not only comprising of knee abduction and hip adduction in the frontal plane but also hip internal rotation and tibial external rotation in the coronal plane (Malfait et al., 2014). The work of McLean et al. (2005) confirmed this noting that 2D knee valgus angles were inherently influenced by hip and knee joint rotations.

The extent to which non-uniplanar motions can be reflected in the uniplanar knee motion, measured with 2D video, has only been investigated in a limited number of studies. These studies have tested for a relationship between 2D measures of knee and hip motion and 3D hip and knee kinematics. For example, McLean et al. (2005) reported the relationship between 2D and 3D motion capture in assessing frontal-plane knee kinematics during side-stepping, side-jumping, and shuttle run. They reported strong correlations of $r = 0.76$ and 0.80 between peak knee abduction angles during 2D and 3D motion capture for side-stepping and side-jumping, respectively; however, the shuttle run yielded a much lower relationship of just $r = 0.20$. Sorenson et al. (2015) found a strong relationship between 2D frontal plane projection angle (knee abduction angle) and 3D knee abduction angle ($R^2 = 0.72$), and between 2D hip adduction and 3D hip adduction ($R^2 = 0.52$) during single leg hop landings. Gwynne and Curran (2014) found FPPA to correlate strongly with 3D knee abduction angle during single leg squat ($r = 0.78$). The study of Willson and Davis (2008)

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found 2D knee abduction angle reflected 23–30% of the variance of 3-D kinematic measurements during single leg squat, and also found knee abduction angle to be significantly correlated with hip adduction ($r = 0.32$). However, none of these studies have looked at the relationship of 2D frontal plane measures to movements in other planes, or the external moments generated at the hip and knee.

There are currently only a limited number of publications which have reported reliability of 2D FPPA for both single leg squat and single leg landing (Gwynne and Curran, 2014; Munro et al., 2012). There would appear to be no studies which have reported on reliability of the 2D video measurement of hip adduction angle during these tasks.

The overall aim of the study was to assess the reliability and validity of 2D kinematic video analysis of single leg squat and single leg landing, specifically: to assess the intra-tester and within and between day reliability of measurement of hip adduction and frontal plane projection angles during SLS and SLL using 2D video; and to assess the validity of these measurements against those found during 3D motion capture. The three hypotheses which will be tested by this study are: that 2D video parameters will have validity when compared to equivalent 3D parameters; 2D parameters measured will show strong between individual and within and between session reliability.

2. Method

2.1. Participants

Fifteen physically active healthy participants, after giving informed consent, volunteered to participate in this study which was approved by the university research ethics committee. Participants had to be free from lower limb or spinal injury or history of injury to participate in the study. Participant's details are to be found in Table 1.

2.2. Procedures

2.2.1. Single leg squat (SLS)

Participants were asked to stand on the test limb, facing the video camera. They were asked to squat down as far as possible, to at least 45° knee flexion, over a period of 5 s. Knee-flexion angle was checked during practice trials using a standard goniometer (Gaiam-Pro), and then observed by the same examiner throughout the trials. There was also a counter for each participant over this 5-s period, in which the first count initiates the movement, the third indicates the lowest point of the squat and the fifth indicates the end. This standardises the test for the participant, thereby reducing the effect of velocity on knee angles. Trials were only accepted if the participant squatted to the minimum desired degree of knee flexion and maintained balance throughout.

2.2.2. Single-leg landing (SLL)

Participants dropped from a 28-cm step, leaning forward and dropping as vertically as possible. They were asked to take a unilateral stance on the ipsilateral limb and to hop forward to drop onto the force platform, ensuring that the contralateral leg made no contact with the ground on landing.

Table 1
Participant demographics.

Characteristic	Gender	
	Males (N = 8)	Females (N = 7)
Age (years)	25.0 (±6.4)	26.6 (±3.5)
Height (cm)	171.0 (±6.7)	163.0 (±5.4)
Mass (kg)	69.7 (±10.7)	63.0 (±8.0)

2.2.3. 3D motion capture

The method is based on the procedure previously reported in Alenezi et al. (2014). A ten-camera motion analysis system (ProReflex, Qualisys, Sweden), sampling at 240 Hz, and a force platform embedded into the floor (AMTI, USA), sampling at 1200 Hz, were used to collect kinematic and kinetic variables during the support phase of single leg squat and landing tasks. Before testing, participants were fitted with the standard training shoes (New Balance, UK) to control shoe-surface interface. Reflective markers (14 mm) were attached with self-adhesive tape to the participants' lower extremities over the following landmarks; anterior superior iliac spines, posterior superior iliac spines, iliac crest, greater trochanters, medial and lateral femoral condyles, medial and lateral malleoli, posterior calcanei, and the head of the first, second and fifth metatarsals (Fig. 1). The tracking markers were mounted on technical clusters on the thigh and shank with elastic bands. The foot markers were placed on the shoes, and the same individual placed the markers for all participants. The calibration anatomical systems technique (CAST) was employed to determine the six-degree of freedom movement of each segment and anatomical significance during the movement trials. The static trial position was designated as the participants' neutral (anatomical zero) alignment, and subsequent kinematic measures were related back to this position. The markers were removed and replaced for the within-session trials and removed and replaced for the between-day trials. To orientate participants with the tasks, each participant was asked to perform 3–5 practice trials of each task before data collection. Participants were required to complete five successful trials for each task. Visual 3D motion (Version 4.21, C-Motion Inc., USA) was used to calculate the joint kinematic and kinetic data. Motion and force plate data were filtered using a Butterworth 4th order bi-directional low-pass filter with cut-off frequencies of 12 Hz and 25 Hz, respectively, with the cut-off frequencies based

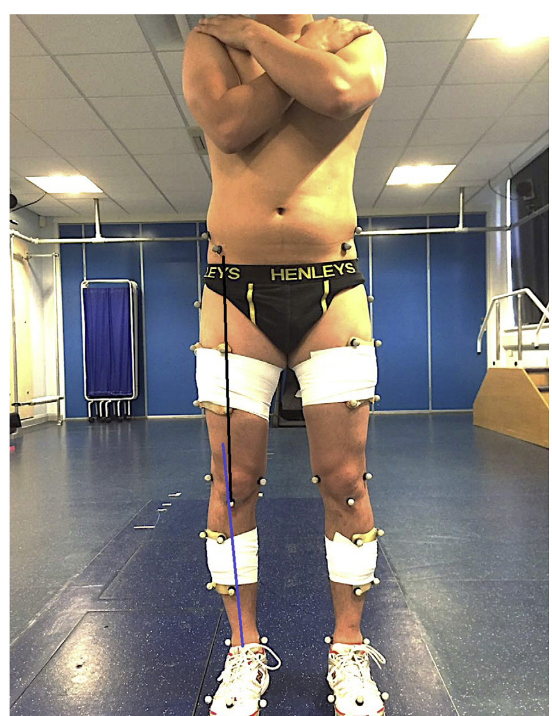

Fig. 1. Marker position and lines used for calculation of FPPA.