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How reliable are knee kinematics and kinetics during side-cutting manoeuvres?

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ABSTRACT

Introduction: Side-cutting tasks are commonly used in dynamic assessment of ACL injury risk, but only limited information is available concerning the reliability of knee loading parameters. The aim of this study was to investigate the reliability of side-cutting data with additional focus on modelling approaches and task execution variables.

Methods: Each subject ($n = 8$) attended six testing sessions conducted by two observers. Kinematic and kinetic data of 45° side-cutting tasks was collected. Inter-trial, inter-session, inter-observer variability and observer/trial ratios were calculated at every time-point of normalised stance, for data derived from two modelling approaches. Variation in task execution variables was regressed against that of temporal profiles of relevant knee data using one-dimensional statistical parametric mapping.

Results: Variability in knee kinematics was consistently low across the time-series waveform (≤5°), but knee kinetic variability was high (31.8, 24.1 and 16.9 Nm for sagittal, frontal and transverse planes, respectively) in the weight acceptance phase of the side-cutting task. Calculations conveyed consistently moderate-to-good measurement reliability. Inverse kinematic modelling reduced the variability in sagittal (~6 Nm) and frontal planes (~10 Nm) compared to direct kinematic modelling. Variation in task execution variables did not explain any knee data variability.

Conclusion: Side-cutting data appears to be reliably measured, however high knee moment variability exhibited in all planes, particularly in the early stance phase, suggests cautious interpretation towards ACL injury mechanics. Such variability may be inherent to the dynamic nature of the side-cutting task or experimental issues not yet known.

1. Introduction

The occurrence of non-contact lower-limb injury in sports that involve dynamic sporting tasks is a substantial burden on clubs and their players, both financially and in terms of playing time [1,2]. Attempts to explore the mechanics of knee ligament injury, particularly of the anterior cruciate ligament (ACL), are well documented and frequently involve the estimation of knee kinematics and kinetics during side-cutting tasks [3–8]. Side-cutting is commonly used as it challenges the knee in a manner that is consistent with the reported ACL injury mechanism [9], and therefore could be important to assess ACL injury risk. Thus, it is important to know the reliability of side-cutting data, as well as the variability within typical protocols so that appropriate limits for detectable differences can be established, and the correct interpretation of injury risk made.

Limited information concerning the reliability of side-cutting data has been presented. The chosen analysis methods are varied and include average intra-class correlation coefficients (ICC) [4,10], coefficients of multiple correlations (CMC) [11,12], and coefficients of multiple determinations (R^2) [13]. As well as different quantification methods, different components of reliability have been observed. Besier et al. [13] reported within and between session reliability for various tasks and found that, of their side-cutting tasks (30° and 60°), transverse knee moments displayed the

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lowest reliability *within-session* (average $R^2 = 0.84 \pm 0.09$), and sagittal knee moments displayed the reliability *between-sessions* (average $R^2 = 0.89 \pm 0.04$). Sigward and Powers [11,12] reported *between-session* reliability and found frontal and transverse plane kinematics (CMC = 0.63 and 0.61, respectively) to be less reliable than frontal and transverse plane kinetics (CMC = 0.90 and 0.93, respectively). Although this reliability evidence exists, they lack a number of facets that are important for clinical inference. Firstly, previous studies failed to consider *between-observer* reliability which is crucial to assess results across laboratories or in clinical practice. Secondly, these methods summarise reliability by either considering discrete time points (e.g. peak values) or collapsing the entire time series (e.g. CMC calculates average reliability over time). Therefore information about whether reliability is evenly distributed across different phases of the side-cutting manoeuvre is unknown. Thirdly, the summary reliability statistics are not presented in the context of the original data, making it difficult to interpret the magnitude of reliability (e.g. ICC of 0.6 versus 0.7) in the context of the magnitude of the actual data signals. A comprehensive observation of side-cutting data reliability is therefore necessary.

We also take the opportunity to address (i) the reliability of the modelling approach as this can affect knee kinematics and kinetics [14] and (ii) the variability of the task itself. Firstly, different modelling approaches can be chosen to either allow or restrict joint rotations or translations and also attempt to reduce soft tissue artefact. In a recent comparison of the direct kinematic (DK) versus inverse kinematic (IK) modelling approaches [14], significantly larger peak knee abduction moments were found using the DK approach yet the reliability of two approaches are unknown. Secondly, as variability can also exist through variations in the execution of the side-cutting task itself, we quantify whether knee kinematic and kinetic variability can be explained through inherent variations in task execution. Such information will help to standardise modelling approaches and evaluate the importance of task execution.

The purpose of this study was to investigate the reliability of side-cutting data from an inter-trial, inter-session, and inter-observer perspective. This will be complemented by investigating the reliability of two modelling approaches (DK versus IK), and by examining the contribution of the side cutting task execution to the variability observed.

2. Methods

2.1. Participants

The participants for this study were eight recreationally active soccer players who had at least 6 years of playing experience and trained 1–2 times per week (four male; four female; age – 25.8 ± 4.4 years; mass – 64.8 ± 7.2 kg; height – 1.7 ± 0.1 m). All participants had no reported ACL injury and had been injury free for 6 months prior to data collection. All participants wore tight fitting shorts and standardised indoor footwear (Highroad). Females also wore a cropped vest, tight fitting base layer or sports bra. Ethical approval for this study was granted by the institutional ethics committee, and written consent was obtained from all participants.

2.2. Protocol

All participants engaged in a familiarisation session which included full replication of one session of the protocol. Prior to side-cutting, all participants completed a ten minute general warm-up. This was followed immediately by a 5 min specific warm-up. Participants nominated their preferred leg for side-cutting and this was standardised for the assessment. Approach speed was controlled using photocell timing gates (Brower Timing Systems, Utah, USA) which were placed 2 m apart, and 2 m from the force plates, where the side-cutting was performed. Cones were also placed 3 m from the force plates to mark a target gate at the required 45°. Trials were excluded if approach speed was not between 4 and 5 m s^{-1}, targeting of the force plate was observed, or if the subjects did not achieve the angle of 45° determined by running between the cones.

Data were collected by two different observers using a repeated measures design over six separate sessions; four on day one, and two on day two (Fig. 1). The observers were both PhD students and had been working with this biomechanical model for approximately 4 months previous, in both application and processing. The two observers conducted three sessions each; two each on day one, and one each on day two, with 48 h between day one and two. This allowed each participant to be tested by each observer, within and between days. A 10-min cool down session was conducted before a 15-min rest, and then the next session would start.

2.3. Data collection

All side-cutting was performed over a 0.9 × 0.6 m Kistler force platform (9287C, Kistler Instruments Ltd., Winterthur, Switzerland) sampling at 1500 Hz for the measurement of ground reaction forces. Simultaneous kinematic data was recorded in Qualisys Track Manager (Qualisys AB, Gothenburg, Sweden) using 10 optoelectronic cameras (Oqus 3, Qualisys AB, Gothenburg, Sweden) sampling at 250 Hz.

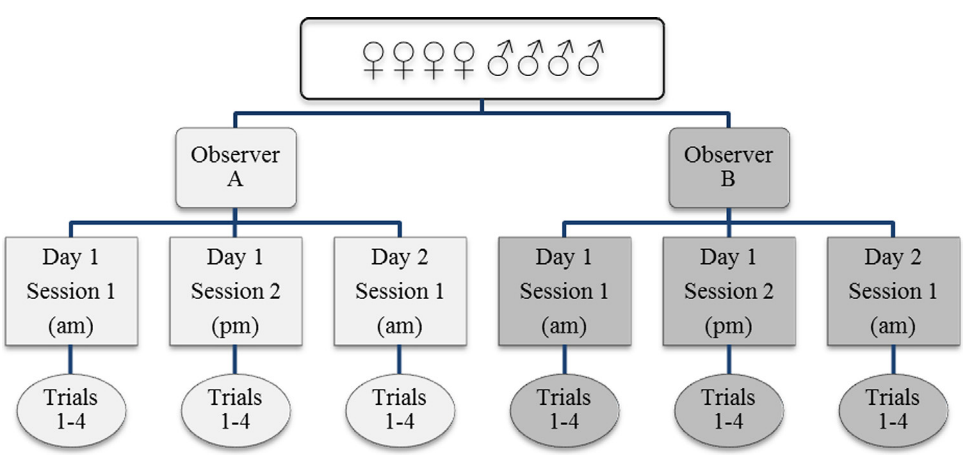

Fig. 1. Schematic representation of the repeated-measures experimental design, showing eight participants; two observers; six sessions; and trials per side-cutting direction.