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Can two-dimensional video analysis during single-leg drop vertical jumps help identify non-contact knee injury risk? A one-year prospective study

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A R T I C L E I N F O

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A B S T R A C T

Background: Previous studies showed that the amount of hip flexion and the combination of knee valgus and lateral trunk motion, measured with two-dimensional video analysis, were related to three-dimensional measured knee joint moments during single-leg drop vertical jumps, but it remains unclear whether these measurements can be used to identify non-contact knee injury risk.
Methods: Fifty injury-free female athletes participated in the study. Two-dimensional video analysis was used to measure hip flexion, knee valgus and lateral trunk motion angles during single-leg drop vertical jumps. Time loss non-contact knee injuries were registered during a one-year follow-up. Independent t-tests and receiver operating characteristic analysis were used to analyze the predictive ability of the two-dimensional angles.
Findings: Seven participants sustained a time loss non-contact knee injury. Hip flexion was not significantly different between groups ($P > .05$). The combination of knee valgus and lateral trunk motion was significantly smaller in the injured ($P = .036$) and non-injured legs ($P = .009$) of the future injured group compared with the respective matched leg of the non-injured group. The receiver operating characteristic analysis showed a significant discriminative accuracy between groups for the combination of knee valgus and lateral trunk motion of the uninjured leg of the future injured group with the matched leg of the non-injured group (area under curve = 0.803; $P = .012$).
Interpretation: The measurement of a combination of increased knee valgus and ipsilateral trunk motion during the single-leg drop vertical jump with two-dimensional video analysis can be used to help identify female athletes with increased non-contact knee injury risk.

1. Introduction

The majority of lower extremity injuries during sports involving running and jumping activities are located at the knee, especially in female athletes (de Loës et al., 2000; Taunton et al., 2002). Acute and overuse knee injuries occur with a 2- to 6-fold greater incidence in female compared to male athletes (Agel et al., 2005; Boling et al., 2010) and are typically caused by non-contact injury mechanisms (Agel et al., 2005; Powers, 2010). Given the high incidence and recurrence rates (Stathopulu & Baildam, 2003; Wright et al., 2011), prolonged absences from competitive sport and high socio-economical costs (de Loës et al., 2000; Mather et al., 2013), it is essential to identify modifiable risk factors to select those athletes at highest non-contact knee injury risk (Bahr & Krosshaug, 2005).

Based on cross-sectional studies relating different movement patterns with knee joint loading patterns (Huberti & Hayes, 1984; Jamison et al., 2012; McLean et al., 2005; Pollard et al., 2010), retrospective studies showing maladaptive movement patterns in pathological populations (Carry et al., 2010; Pappas et al., 2013), and prospective studies showing biomechanical deficiencies in those athletes who sustain knee injuries (Boling et al., 2009; Hewett et al., 2005; Myer et al., 2010; Noehren et al., 2013), there is increasing evidence that some particular movement and joint loading patterns are related to increased non-contact knee injury risk. More specifically, dynamic malalignment patterns consisting of increased ipsilateral trunk motion, pelvic drop, hip adduction and

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internal rotation, knee valgus (KV), tibial internal or external rotation and foot hyperpronation (Powers, 2010; Powers, 2003), in addition with decreased hip and knee flexion have been related to increased knee loading and subsequent increased non-contact knee injury risk (Aerts et al., 2013; Mendiguchia et al., 2011; Powers, 2010). These findings are supported by studies investigating the injury mechanisms of non-contact knee injuries (Boden et al., 2009; Hewett et al., 2009; Powers, 2010; Powers, 2003; Sheehan et al., 2012), as well as intervention studies showing improved clinical outcomes (Baldon et al., 2014; Noehren et al., 2011; Willy et al., 2012) and decreased injury risk (Sugimoto et al., 2012) with specific training programs focusing on improving movement patterns (Ter Stege et al., 2014).

The exploration of the relationships between movement patterns, knee loading and non-contact knee injury risk is mainly based on measurements executed in complex laboratory settings using three-dimensional motion analysis systems (Boling et al., 2009; Hewett et al., 2005; Myer et al., 2010; Noehren et al., 2013). Although this methodology is considered as the gold standard to perform biomechanical screenings, there is an increasing need to prospectively identify those athletes with highest injury risk with objective methodologies that are less expensive, less time consuming and easier to use and interpret in clinical settings. In this perspective, two-dimensional (2D) video analysis has been suggested as an alternative method to evaluate movement patterns throughout the entire kinetic chain. Using unipodal functional screening tests may help to achieve this goal, as the earlier mentioned dynamic multi-segmental malalignment patterns may become more apparent, especially at the trunk, as a result of the absence of the support of the contralateral leg and smaller base of support (Dingenen et al., 2013a). However, the majority of prospective studies focused on bipodal jump-landing tasks (Boling et al., 2009; Hewett et al., 2005; Myer et al., 2010), while most studies using 2D video analysis only measured KV angles to detect high risk lower limb biomechanics (Miller & Callister, 2009; Mizner et al., 2012; Munro et al., 2012; Stensrud et al., 2011; Willson & Davis, 2008). Given the increasing scientific support in literature of the mechanical interaction between multiple segments of the kinetic chain within multiple planes (Hewett & Myer, 2011; Mendiguchia et al., 2011; Powers, 2010), it was suggested that this simplified approach may lead to misinterpretations when assessing knee injury risk and prohibit the application of optimal interventions to reduce injury risk (DiCesare et al., 2014; Dingenen et al., 2015b; Dingenen et al., 2013a). In a more recent study, frontal plane trunk motion was therefore included during 2D video analysis of unipodal functional screening tests (Dingenen et al., 2013a). Hereby, the combination of increased 2D measured KV and lateral trunk motion (LTM) in the direction of the stance limb was found to be associated with an increased external peak knee abduction moment during the single leg drop vertical jump (SLDVJ) (Dingenen et al., 2013a). In the sagittal plane, the amount of hip flexion (HF) at the deepest landing position of this task was significantly related to the external knee and hip flexion moments during the time frames where peak joint moments occurred (Dingenen et al., 2015b). Based on the relations between 2D measured angles and 3D measured joint moments, it was suggested that 2D video analysis may help to identify those athletes at highest non-contact knee injury risk (Dingenen et al., 2015b; Dingenen et al., 2013a). However, no prospective studies using this methodology during a unipodal functional screening test such as the SLDVJ have been conducted to prove this assumption.

The purpose of this study was therefore to investigate prospectively whether 2D measured angles during the SLDVJ can help identify non-contact knee injury risk in a population of female athletes. Establishing this clinical highly relevant question may help to select those athletes with highest injury risk on larger scales, and enhance our understanding of the etiology of non-contact knee injuries to target specific interventions and decrease injury risk. We hypothesized that athletes with a combination of increased KV and LTM, and decreased HF during the deepest landing phase of the SLDVJ were more likely to sustain non-contact knee injuries.

2. Methods

2.1. Participants

A total of 50 elite female athletes (27 soccer, 7 handball and 16 volleyball) were included in this prospective study. All athletes were tested at the beginning of the season and were recruited from one soccer, one handball and one volleyball team of the highest national competition level, fully able to participate in training and matches and above 16 years old. To eliminate the influence of previous injuries on movement patterns and injury risk, exclusion criteria were a history of knee injuries, lower extremity surgery, recent lower extremity injury (within 3 months) and chronic ankle instability (based on the definition of at least 2 ankle sprains at the same ankle and the subjective feeling of "giving way" of the ankle) (Dingenen et al., 2013b). Appropriate ethical approval was granted by the local ethical committee prior to the commencement of the study. Before participating in the study, all participants read and signed the informed consent form.

2.2. Single-leg drop vertical jump

The following procedure is based on two previous studies (Dingenen et al., 2015b; Dingenen et al., 2013a). All participants wore a sports bra, tight-fitting shorts and standardized neutral indoor shoes (Kelme Indoor Copa). If necessary, long hair was tied up to avoid marker occlusion. Before the start of the tests, all participants executed a standardized warm-up program, consisting of a series of double-leg squats (2×8) and jumps (2×5) (Stensrud et al., 2011). All participants completed the SLDVJ. Participants were allowed to familiarize themselves with the tests by performing 3 practice repetitions before the start of the tests. The same researcher provided all specific instructions to each participant.

Participants were asked to drop off a box of 10 cm with one leg, followed by a maximum vertical jump on the same leg (Dingenen et al., 2015b; Dingenen et al., 2013a; Stensrud et al., 2011). Participants were instructed to jump as high as possible by attempting to reach an overhead target at an unobtainable height of 300 cm with both hands (Dingenen et al., 2015b). A trial was not valid if the participants jumped off the box instead of dropping, if the non-supporting leg touched the ground, if they reached with only one hand, or if they clearly lost balance or fell during the test (Dingenen et al., 2015b; Dingenen et al., 2013a; Stensrud et al., 2011).

The first three valid trials were selected based on the previously mentioned criteria and included for further analysis. Both the preferred and the non-preferred leg were tested. The preferred leg was defined as the preferred leg to kick a ball (Dingenen et al., 2015a). The leg that was tested first was determined randomly. Afterwards, body height and weight were measured using respectively a scale and a portable stadiometer (SECA, Hamburg, Germany).

2.3. Two-dimensional video analysis

The methodology was based on two previous studies (Dingenen et al., 2015b; Dingenen et al., 2013a) and is therefore described briefly. The SLDVJs were captured with 2 standard digital video cameras (Sony DCR-HC20E) sampling at a rate of 50 Hz. The cameras were placed on a tripod perpendicular to the frontal and sagittal plane, at a height of 60 cm and a distance of 3.5 m. The video recordings were analyzed using a commercial software package (Dartfish software 6.0, Fribourg, Switzerland). The deepest initial landing position of the SLDVJ was determined visually and was used to take a digital picture of each trial.

Reflective markers were placed on the acromioclavicular joint, manubrium sterni, anterior superior iliac spine (ASIS), trochanter major, medial and lateral femoral epicondyles and medial and lateral malleoli to assist manual digitization.