LANDING KINEMATICS AFTER A SPORT-SPECIFIC TASK IN TEAM HANDBALL

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Currently, screening for ACL injury risk is mostly conducted in a laboratory setting using a drop vertical jump. There remains a lack of knowledge on lower extremity kinematics and injury risk during sport-specific landing movements. Therefore the purpose of this study was to describe the landing kinematics of elite female handball players after a jump shot in a sport-specific field test. Players' 3D knee and trunk angles were measured using inertial sensors during landing from a jump shot. Average knee flexion at initial contact (IC) was 19.7° ± 5.9 and range of motion (ROM) was 26.2° ± 14.9. Significant between-player differences for all joint angles at IC and ROM were observed. As a variety of landing strategies were utilised, the question arises whether the drop vertical jump test in the lab setting is ecologically valid for identifying ACL injury risk in the field.

KEY WORDS: INJURY PREVENTION, INERTIAL SENSORS, FIELD TEST

INTRODUCTION: In team handball, an anterior cruciate ligament (ACL) injury often occurs during landing after a jump shot, especially with one leg (Koga et al., 2010; Olsen et al., 2004). As it is such a debilitating injury, ACL injury risk screening tools have been developed to quantify the injury risk during a drop vertical jump (Myer et al., 2011). These studies are often conducted in a laboratory setting with a motion analysis system or with high-speed cameras. Landing technique of a drop vertical jump is considered to be low risk when knee flexion range is greater than 45°, the knee is placed over the toe or has a Landing Error Scoring System (LESS) score lower than 5 (Padua et al., 2015). This LESS score is used for identifying potentially high risk movement patterns. Furthermore, after identifying whether athletes have a higher ACL injury risk (e.g. knee flexion range lower than 45° or LESS score higher than 5), studies with intervention programs evolved, based on these landing 'error' estimations. Intervention programs have focused on reducing this injury risk by instructing athletes to land more safely (Benjaminse et al., 2017). Data analyses using high speed video can be time consuming. More importantly, it is unknown whether drop vertical jump reflects landing after a jump shot in an applied sports environment. For this reason, as ACL injuries mainly occur in the field, it is important to describe landing technique during sport-specific tasks.

The development of inertial sensors may provide the opportunity to perform these measurements in the field. Previous research showed good reliability with an ICC being good to excellent (van der Straaten et al., 2019), and good concurrent validity of kinematics measured by an inertial sensor based Xsens MVN system against a high-speed camera method (Janssen et al., 2019). Results of Xsens compared to high-speed cameras demonstrated that Xsens overreported knee abduction excursion and most joint flexions. Nevertheless, as this system is portable, Xsens may be useful in the applied setting to identify ACL injury risk during handball. For this reason, the aim of this study was to investigate and describe the landing kinematics of elite female handball players in a sport-specific field test.

METHODS: Four elite female handball players (age: 18.5 ± 1.2 years; height: 173.4 ± 4.7 cm; mass: 67.0 ± 5.1 kg) participated in this study, with 2 left-handed and 2 right-handed players. Handedness was determined by asking players which hand they throw with. All players competed in handball at the highest national level, had no current injuries, and provided written informed consent. Each player wore the Xsens system (Awinda, 100Hz; Xsens technologies, Enschede, The Netherlands) composed of 8 inertial measurement units (IMUs), which demonstrated good reliability and validity compared to a high-speed camera method (Janssen et al., 2019; van der Straaten et al., 2019). The IMUs were positioned bilaterally on top of the feet, shanks, mid-thighs, and one on the pelvis and sternum. Each sensor integrated a tri-axial accelerometer (±160 m/s2), gyroscope (±2000 deg/s) and magnetometer (±1.9 Gauss). Player anthropometrics including body height, arm span, shoulder width, foot length, ankle height, knee height, hip height and hip width were collected for input into the Xsens MVN model. A static N-pose and dynamic walking trial were used to calibrate the position of the sensors and segment orientations. The protocol developed for this study was a combination of the protocols described by Dos'Santos et al. (2019) and Kristianslund et al (2014). In order to collect data on a sport-specific test, several elements were included, such as reaction and inhibition (Figure 1). Prior to data collection, each player conducted a ten minute warm-up followed by two familiarisation trials of the experimental task. Players performed eight trials of the experimental task with the instructions to complete the task as fast as possible (i.e. time pressure) while holding a ball. The first four trials were executed starting on the right side of the court, then four trials on the left side of the court. Completion time was registered using two sets of timing lights (Smartspeed, FusionSports, Brisbane, Australia) placed at hip height, and were used to randomly alight and buzz in order to let the player pass the dummy (Figure 1, D) left or right. For example, when the left timing light buzzed and alighted, players had to react by faking going to the right and then cut to the left. Of these four trials, players had to pass the dummy twice on the left and right side. Following the cut, the players had to perform a jump shot on goal. It was this jump shot that was used for landing kinematic analysis.

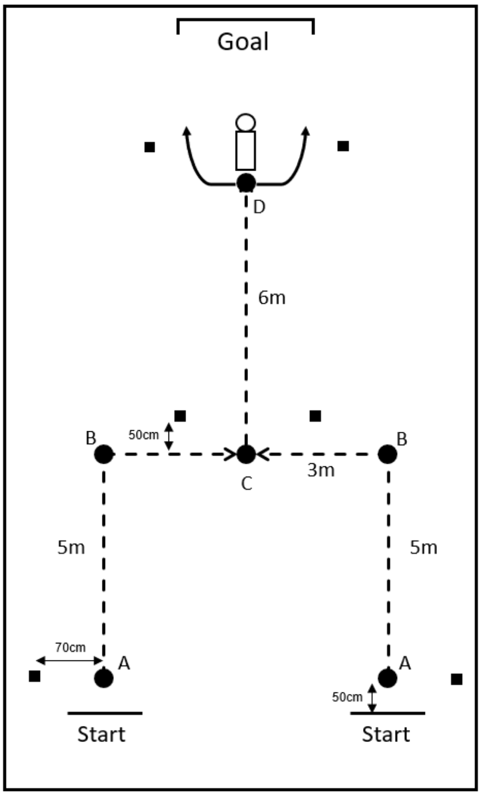

Figure 1. Experimental task set up: Players started at A (either left or ride side) and accelerated forward to turning point B. At turning point B, players decelerated and cut 90 degrees sideways with their face pointing to the goal towards point C. Players then accelerated forward to the dummy (D) and passed it either left or right, depending on the randomly lighting timing gate (■). Then a jump shot was performed.

Xsens data was collected at multilevel and was high-definition reprocessed using the MVN Analyze software (v.2019.1). Knee flexion, abduction and rotation angles at initial contact (IC) and peak values, as well as trunk rotation angles at IC and peak value after the jump shot were analysed. Consequently, range of motions (ROM) in all planes were calculated. IC was defined as the moment when the toe segment decelerated abruptly in the Z-axis, as visually inspected. Knee adduction, knee and trunk internal rotation were reported as positive values. Full extension of all joints were used as neutral, where greater knee flexion angles indicated that the knee was less flexed than smaller knee joint angles. Group and individual means as well as standard deviations were reported. In order to investigate possible between-player differences for all joint angles, a one-way ANOVA was performed (Microsoft Excel 2014). Significance was set at α<.05.

RESULTS: Table 1 shows the angles at IC, peak values and ROM of knee flexion, abduction and rotation, and trunk rotation. Average knee flexion at IC and ROM were 19.7° ± 5.9 and 26.2° ± 14.9 respectively. Average knee adduction angles at IC was 0.7° ± 2.4 and ROM was 0.6° ± 5.9. Significant between-player differences for all joint angles at IC and ROM were observed. Furthermore, significant between-player differences for peak knee flexion (F=22.26, p<.001) and peak trunk rotation (F=7.51, p<.001) were shown. Between-player differences for peak knee abduction (F=2.52, p=.079) and knee rotation (F=1.68, p=.19) were not significant. High variability was present between players as observed by the high standard deviation of the means of all variables. Furthermore, high variability was observed within certain players (e.g. Player 2). Notably, only Player 1 rotated internally with her trunk, in contrast to other players, whom showed external trunk rotation.

Table 1: Joint angles at IC, peak value and total ROM of Player 1 to 4 and group means. Significant between-player differences (*) were observed.

	Player 1	**Player 2**	**Player 3**	**Player 4**	**All Players**	
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	*F*
Initial contact						
Knee flexion (°)	20.2 ± 5.9	25.3 ± 3.8	12.0 ± 3.7	21.3 ± 2.9	19.7 ± 5.9	12.23***
Knee abduction^a (°)	1.0 ± 0.8	3.5 ± 2.4	-0.6 ± 0.8	-1.0 ± 2.2	0.7 ± 2.4	10.04***
Knee rotation^b (°)	1.2 ± 3.0	4.9 ± 2.9	0.0 ± 3.5	-2.8 ± 4.7	0.8 ± 3.0	5.54**
Trunk rotation (°)	-7.6 ± 6.8	7.0 ± 13.4	3.6 ± 8.4	9.9 ± 8.9	3.2 ± 11.7	4.35*
Peak value						
Knee flexion (°)	53.5 ± 8.4	65.7 ± 13.9	28.2 ± 6.5	36.2 ± 7.3	45.9 ± 17.5	22.26***
Knee abduction (°)	1.3 ± 3.1	-3.2 ± 5.2	0.0 ± 1.3	-0.1 ± 1.8	-0.5 ± 3.6	2.52
Knee rotation (°)	3.8 ± 2.9	1.9 ± 1.8	1.7 ± 2.5	4.1 ± 2.9	2.8 ± 2.8	1.68
Trunk rotation (°)	-1.5 ± 7.0	0.7 ± 11.4	-2.0 ± 2.7	0.6 ± 2.2	-0.6 ± 7.0	7.51***
Range of Motion						
Knee flexion (°)	33.3 ± 10.1	40.4 ± 14.0	16.1 ± 6.9	14.9 ± 7.8	26.2 ± 14.9	11.12***
Knee abduction (°)	2.9 ± 2.0	-4.4 ± 9.1	1.2 ± 1.4	2.9 ± 3.9	0.6 ± 5.9	3.20*
Knee rotation (°)	5.2 ± 3.0	-0.8 ± 5.9	4.2 ± 4.9	9.2 ± 6.4	4.5 ± 6.3	4.37*
Trunk rotation (°)	6.1 ± 5.4	-6.3 ± 7.5	-4.0 ± 7.6	-8.1 ± 12.8	-3.1 ± 10.4	6.36**

*p<.05; **p<.01; ***p<.001

^{a}abduction/adduction of tibia relative to femur (negative = abduction; positive = adduction)

^{b}rotation of tibia relative to femur (negative = external rotation; positive = internal rotation)

DISCUSSION: ACL injury risk screening is often conducted in a standardised laboratory environment. In this study, the landing kinematics of elite female handball players in a sport-specific field test were collected using a validated inertial sensor system. The results of this study indicate that the Xsens Awinda can provide useful information on the landing kinematics in a real-world applied setting. Large standard deviations of lower limb kinematics were observed. In addition, players utilised a variety of landing strategies during the field test, implications of which are discussed below.

Previous research investigating landing after a drop vertical jump in a lab setting reported that knee flexion ROM for a low injury risk landing should be greater than 45° (Myer et al., 2011; Padua et al., 2015). All of the players in the present study demonstrated knee joint ROM lower than these values. This would suggest that every athlete tested had a high ACL injury risk, would these values be shown in a lab setting. However it should be noted that in the study by Myer et al. (2011), a different assessment method was used and players performed different landing tasks. To the best of our knowledge, only one study has investigated the knee joint kinematics during an ACL injury in women’s handball (Koga et al., 2010). They found mean knee flexion angles of 23° and 24° at IC and ROM to 40 milliseconds after IC, respectively, whilst on one leg. Using that study as a reference would suggest that Players 3 and 4 in the current study have a high ACL injury risk due to their lower ROM knee flexion angles, but Players 1 and 2 do not.

However, Player 3 landed on both feet in 5 out of 8 trials after the jump shot. Previous research has shown that landing on two feet reduces the ACL injury risk (Myklebust et al., 2013), suggesting that these 5 trials were low risk landing techniques. Practically, we observed a variety of landing strategies suggesting that it may be challenging to compare the jump shot landing kinematics of a field test with a laboratory based drop vertical jump. During a drop vertical jump players do hardly move horizontally. However, with the landing after a jump shot in the applied setting players indeed moved forward which had consequences for the landing kinematics. For example, due to the horizontal movement, players landed earlier (almost together with the landing limb) with the non-landing limb. Furthermore, we observed that after landing, some players quickly crossed the not-landing limb over the landing-limb. Consequently, questions arise whether the drop vertical jump test in the lab setting is ecologically valid for identifying ACL injury risk in the field. As a result, landing kinematics in a lab setting should be interpreted with caution for extrapolation towards ACL injury risk during landing after a sport-specific test.

Due to these results, it is evident that more research is needed in order to understand the requirements for having low ACL injury risk after the jump shot during handball. We have developed a first field-test which incorporates several handball specific elements, to more ecological validly investigate ACL injury risk. Within and between individual variation also indicate that injury prevention should be individualized, as there is not one optimal way of movement solution. Finally, as the reactive side step movement is closely related to ACL injury risk in handball (Myklebust et al., 2013), we will further investigate these kinematics during a handball field test.

CONCLUSION: Landing kinematics in a sport-specific jump shot in handball appear to be different than kinematics investigated in a laboratory setting. These data can be utilised to identify athletes at risk of sustaining an ACL injury, although further research is needed to identify low ACL injury risk in sport-specific settings. There remains a lack of research and knowledge on the low injury risk kinematics during sport-specific landing movements, although this is a crucial step for the development of injury prevention programs.

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