COMPARING AN INERTIAL SENSOR SYSTEM TO VIDEO FOR ACL INJURY RISK SCREENING

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Quantifying landing technique in sport-specific environments is desirable for effective injury prevention programs. The aim of this study was to compare an inertial sensor (Xsens) with two high-speed cameras during landing. Ten participants performed double and single-leg drop vertical jumps while data from both systems were collected. Joint angle and excursion from Xsens was compared with the high-speed video. Bland and Altman plots and root mean of the squared difference quantified validity. Larger values of knee valgus excursion was reported with Xsens by 0.4-0.7cm. Additionally, Xsens overreported most joint flexion. Although an inertial sensor system may provide valuable information of landing kinematics in an applied environment, the resultant data must be carefully examined prior to drawing conclusions regarding the ACL injury risk of the athlete.

KEYWORDS: INJURY PREVENTION, SPORT-SPECIFIC, HANDBALL

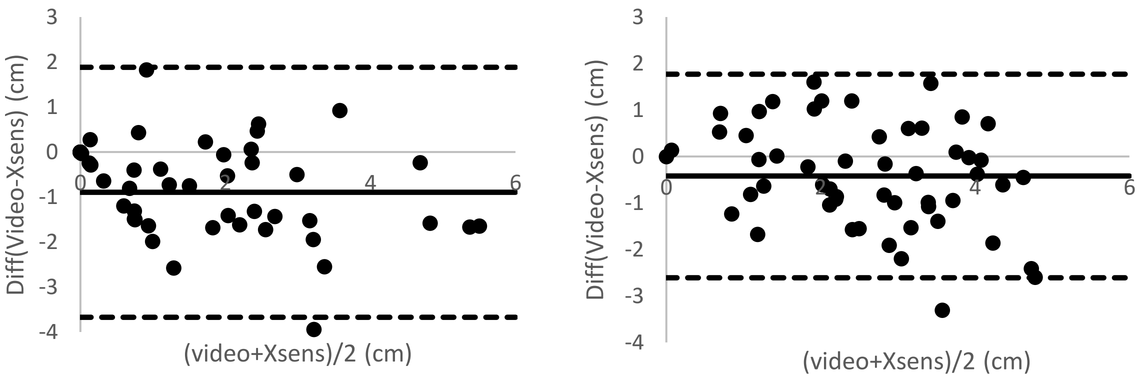
INTRODUCTION: One of the most devastating knee injuries incurred in sport is the anterior cruciate ligament (ACL) injury. In a sport such as team handball, this injury often occurs during noncontact single legged landings (Myklebust, Skjolberg, & Bahr, 2013). Worldwide, more than 2 million injuries occur annually resulting in a long absence from sport. In addition, early onset of osteoarthritis in individuals who sustained an ACL injury places a burden on the health system. For this reason, proactive assessment of landing technique is often conducted to identify participants that may be susceptible to an ACL injury and may benefit from an injury prevention program (Myer, Ford, Khoury, Succop, & Hewett, 2010).
Injury risk screening for an ACL injury is often conducted in a laboratory setting in order to quantify the kinematics with a motion analysis system or with high-speed camera's which require digitising of reflective markers post testing. The data analysis of these two methods remain time consuming and due to the requirements of a standardized environment, these tests are often conducted in a laboratory and not in an applied sports environment making it less ecologically valid. Recently, the development of inertial sensors have allowed for these measurement to be taken to the applied sports environment. Testing in a sport-specific environment provides greater ecological validity of the landing strategy. Prior to being able to utilize inertial sensor systems in the field, a comparison of the conventional high speed video method and an inertial sensor system need to be conducted on the clinical landing assessment.
For this reason, the purpose of this study was to investigate the concurrent validity of kinematics measured by an inertial sensor based Xsens MVN system against a high-speed camera method of a drop vertical jump for implications of ACL injury risk. It was hypothesized that there would be a strong relationship between the kinematic output of these two methods.

METHODS: Five active male (28.8±3.1yrs, mass 78.6±9.4kg, height 182.0±7.3cm) and five active female (23.6±3.0yrs, mass 60.3±4.3kg, height 170.0±3.1cm) participants volunteered in this study and completed an informed consent form. Each participant wore black fitted pants with reflective markers placed on the their left and right medial and lateral condyles of the knee, the right hip joint centre, and the right lateral malleolus. The Xsens system (Awinda, 100hz; Xsens technologies, Enschede, The Netherlands) composed of 8 IMUs were positioned bilaterally on the feet, shanks, mid-thighs, and one on the pelvis and sternum. Each sensor integrates a tri-axial accelerometer (±160m.s^2), gyroscope (±2000deg.s) and magnetometer (±1.9Gauss). Participant 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.

Two calibrated high-speed cameras (240hz; Quintic Consultancy Ltd, Coventry, United Kingdom) were position in the frontal and sagittal plane of the landing movement. In line with the clinical protocol described by Myer et al. (2010), participants performed a bilateral drop vertical jump off a 30cm box down to the ground and immediately rebounded for a maximum vertical jump. The first landing off the box was investigated in this study. In order to collect various landing techniques, participants were asked to perform two trials with their natural landing technique, two using a stiff landing, and two using a soft landing. Following this, six single leg jumps with the right leg (normal, stiff, soft) were collected to make the task more sport-specific. Data from the reflective markers and sensors were simultaneously collected. Markers were digitized and Butterworth filtered with a 30hz cut off frequency using analysis software (Quintic Biomechanical Software v. 29). Xsens data was collected at multilevel and high-definition reprocessed using the MVN Analyse software (v.2019.0). Sagittal plane ankle, knee, hip and trunk flexion at initial contact and peak knee flexion of the right limb were recorded. Maximum knee excursion between initial contact and peak valgus position in the frontal plane until the point of peak right leg flexion were also calculated. Full extension of all joints were used as the neutral position of 0 degrees with joint flexion reported as positive numbers. Ankle dorsiflexion is reported as a positive number with plantarflexion as a negative number.

In order to investigate whether there were between-method differences in initial contact, peak knee flexion joint angles, and valgus excursion, Bland-Altman (1987) scatter plots with bias and limits of agreement (LoA) were performed for frontal plane knee excursion with the video-derived angles as the reference measure. Furthermore, to compare the closeness in amplitude of the video-derived joint angles and excursion and those exported by the Xsens system, the root mean square error (RMSe) was calculated for each kinematic parameter.

RESULTS: Bland-Altman scatter plots (Figure 1) represent the level of agreement between the Xsens system and video for frontal plane knee excursion of the right leg for the double leg landing (A) and single leg landing (B). This analysis revealed that larger values were determined using Xsens in the frontal plane knee valgus excursion compared to the video. The 95% LoA was found to be -2.7 to 1.3 for the double leg landing and -2.6 to 1.8 for the single leg landing.



A B

Figure 1: Bland-Altman plots for validity of frontal plane right leg knee excursion during double (A) and single (B) legged jumps.

The RMSe for the all kinematic parameters are reported in Table 1. Analysis revealed that larger values were determined using the Xsens system in all joints except for the ankle angle at initial contact compared with the high-speed video. The highest difference was observed at ankle, knee, and hip during initial contact. Peak knee flexion and hip flexion at peak knee flexion had the least amount of difference. In addition, the Xsens system indicated a higher magnitude of knee valgus excursion for the left and right knee in both the double and single leg jump landings by 0.4-0.7cm.

Table 1: Concurrent validity of kinematic parameters measured by high speed video compared with Xsens. The root mean square error (RMSe) is reported between the two methods.

	Video mean ± SD	Xsens mean ± SD	RMSe
Double leg jump			
Ankle angle at initial contact	-23.8 ± 8.5°	-9.3 ± 8.9°	16.7°
Knee flexion at initial contact	24.8 ± 11.0°	35.4 ± 10.2°	10.9°
Peak knee flexion	73.8 ± 15.9°	77.8 ± 16.9°	5.8°
Hip flexion at initial contact	35.9 ± 13.4°	41.5 ± 13.3°	10.1°
Hip flexion at peak knee flexion	61.1 ± 25.5°	60.9 ± 21.8°	11.6°
Trunk angle at initial contact	18.1 ± 7.3°	22.3 ± 12.3°	8.8°
Knee valgus right	1.3 ± 1.5cm	2.0 ± 1.9cm	1.2cm
Knee valgus left	3.9 ± 1.9cm	4.6 ± 2.4cm	1.9cm
Single leg jump			
Ankle angle at initial contact	-27.5 ± 7.0°	-17.3 ± 8.3°	13.3°
Knee flexion at initial contact	17.0 ± 7.0°	26.4 ± 6.5°	9.5°
Peak knee flexion	58.7 ± 10.7°	63.2 ± 10.5°	5.4°
Hip flexion at initial contact	28.6 ± 8.9°	33.2 ± 8.7°	9.3°
Hip flexion at peak knee flexion	47.4 ± 17.3°	47.1 ± 13.1°	9.3°
Trunk angle at initial contact	15.2 ± 8.7°	18.1 ± 13.0°	14.9°
Knee valgus right	2.4 ± 1.2cm	2.8 ± 1.5cm	1.2cm

DISCUSSION: In order to assess a participants' risk of sustaining an ACL injury, landing technique assessments are often conducted, albeit in the laboratory setting. With the development on an inertial sensor system, these technique assessments can be moved to the sport-specific environment improving the ecological validity of the screening. The results of the current study suggest that using a portable inertial system may be useful in the applied setting, although care must be taken when interpreting the data to identify participants at risk of sustaining an ACL injury. Identifying where the differences between the two systems arise from needs to be further investigated.

The purpose of ACL injury risk screening is to identify whether particular athletes or participants demonstrate landing strategies that may lead to an injury. In this study, Xsens reported higher values of frontal plane knee valgus excursion compared to the video. As both systems were collected simultaneously, differences in data analysis may present different in joint angles. For example, the experimental task of the participants is to jump forward off the box towards lines on the ground and perform a vertical jump. By having a target to land on, the chance of perspective error being present in the frontal camera is reduced. However, it is likely that there were some trials where the participant did not perform the landing in the same plane as the frontal calibration if they jumped towards the front or the back of the line. A benefit of using the inertial sensor system, however, is that perspective error would not have played a role in the quality of the data. In addition, using the high speed video method, frontal plane knee excursion for the left leg is based on the magnitude of excursion until the point of peak knee flexion of the right leg as left leg knee flexion was not collected. In the current study, for some participants peak left knee valgus excursion occurred after right leg peak knee flexion. This would indicate that the amount of valgus is underestimated in the traditional high speed camera method. With the use of an inertial sensor system, peak knee flexion of the left leg and total excursion can be collected, providing more specific information regarding injury risk for that particular athlete. As higher values were reported with the Xsens system, the system will not exclude those who need landing training, albeit may include some who do not.

The least amount of difference between the two systems was found for peak knee flexion and hip flexion at peak knee flexion, suggesting using the Xsens system to measure peak knee joint flexion is suitable. There was a substantial difference in the joint angles at initial contact between the two systems. One of the limitations of the current study was the difference in sample frequency used; high speed video at 240hz and Xsens at 100hz. Currently, collecting Xsens Awinda data at a high frequency with this amount of sensors is not possible. It is possible that when the Xsens data is able to collect at a higher sample frequency there would be less differences between these two methods. Additionally, it would be beneficial for future research to compare landing kinematics from the Xsens system with that of a three-dimensional lab-based system.
Although it is well established that ACL injury occurs as a result of decreased knee, hip and trunk flexion combined with knee valgus and knee internal rotation (Krosshaug et al., 2007), quantifying internal rotation with video is challenging. For this reason, tibial rotation is not considered in the traditional clinical screening. A valid, portable three-dimensional inertial sensor system presents a unique opportunity to include rotational plane and analyze landing kinematics in a sport-specific environment. For example, athletes can wear their usual training shoes, such as football cleats, and perform landing movements on the surface they are accustomed to in their sport. The traditional laboratory methods of analysing landing technique for ACL injury risk are unable to account for this. In addition, due to its portability and ability to provide quick feedback to the participants, an inertial sensor system may assist in improving landing technique during a training session, enhancing motor learning (Benjaminse, Postma, Janssen, & Otten, 2017).
In the sport of handball, an ACL injury often occurs after performing a single leg jump landing movement, such as a jump shot. The traditional method of ACL screening is of a double leg jump landing. However, during such movement the participant may be favoring one leg and masking problems with the other leg. In the applied setting, it is important to identify whether there are problems during the landing. For this reason, and due to the sport-specific movement, a single-leg landing is often used. The results of the current study suggest that using Xsens during field testing may be appropriate as long as careful consideration is made with the data analysis. Whether the cutting movement during landing, also often an injury mechanism which loads the ACL, is also useful with Xsens remains to be investigated. Overall, there continue to be challenges present when utilizing an inertial sensor system to quantify ACL injury risk. Nevertheless, with these results we plan on performing on court measurements during handball training to investigate the sport-specific landing kinematics.

CONCLUSION: Using an inertial sensor system such as Xsens Awinda may provide useful information on the landing kinematics of a participant. Although the system overreported joint flexion and valgus, these data can be utilized to identify athletes at risk of sustaining an ACL injury. Due to its portability and quick feedback, this system may assist in making injury prevention programs more sport-specific and, as a result, more effective.

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