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Comparison of drop jumps and sport-specific sidestep cutting

Implications for anterior cruciate ligament injury risk screening

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Footnote regarding figure 1:

Abstract

Background: Anterior cruciate ligament (ACL) injuries is a serious problem with a high incidence and serious consequences. Published clinical screening tests are based on two-legged and controlled drop jumps, but ACL injuries are known to occur in single-leg landings and sidestep cutting, where the load is predominantly distributed to one single leg.

Purpose: To describe knee kinematics and kinetics in drop jumps and sidestep cutting and investigate the rank correlation of knee valgus angles and knee abduction moments between and within these movements.

Study design: Cross-sectional study

Methods: 120 elite female handball players (mean±SD, 22.4±7.1 years,171±7 cm, 67±7kg), each performing three drop jumps and three sport-specific sidestep cuts to each side. Kinematics and kinetics calculated from high-speed 3D motion analysis.

Results: Knee kinematics and kinetics were significantly different between drop jumps and sidestep cutting. The knee abduction moment was five times higher in sidestep cutting (1.58±0.60 vs. 0.25±0.16). There was a poor correlation between knee abduction moments (ρ= 0.135) in the two tasks, but a moderate correlation (ρ=0.706) for knee valgus angles. There was a poor correlation between knee valgus angles in drop jumps and knee abduction moments in sidestep cuts (ρ=0.238).

Conclusion: Motion patterns are different between drop jumps and sidestep cutting. There is a moderate correlation for knee abduction moments between the two tasks, but knee abduction moments are less consisten across tasks.

Clinical Relevance: Knee valgus angles during drop jumps do no predict knee abduction moments during sidestep cutting. The moderate correlation of knee valgus angles in drop jumps and sidestep cutting indicates that this measure may be more relevant for screening efforts.

Key Terms: Anterior cruciate ligament injury, pre-participation screening, drop jump, sidestep cutting

What is known about the subject: Knee valgus angles and abduction moments are different between drop jumps and sidestep cutting.

What this study adds to existing knowledge: Knee valgus angles and abduction moments in drop jumps show a poor correlation to knee abduction moments in sport-specific sidestep cutting. Knee valgus angles are more consistent across tasks, and may be more important for ACL injury risk screening.

Introduction

High knee valgus angles and high knee abduction moments during vertical drop jumps have been found to predict non-contact anterior cruciate ligament (ACL) injury in a cohort of 205 basketball, football and volleyball players using high-speed, marker-based 3D motion analysis.[6] Due to the complexity and cost associated with 3D motion analysis, others have later investigated whether simple visual assessment of kinematics in drop jumps can identify athletes with high frontal plane movement and loading in jumps.[5, 12, 17, 20] These drop jump tests mainly focus on identifying frontal plane movement of the knee using visual methods. In the large cohort study of Smith et al., 5047 players were screened using the Landing Errors Scoring System, but in contrast to the earlier 3D motion analysis study, this jump test was not found to be predictive for future injuries.[19]

There can be several reasons for the lacking predictive value of the simple screening test based on jump tests. Drop jumps are bilateral, but ACL injuries usually occur during unilateral loading in sidestep cutting or single-leg landing.[11] Furthermore, testing situations close to actual injury situations are likely more valid for predicting injury risk, but these tests are more complicated to perform than the drop jump tests due to the high speed and multi-planar motion.

Previous research on both drop jumps and sidestep cutting is abundant. Previous studies comparing drop jumps and sidestep cutting have mainly compared the magnitude knee joint moments, but the correlation between frontal plane measures in drop jumps and sidestep cutting is unclear. The main differences found between drop jumps and sidestep cutting are lower knee flexion angles and higher knee valgus angles and knee abduction moments in sidestep cutting.[3, 4, 14] One study has done a factor analysis of drop jumps and sidestep cutting.[15] They found poor correlation between frontal plane measures in drop jumps and unanticipated cutting. Like most of the previous studies, the cutting task was a simple change of direction, which can be substantially different from the side step cutting maneuvers known to cause injuries in game play.[11, 22]

Ultimately, the underlying goal for frontal plane visual assessment of a jump tasks is to predict knee abduction loading in ACL risk situations such as e.g. single-leg landings or sidestepping maneuvers. In that case, there must be a correlation between the kinematics of the jump task and the kinematics and kinetics of the risk situations.

The purpose of this study was therefore to describe knee kinematics and kinetics in drop jumps and sidestep faking maneuver in elite female handball players and test the rank correlation of knee valgus angles and knee abduction moments between these two tasks. Furthermore, we want to describe the rank correlation between valgus angles and knee abduction moments in the two tasks. Finally, the rank correlation between knee valgus angles in drop jumps and knee abduction moments in sidestep cutting will be compared.

Methods

All players of the elite female handball series were invited to baseline testing for a cohort study to investigate anterior cruciate ligament injury risk factors. A high ACL injury incidence has previously been found in this cohort.[13] We tested 184 players, and from 173 match fit players the 125 back and wing players were selected for analysis as they are most accustomed to sidestep cutting during match play. Four players were excluded due to technical problems and one due to physical complaint during jumping. The final sample consisted of 120 players (22.4±7.1 years,171±7 cm, 67±7kg, mean±SD).

The study was approved by the Regional Ethics Committee and informed consent was obtained from all players.

Sidestep cutting and drop jumps were performed in a motion analysis lab with eight 240 Hz infrared cameras (ProReflex, Qualisys, Gothenburg, Sweden) and two 960 Hz force platforms (AMTI, Watertown, Massachusetts, USA). Marker placement and sidestep cutting procedure was performed as described in a previous study from this cohort (figure 1).[10] The players were told to perform their regular sidestep cut, trying to fake a static defender into going one way while cutting to the other side. They received a pass prior to cutting.

Drop jumps were conducted using a 30 cm box. The subjects were instructed to drop off the box and perform a maximal jump after landing. The box was adjusted so the players landed with one foot on each platform. Static recordings of the athlete in an anatomically neutral position were performed prior to testing. Sidestep cutting to both sides were completed before the jumping trials.

Figure 1: Testing situation. The approach of the players was approximately 33° on the long axis of the runway. Their instruction was to fake the defender into going to one side and cut to the other. The defender was static during recording and adjusted her position between the trials to make sure the athletes hit the force platform with their normal sidestepping technique. (Reprinted from Kristianslund E, Krosshaug T, van den Bogert AJ. Effect of low pass filtering on joint moments from inverse dynamics: implications for injury prevention. J Biomech. 2012;45:666-671. With permission from Elsevier.)

The contact phase was defined as the period where the unfiltered vertical ground reaction force exceeded 20N. Kinematics and kinetics were calculated as previously described,,[10] except from the hip joint center that was calculated by the regression equations of Bell et al.[1] A 15 Hz cut-off frequency for signal filtering of both force and position data. External joint moments are reported. Both knees were analyzed in drop jumps, whereas the right knee was analyzed in right-left sidestep cuts and the left knee in left-right cuts.

Three drop jumps and three sidestep cuts from each side were selected for analysis.

Statistical treatment

The following variables were extracted from the motion analysis of drop jumps and sidestep cuts: Maximum knee abduction and knee internal rotations moments first 100 ms after initial contact, maximum knee flexion moment during contact with force platform, knee flexion, knee abduction and knee internal rotation at initial contact (IC) and maximum knee flexion, knee abduction and knee internal rotation. Maximum knee abduction and knee internal rotation moments during the first 100 ms were chosen because ACL injuries are likely to occur in this period.[9] Average values over three trials for each knee were used for analysis, and sidestep cutting and drop jumps were compared for each knee. Spearman's rank correlation coefficient ρ was calculated between knee abduction moments and knee valgus angles in jumps and sidestep cuts to assess if there was a difference of ranking of players based on these parameters between the tasks. The correlation between knee valgus angles and knee abduction moments in drop jumps and sidestep cuts as well as the correlation between knee valgus angles in drop jumps and knee abduction moments in sidestep cutting were also found using Spearman's rank correlation.

Results

Figure 2: Knee abduction moments (Mean ± SD) during the first 150 ms of stance in jumps and sidestep cuts. Both knees, N = 720 trials.

Figure 3: Maximal knee joint moments during the first 100 ms of stance. N = 240 knees.

We observed a peak in knee abduction moments shortly after initial contact in sidestep cuts but not in drop jumps (figure 2). The sidestep cuts were performed with mean approach speed of 3.4 m/s and cutting angle was 69°. Knee joint angles (table 1) and knee joint moments (figure 3) were substantially different between jumps and sidestep cuts. The Spearman's ρ was 0.135 for knee abduction moments (figure 4) and 0.706 for knee valgus angles (figure 5), indicating poor and moderate agreement between tasks, respectively. There was limited correlation between valgus angles and knee abduction moments within each of the movement tasks. In the drop jumps, we observed a rank correlation of 0.506, whereas the rank correlation for sidestep cuts was ρ=0.339. The rank correlation between knee valgus angles in drop jumps and knee abduction moments in sidestep cuts was poor (ρ=0.238).

Table 1: Knee joint angles and moments in vertical drop jumps and sidestep cuts. N = 240 knees.

	Jumps			Sidestep cuts		
	Mean	SD	95% CI	Mean	SD	95% CI
Flexion at IC	31.5	6.48	(30.70,32.35)	20.9	5.37	(24.52,25.95)
Valgus at IC	-1.2	4.03	(-1.75,-0.72)	4.6	3.81	(4.11,5.08)
Internal rotation at IC	-1.4	5.95	(-2.12,-0.60)	2.0	7.59	(1.01,2.94)
Maximum flexion	82.2	11.76	(80.70,83.69)	62.2	5.10	(61.57,62.86)
Maximum valgus	5.6	4.63	(4.98,6.16)	11.5	4.94	(10.82,12.08)
Maximum internal rotation	9.3	5.25	(8.63,9.96)	12.6	5.22	(11.98,13.31)

Figure 4: Scatter plot of maximum knee abduction moment first 100 ms (Nm/kg) in jumps and sidestep cuts. N = 240 knees. Lines at mean+1SD.

Figure 5: Scatter plot of maximum knee valgus angle (º) during stance phase in jumps and sidestep cuts. N = 240 knees. Lines at mean+1SD.

Discussion

There was a substantial difference in kinematics and kinetics between drop jumps and sport-specific sidestep cutting, as previously reported by others. [3, 4, 14, 15] In sidestep cutting the athletes had lower knee flexion angles and higher knee valgus and internal rotation angles at IC and at maximum. The knee joint moments were higher in all three planes for the sidestepping movement. Most notably, the knee abduction moments were five times higher in sidestep cutting compared to drop jumps. Sidestep cutting is a high energy situation with a high approach speed, direction change and single-legged stance, compared with the more controlled double-leg drop jump, and this may explain the differences in kinematics and kinetics.

There was a weak correlation between knee abduction moments in drop jumps and sidestep cutting, while the correlation was better for the knee valgus angles. Abduction motion and loading are important components of the injury mechanism.[8, 9, 21] Unfortunately the correlation of drop jump knee valgus angles to sidestep cutting knee abduction moments was poor, hence visual drop jump tests cannot predict loading of the knee during the sidestep cutting maneuver in which a high proportion of ACL injuries occur.[11, 16] However, in the prospective study of Hewett et al., both knee valgus angles and knee abduction moments in drop jumps predicted ACL injuries among adolescents.[6] The moderate correlation between knee valgus angle in drop jumps and sidestep cutting indicates that drop jump tests may have potential to identify athletes with high knee valgus angles during cutting activities, and provides an opportunity for screening of motion patterns that are likely to be relevant to ACL injury causation.

Knee abduction moments may be less relevant for ACL injury risk in our cohort of elite female handball players, as the high knee abduction moments seen among injured players in the prospective study of Hewett et al are not seen in our cohort.[6] Our athletes are older, and players with such high knee abduction moments may have been injured or have other characteristics that have excluded them from elite level sports. In addition the prospective study may have been affected by artefacts due to inconsistent filtering of force and movement data.[7, 10, 18]

Injuries occur mostly during single-legged activities, and efforts should be made to find tests that can identify players with high knee valgus angles during sporting activities. The limited ability of a clinical drop jump test to predict ACL injury may indicate that more sport-specific tests are needed. Based on the present knowledge, all female team sports athletes should perform preventive exercises regularly, regardless of presumed injury risk.

A limitation of all laboratory studies is that one cannot conclude how the measured movement patterns relate to the biomechanics of real sporting motions. However, we attempted to simulate real sport-specific situations for sidestep cutting by including a static opponent and a ball, with observers continually assessing the intensity and sport-specific quality of the cuts. The players were specifically told to perform the cut as if they were trying to fake the static defender into going the opposite way. This requires a high intensity of the cut to trick the opponent. The loads calculated during this more sport-specific sidestep faking maneuver are likely closer to the loads experienced during game play than loads from analyses of simple changes of direction. The conclusions can likely be extrapolated to other sports, as faking a defender and cutting past him or her is very common in different team sports, e.g. basketball and soccer.

A limitation of this cutting protocol is that it is harder to standardize, as all athletes use their preferred cutting technique. On the other hand the resulting variation in sidestep cutting technique likely reflects the variation in cutting techniques used during active game play, and the high number of subjects ensures representable data. Sidestep faking and cutting maneuvers during active game play usually include an element of unanticipation.[2] However, with inclusion of unanticipation the task would be less standardized.

Although this is a cross-sectional study with no data on actual injury risk, the findings are useful for screening for ACL injuries and development of ACL injury prevention programs. Knowledge of the relation between joint kinematics and kinetics in the drop jump screening test and in potential injury situations can help design better screening tests.

Conclusion

There was a substantial difference in the magnitude of knee joint deflections and knee joint loading between drop jumps and sport-specific sidestep cutting. There was a poor correlation between knee abduction moments between the tasks, indicating that the players with high frontal plane loading in drop jumps not necessarily experience high frontal plane loads in sidestep cutting. The kinematics is more consistent across tasks than the kinetics, and may be a more relevant target for ACL injury risk screening.

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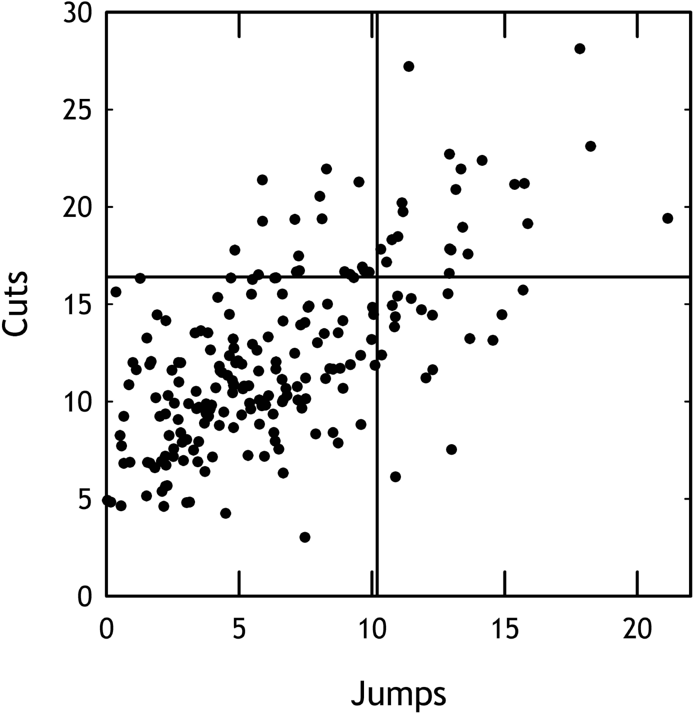

30
25
20
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10
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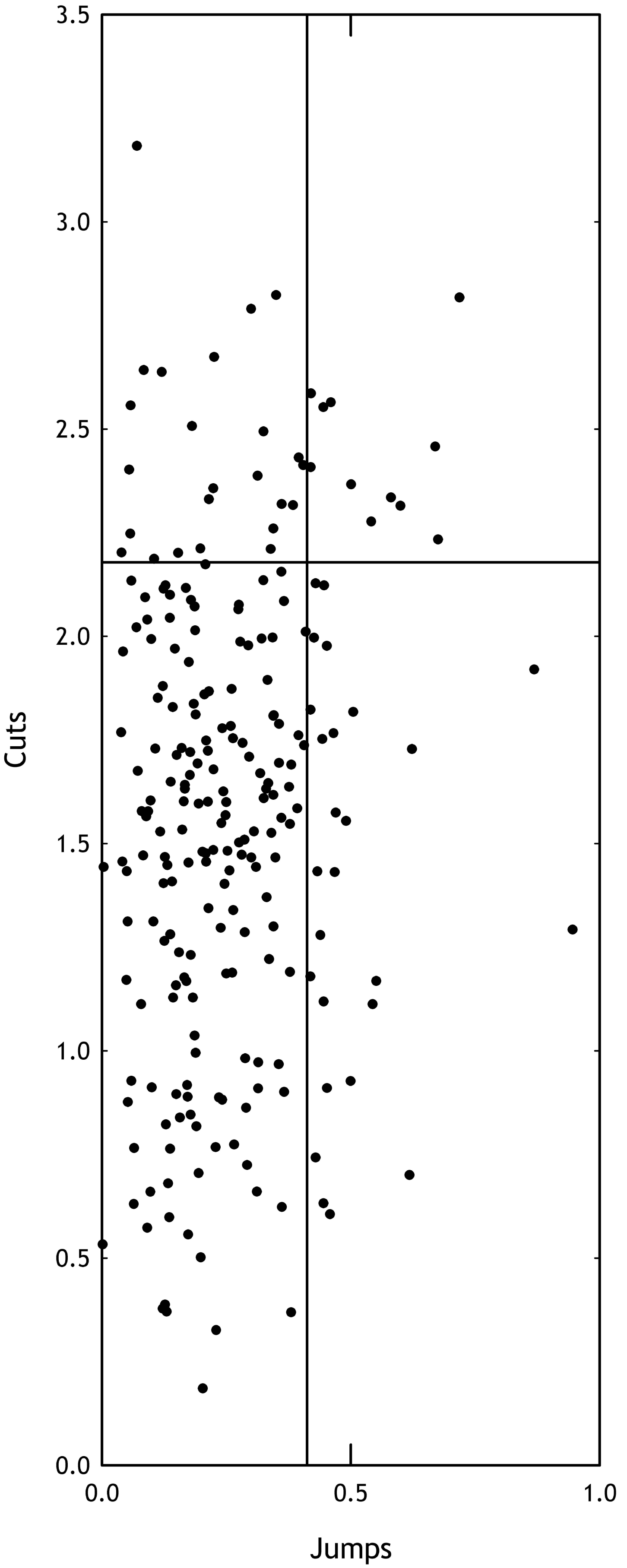
20
Cuts
Jumps



3.5
3.0
2.5
2.0
1.5
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Cuts
0.0
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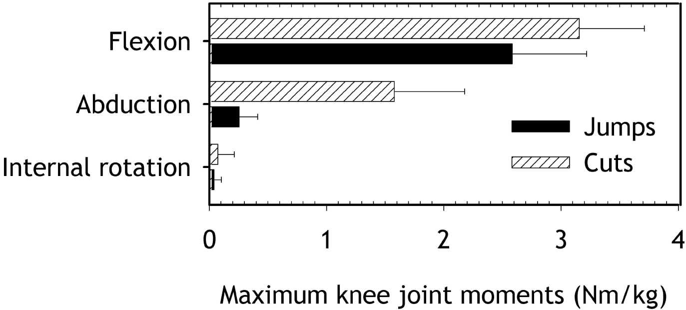
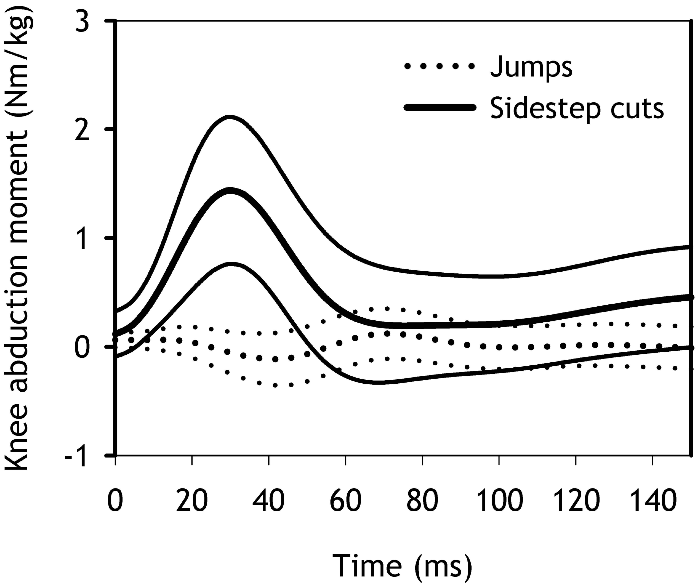
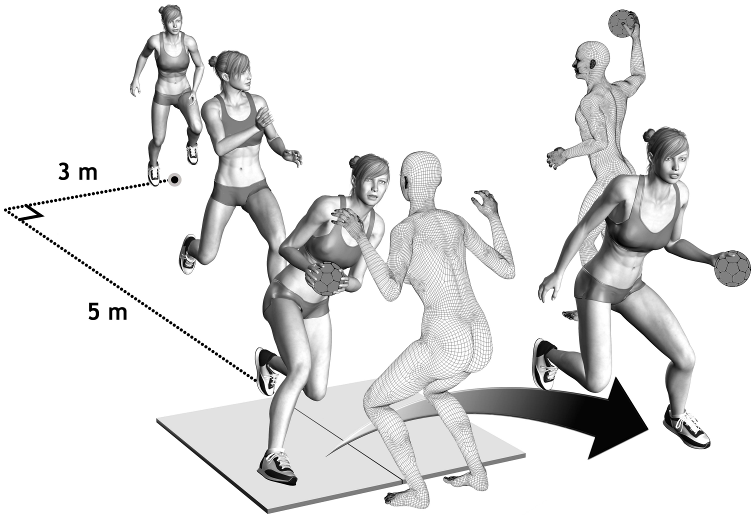
Jumps



Flexion
Abduction
Internal rotation
Jumps
Cuts
0
1
2
3
4
Maximum knee joint moments (Nm/kg)


3
2
1
0
-1
Knee abduction moment (Nm/kg)
Jumps
Sidestep cuts
0
20
40
60
80
100
120
140
Time (ms)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