RELIABILITY OF KNEE JOINT MEASURES IN A CUTTING MOVEMENT

Mitchell Stephenson[1], Sarah Leissring[1], Bryanne Bellovary[1], Alexander Wolfe[1], Caitlin Glendenning[1], Erika Purdy[1], Bailey Hagner[1], Erich Petushek[1, 2], and Randall Jensen[1]

Department of HPER, Northern Michigan University, Marquette, MI USA[1]
Department of Kinesiology and Integrative Physiology, Michigan Technological University, Houghton, MI USA[2]

Eight female soccer athletes performed six horizontal jump and cut maneuvers onto two AMTI force platforms. 3D kinematic analysis of 22 marked body landmarks coupled with ground reaction forces (GRF) were analyzed for peak knee flexion and valgus angles, GRF, and knee abduction moments with repeated measures ANOVA. Analysis indicated no significant difference between trials ($p > 0.05$). Average measures Intraclass Correlation Coefficients resulted in values of r = 0.71 to 0.99. Results indicate good reliability for flexion angles and excellent reliability for valgus angles, GRF, and knee abduction moments.

KEYWORDS: angles, moments, ground reaction forces.

INTRODUCTION: Previous literature has indicated that female athletes have four times higher risk of Anterior Cruciate Ligament (ACL) injuries than male athletes in multiple sport settings (Arendt & Dick, 1995). Internal and external rotations and valgus movements at the knee, often a function of cutting motions found in sports such as tennis, soccer, and volleyball, have been related to increased ACL injury risk (Markolf, Burchfield, Shapiro, Shepard, Finerman, & Slauterbeck, 1995; McLean, Lipfert & van den Bogert, 2004). Female athletes have less passive support of and active control over these motions compared to their male counterparts (Wojtys, Huston, Schock, Boylan, & Ashton-Miller, 2003; Hsu, 2006). This has led to the investigation and analysis of such motions on the knee joint in female athletes.
The previous literature has investigated reliability measures in jumping and running movements, but there is a lack of reliability analyses for jumping and cutting (Ford, Myer, & Hewett, 2007; Whatman, Hing, & Hume, 2010). Lack of reliability in a measure leads to an inability to gauge the origin of performance variability, as a possible function of learning, fatigue in performance, training, or other sources (Morrow & Jackson, 1995). If a measure is found to be reliable, it allows for comparison in varying conditions as well as across time. As such, the current study examined the reliability of the measurement of peak knee flexion and valgus angle, peak ground reaction force, and peak abduction moments at the knee in jump and cut maneuvers.

METHODS: Eight division II women soccer players (Mean ±SD Age = 19.80 ±0.63 years; Height = 165.25 ±8.27 cm; Weight = 62.44 ±8.49 kg) performed six horizontal jump and cut maneuvers, with three left cuts and three right cuts in random order. All subjects were without orthopedic lower limb or known cardiovascular pathology. Subjects completed a Physical Activity Readiness-Questionnaire and provided informed written consent. The study was approved by the Institutional Review Board of the university. All subjects wore spandex compression shorts and court shoes during the trials.
Subjects started with five minutes of low intensity warm up on a cycle ergometer, after which they performed dynamic stretching of the lower body. Subjects then completed several practice trials for familiarization of the jumping, landing, and cutting movements. They then rested for five minutes prior to completing the trials.
Each subject performed six trials consisting of a forward horizontal bound of 70 cm, landing with each foot on a separate force platform (OR6-5-2000, AMTI, Watertown, MA, USA). A directional indicator light appeared mid-flight of the horizontal bound, prompting the subject

to cut in the indicated direction upon landing and run down a path at an angle of 45° for approximately two meters.

Three-dimensional kinematic data were obtained at 200 Hz using a 6-camera infrared motion analysis system (Motion Analysis Corporation, Santa Rosa, CA, USA).

Reflective markers were placed on the acromion processes, the anterior superior iliac spines, thighs, medial and lateral knee joint lines, shanks, medial and lateral malleoli, heels, and third metatarsals on both the right and left sides of the body, with an additional marker on the subject's sacrum and posterior mid-torso offset for a total of 22 markers.

Data were analyzed using Cortex software version 2.5.3 (Motion Analysis Corporation, Santa Rosa, CA, USA). Coordinate data were low-pass filtered using a fourth-order Butterworth filter with a 6-Hz cutoff frequency (Winter, 1990). The right knee was analyzed during left cuts and the left knee was analyzed during right cuts. Subjects were asked to indicate their preferred kicking (dominant) and planting (non-dominant) legs.

Statistical analyses were performed with SPSS (v.18.0) for peak flexion and valgus angles and peak abduction moments at the knee as well as peak GRF. Reliability between trials utilized average measures of intraclass correlation (ICC_{AVE}). Intraclass correlations were classified following the guidelines of Fleiss (1986), where less than 0.4 is considered poor, 0.4 to 0.75 is fair to good, and greater than 0.75 is excellent. A repeated measures ANOVA was used to detect differences between trials (with an alpha significance value of $p < 0.05$).

RESULTS: Means and Standard Deviations (SD) for three trials of peak knee flexion and valgus angles, ground reaction force and knee abduction moments are presented in Table 1 for the dominant and non-dominant legs. Intra-trial reliability for the dominant and non-dominant peak knee joint flexion, valgus movement, abduction moments, and the ground reaction force are depicted by average measures of intraclass correlation coefficients in Table 2. None of the measures differed significantly between the three trials ($p > 0.05$).

Table 1: Mean ±SD of the peak knee flexion angle, valgus angle, ground reaction forces, and abduction moments on the dominant and non-dominant legs during right and left cutting movements. (n=8)

	Dominant Knee				**Non-Dominant Knee**			
	Flexion (°)	Valgus (°)	GRF (N)	Moments ($Nm•kg^{-1}$)	Flexion (°)	Valgus (°)	GRF (N)	Moments ($Nm•kg^{-1}$)
Trial 1	58.3 ±6.5	19.5 ±3.8	1109.1 ±178.0	-0.931 ±0.177	65.0 ±9.2	14.2 ±4.6	1056.4 ±220.0	-0.810 ±0.331
Trial 2	56.7 ±8.1	19.4 ±4.6	1101.3 ±222.7	-0.873 ±0.463	61.7 ±10.6	13.8 ±4.9	1078.7 ±166.4	-0.794 ±0.238
Trial 3	54.8 ±9.0	20.4 ±3.8	1170.0 ±162.3	-0.998 ±0.563	60.8 ±13.4	13.5 ±4.7	1069.6 ±159.1	-0.819 ±0.358

Table 2. Intraclass Correlation Coefficient average measure and 95% Confidence Limit (Upper and Lower Bounds) for peak knee flexion angle, valgus angle, ground reaction forces, and abduction moments on the dominant and non-dominant legs during right and left cutting movements. (n=8)

	Dominant Knee				**Non-Dominant Knee**			
	Flexion	Valgus	GRF	Moments	Flexion	Valgus	GRF	Moments
ICC_{ave}	0.707	0.973	0.921	0.863	0.930	0.985	0.835	0.892
Upper 95% CL	0.936	0.993	0.981	0.970	0.985	0.996	0.960	0.976
Lower 95% CL	0.011	0.916	0.752	0.537	0.764	0.952	0.485	0.634

DISCUSSION: Results indicate good or excellent ICC_{AVE} for all investigated measures. Non-dominant peak knee flexion, valgus movement, GRF, and moments as well as dominant peak knee valgus movements, GRF, and moments range from 0.835 to 0.985; all well within the excellent range. Dominant knee flexion reported an ICC_{AVE} of 0.707, indicating good reliability. Overall this indicates that a subject's same-day, repetitive performance in an unanticipated cutting maneuver is reliable.

These results echo previous literature investigating the reliability of knee joint angles and moments in differing exercises. Ford et al. (2007) reported excellent reliability for flexion (r = 0.933) and abduction (r = 0.993) angles as well as abduction moments (r = 0.931) for male and female subjects performing drop jumps. Whatman et al. (2010) also reported excellent reliability in lunges and small knee bends for knee flexion (r = 0.94 to 0.99) and abduction (r = 0.93 to 0.99) movements. It is possible that the current study's reported values were lowered slightly due to the inability of the subject to predict direction of the cutting movement. The reported values for knee flexion and valgus angles in cutting motions are similar to the literature (Ford, Myer, Toms, & Hewett, 2005) concerning the same motion.

CONCLUSION: The current study indicates that peak knee joint angles and moments as well as ground reaction forces are reliable measures in a landing and cutting movement for dominant and non-dominant legs. Athletes can be expected to perform similarly from trial to trial when executing such a maneuver. As such, variability in performance will be due to other factors and practitioners may analyze this variability for fatigue, learning, or other sources.

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