A Comparison of Cutting Technique Performance in Rugby Union Players

Brian S. Green,[1,2] Catherine Blake,[1] and Brian M. Caulfield[1]

[1]Motion Analysis Laboratory, School of Physiotherapy and Performance Science, Health Sciences Center, University College Dublin, Dublin, Republic of Ireland; and [2]Sports Medicine Department, Irish Rugby Football Union, Dublin, Republic of Ireland

Abstract

Green, BS, Blake, C, and Caulfield, BM. A comparison of cutting technique performance in rugby union players. *J Strength Cond Res* 25(10): 2668–2680, 2011—Rugby union is a dynamic running game requiring players to regularly perform change of direction maneuvers to avoid player opposition. The change of direction/cutting task is characterized by rapid deceleration onto the plant leg (PL) then reacceleration by the push-off leg (POL) into the new direction. Identification of the kinematic characteristics of cutting tasks and their relationship to playing ability may offer practical guidelines for coaches and strength and conditioning staff to design effective agility drills and provide player feedback to improve technique. Therefore, the purpose of this study was to investigate the kinematic and temporal characteristics of cutting tasks and their relationship to performance in rugby union players. Semiprofessional rugby union players from the All-Ireland League were placed in a Starters ($N = 13$) or Nonstarters ($N = 10$) group based on whether they were routinely selected in the starting team or were reserve 'bench' players. Each participant was fitted with reflective markers and performed 10 cutting trials (5 left, 5 right) of a single 45° cutting task to collect relevant kinematic data. The directions of the cutting trials were classified as a dominant or nondominant cut based on the participant's dominant leg. All trials were then analyzed to determine the timings, angular displacements, and velocities during key events of the PL and POL in the cutting task. The total time to complete the cutting task was not statistically significant between groups; however, Starters demonstrated significantly shorter contact time of the PL during dominant cuts and initiated knee extension of the POL faster than Nonstarters in dominant and nondominant cuts. This preliminary study demonstrates that components of the cutting task differed between groups and may provide an insight for strength and conditioning professionals to assess change of direction technique.

Key Words agility, kinematics, evasion, contact time

Introduction

Because rugby union turned professional in 1995, the popularity of the sport has greatly increased to the extent that the 2007 World Cup in France attracted 2 million spectators and a television audience of 4 billion (12,13). As rugby union continues to grow, the financial stakes and pressures on club and national level teams to succeed will significantly increase therefore placing greater emphasis on player development and measurement of factors that determine elite performance in rugby players. Professional clubs have addressed this by implementing academy structures whereby players from semiprofessional competitions are identified and developed for potential full-time professional contracts. However, there is paucity in the literature investigating performance-testing ability to distinguish players of varying playing levels and ability in the professional era.

Recently, the International Rugby Board have begun implementing new rules to maintain rugby union's fundamental value of an open and dynamic running game, thus encouraging a more spectator friendly game with frequent scoring opportunities (10). These rule changes place significant emphasis on professional clubs and nations to develop mobile and agile players. Specifically, the physical demands of the game require players to perform dynamic running and cutting maneuvers to create open running space and evade tacklers. Previous studies have demonstrated that cutting speed (as determined by time taken to perform a 45° agility Y-test) can differentiate between rugby union players of different playing levels (6). This field test required players to sprint 5 m followed by a 45° change of direction maneuver before sprinting another 5 m. However, it is unclear whether the differences observed were because of linear sprinting speed or related to the cutting technique chosen by individual players, physical ability, or even biomechanical variables influencing the performance of the cutting technique. Although linear running mechanics have been investigated extensively (11,15,16), the kinematic characteristics that link linear running, that is, the transition into change of direction

Address correspondence to Brian S. Green, brian.green@irfu.ie.

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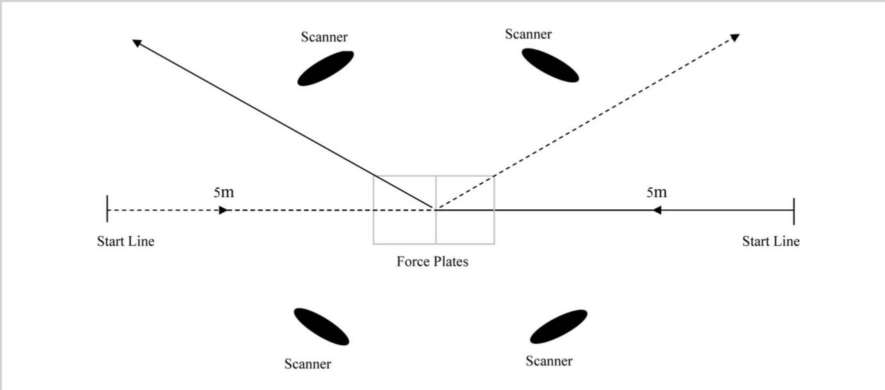

Figure 1. Schematic of laboratory setup.

maneuvers and reacceleration into the new direction, are not fully understood.

Technique chosen to perform high-speed change of direction tasks was studied by Andrews et al. (1) who described 2 distinct cutting techniques in American football players. For example, when performing a sidestep cut to the right, an athlete will plant the left leg to decelerate and push off onto the right leg to accelerate in the new direction. A crossover cut to the right occurs by the athlete planting the right leg to decelerate and push off as the left leg swings in the air to accelerate in the new direction. This initial work has been followed up by several researchers who have investigated the kinematics and kinetics of side-step and crossover cutting tasks, and their potential relationship to biomechanical loading factors in each technique and knee injury (2,8,9). However, there is paucity in the literature investigating biomechanical variables during cutting tasks and their relationship to performance in field-based sports. Therefore, the purpose of this investigation was to perform a novel explorative analysis of change of direction tasks using an active marker-based motion system to determine whether kinematic or temporal differences exist in cutting technique between rugby union players of different playing levels. Analysis of the components that comprise change-of-direction tasks may provide performance and strength and conditioning coaches with key information in designing effective training and agility drills, and providing players with useful feedback for improving technique and agility performance.

Methods

Experimental Approach to the Problem

This was a cross-sectional comparative study of kinematic performance during a single 45° cutting task between rugby union players of varying playing ability. The independent variables in this study included the 45° change of direction test and Starter and Nonstarter groupings. The dependent variables included anthropometric measurements, the kinematic components of the cutting task, and their relative timings to complete the task. It was hypothesized that kinematic and temporal comparison of key events of the cuttings task would demonstrate the Starter group would perform better than the Nonstarter group.

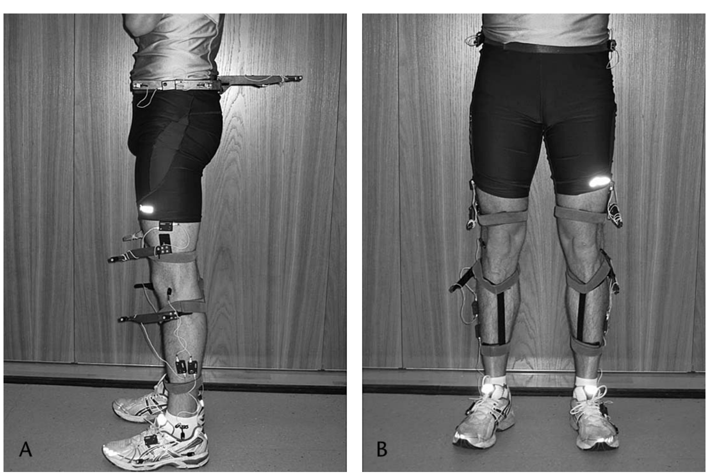

Figure 2. Sagittal (A) and frontal (B) view of CODA markers and wands.

Subjects

The investigation was approved by the local University ethics committee. Recruitment of study participants was carried out by contacting the coaching staff of several local rugby clubs. Players were informed of the experimental risks, and they signed an informed consent form before participation. Data were collected at the same point of the season (month 2 of an 8-month season) from 23 rugby union players from 3 different teams of the All-Ireland League (AIL) and were registered with

Table 1. Anthropometric data measured and measurement landmarks chosen.*

Anthropometric measurement (mm)	Measurement landmarks
Pelvic width	ASIS to ASIS
Pelvic depth	ASIS to PSIS
Knee width	Medial knee joint line to lateral knee joint line
Ankle width	Medial malleolus to lateral malleolus
Foot length	Heel to second toe
Height	In standing to top of head
Weight	In standing with shorts and T-shirt

*ASIS = anterior superior iliac spine; PSIS = posterior superior iliac spine.

the Irish Rugby Football Union. The AIL is a semiprofessional development league immediately below full-time professional (Provincial) competitions such as the Celtic League and the European Rugby Cup. The AIL preseason begins during August to September with the regular season running from October to April. At the time of data collection all players included in the study were performing a weekly training regime, which included 1 upper and 1 lower limb strength training program, a speed and agility session, and 3 squad practice sessions.

Table 2. Anatomical landmarks located and position of skin marking.*

Anatomical landmark	Position of skin marking
Left ASIS	Anterior central tip
Right ASIS	Anterior central tip
Left PSIS	Posterior central tip
Right PSIS	Posterior central tip
Greater trochanter	Superior medial tip
Anterior quadriceps muscle	4 cm Above superior border of the patella
Medial knee joint line	Medial frontal plane
Lateral knee joint line	Medial frontal plane
Lateral shank in median frontal plane	4 cm Below lateral knee joint line
Medial malleolus	Distal medial tip
Lateral malleolus	Distal anterior tip
Heel	Posterior inferior lateral point
Fifth metatarsal	Lateral prominent point

*ASIS = anterior superior iliac spine; PSIS = posterior superior iliac spine.

Players were assigned to 1 of 2 groups as determined by rugby playing ability, that is, whether or not a player was currently a first team player (starter) or reserve team player (Nonstarter). Players in the starter group were routinely selected on the starting 15 for AIL games. However, players in the Nonstarter group were routinely reserve squad members who only started games (or came on as substitute during games) as a result of injury or suspension to a starter. Confirmation of playing ability was obtained from the player's coach. Therefore, all players were from the same playing level (AIL) but varied in playing ability (starter or nonstarter). The starter group included 13 participants, whereas the remaining 10 participants comprised the Nonstarter group.

Before testing, all participants completed a physical screening questionnaire, anthropometric measurements, physical assessment to ensure there were no ongoing injuries, and a structured warm-up. Inclusion criteria were that participants (a) be within the ages of 18–23, (b) be healthy and physically active as determined by a Physical Activity Readiness Questionnaire and physical assessment, (c) currently play rugby for a rugby union club participating in the AIL. Exclusion criteria included (a) a lower extremity injury within the past 3 months resulting in loss of participation for 3 consecutive practice sessions or games, (b) currently suffering from spine, hip, knee, or ankle pain, which is aggravated by exercise, (c) history of lower extremity neurovascular symptoms. Subjects were also asked to identify their dominant lower extremity by indicating their preferred kicking leg with all subjects able to identify this. The primary author performed all anthropometric measurements and the inclusion and exclusion of participants.

Procedures

Kinematic and Kinetic Data Capture. Data were collected in a carpeted motion analysis laboratory room measuring 15 × 10 m. We used an active marker based motion capture system (CODA, Charnwood Dynamics Ltd, Leicestershire, United Kingdom) to acquire kinematic data during side-step cutting trials. The CODA cx-1 is a general-purpose motion analysis tracking system, which tracks the position of light emitting diode (LED) markers, which are powered by an individual battery pack attached via a short lead wire. Four CODA cameras were placed in a 6- × 5-m rectangular grid and oriented at a 45° to the longitudinal axis of the motion analysis laboratory. The cameras were faced toward the center of the room where 4 AMTI force plates (Advanced Medical Technology Inc, Watertown, MA, USA) were embedded in the laboratory floor to capture the straight-line approach, the cutting maneuver, and subsequent follow through toward the new direction. This allowed for calculation of contact time of the plant leg during each cutting trial. All cameras were positioned 75 cm from the ground to capture the infrared

TABLE 3. Marker and wand positions.*

Markers	Wands
Lateral aspect of the knee joint line in the median frontal plane	Pelvis (aligned with ASIS and PSIS)
Anterior aspect of the lateral malleolus	Thigh (aligned perpendicular to the knee joint line)
Posterior inferior aspect of the heel (on training shoe)	Shank (aligned perpendicular to the ankle joint)
Lateral aspect of fifth metatarsal (on training shoe)	

*ASIS = anterior superior iliac spine; PSIS = posterior superior iliac spine.

LED markers that were placed on the subject. Kinematic data were collected at a sampling rate of 200 Hz and kinetic data at 1,000 Hz. Several pieces of white tape were placed to guide the participant in the straight-line approach and the angle in which to perform the cutting maneuvers. A piece of tape was placed 5 m from the force plates and acted as the starting line for each cutting trial. Tape was also placed from the starting line to the edge of the force plate as a guide for the straight-line approach. A goniometer was used to place a 2.5-m piece of white tape on a 45° angle from the center of the force plates to act as a guide for the direction of the cutting task to occur. Finally, the tape was placed at the end of the 45° piece of tape to encourage the participant to "follow through" and continue to sprint in the new direction (Figure 1).

The marker and wand setup used in this study have been previously investigated for reliability and clinical application (5,14). Internal joint centers for the lower limb were calculated by obtaining the anthropometric data (Table 1) with measurements recorded in millimeters using calipers (Lafayette Instrument Co. Europe, Leistershire, United Kingdom). Subjects had anatomical landmarks (Table 2) marked with a skin marker pencil before recording their anthropometrics and attaching markers and marker wands. The limb lengths of the thigh, the shank, and the foot were determined using a measuring tape. The subjects' height and weight were also acquired. The infrared LED markers were attached to specific lower limb anatomical positions in accordance with the manufacturer's guidelines as per the gait analysis setup of the CODA mpx 30 users manual. The same investigator applied the markers and wands on all subjects in accordance with the manufacturer's guidelines (Table 3). Markers on the skin and battery packs were attached to the skin and marker wands (anterior and posterior) with double-sided adhesive tape. The same tape was placed on the internal aspect of the wand to secure it to the leg along with Velcro strap on the external aspect of the wand.

TABLE 4. Hip and knee angular displacement and angular velocity.*

	Angular displacement variables	Angular velocity variables
IC-PL		
Hip	Value at IC	Value at IC
	Max flexion pre-IC	Max value pre-IC
Knee	Value at IC	Value at IC
	Peak flexion pre-IC	Minimum extension velocity pre-IC
	Peak flexion post-IC	Max flexion velocity in first 100-ms post-IC
IC-POL		
Hip	Value at IC	Value at IC
	Max flexion pre-IC	Max flexion velocity pre-IC
Knee	Value at IC	Value at IC
	Peak flexion pre-IC	Max extension velocity pre-IC
	Peak flexion post-IC	Max flexion in first 100-ms post-IC
KE-POL		
Hip	Value at IC	Value at IC
	Max flexion pre-IC	
Knee	Value at IC	Value at IC
	Peak extension pre-IC	Max peak flexion velocity pre-IC
	Peak extension post-IC	Max extension velocity in first 100-ms post-IC

*PL = plant leg; POL = push-off leg; KE = knee extension; IC = initial contact.

Testing Procedure. Each subject wore a pair of shorts, a light T-shirt, ankle socks, and their normal training shoes during the testing procedure that allowed for unobstructed identification of the testing equipment. For each testing session, subjects performed a structured warm-up, which included

TABLE 5. Transitions between events.*

Transition	Definition and method of calculation
PL contact time (ms)	Time between IC-PL and TO-PL
POL contact time (ms)	Time between IC-POL and TO-POL
Flight time (ms)	Time between TO-PL and IC-POL
Total transition time (ms)	Time from IC-PL to TO-POL
PL contact time (%)	PL time as percentage of total transition time
POL contact time (%)	Time contribution between IC-POL and TO-POL to total transition time
Flight time (%)	Time contribution between TO-PL and IC-POL to total transition time
KE-PL time (%)	Timing of KE-PL as a percentage of total transition ime
KE-POL time (%)	Time contribution between IC-POL and KE-POL to total transition time
IC-PL to KE-PL time	Time of deceleration of the PL from IC to KE
KE-PL to TO-PL time	Time of acceleration of the PL from KE to TO
IC-POL to KE-POL time	Time of deceleration of the POL to IC to KE
KE-POL to TO-POL time	Time of acceleration of POL to KE to TO

*PL = plant leg; POL = push-off leg; KE = knee extension; IC = initial contact; TO = toe-off.

dynamic stretching, overhead squats, forward and lateral lunges, and squat and countermovement jumps. Subjects were then given a verbal and physical demonstration, which did not encourage a specific change of direction technique before performing at least 5 submaximal effort practice trials of left and right cutting tasks, respectively. Each participant was instructed to sprint forward at maximum pace and perform a cutting maneuver as if to evade an opposition player. Also, subjects were instructed to follow the white tape during the approach and the change of direction to ensure that a 45° change of direction occurred on the force plates allowing for kinematic capture and contact time measurement. Subjects were given more practice if needed to feel comfortable and safe while performing the task and to ensure that the initiation of the cutting maneuver occurred on the force plates. After completion of the subject setup, the subject performed the same warm-up and practice session to get accustomed to the wands and markers on the body. Cutting trials were performed in a nonrandomized fashion by first performing 5 cutting trials to the left then 5 cutting trials to the right with 2 minutes of rest between each trial. The choice of performing 5 cutting trials in each direction was chosen because this was determined to be a repeatable methodology in motion capture and analysis of gait (14).

Data Analysis. In each cut, the limbs were classified as plant leg (PL) or push-off leg (POL). The PL was defined as a support limb that decelerates the body from linear running and initiates the change of direction task and the POL was defined as the limb that initiates acceleration of the body into the new direction. All cuts were further classified as dominant or nondominant with respect to the change of direction, with the subject's dominant limb being used to designate the direction of the cut. For example, in a right dominant cut, the left leg is the PL, whereas the right leg is the POL. Separate analyses were performed for dominant and nondominant cutting trials.

TABLE 6. Demographic and anthropometric data.*

	Nonstarter (n = 10)†	Starter (n = 13)†	LS	ES
Age (y)	18 ± 1.22	21 ± 1.65	0.0004‡	2.07
Weight (kg)	81.2 ± 10.1	88.9 ± 11.35	0.1	0.72
Height (cm)	176.8 ± 5.44	181 ± 5.92	0.09	0.74
BMI (kg·m^{-2})	26.33 ± 4.10	27 ± 2.42	0.66	0.20

*LS = level of significance; ES = effect size; BMI = body mass index.
†Values are given as mean ± *SD.*
‡Independent t test: Starter group significantly older than Nonstarter group at $p < 0.001$ level.

TABLE 7. Comparison of angular displacement variables between groups.*†

	Angular displacement variable	Dominant cuts				Nondominant cuts			
		Nonstarter	Starter	LS	ES	Nonstarter	Starter	LS	ES
IC-PL									
Hip	Max flexion pre-IC	65.0 ± 6.8	66.2 ± 11.3	0.8	0.13	60.6 ± 8.9	63.1 ± 10.3	0.5	0.26
	Value at IC	51.6 ± 9.6	50.8 ± 10.6	0.9	0.08	50.5 ± 7.0	47.4 ± 7.2	0.3	0.44
Knee	Peak flexion pre-IC	87.7 ± 14.9	87.0 ± 12.2	0.9	0.05	87.5 ± 15.8	89.2 ± 13.8	0.8	0.11
	Value at IC	20.3 ± 7.7	19.0 ± 7.2	0.7	0.13	21.6 ± 6.0	21.0 ± 8.0	0.8	0.1
	Peak flexion post-IC	46.6 ± 6.4	41.9 ± 6.1	0.1	0.68	47.3 ± 4.8	45.8 ± 7.1	0.6	0.25
IC-POL									
Hip	Max flexion pre-IC	68.1 ± 9.8	70.2 ± 10.0	0.6	0.21	68.6 ± 7.9	69.8 ± 9.7	0.8	0.13
	Value at IC	53.3 ± 12.1	56.3 ± 6.7	0.5	0.3	50.2 ± 10.0	53.6 ± 8.7	0.4	0.4
Knee	Peak flexion pre-IC	101.3 ± 15.6	111.9 ± 9.3	0.1	0.83	99.9 ± 21.9	105.9 ± 10.1	0.4	0.35
	Value at IC	23.8 ± 11.8	28.1 ± 8.0	0.3	0.43	24.0 ± 14.2	25.0 ± 11.6	0.9	0.07
	Peak flexion post-IC	42.6 ± 9.3	43.5 ± 9.6	0.8	0.1	43.4 ± 7.9	43.4 ± 10.5	1.0	0.00
KE-POL									
Hip	Max flexion pre-IC	66.9 ± 10.5	69.0 ± 10.3	0.7	0.2	66.8 ± 11.4	68.3 ± 9.2	0.7	0.14
	Value at IC	35.2 ± 9.5	38.8 ± 7.3	0.3	0.42	32.8 ± 7.6	36.9 ± 10.6	0.3	0.44
Knee	Peak extension pre-IC	21.5 ± 12.4	29.4 ± 7.1	0.1	0.78	20.5 ± 12.7	24.8 ± 13.4	0.4	0.33
	Value at IC	42.3 ± 9.7	43.8 ± 9.7	0.7	0.15	43.1 ± 7.7	43.9 ± 10.6	0.9	0.08
	Peak extension post-IC	22.3 ± 13.9	18.8 ± 6.9	0.5	0.32	25.2 ± 14.8	18.8 ± 9.8	0.3	0.51

*LS = level of significance; ES = effect size; PL = plant leg; POL = push-off leg; KE = knee extension; IC = initial contact.
†Values are given as mean ± *SD.*

TABLE 8. Comparison of angular velocity variables between groups.*†

	Angular velocity variable	Dominant cuts				Nondominant cuts			
		Nonstarter	Starter	LoS	ES	Nonstarter	Starter	LoS	ES
IC-PL									
Hip	Max value pre-IC	7.9 ± 2.7	9.5 ± 2.1	0.2	0.66	7.8 ± 2.2	8.8 ± 1.8	0.3	0.5
	Value at IC	−4.3 ± 1.9	−5.6 ± 1.2	0.1	0.82	−4.2 ± 1.4	−5.0 ± 2.1	0.3	0.45
Knee	Minimum extension velocity pre-IC	−12.1 ± 1.3	−12.3 ± 2.4	0.8	0.1	−13.0 ± 2.7	−12.6 ± 2.2	0.7	0.16
	Value at IC	0.6 ± 2.9	−0.1 ± 2.3	0.5	0.27	1.4 ± 3.4	0.0 ± 2.7	0.3	0.46
	Max flexion velocity in first 100 ms post-IC	10.7 ± 3.2	9.7 ± 1.8	0.4	0.4	10.6 ± 2.9	11.0 ± 3.5	0.8	0.12
IC-POL									
Hip	Max flexion velocity pre-IC	8.6 ± 4.2	11.4 ± 2.2	0.1	0.83	8.9 ± 4.4	10.9 ± 2.0	0.2	0.6
	Value at IC	−4.0 ± 1.9	−5.2 ± 1.5	0.1	0.7	−4.8 ± 1.2	−5.0 ± 2.0	0.8	0.12
Knee	Max extension velocity pre-IC	−12.0 ± 2.5	−13.7 ± 2.1	0.1	0.73	−11.9 ± 3.4	−13.2 ± 2.9	0.4	0.41
	Value at IC	0.7 ± 2.3	−0.1 ± 1.9	0.4	0.38	0.8 ± 1.6	0.8 ± 2.1	1	0.00
	Max flexion in first 100 ms post-IC	7.0 ± 4.1	5.7 ± 2.7	0.4	0.37	6.0 ± 4.3	7.3 ± 3.8	0.5	0.32
KE-POL									
Hip	Value at IC	−5.0 ± 1.4	−4.6 ± 1.1	0.5	0.31	−4.0 ± 1.9	−4.6 ± 0.8	0.4	0.41
Knee	Max peak flexion velocity pre-IC	−10.2 ± 3.3	−11.9 ± 2.8	0.2	0.55	−10.4 ± 3.6	−11.6 ± 3.5	0.4	0.34
	Value at IC	−0.8 ± 0.7	−0.4 ± 0.5	0.1	0.66	−0.6 ± 0.9	−0.3 ± 0.5	0.4	0.41
	Max extension velocity in first 100 ms post-IC	−4.0 ± 2.0	−5.5 ± 1.6	0.1	0.82	−3.9 ± 2.7	−5.2 ± 1.6	0.2	0.59

*LoS = level of significance; ES = effect size; ES = effect size; PL = plant leg; POL = push-off leg; KE = knee extension; IC = initial contact.
†Values are given as mean ± *SD.*

TABLE 9. Comparison of transitions between groups.*†

Limb transitions	Dominant cuts Nonstarter	Starter	LoS	ES	Nondominant cuts Nonstarter	Starter	LoS	ES
Knee position at IC-PL (°)	20.3 ± 7.6	19.1 ± 7.1	0.72	0.16	21.6 ± 6.3	20.8 ± 7.7	0.78	0.11
Knee position at KE-PL (°)	46.3 ± 6.7	42.2 ± 6.1	0.14	0.64	47.6 ± 5.3	46.1 ± 7.1	0.55	0.24
PL knee stiffness (°)	26.0 ± 9.2	23.0 ± 4.6	0.36	0.41	26.0 ± 7.2	25.3 ± 7.0	0.81	0.10
KE-PL timing (ms)	106.9 ± 23.8	85.4 ± 22.8‡	0.04	0.92	96.8 ± 25.3	84.1 ± 25.0	0.25	0.50
PL contact time (ms)	241.1 ± 29.5	212.6 ± 28.6‡	0.03	0.98	233.0 ± 20.1	216.7 ± 30.1	0.14	0.64
Knee position at IC-POL (°)	23.5 ± 12.2	28.1 ± 7.9	0.32	0.45	23.1 ± 12.7	25.1 ± 11.5	0.71	0.16
Knee position at KE-POL (°)	42.4 ± 9.6	43.9 ± 9.3	0.70	0.16	43.1 ± 7.9	43.6 ± 10.7	0.90	0.05
POL knee stiffness (°)	19.2 ± 12.8	15.9 ± 8.3	0.49	0.31	20.0 ± 10.2	18.6 ± 12.1	0.76	0.12
KE-POL timing (ms)	97.0 ± 18.8	88.2 ± 19.8	0.29	0.46	96.8 ± 25.3	84.1 ± 25.0	0.25	0.50
POL contact time (ms)	212.8 ± 25.3	209.2 ± 37.9	0.82	0.11	209.9 ± 17.2	214.2 ± 40.1	0.73	0.14
Flight time (ms)	82.9 ± 48.7	67.0 ± 21.7	0.35	0.42	85.5 ± 31.6	71.7 ± 22.4	0.26	0.50
Total transition time (ms)	536.3 ± 65.6	488.9 ± 75.6	0.12	0.67	528.4 ± 42.0	513.9 ± 73.6	0.56	0.24
PL contact time (%)	45.3 ± 5.9	43.7 ± 2.7	0.44	0.35	44.2 ± 3.1	43.0 ± 3.8	0.41	0.35
POL contact time (%)	39.7 ± 3.3‡	42.8 ± 3.0	0.04	0.98	39.8 ± 2.7	42.2 ± 2.8	0.06	0.87
Flight time (%)	15.0 ± 7.5	13.5 ± 3.4	0.58	0.26	16.0 ± 5.2	13.8 ± 3.5	0.28	0.50
KE-PL time (%)	20.3 ± 4.6	17.0 ± 3.2	0.08	0.83	18.0 ± 3.9	16.7 ± 3.9	0.63	0.33
KE-POL time (%)	78.0 ± 2.5	74.7 ± 3.1‡	0.01	1.17	79.0 ± 3.1	73.4 ± 3.4§	0.001	1.72

*LoS = level of significance; ES = effect size; PL = plant leg; POL = push-off leg; KE = knee extension; IC = initial contact.
†Values are given as mean ± *SD.*
‡Sig diff from column to left at $p < 0.05$ level.
§Sig diff from column to left at $p < 0.001$ level.

TABLE 10. Dominant and nondominant angular displacement power calculations of starters ($N = 10$) and Nonstarters ($N = 10$).*

	Angular displacement variables	Dominant	Nondominant
IC-PL			
Hip	Max flexion pre-IC	0.05	0.12
	Value at IC	0.04	0.27
Knee	Peak flexion pre-IC	0.04	0.05
	Value at IC	0.08	0.04
	Peak flexion post-IC	0.64	0.1
IC-POL			
Hip	Max flexion pre-IC	0.1	0.06
	Value at IC	0.12	0.19
Knee	Peak flexion pre-IC	0.57	0.14
	Value at IC	0.21	0.04
	Peak flexion post-IC	0.05	0.02
KE-POL			
Hip	Max flexion pre-IC	0.09	0.06
	Value at IC	0.22	0.4
Knee	Peak extension pre-IC	0.52	0.17
	Value at IC	0.07	0.04
	Peak extension post-IC	0.17	0.28

*PL = plant leg; POL = push-off leg; KE = knee extension; IC = initial contact.

Marker data from all trials were processed using the CODA motion gait model to calculate angular displacement and angular velocity for the hip and knee joints of both legs during the cutting task. Subsequent to this, timings of key events throughout the cutting task were extracted to facilitate further data analysis. Initial contact (IC) and toe-off (TO) of the plant leg (IC-PL and TO-PL, respectively) were identified using the vertical ground reaction force from the force plates using a 10 N threshold level (7). Initial contact of the push-off leg (IC-POL) was determined as the point where the vertical acceleration of the heel marker in the Z plane crossed the horizontal axis, whereas toe-off of the push-off leg (TO-POL) was identified using the local peak vertical acceleration of the toe marker (7). The timings of initiation of knee joint

TABLE 11. Dominant and nondominant angular velocity power calculations of starters ($N = 10$) and Nonstarters ($N = 10$).*

	Angular velocity variables	Dominant	Nondominant
IC-PL			
Hip	Max value pre-IC	0.47	0.3
	Value at IC	0.58	0.23
Knee	Minimum extension velocity pre-IC	0.04	0.07
	Value at IC	0.12	0.26
	Max flexion velocity in first 100-ms post-IC	0.17	0.05
IC-POL			
Hip	Max flexion velocity pre-IC	0.56	0.3
	Value at IC	0.51	0.05
Knee	Max extension velocity pre-IC	0.58	0.23
	Value at IC	0.19	0.02
	Max flexion in first 100-ms post-IC	0.17	0.16
KE-POL			
Hip	Value at IC	0.15	0.17
Knee	Max peak flexion velocity pre-IC	0.37	0.18
	Value at IC	0.44	0.18
	Max extension velocity in first 100-ms post-IC	0.66	0.33

*PL = plant leg; POL = push-off leg; KE = knee extension; IC = initial contact.

TABLE 12. Power calculations of limb transitions for starters ($N = 10$) and nonstarters ($N = 10$) during dominant and nondominant cuts.*

Limb transitions	Dominant	Nondominant
Knee position at IC-PL (°)	0.07	0.05
Knee position at KE-PL (°)	0.49	0.18
PL knee stiffness (°)	0.18	0.05
KE-PL timing (ms)	0.82	0.35
PL contact time (ms)	0.87	0.4
Knee position at IC-POL (°)	0.22	0.07
Knee position at KE-POL (°)	0.07	0.03
POL knee stiffness (°)	0.13	0.06
KE-POL timing (ms)	0.29	0.35
POL contact time (ms)	0.05	0.05
Flight time (ms)	0.18	0.28
Total transition time (ms)	0.51	0.09
PL contact time (%)	0.14	0.17
POL contact time (%)	0.84	0.77
Flight time (%)	0.09	0.27
KE-PL time (%)	0.63	0.18
KE-POL time (%)	0.92	1

*PL = plant leg; POL = push-off leg; KE = knee extension; IC = initial contact.

extension (KE) in the PL and POL (KE-PL and KE-POL) were then identified. Finally, angular displacement of the knee joint at IC and KE for both PL and POL were identified. The difference in knee angular displacement between IC and KE was used to calculate range of motion during the deceleration phase for the PL and POL defined as KROM. These variables represented knee stiffness during the deceleration phase for each limb during the cut.

A qualitative analysis of the kinematic data suggested that further analysis of knee and hip joint angular displacement and velocity should be carried out with respect to 3 critical anchor points during the cutting task. These points were IC-PL, IC-POL, and KE-POL and correspond to IC of the limb responsible for initial deceleration, IC of the leg responsible for acceleration in the new direction, and the point of initiation of acceleration in the new direction. Knee and hip angular displacement and angular velocity were analyzed with respect to 200-ms periods of time either side of these anchor points. Relevant kinematic data were extracted for each cutting trial for each study participant, and the average kinematic profiles with respect to each of the anchor points were calculated for dominant and nondominant cutting trials. See Table 4 for a full list of angular displacement and angular velocity variables analyzed.

Finally, timings of transitions between key events and their respective contribution to the total transition time (ToTT) during the cutting task were identified for each trial and were averaged for each study participant with respect to dominance (Table 5).

Table 13. Intraclass correlation coefficients for angular displacement variables during dominant and nondominant cuts.*

	Angular displacement variable	ICC	
		Dominant cuts	Nondominant cuts
IC-PL			
Hip	Max flexion pre-IC	0.95	0.98
	Value at IC	0.97	0.95
Knee	Peak flexion pre-IC	0.96	0.98
	Value at IC	0.96	0.96
	Peak flexion post-IC	0.94	0.93
IC-POL			
Hip	Max flexion pre-IC	0.96	0.97
	Value at IC	0.96	0.97
Knee	Peak flexion pre-IC	0.96	0.95
	Value at IC	0.95	0.95
	Peak flexion post-IC	0.93	0.95
KE-POL			
Hip	Max flexion pre-IC	0.96	0.96
	Value at IC	0.87	0.91
Knee	Peak extension pre-IC	0.92	0.92
	Value at IC	0.93	0.94
	Peak extension post-IC	0.92	0.90

*PL = plant leg; POL = push-off leg; KE = knee extension; IC = initial contact; ICC = intraclass correlation coefficient.

Table 14. Intraclass correlation coefficients for angular velocity variables during dominant and nondominant cuts.*

	Angular velocity variable	ICC	
		Dominant cuts	Nondominant cuts
IC-PL			
Hip	Max value pre-IC	0.94	0.94
	Value at IC	0.89	0.88
Knee	Minimum extension velocity pre-IC	0.96	0.80
	Value at IC	0.89	0.94
	Max flexion velocity in first 100-ms post-IC	0.94	0.96
IC-POL			
Hip	Max flexion velocity pre-IC	0.97	0.95
	Value at IC	0.89	0.86
Knee	Max extension velocity pre-IC	0.97	0.98
	Value at IC	0.90	0.89
	Max flexion in first 100-ms post-IC	0.97	0.98
KE-POL			
Hip	Value at IC	0.77	0.37
Knee	Max peak flexion velocity pre-IC	0.93	0.95
	Value at IC	0.58	0.66
	Max extension velocity in first 100-ms post-IC	0.85	0.85

*PL = plant leg; POL = push-off leg; KE = knee extension; IC = initial contact; ICC = intraclass correlation coefficient.

Statistical Analyses

Performance differences in all variables between players in the Starter and Nonstarter groups were compared using independent 2-sided *t*-tests, with a confidence level of 95% ($p \leq 0.05$). Considering this was a preliminary study on the potential differences between cutting performance in these groups, a Bonferroni adjustment was not performed. Therefore, each variable was analyzed independently of each other as to decrease the likelihood of type 2 error (17). Intraclass class correlation coefficients (ICCs) were performed on all dependent variables. The ICC is an index of reliability calculated from variance estimates derived from, in this case a repeated measures, analysis of variance (23). Intraclass class correlation values of 0.75 or above are considered to indicate good reliability (18). Effect sizes (ESs) for group differences were calculated by dividing the differences between group means by the pooled standard deviation (4). The strength of ESs were interpreted using guidelines described by Cohen (4) with values between 0.2 and 0.49 interpreted as weak, 0.5–0.79 as medium, and from >0.8 as strong.

Results

The anthropometric profiles of both groups are presented in Table 6. The Starter group (21 ± 1.65) was significantly older ($p = 0.004$; ES = 2.07) compared to the Nonstarter group (18 ± 1.22); however, no significant differences existed with height, weight, and body mass index.

No significant differences between groups were observed for hip and knee angular displacement and velocity during

TABLE 15. Intraclass correlation coefficients for limb transitions during dominant and nondominant cuts.*

	ICC	
Limb transitions	Dominant cuts	Nondominant cuts
Knee position at IC-PL (°)	0.96	0.96
Knee position at KE-PL (°)	0.96	0.97
PL knee stiffness (°)	0.94	0.95
KE-PL timing (ms)	0.92	0.83
PL contact time (ms)	0.96	0.96
Knee position at IC-POL (°)	0.94	0.94
Knee position at KE-POL (°)	0.94	0.96
POL knee stiffness (°)	0.95	0.96
KE-POL timing (ms)	0.78	0.87
POL contact time (ms)	0.96	0.96
Flight time (ms)	0.93	0.90
Total transition time (ms)	0.97	0.75
PL contact time (%)	0.94	0.84
POL contact time (%)	0.89	0.68
Flight time (%)	0.92	0.84
KE-PL time (%)	0.87	0.77
KE-POL time (%)	0.68	0.60

*PL = plant leg; POL = push off leg; KE = knee extension; IC = initial contact; ICC = intraclass correlation coefficient.

IC-PL, IC-POL, and KE-POL anchor points during dominant and nondominant cuts (Tables 7 and 8).

Comparison between Starter and Nonstarter groups for transitions during dominant and nondominant cuts is presented in Table 9. Plant leg and POL knee angular displacement at IC and KE initiation during dominant and nondominant cuts were similar in both groups. There were no significant differences in KROM-PL and KROM-POL between groups in either dominant or nondominant cuts. During dominant cuts, the Starter group initiated KE-PL (85.4 ± 22.8 ms) significantly earlier ($p = 0.04$; ES = 0.92) than the Nonstarter group (106.9 ± 23.8 ms). Also, PL contact time on dominant cuts was significantly shorter ($p = 0.03$; ES = 0.98) in the Starter group (212.6 ± 28.6 ms) compared to the Nonstarter group (241.1 ± 29.5 ms); however, PL contact time during nondominant cuts was similar between groups. With respect to dominant and nondominant POL contact times, no significant differences between groups were observed. Dominant cut KE-POL (%) occurred significantly sooner ($p = 0.01$; ES = 1.17) relative to the ToTT in Starters (74.7 ± 3.1%) compared to Nonstarters (78.0 ± 2.5%). A similar result existed in nondominant cut KE-POL (%) because this transition occurred significantly sooner ($p = 0.001$; ES = 1.72) in Starters (73.4 ± 3.4%) compared to in Nonstarters (79.0 ± 3.1%). Push-off leg contact time (%) in dominant cuts occurred significantly sooner ($p = 0.04$; ES = 0.98) relative to the ToTT in the Nonstarters (39.7 ± 3.3%) compared to in Starters (42.8 ± 3.0%). Mean ToTT of dominant and nondominant cuts was faster in the Starter group compared to in the Nonstarter group; however, this difference was not statistically significant.

A post hoc check was performed for statistical power of observed differences between groups ($N = 10$ in each group) using pooled *SD* from players in both groups during dominant and nondominant cuts (Tables 10–12).

Intraclass correlation coefficient analysis for all angular displacement, and velocity and limb transition–dependent variables are presented in Tables 13–15. Acceptable stability was noted for all angular displacement variables because all ICC values were >0.87. Overall, angular velocity and limb transition variables demonstrated acceptable reliability; however, ICC for KE-POL angular velocity of the hip and knee during dominant and nondominant cuts ranged from 0.37 to 0.77 (Table 14). Also, KE-POL (%) times during dominant and nondominant cuts were 0.68 and 0.60, respectively.

DISCUSSION

The aim of this study was to investigate whether kinematic or temporal differences exist between rugby players of differing playing ability during change of direction maneuvers. Such information would provide performance and strength and conditioning staff practical guidance in providing proper feedback to athletes to develop efficient cutting ability. The principal finding in this study was kinematic profiles (angular displacement and velocities at the hip and knee) during dominant and nondominant cuts were the same between Starters and Nonstarters. Furthermore, no differences between groups were observed in ToTT during dominant and nondominant cuts. However, further analysis of temporal components between the period of IC-PL and TO-POL demonstrated significant differences between groups.

The initiation of the cutting task is characterized by significant deceleration resulting in reduced velocity of forward progression. A player cannot reach a similar progression velocity in the new direction until KE-POL has occurred. This key phase in the cutting task occurred sooner as a percentage of ToTT in the Starter's group than the Nonstarter's group, with differences between groups during dominant and nondominant cuts of between 5 and 8%, respectively. This indicates that the Starters are accelerating into the new direction earlier than their Nonstarter counterparts, which may give a player an advantage during ball carrying and opposing player evasion. Such an advantage reduces the time for defenders to react to the players cutting maneuver and close down on the ball carrier to make a tackle.

The transitional phases were further analyzed to examine contact time of the PL during dominant and nondominant cuts. Starters demonstrated significantly shorter mean contact time of the PL during dominant cuts. To explain this difference, PL contact time was subsequently divided into a deceleration and acceleration phase based on whether the knee was flexing or extending. During the transition of IC-PL to KE-PL, the Nonstarters required a longer period of time to decelerate knee flexion signifying that the Nonstarters were proportionately slower in this initial transition, thus reacceleration at KE-PL occurred later compared to Starters. However, during nondominant cuts, PL contact time was not statistically significant between groups suggesting that both groups were proficient in using the dominant limb to decelerate and reaccelerate during IC-PL to KE-PL.

Interestingly, despite the participants in this study not having been instructed to perform a specific cutting maneuver, all subjects performed a side-step cutting task as opposed to a crossover technique. Therefore, the data analysis and group comparisons could be performed without the need to form subgroups. Distinct cutting techniques and their kinematic and kinetic characteristics have been previously described in relation to lower limb injury (2,8,9). Further investigations into side-step and crossover cutting techniques are required to determine if their biomechanical characteristics also play a role in change of direction performance. By comparing the techniques, it is possible that one cutting technique is more effective in different situations based on velocity before initiation or the desired angle of the change of direction.

The participants in this study all played rugby in the same league and in some cases were teammates. However, the Starters were considered first choice players because they would play regularly in their respective club's senior team, whereas members of the Nonstarter group only play on a reserve basis with limited opportunity to play. Also, both groups were essentially the same in terms of training history, because the overall weekly training regime for game preparation did not differ significantly between groups. Observed differences in relative transition times are therefore more likely to be related to a combination of skill level and game experience rather than a manifestation of training history.

Studies investigating field and laboratory test performances in players from distinctly different physical training and game experiences have often demonstrated significant differences between groups. It is possible that the differences observed in this study would have been even larger had we followed a similar approach and had, for example, compared cutting technique in AIL players and elite international players. This would be expected and may not add relevance to coaches and scouts who are interested in performance factors for selection of players for further development, talent identification, and player potential for success in higher-level competitions.

The agility task in this study was a single 45° anticipated change of direction test. This means players did not have to react to a stimulus that would indicate to the participant the direction to perform the cut. It is possible that if this same test had included a reactive element performance, differences between Starters and Nonstarters would have been clearer. Sheppard et al. (21) previously demonstrated this when performing a 45° agility field test with Australian Rules Football players of varying playing level. The anticipated element of the test did not distinguish between the player groups; however, once the same test became reactive to a sports-specific stimulus, the higher-level players performed the test faster. Although all participants were involved in a similar training week for preparation for weekend games, the specifics of their strength and conditioning programs and training volume was not controlled. It is possible that fatigue could have influenced the results; however, all players were tested at the same point in their season. A vast difference in training volume exists between the rugby preseason and in-season. Other possible limitations of this study are that the time of the day and hydration status of the participants were not controlled or monitored before testing.

Practical Applications

A common phrase used by strength and conditioning coaches to describe a player with effective cutting technique and agility performance is "he/she has good feet." The practical question is what exactly does this mean? This study has attempted to demonstrate that the side-step cutting maneuver has several components that influence change of direction performance. Several biomechanical components of the side-step cutting task presented in this study may provide coaches with practical guidance to effectively evaluate a player's cutting performance and design of appropriate agility drills. First, it is worthwhile to imagine the cutting task as consisting of 2 weight-bearing stages with a period of flight (both limbs are not in contact with the ground) between each weight-bearing stage. At initiation of the cutting task, the first stage of weight bearing occurs as the PL rapidly decelerates the body. The PL must demonstrate significant stability and stretch-shortening cycle efficiency to quickly decelerate and then accelerate the body onto the POL. These stages may be followed by a period of flight whereby both limbs are not in contact with the ground. The second weight-bearing stage occurs when the POL contacts the ground and must also quickly decelerate the load placed onto it to finally accelerate into the new direction. Perhaps these specific transitions and events could be part of a checklist or performance criteria for coaches to accurately assess cutting technique? For example, a coach could compare players based on their relative speed in transitioning from PL to POL to determine whether they need additional training drills aimed at optimizing their ability to shift weight from 1 limb to the other at speed during game play situations.

It is important to relate these findings to practical suggestions for training drills. Contact times of the PL and POL and the time to decelerate knee flexion during IC of the PL and POL appear to influence cutting performance. Furthermore, all subjects demonstrated PL and POL contact times in $<$0.24 seconds, which can be classified as a fast stretch-shortening cycle action. This has significant training implications because several studies have demonstrated that plyometric activities, such as drop jumps, countermovement jumps, and sprint-specific bounding, can improve sprinting (19) and agility (22) performance. This suggests that plyometric training including skipping rope, stiff ankle hops, and drop and countermovement jumps may improve the stiffness of the lower limb by decreasing the contact time during the cutting task. First, this reinforces the concept of specificity as plyometric drills activate a similar stretch-shortening process in the lower limbs that occur in cutting tasks. However, change of direction maneuvers require movement in the frontal and transverse planes, which is vastly different from straight-line running where the lower limbs are primarily functioning in the sagittal plane. Therefore, the plyometric program should be performed primarily in the frontal and transverse planes resulting in more horizontal displacement of the body as opposed to vertical displacement. A progression from this would be to perform jumps that combine the frontal and transverse planes resulting in the athlete landing with the hips pointing in a different direction, which is exactly what happens in cutting tasks.

Finally, it must be appreciated that cutting tasks are regularly performed in field and court sports such as American football, basketball, and tennis. Rugby union players must demonstrate adequate mobility and cutting performance, because a ball carrier attempts to evade defenders and vice versa. These sports also require players to not only execute preplanned "plays" but also to react to game-specific stimuli to effectively carry the ball or defend. This mix of temporal and spatial uncertainty was described by Chelladurai (3) as a "universal" playing environment, where players must effectively perform tasks without knowing when or where the game-specific stimuli will arise. Considering that many team and court sports players must perform in this universal playing environment, it suggests there may be several factors that contribute to cutting performance. Sheppard and Young (20) highlight that the contemporary definition of agility may be flawed in that it does not appreciate that cutting tasks require physical characteristics (strength, speed, and stretch-shortening cycle efficiency), cognitive processes (motor learning), and technical skill (biomechanical) to perform cutting tasks in universal playing environments. In practice, this suggests that sports scientists and coaches should consider these components of agility and cutting tasks in future research design and training programs. A simple drill to address these components would be to place 2 different color cones on the ground and directing the athlete to perform a 45° change of direction maneuver toward one of them. The athlete would first perform repetitions of a cutting maneuver to either cone of their choice. Once this was performed to each cone, the athlete would perform the same drill in a reactive environment. This would entail the athlete accelerating forward and the coach calling out the color of 1 of the cones. The athlete would react to the auditory stimulus and change direction toward the corresponding cone. The next progression would be to instruct the athlete to change direction to the opposite cone that is called out. During this progression of drills, the athlete is being asked to perform in a progressively challenging cognitive environment which would likely see a decrease in the performance of the cutting task. The aforementioned checklist could be used by the coach to critique and provide feedback on the cutting task.

This study has provided encouraging results that demonstrate the potential value for using temporal analysis of cutting technique in rugby players to highlight training needs and talent identification. It is important to point out that this was an exploratory study in which multiple comparisons were performed without an alpha correction. Therefore, our significant findings should be confirmed with a targeted follow-up investigation. Then, further research in the area can give a greater insight into the relative differences in technique that prevail in players from differing levels, and concentrating in translating the testing protocol to a field environment.

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