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Research article

Acceleration Kinematics in Cricketers: Implications for Performance in the Field

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Abstract
Cricket fielding often involves maximal acceleration to retrieve the ball. There has been no analysis of acceleration specific to cricketers, or for players who field primarily in the infield (closer to the pitch) or outfield (closer to the boundary). This study analyzed the first two steps of a 10-m sprint in experienced cricketers. Eighteen males (age = 24.06 ± 4.87 years; height = 1.81 ± 0.06 m; mass = 79.67 ± 10.37 kg) were defined as primarily infielders (n = 10) or outfielders (n = 8). Timing lights recorded 0-5 and 0-10 m time. Motion capture measured first and second step kinematics, including: step length; step frequency; contact time; shoulder motion; lead and rear arm elbow angle; drive leg hip and knee extension, and ankle plantar flexion; swing leg hip and knee flexion, and ankle dorsi flexion. A one-way analysis of variance ($p < 0.05$) determined between-group differences. Data was pooled for a Pearson's correlation analysis ($p < 0.05$) to analyze kinematic relationships. There were no differences in sprint times, and few variables differentiated infielders and outfielders. Left shoulder range of motion related to second step length (r = 0.471). First step hip flexion correlated with both step lengths (r = 0.570-0.598), and frequencies (r = -0.504--0.606). First step knee flexion related to both step lengths (r = 0.528-0.682), and first step frequency (r = -0.669). First step ankle plantar flexion correlated with second step length (r = -0.692) and frequency (r = 0.726). Greater joint motion ranges related to longer steps. Cricketers display similar sprint kinematics regardless of fielding position, likely because players may field in the infield or outfield depending on match situation. Due to relationships with shoulder and leg motion, and the importance and trainability of step length, cricketers should target this variable to enhance acceleration.

Key words: Biomechanics, cricket, fielding, step length, sprinting, swing leg flexion.

Introduction

Cricket is a popular sport played in many countries, including England, Australia, India, New Zealand, and South Africa. There are several versions of cricket, such as the long form played over five consecutive days, and shorter formats including one-day and Twenty20 (T20) cricket. T20 cricket, which is played over a duration of approximately three hours, has grown in popularity in recent years, and its proliferation has changed the emphasis of certain physical requirements for players (Petersen et al., 2010; 2011). For example, T20 cricket requires approximately 50-100% more maximal sprints per hour for all players when compared to multi-day matches (Petersen et al., 2010). Sprints during cricket are often centered about crucial match situations such as running between the wickets, the run-up and delivery during fast bowling, or sprinting to field a ball (Bartlett, 2003; Duffield and Drinkwater, 2008; Petersen et al., 2010; Rudkin and O'Donoghue, 2008). In cricket only select players will bowl, while certain players will have greater responsibility to score runs when batting. However, all cricketers must field, and complete maximal sprints when fielding.

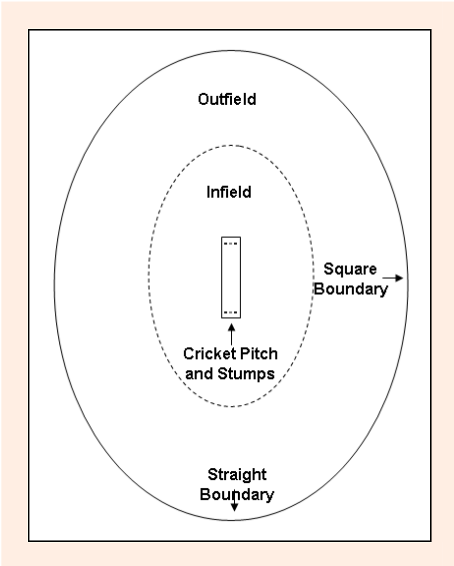

Figure 1. A standard cricket field.

A cricket field can be divided into two main sections about the pitch – an infield and an outfield (Figure 1). As defined by the International Cricket Council (2012a), to set the infield, two semi-circles with a radius of 27.43 meters (m) are drawn, with the middle stump at each end of the pitch as the center. The outfield lies from the infield to the boundary. The square boundaries are a minimum of 137.16 m apart, with the shorter of the two being a minimum 59.43 m from the center of the pitch. The straight boundaries at both ends of the pitch are a minimum of 64 m from the pitch center. In one-day (International Cricket Council, 2012a) and T20 (International Cricket Council, 2012b) cricket, there are restrictions on how many players are allowed to field in the outfield during certain overs to increase scoring opportunities for the batsmen. As the match progresses, more players are allowed in the outfield. For example, at the start of a T20 innings, only two players are allowed in the outfield; at the end of an innings, a maximum of five players will be in the outfield (International Cricket Council, 2012b).

Certain players will specialize in particular field-

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ing positions, often due to other skills important to cricket. For example, a good reaction time is needed in the infield, as fielders are closer to the batsman and have less time to react to balls that are hit hard by batsmen (Bartlett, 2003), whereas outfielders require a strong throwing arm to field the ball back to the infield (Figure 1). Nonetheless, cricketers must be adept at fielding in either the infield or outfield, depending on what is required during a match. Fielders are expected to reduce the number of runs a batting side can accumulate by restricting the number of scoring shots and aiding in dismissals, by catching a ball on the full or performing a run-out. Fielding in cricket will often require a maximal sprint in pursuit of the ball after it has been hit by a batsman, and these sprints tend to be over a short distance (Rudkin and O'Donoghue, 2008). For example, state-level Australian cricketers had an average sprint distance of 15 ± 4 m when in the field (Petersen et al., 2010). As a result, the acceleration capacity of a cricketer takes on paramount importance.

It must be acknowledged that not every time a cricketer fields a ball will involve a maximal sprint. However, in those situations which do, it will be critical to the teams' performance, as the fielder must move to the ball as quickly as possible to dismiss a batsman or to prevent runs being scored. There has been little analysis of sprinting in cricket, with the focus previously upon testing (Johnstone and Ford, 2010, Lockie et al., 2012a; 2013a), and the influence of leg guards when running between the wickets (Webster and Roberts, 2011). It is of interest to analyze the sprint acceleration abilities of those players who field predominantly in the infield or outfield, as there may be certain aspects to technique (e.g. a faster first step for infielders) that are typical of cricketers that field in a certain position. However, there could be no differences given that many players may be required to field in both the infield and outfield during a match. This must be confirmed through analysis of acceleration technique in cricketers.

The technique adopted by cricketers when sprinting in the field should be typical of other team sport athletes. Regarding step kinematics, a high step frequency and low contact time during stance has been advocated for faster sprint times (Lockie et al., 2011, Murphy et al., 2003). Longer step lengths have also been found to be beneficial for speed over 10 m (Lockie et al., 2013). The step kinematics produced will be influenced by upper- and lower-body movement. Greater arm range of motion has been said to assist with leg drive during acceleration (Bhowmick and Bhattacharyya, 1988). Greater extension of the drive leg (the leg in contact with the ground) accompanies increased running speed (van Ingen Schenau et al., 1994). For the swing leg (the leg not in contact with the ground), increased hip and knee flexion reduces the moment of inertia of the limb during the recovery phase of the sprint step (Mero et al., 1992). However, the extent to which these movements influence acceleration step kinematics in cricketers has yet to be defined. Given the importance of acceleration for fielders when pursuing the ball (Petersen et al., 2010), this is a situation that should be rectified. This is more pertinent when considering that fielding practice for cricketers may focus purely on throwing and catching, without considering the need to move rapidly to retrieve the ball (Finch et al., 2010).

In modern-day cricket, batsmen attempt more quick singles for balls hit into the infield (Duffield and Drinkwater, 2008), and attempt to complete more runs for balls hit into the outfield (Petersen et al., 2010). Fielders must be able to accelerate effectively to restrict these scoring options. Therefore, this research analyzed the sagittal plane kinematics of experienced cricketers during the first two steps of a 10-m sprint. A 10-m sprint was used as it is a common assessment of acceleration in team sport athletes (Jarvis et al., 2009, Lockie et al., 2011; 2013b). The first two steps were analyzed because of their importance for acceleration (Lockie et al., 2011, Murphy et al., 2003). The first goal of this research was to ascertain whether there are acceleration kinematics that differentiates cricketers who primarily field in the infield or outfield. The second goal was to determine whether there are technique characteristics that have a greater influence on sprint acceleration and step kinematics. It is hypothesized that there will be no differences in sprint kinematics for infielders or outfielders, as all cricketers may field in both the infield and outfield during a match. Furthermore, parameters such as greater joint ranges of motion will relate to faster acceleration, and longer step lengths and faster step frequencies. This research will provide beneficial information for cricket and strength and conditioning coaches, as it will detail acceleration kinematics that should be trained specifically for cricketers.

Methods

Subjects

Eighteen (n = 18) experienced male cricketers from the same cricket club that played in a regional competition (age = 24.06 ± 4.87 years; height = 1.81 ± 0.06 m; mass = 79.67 ± 10.37 kilograms [kg]) were recruited for this study. Subjects were recruited if they: were 18 years of age or older; were currently playing premier league or division one in the regional competition; had at least three years' experience playing cricket; were currently training for cricket (greater than or equal to three hours per week); and did not have any medical conditions that would compromise participation in the study. The methodology and procedures used in this study were approved by the institutional ethics committee, and conformed to the policy statement with respect to the Declaration of Helsinki. All subjects received a clear explanation of the study, including the risks and benefits of participation, and written informed consent was obtained prior to testing.

The method for defining subjects as infielders or outfielders was adapted from research that used subjective methods to rank or define athletes (Wilkinson et al., 2009). The premier league team coach and captain were asked to define each subject as an infielder or outfielder. Although cricketers will field in both the infield and outfield, the coach and captain were asked where they would prefer the subject to field during a match. If there was a difference in opinion, a resolution was obtained through discussion between the coach and captain (Wilkinson et al., 2009). Following this process, 10 subjects were defined as infielders (age = 24.70 ± 4.86 years; height = 1.79 ± 0.04 m; mass = 75.80 ± 10.37 kg), and 8 as outfielders (age = 23.25 ± 4.76 years; height = 1.85 ± 0.07 m; mass = 84.51 ± 8.08 kg). No wicketkeepers were analyzed in this study, due to their unique movement patterns involving minimal sprinting when compared to other fielders (Petersen et al., 2010).

Testing procedures

Two sessions were used for this study. The first session was used for familiarization, such that subjects could have their anthropometry measured for the motion capture system, and become accustomed to the testing procedures. At the start of the familiarization session, the subject's age, height, body mass, and selected anthropometric data needed for three-dimensional analysis were collected. The second session involved the sprint testing data collection. All testing occurred in the biomechanics laboratory, with a textured concrete floor, and each session lasted approximately 30 minutes. Prior to data capture in the testing session, each subject completed a standardized warm-up. This consisted of five minutes of jogging on a treadmill at a self-selected pace, followed by 10 minutes of dynamic stretching of the lower limbs, and progressive speed runs over the 10-m testing distance.

10-meter sprint

10-m sprint time was measured through the use of timing gates (Fusion Sports, Coopers Plains, Australia). Gates were positioned at 0 m, 5 m, and 10 m to measure the 0-5 m and 0-10 m intervals. Sprints over 5 m (Lockie et al., 2011; 2013), and 10 m (Jarvis et al., 2009; Lockie et al., 2011; 2013), have previously been used to assess team sport athletes. Gates were placed at a height of 0.8 m and a width of 2.5 m to not interfere with the motion capture cameras. Subjects began each sprint 30 centimeters behind the start line, placing their preferred foot in the forward position. Once the subject and motion capture system was ready, subjects started in their own time. If they hesitated prior to starting, the trial was disregarded and reattempted. Three trials were completed, with rest periods of three minutes between trials. Time for each distance was recorded to the nearest 0.001 seconds (s). The average time for each interval from the three trials was used for analysis.

Motion capture

Trials were recorded using a 200 Hertz Vicon motion capture system (Oxford Metrics Group, Oxford, United Kingdom), via six MX infrared cameras mounted on 2.1-m high tripods. The six cameras were fixed about the start position for each trial, with a capture volume of approximately 5 m (length) by 2 m (width) by 2 m (height). Prior to testing, the laboratory was dynamically calibrated using a five-marker wand and L-frame to define the global coordinate system. After subjects completed the warm-up, 59 reflective markers were affixed on landmarks on the upper- and lower-body with double-sided tape (Figure 2). This number of markers is greater than that typically used for a full-body model in the Vicon system. The benefit of the extra markers, placed in clusters about the knee, tibia, and ankle, ensured accurate lower-body segment definitions considering the use of six cameras. Marker locations were determined through palpation. A static trial was recorded prior to testing, so that markers could be labeled and the subject calibrated. This involved the subject adopting a stationary T-pose (Figure 2), at the center of the capture volume so that no markers were occluded. Subjects then completed the sprint tests.

Each sprint trial was digitized in the Vicon Nexus 1.8.3 software. Data filtering was used to address gaps in the data from marker occlusion, and any digitizing errors. Smoothing algorithms inherent to the software (spline fill and pattern fill), were selected on an individual basis to address any gaps in the data. A Woltring filter with a maximum gap length of five frames was then passed over the data (Fosang and Baker, 2006). Finally, the Vicon Bodybuilder 3.6.1 software (Oxford Metrics Group, Oxford, United Kingdom) was used to establish and export all kinematic variables to Microsoft Excel (Microsoft Corporation, Washington DC, USA) for analysis. Data was computed for all trials, and averages were used for analysis. Kinematic variables were assessed during the first and second step of each sprint. The analyzed step kinematics were; step length: horizontal distance in the anteroposterior plane from toe-off to toe-off of consecutive steps; step frequency: calculated from the inverse of step time (step frequency = $[1\cdot\text{step time}]^{-1}$) (Hunter et al., 2004, Lockie et al., 2013b); and contact time: duration when the foot is in contact with the ground.

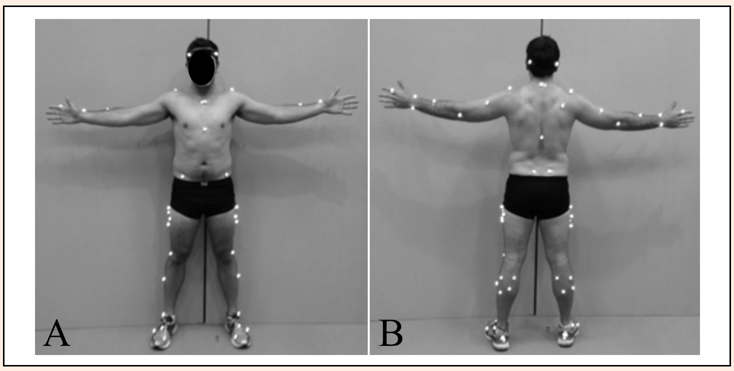

Figure 2. The anatomical landmark positions of the 59 reflective markers used for motion capture, as demonstrated in the T-pose static calibration position (A: anterior; B: posterior).

Table 1. **0-5 meter (m) and 0-10 m sprint times, and step kinematics for the first and second steps in a 10-m sprint, in experienced male cricketers, and when split into groups of infielders and outfielders. Data are means (±SD).**

		All Subjects (n = 18)	Infielders (n = 10)	Outfielders (n = 8)	*p* value	Effect Size
Sprint Times	0-5 m (seconds)	1.066 (.037)	1.071 (.043)	1.060 (.030)	.552	.30
	0-10 m (seconds)	1.870 (.145)	1.903 (.179)	1.827 (.075)	.273	.55
First Step	Step Length (m)	.96 (.12)	.94 (.13)	.98 (.11)	.580	.33
	Step Frequency (Hertz)	4.05 (.33)	4.09 (.35)	4.00 (.32)	.591	.27
	Contact Time (sec)	.174 (.013)	.168 (.009)	.182 (.013)	.010 *	1.25
Second Step	Step Length (m)	1.13 (.11)	1.12 (.11)	1.14 (.12)	.649	.17
	Step Frequency (Hertz)	4.16 (.33)	4.22 (.36)	4.10 (.31)	.467	.36
	Contact Time (sec)	.152 (.016)	.149 (.014)	.156 (.018)	.391	.43

* Significant ($p < 0.05$) difference between the infielders and outfielders.

The results from the data for the joint rotations are reported in Euler angles, with an axes order of YXZ. For the upper-body, shoulder range of motion in the flexion/extension axes was calculated as the difference between maximum values about this axis of rotation. Wu et al. (2005) stated that the clinical definitions of the shoulder joint are not consistent in three-dimensional space, partially due to the complex nature of the joint, with no clearly defined proximal segment. Due to this complexity, the investigators focused upon the range of motion for the shoulder. Elbow angle was calculated as the relative angle between the upper-arm and the forearm. Arms were defined as either the lead arm (the arm opposite to the drive leg), which was when peak flexion was measured, or the rear arm (the arm opposite to the swing leg), which was the point of maximum extension (Ambrose, 1978).

Lower-body kinematic variables were divided into step one and step two, which were then sub-divided into the drive and swing leg for each step (Maulder et al., 2008, Simonsen et al., 1985). This was based upon the actions of the leg during the step cycle. Hip angle was calculated as the relative angle between the trunk and thigh. Peak hip extension of the drive leg, and peak flexion of the swing leg, were measured. Knee angle was calculated as the relative angle between the thigh and shank, and peak drive leg extension and swing leg flexion were measured. Ankle angle was the relative angle between the shank and foot. Peak plantar flexion of the drive leg, and dorsi flexion of the swing leg, was assessed.

Statistical analyses

Means and standard deviations were calculated for all subjects, and the two fielding groups. The Levene statistic was used to determine homogeneity of variance of the data. Outliers in the data were treated with the winsorization method (Lien and Balakrishnan, 2005). A one-way analysis of variance was used to determine any significant differences between the sprint times, step kinematics, and upper- and lower-body kinematics for the infielders and outfielders. An alpha level of $p < 0.05$ was the criterion for significance. Effect sizes (ES) were also calculated, from the difference between the means divided by the pooled standard deviations (Cohen, 1988). For the purpose of this research, less than 0.20 was considered a trivial effect; 0.20 to 0.59 a small effect; 0.60 to 1.19 a moderate effect; 1.20 to 1.99 a large effect; 2.00 to 3.99 a very large effect; and 4.00 and above an extremely large effect (Hopkins, 2004).

All subject data (n = 18) was combined for a Pearson's two-tailed correlation analysis ($p < 0.01$ and $p < 0.05$) that was used to determine the relationships between sprint times and step kinematics, and the sprint times, step kinematics, and upper- and lower-body kinematics. The strength of the correlation coefficient (r) was described as per Hopkins (2009). An r value between 0 to 0.30, or 0 to -0.30, was considered small; 0.31 to 0.49, or -0.31 to -0.49, moderate; 0.50 to 0.69, or -0.50 to -0.69, large; 0.70 to 0.89, or -0.70 to -0.89, very large; and 0.90 to 1, or -0.90 to -1, near perfect for predicting relationships. All statistical analyses were processed using the Statistics Package for Social Sciences (Version 20.0; IBM Corporation, New York, USA).

Results

There were no significant between-group differences in age ($p = 0.558$, ES = 0.28), height ($p = 0.051$, ES = 1.05), or body mass ($p = 0.085$, ES = 0.88), although there were moderate effects for height and body mass. Table 1 displays the 0-5 m and 0-10 sprint times, and the step kinematics for all subjects, and the infield and outfield groups. The 8% shorter first step contact time for the infielders was significantly ($p = 0.010$) different from the

Table 2. **Shoulder and elbow kinematics for the first and second steps in a 10-m sprint in experienced male cricketers, and when split into groups of infielders and outfielders. Data are means (±SD).**

		All Subjects (n = 18)	Infielders (n = 10)	Outfielders (n = 8)	*p* value	Effect Size
Shoulder ROM	Left Arm (°)	118.24 (17.33)	118.53 (11.76)	117.87 (23.47)	.939	.04
	Right Arm (°)	111.15 (25.05)	109.95 (28.72)	112.65 (21.43)	.828	.11
Elbow Step 1	Lead Arm Flexion (°)	102.73 (11.59)	100.96 (10.86)	104.95 (12.83)	.484	.34
	Rear Arm Extension (°)	45.40 (15.19)	38.74 (13.14)	53.73 (14.00)	.001 *	1.10
Elbow Step 2	Lead Arm Flexion (°)	101.34 (10.27)	95.12 (8.54)	109.12 (6.15)	.033 *	1.88
	Rear Arm Extension (°)	52.05 (11.15)	48.68 (5.74)	56.19 (14.96)	.162	0.66

ROM= Range of Motion. ° = degrees. * Significant ($p < 0.05$) difference between the infielders and outfielders.

Table 3. Hip, knee, and ankle kinematics for the drive and swing leg in the first step in a 10-m sprint in experienced male cricketers, and when split into groups of infielders and outfielders. Data are means (±SD).

		All Subjects (n = 18)	Infielders (n = 10)	Outfielders (n = 8)	*p* value	Effect Size
Hip	Drive Leg Extension (°)	6.22 (3.93)	5.76 (3.04)	6.80 (4.98)	.873	.25
	Swing Leg Flexion (°)	97.60 (8.81)	98.03 (10.76)	97.06 (6.22)	.825	.11
Knee	Drive Leg Extension (°)	26.38 (11.89)	25.34 (12.46)	27.67 (11.85)	.693	.19
	Swing Leg Flexion (°)	124.70 (12.14)	122.57 (14.52)	127.37 (8.51)	.421	.40
Ankle	Drive Leg Plantar Flexion (°)	-38.76 (9.11)	-37.96 (8.34)	-40.20 (11.25)	.677	.23
	Swing Leg Dorsi Flexion (°)	33.22 (12.98)	33.22 (15.47)	33.22 (10.66)	.999	.00

° = degrees. * Significant ($p < 0.05$) difference between the infielders and outfielders.

outfielders, which also had a large effect (ES = 1.25). There were no significant differences in times, or any other step kinematics, between the two groups.

The kinematics of the arms during the first two steps is displayed in Table 2. There were no differences in shoulder range of motion between infielders and outfielders. The 28% smaller elbow extension angle of the rear arm in the first step for the infielders, which was followed by a 13% smaller lead arm elbow flexion angle in the second step, was significantly different to those of the outfielders ($p = 0.001$, ES = 1.10, and $p = 0.033$, ES = 1.88, respectively). The data for lower-body kinematics in the first and second step are shown in Tables 3 and 4, respectively. There were no significant differences in first step kinematics between the groups. For the second step, the outfielders had a significantly ($p = 0.005$) greater drive leg hip extension when compared to the infielders, which had a large effect (ES = 1.49).

Table 5 displays the sprint times, step kinematics, and upper-body kinematics correlations. There were no significant relationships for the sprint times. Step length for the first and second step had a very large correlation ($p < 0.001$) with each other, as did first and second step frequency ($p < 0.001$). First and second step contact time had a large correlation ($p = 0.012$). First step length had negative correlations with first (very large; $p < 0.001$) and second (large; $p = 0.004$) step frequency, as did second step length (both very large; $p < 0.001$). Left shoulder range of motion had a moderate, positive relationship with second step length ($p = 0.048$). The lead arm elbow flexion angle had a moderate, negative correlation with first step contact time ($p = 0.043$).

Table 6 shows the relationships between lower-body kinematics with sprint times and step kinematics. No significant relationships were found with 0-5 m and 0-10 m sprint time. Swing leg hip flexion for the first step had large, positive correlations with first ($p = 0.013$) and second ($p = 0.009$) step length, and negative correlations with first ($p = 0.008$) and second ($p = 0.033$) step frequency. First step swing leg knee flexion had large, positive correlations with first ($p = 0.002$) and second ($p = 0.024$) step length, and a negative correlation with first step frequency ($p = 0.002$). There was a negative correlation between first step ankle plantar flexion and second step length (large; $p = 0.006$), and a positive correlation with second step frequency (very large; $p = 0.003$). The negative angle for plantar flexion (Table 3) meant that greater plantar flexion related to a longer step length, and lower step frequency.

Discussion

This is one of the first studies to investigate sprint acceleration technique specific to cricketers with implications for fielding. Furthermore, this is the first study to compare the acceleration kinematics of cricketers who field predominantly in the infield or outfield. There were moderate effects for differences in height and body mass for the infielders and outfielders, even though the differences were not significant. This may be attributed to a greater prevalence of bowlers being in the outfield group. Bowlers tend to spend more time in the outfield, which can be partly evidenced through time-motion research that documents the distances these cricketers cover during matchplay, where aside from the movement demands of bowling, they will often run from the pitch to the boundary in between overs (Petersen et al., 2009; 2010). In English county cricketers, bowlers were found to be taller (ES = 0.70) and heavier (ES = 0.60) than batsmen, but differences were non-significant with moderate effects (Johnstone and Ford, 2010). Nonetheless, the anthropometrical results infer that the subjects in the current study are physically representative of experienced cricketers.

There were relatively few kinematic variables that differentiated between the groups, which is not uncommon for research analyzing the sprint technique of athletes (Murphy et al., 2003). Furthermore, there were no differences in sprint times between infielders and

Table 4. Hip, knee, and ankle kinematics for the drive and swing leg in the second step in a 10-m sprint in experienced male cricketers, and when split into groups of infielders and outfielders. Data are means (±SD).

		All Subjects (n = 18)	Infielders (n = 10)	Outfielders (n = 8)	*p* value	Effect Size
Hip	Drive Leg Extension (°)	7.67 (6.42)	4.17 (3.95)	12.05 (6.38)	.005 *	1.49
	Swing Leg Flexion (°)	96.16 (8.76)	96.47 (8.91)	95.77 (9.16)	.873	.08
Knee	Drive Leg Extension (°)	22.67 (10.18)	21.02 (8.37)	24.73 (12.36)	.459	.35
	Swing Leg Flexion (°)	124.29 (10.28)	127.64 (6.89)	120.11 (12.64)	.126	.74
Ankle	Drive Leg Plantar Flexion (°)	-38.17 (17.51)	-37.14 (18.86)	-39.50 (16.99)	.800	.13
	Swing Leg Dorsi Flexion (°)	34.37 (8.74)	32.21 (7.66)	37.61 (9.96)	.255	.61

° = degrees. * Significant ($p < 0.05$) difference between the infielders and outfielders.

Table 5. Pearson's correlation coefficients between 0-5 meter (m) and 0-10 m time, step length (SL), step frequency (SF) and contact time (CT) for the first (1) and second (2) steps, and shoulder range of motion for the left (LSROM) and right (RSROM) arms, and lead arm elbow flexion (LAEF) and rear arm elbow extension (RAEE) for the first and second steps in a 10-m sprint.

	0-5 m	0-10 m	SL1	SF1	CT1	SL2	SF2	CT2
SL1	-.395	-.355						
SF1	-.001	.258	**-.794** †					
CT1	-.276	-.313	.273	-.370				
SL2	-.174	-.325	**.890** †	**-.829** †	.245			
SF2	-.141	.303	**-.648** †	**.790** †	-.314	**-.829** †		
CT2	.271	-.212	-.023	-.168	**.579** *	.081	-.452	
LSROM	.106	-.097	.332	-.376	-.030	**.471** *	-.437	.192
RSROM	-.133	.170	-.013	.091	.155	.023	-.269	.379
LAEF1	.177	.128	.348	-.214	-.295	.304	-.318	-.237
RAEE1	.042	-.194	-.011	-.051	-.287	.055	-.054	-.097
LEEF2	.291	.400	.057	-.205	**-.482** *	.153	-.151	-.234
RAEE2	-.189	-.090	-.058	-.235	.029	-.183	.182	.109

† Significant ($p < 0.01$) relationship between variables.* Significant ($p < 0.05$) relationship between variables.

outfielders (Table 1), and no kinematic variables measured in this study that correlated with 0-5 m and 0-10 m time (Tables 5 and 6). In line with the study hypothesis, these results indicate that subjects had relatively similar sprint technique, regardless of their tendency to field in a particular area of the cricket field. It must also be acknowledged that out of all the technique correlations, only 18 were significant. A limitation of correlation investigations is that in addition to sprint kinematics, other technique parameters such as stance kinetics, and factors like flexibility, strength, and power, can have an effect on the statistical models (Brughelli et al., 2008). Future research should investigate other aspects of cricket acceleration technique, including stance kinetics and muscle recruitment during the sprint step, as well as the strength and power capabilities of cricketers. Nonetheless, there are important implications for cricketers that can be drawn from the analysis of acceleration technique in this study.

Running speed is the product of step length and step frequency, and there can be a negative interaction between these variables, in that if one value is increased, the other may decrease (Hunter et al., 2004). This was seen in the current study, where there were negative relationships between step length and frequency (Table 5). A high step length (Lockie et al., 2013b) and step frequency (Lockie et al., 2011, Murphy et al., 2003) have been advocated for faster acceleration. There were no differences in step length and frequency between the infielders and outfielders (Table 1), and there was no one step variable that appeared to be more notable than the other (Tables 5 and 6). These results highlight the similarities in the selected step kinematics between infielders and outfielders. Given the fielding restrictions that occur during one-day and T20 matches (International Cricket Council, 2012a, b), it is important for cricketers to be able to produce step kinematics appropriate for both infielding and outfielding. The results suggest that the cricketers investigated in this study could achieve this.

The infielders did have a significantly lower first step contact time when compared to the outfielders (Table 1). Shorter contact times have been recommended for faster acceleration (Lockie et al., 2011, Murphy et al., 2003), and this is needed for first step quickness. An effective first step is important for acceleration over short distances in team sport athletes (Lockie et al., 2011, Murphy et al., 2003), as well as for a fast change-of-direction (Hewit et al., 2013), which may be required to accelerate in the direction of the ball. This could be a function of the requirements of infielders, as they are positioned much closer to the batsmen, and have less time to react to balls when fielding (Bartlett, 2003). In addition, they are in a position to complete run-outs should batsmen attempt a quick single. Speed over short distances is key for cricketers when fielding, with Rudkin

Table 6. Pearson's correlation coefficients between 0-5 meter (m) and 0-10 m time, step length (SL), step frequency (SF) and contact time (CT) for the first (1) and second (2) steps, with drive leg hip extension (HE), knee extension (KE), and ankle plantar flexion (APF), and swing leg hip flexion (HF), knee flexion (KF), and ankle dorsi flexion (ADF), for the first and second steps in a 10-m sprint.

	0-5 m	0-10 m	SL1	SF1	CT1	SL2	SF2	CT2
HE1	.048	-.165	-.375	.388	-.220	-.375	.297	-.121
HF1	-.177	-.371	**.570** *	**-.606** †	-.012	**.598** †	**-.504** *	-.043
KE1	.020	-.012	-.085	.050	.217	-.152	.164	.094
KF1	-.280	-.065	.682†	**-.669** †	.373	**.528** *	-.361	.065
APF1	-.165	.236	-.416	.404	.114	**-.692** †	**.726** †	-.168
ADF1	.036	-.157	.273	-.392	-.091	.349	-.301	.154
HE2	-.171	-.212	-.031	.064	.048	-.059	.252	-.442
HF2	-.215	-.218	.227	-.193	.219	.129	-.066	.199
KE2	-.127	-.250	.388	-.243	-.058	.212	.002	-.444
KF2	-.178	.195	.284	-.085	-.345	.160	.044	-.328
APF2	-.124	-.022	-.007	.143	-.059	-.246	.402	-.107
ADF2	-.385	-.452	.032	-.188	.224	.096	-.046	-.121

† Significant ($p < 0.01$) relationship between variables. * Significant ($p < 0.05$) relationship between variables.

and O'Donoghue (2008) finding high-intensity effort durations last approximately 1.3 s, which is slightly greater than the 0-5 m times from this study (Table 1). Nonetheless, there were no between-group differences in second step contact time (Table 1), and no significant correlations between contact time and lower-body kinematics (Table 6).

There was, however, a significant correlation between second step lead elbow flexion and first step contact time (Table 5). This result suggests that a lower contact time relates to a greater degree of elbow flexion. Bhowmick and Bhattacharyya (1988) suggested that the horizontal component of the arm swing acceleration may aid in increasing step length and regulating leg movement, while the vertical component may create a condition that enhances leg drive during stance. Potentially, a higher degree of elbow flexion could contribute to an enhanced leg drive that reduces the duration of stance. Further to this, the current investigation found that greater left shoulder range of motion related to a longer second step (Table 5). These results could also relate to the need for the arm movements during sprinting to help maintain dynamic stability, by facilitating the transfer of angular momentum between the upper- and lower-body about the vertical axis (Hinrichs, 1992). This is because a longer second step related not only to greater shoulder range of motion, but also greater flexion angles of the hip and knee.

There were positive correlations between first step hip and knee flexion with first and second step length (Table 6). In line with the interaction between step length and frequency (Hunter et al., 2004), hip and knee flexion negatively correlated with step frequency (Table 6). As stated previously, flexion of the hip and knee is important for reducing the moment of inertia of the swing leg during this phase of the sprint step, and allows for a more effective leg recovery (Mero et al., 1992). Furthermore, with increases in running velocity, hip and knee range of motion and step length will increase (Mann and Hagy, 1980). Cricketers from this study with longer steps, and a lower step frequency, tended to flex the hip and knee to a greater extent during the swing phase. Additionally, there were no differences in hip and knee flexion during the first two steps of the 10-m sprint between infielders and outfielders (Tables 3 and 4), indicating similarities in leg recovery during the sprint step for all cricketers from this study.

Knee extension tends to be abbreviated during sprinting, to allow for the leg to clear from the ground more quickly (Mann and Herman, 1985, Murphy et al., 2003). For the cricketers in this study, full knee extension for either the first or second step did not occur (Tables 3 and 4). In contrast to the knee, a more complete hip extension has been suggested for acceleration (van Ingen Schenau et al., 1994). Interestingly, the outfielders had a significantly greater drive leg hip extension in the second step (Table 4). Given the need to balance angular momentum within the body (Hinrichs, 1992), this may be linked to the greater elbow flexion produced by the outfielders (Table 3). Nonetheless, this did not result in any differences in sprint time between the groups. It would be expected that for cricketers, as for other team sport athletes (Murphy et al., 2003), an effective extension of the drive leg is necessary for fast acceleration.

There were no differences in first or second step plantar flexion and dorsi flexion between infielders or outfielders (Tables 3 and 4). However, a higher degree of first step ankle plantar flexion related to a greater second step length, and in turn a lower step frequency (Table 6). Greater plantar flexion, driven by the triceps surae to facilitate leg drive (Mann and Hagy, 1980), occurs with increases in running speed. As for hip and knee flexion, greater plantar flexion contributed to increased step length in cricketers. The influence of these hip, knee, and ankle actions on increasing step length has important implications for cricket sprint acceleration.

Greater step lengths could be more beneficial for acceleration in cricket. Unlike other team sport athletes, cricketers do not have to evade opponents during match-play. This is one of the primary reasons why greater step frequencies have been previously recommended for acceleration in other team sport athletes (Murphy et al., 2003; Sayers, 2000). However, increasing step length has also been encouraged for sprint acceleration (Santana, 2000), and longer steps can enhance speed over short distances (Lockie et al., 2013b), In addition, Donati (1995) suggested that there are more training mechanisms that can be used to improve step length, more so than for step frequency. This includes traditional sprint training (Kristensen et al., 2006, Lockie et al., 2012b), as well as supplementary protocols such as weights, plyometrics, and resisted sprint training (Lockie et al., 2012b). Cricket and strength and conditioning coaches could target this aspect of technique during speed training. As the results from this study suggested that cricketers demonstrated similar sprint kinematics regardless of whether they tend to field in the infield or outfield, this means that step length development could be beneficial for all cricketers.

It should be acknowledged that this research used standard field testing protocols for assessing sprint acceleration, i.e. the subjects used a stationary start. Unless they are fielding in the slips cordon, cricketers will often walk towards the pitch as the bowler enters their delivery, then react while already moving to the path of the ball once hit. There should be further investigation of how cricketers can transition from this slow moving position, into a maximal acceleration, or a maximal acceleration following a change-of-direction to pursue the ball. In addition to the kinematics analysis conducted in this study, this could also incorporate the investigation of stance kinetics, given the importance of this component of technique (Lockie et al., 2013b; Spiteri et al., 2013). The analysis of the transition from maximal sprint acceleration to either catch or retrieve and throw a ball could then be conducted, to make the analysis even more specific to cricket. Perhaps most importantly, research should determine whether an improvement in sprint acceleration capabilities in cricketers will translate to what they do in the field. This would mean that a cricketer who can accelerate faster will decrease the time it takes to field a ball, and potentially make them a more effective fielder. Nevertheless, this research provides valuable insight into the acceleration technique of experienced cricketers. It is suggested that cricketers target step length development to improve acceleration over short distances specific to fielding.

Conclusion

Whether a cricketer fields predominantly in the infield or outfield, they must be able to sprint effectively over short distances to aid in dismissals, or restrict the runs scored by batsmen. The study results indicated that there were minimal differences in first and second step sprint acceleration kinematics between cricketers who field predominantly in the infield or outfield. This is likely a function of the need for cricketers to field in both the infield and outfield, depending on the match situation. Infielders did have a lower first step contact time, which may relate to their need to react quickly to balls hit by batsmen, as they are positioned closer to the pitch. There were no kinematic variables that significantly related to 0-5 m and 0-10 m times. However, selected upper- and lower-body kinematic variables did relate to step kinematics. Left-arm shoulder range of motion related to a longer second step. Greater swing leg hip and knee flexion, and greater drive leg ankle plantar flexion, correlated with longer step lengths and lower step frequencies. Given that longer step lengths can contribute to faster sprint acceleration, and step length can also be enhanced through specific speed training, this is a technique variable that could be targeted specifically for cricketers.

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Key points

- Regardless of whether cricketers field predominantly in the infield or outfield, they will produce relatively similar sprint acceleration kinematics. This is likely due to the fact that cricketers will often field in both areas of the cricket ground, depending on the requirements of the match.
- Due to the complexity of sprint acceleration, there were relatively few significant correlations between technique variables. However, step length had positive relationships with shoulder range of motion, swing leg hip and knee flexion, and drive leg ankle plantar flexion.
- As previous research has established the importance of step length to acceleration, as well as the trainability of this kinematic variable, training specifically to improve step length could lead to enhanced sprint acceleration in cricketers.

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