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STEP KINEMATIC PREDICTORS OF SHORT SPRINT PERFORMANCE IN FIELD SPORT ATHLETES

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Abstract Field sport athletes must generate high velocities over short distances (10 meters [m] or less). The interaction between step kinematics (step length, step frequency, contact time, flight time) determines sprint velocity. This study determined the step kinematics that predicted 10-m sprint performance (0-5, 5-10, 0-10 m intervals) through stepwise multiple regression ($p \leq 0.05$). Spearman's correlations ($p \leq 0.05$) were also conducted between step kinematics and velocity for each interval. 0-5 m step length and 0-10 m contact time predicted 0-5 m velocity (R = 0.685; $p = 0.006$). 0-5 m contact time, and 5-10 m step length and step frequency predicted 5-10 m velocity (R = 0.715; $p = 0.002$). 5-10 m step length and step frequency predicted 0-10 m velocity (R = 0.606; $p = 0.001$). Correlations were found between 0-5 m velocity and step length in all intervals, and 0-5 m flight time (ρ = 0.406-0.515; p = 0.011-0.045). 0-10 m velocity correlated with 5-10 and 0-10 m step length, and 0-5 m flight time (ρ = 0.398-0.444; p = 0.026-0.048). Longer step lengths were integral for short sprint speed in field sport athletes. Step length should be developed in these athletes to improve short distance velocities.

Key words: Acceleration, sprint velocity, step length, step frequency, flight time

INTRODUCTION

Sprinting speed, and especially acceleration, is an essential component of many different sports [7]. Field sports, such as the various football codes (e.g. rugby league, rugby union, soccer, American football, Australian Rules), lacrosse, and field hockey, require the ability to generate speed quickly from a stationary or near stationary position [23]. Importantly, many of the sprints completed in field sports tend to be relatively short. For example, in sports such as rugby union [8], Australian football [6], and soccer [2], maximal sprints will often have a duration of two seconds (s) or less, which would equate to distances of approximately 10 meters (m). This places a great emphasis on the ability to accelerate [15], which is the capacity to generate as high a running velocity in as short a distance or time as possible. In order to maximize acceleration, a field sport athlete must ensure that their running technique allows them to attain a high sprint velocity very quickly. Indeed, the kinematics of the field sport athlete's running technique will greatly affect the resulting sprint performance.

Some of the traditional step kinematic measures used to describe running technique include: step length, which is the distance between alternating contacts of the left and right feet; step frequency, which is the rate at which steps can be reproduced; contact time, which is the duration of the contact between the support leg and the ground; and flight time, which is the period when the athlete is airborne during the sprint step. It is generally thought that to improve sprint performance, there must be an increase in one or both of the factors that affect velocity – step length or step frequency [9, 28]. Previous research has illustrated the importance of high step frequency for faster acceleration [16, 22]. However, following specific speed training in field sport athletes, an increase in step length was the major kinematic factor linked to enhanced sprint velocity during acceleration [17]. It is important for field sport and strength and conditioning professionals to understand which of these factors is more closely linked to higher running velocity during the initial stages of a short sprint.

The temporal characteristics of the sprint step must also be considered when analyzing the important kinematic factors during field sport acceleration. Contact time has also been linked to effective acceleration [16, 22], and may also assist with increasing step frequency [22]. However, specific speed training generally did not result in changes to contact time during 10-m sprint performance in field sport athletes, despite there being improvements in running velocity [17]. There are relatively fewer data concerning the implications of flight time during a short sprint performance in field sport athletes. During track sprint acceleration, short steps have been recommended [4, 24, 25]. As flight time is a function of step length, this would imply that track sprint acceleration would benefit from shorter flight times. Further to this, Sayers [23] has recommended shorter steps, and by extension shorter flight times, for field sport acceleration. However, if greater step lengths may ultimately benefit field sport acceleration [17], this could also mean that faster field sport athletes may produce longer flight times. The influence of contact and flight time on acceleration capabilities of field sport athletes requires additional explanation.

Although there have been investigations of the step kinematics in field sport athletes, there is a need for further clarification of the most important aspects of short sprint performance (i.e. a 10-m sprint). Therefore, the purpose of this research was to determine the step kinematics that most strongly related to and predicted sprint velocity during a 10-m sprint in field sport athletes. It is hypothesized that step length and step frequency will be the strongest predictors of 10-m sprint performance in field sport athletes. It is further hypothesized that a rank-order correlation analysis would indicate that greater step lengths, step frequencies, and flight times, and lower contact times, would be significantly related to higher sprint velocities. The results from this study will benefit field sport coaches and strength and conditioning professionals by illustrating the step kinematic variables that should be targeted to improve short sprint performance.

MATERIALS AND METHODS

SUBJECTS

Twenty-five healthy men (age = 22.6 ± 3.2 years; mass = 83.6 ± 7.4 kilograms [kg]; height = 1.81 ± 0.07 m) volunteered to participate in this study. Subjects were recruited if they: were currently active in a field sport (i.e. rugby union, rugby league, Australian football, soccer, and field hockey); had a general field sport training history (≥two times per week) extending over the previous 12 months; were currently training for a field sport (≥three times per week); and, did not have any existing medical conditions that would compromise participation in the study. The methodology and procedures used in this study were approved by the ethics committee of the University of Technology, Sydney. 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.

PROCEDURES

Testing was conducted on an indoor basketball court. Subjects completed six 10-m sprint tests filmed for kinematic analysis. This 10-m distance is indicative of the initial acceleration phase important to field sport athletes [10, 16, 17, 26]. The reliability of the data collection procedures used in this study have been established in previous research [16]. Prior to data collection, the subjects' age, height, and mass were recorded. Height was measured using a stadiometer (Ecomed Trading, Seven Hills, Australia) and recorded to the nearest 0.01 centimeters. Subjects were measured barefoot, and they stood on the base of the stadiometer, with their feet together and the heels, buttocks and upper back touching the scale. Body mass was recorded using electronic digital scales (Tanita Corporation, Tokyo, Japan) to the nearest 0.1 kg. A standardized warm-up was conducted before the testing session. The warm-up consisted of 10 minutes of jogging, 10 minutes of dynamic stretching of the lower limbs, and progressive speed runs over the 10-m sprint distance (two repetitions each at 60%, 70%, 80%, and 90% of perceived maximum velocity). A recovery time of three minutes was allocated between all progressive runs and sprint trials.

KINEMATIC ACCELERATION ASSESSMENT

Each subject completed six sprints over 10 m for the kinematic assessment. The 0-5 m interval was filmed during the first three sprints, while the 5-10 m interval was filmed in the second three sprints. Time was measured through the use of a velocimeter (Onspot, Wollongong, Australia) placed upon a table which was 0.72-m high, and positioned 1.5 m behind the subject. The velocimeter consisted of a nylon line that was attached to the subject's shorts. The line was connected to a reel, which unwound when the subject began their sprint. An optical sensor sent electrical impulses to the velocimeter processor for every 0.1-metre of linear line displacement, and time was recorded via an attached stopwatch (Seiko, Tokyo, Japan). Subjects used a split-stance, standing start for the sprint trials, were free to choose their front leg in this stance, and started in their own time when ready. Time splits were recorded for every 5-m interval. Velocity for the three intervals (0-5, 5-10, and 0-10 m) was calculated through the equation $velocity = displacement \cdot time^{-1}$.

A Super-VHS high-speed video camera (Vicon/Peak Performance Technologies, Englewood, USA) was used to assess the kinematics of acceleration. The camera was placed 8.75 m away from the subject's running plane, and calibrated prior to a testing session using a meter-long scale. For the filming of the 0-5 m interval, the camera was positioned at the 2.5-m mark. When filming the 5-10 m interval, the camera was positioned at the 7.5-m mark. A sampling rate of 200 Hz was used. A television set (Panasonic, Tokyo, Japan) and a video cassette recorder (Vicon/Peak Performance Technologies, Englewood, USA) were connected to the camera to record and view each trial. External light was provided by two portable 500-watt lights.

Reflective tape was placed on two landmarks, determined through palpation, on the right (fifth metatarsal) and left (first metatarsal) feet. These landmarks were chosen to calculate step length, contact time, and flight time. The video recordings were transferred onto a computer and edited, before being exported into custom software (UTS Kinematic Data Collection Software, Lindfield, Australia). All trials used for each interval were assessed, and averages were used for analysis. To calculate the mean step kinematics, the total number of steps and contacts a subject had within an interval were analyzed. Contact time was calculated as the period between touchdown and toe-off of one foot during ground support. Step length was defined as the distance between toe-off of one foot, and touchdown of the opposing foot. Flight time was defined as the duration of this action. For the purpose of this research, step frequency was calculated from the inverse of step duration (*step frequency = 1·step duration*$^{-1}$) [12].

STATISTICAL ANALYSIS

Means and standard deviations for sprint velocity and step kinematics over the 0-5 m, 5-10 m, and 0-10 m intervals were calculated for all subjects. The Levene statistic was used to check the homogeneity of variance of the data. A stepwise multiple regression analysis ($p \leq 0.05$) was conducted to explain relationships between the step kinematics variables (mean step length, step frequency, contact time, and flight time from each interval), and velocity in the 10-m sprint. 0-5 m, 5-10 m, and 0-10 m velocity each acted as a dependent variable. The strength of the stepwise regression was described by the multiple correlation coefficient (R) and coefficient of determination (R^2). Spearman's rank-order correlation analysis ($p \leq 0.05$) was then conducted to examine the relationships between 0-5 m, 5-10 m, and 0-10 m velocity, with step kinematics. The strength of the Spearman's rho (ρ) correlation coefficient was described as per Hopkins [11]. For this study, a ρ value less than 0.3 was considered small; 0.31 to 0.49 moderate; 0.5 to 0.69 large; 0.7 to 0.89 very large; and 0.9 and higher near perfect for predicting relationships. All statistical analyses were computed using the Statistics Package for Social Sciences (Version 20.0; IBM Corporation, New York, USA).

RESULTS

The mean velocity attained in the 0-5 m, 5-10 m, and 0-10 m intervals is displayed in Figure 1. The step kinematics data for each interval are shown in Table 1. Table 2 displays the stepwise multiple regression data for velocity in the 0-5 m, 5-10 m, and 0-10 m intervals. For the 0-5 m interval, 0-10 m step length was a predictor of sprint velocity (R = 0.535; R^2 = 0.286; p = 0.016). When 0-10 m contact time was added to the stepwise regression process, the predictive relationship was further strengthened (R = 0.685; R^2 = 0.469; p = 0.006). With regards to 5-10 m velocity, 0-5 m contact time was a significant predictor (R = 0.506; R^2 = 0.256; p = 0.010). When step length in the 5-10 m interval (R = 0.619; R^2 = 0.384; p = 0.005), and step frequency in the 5-10 m interval (R = 0.715; R^2 = 0.511; p = 0.002) were added to the regression process, the prediction was improved. 5-10 m step length was also a predictor of 0-10 m velocity (R = 0.475; R^2 = 0.225; p = 0.006). The addition of 5-10 m step frequency increased the multiple regression prediction strength for 0-10 m velocity (R = 0.606; R^2 = 0.367; p = 0.001).

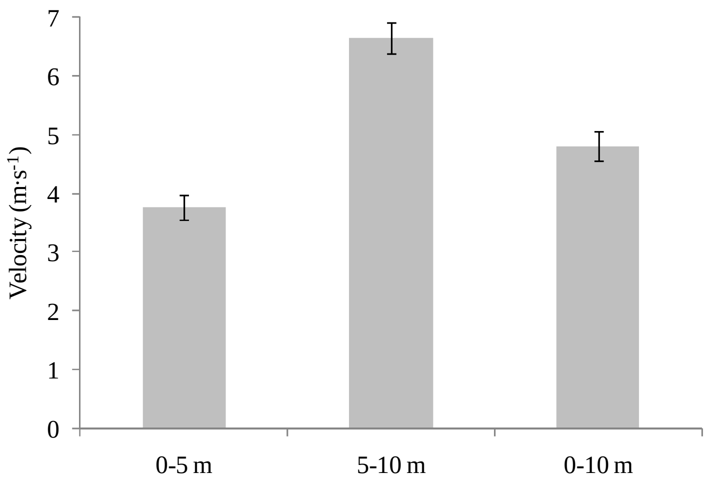

Figure 1. Velocity (mean ± standard deviation) of field sport athletes (n = 25) in the 0-5 meter (m), 5-10 m, and 0-10 m intervals of a 10-m sprint; m·s^{-1} = meters per second

Table 1. Step length, step frequency, contact time and flight time (mean ± standard deviation) of field sport athletes (n = 25) in the 0-5 meter (m), 5-10 m, and 0-10 m intervals of a 10-m sprint; Hz = Hertz; s = seconds

Kinematics	Subject Mean
0-5 m Step Length (m)	1.188 ± 0.130
0-5 m Step Frequency (Hz)	4.131 ± 0.321
0-5 m Contact Time (s)	0.148 ± 0.015
0-5 m Flight Time (s)	0.098 ± 0.015
5-10 m Step Length (m)	1.636 ± 0.119
5-10 m Step Frequency (Hz)	4.167 ± 0.311
5-10 m Contact Time (s)	0.126 ± 0.013
5-10 m Flight Time (s)	0.123 ± 0.014
0-10 m Step Length (m)	1.414 ± 0.115
0-10 m Step Frequency (Hz)	4.143 ± 0.308
0-10 m Contact Time (s)	0.140 ± 0.012
0-10 m Flight Time (s)	0.112 ± 0.012

Table 2. Stepwise linear regression analysis between 0-5 meter (m), 5-10 m, and 0-10 m velocity (dependent variables) and step length and frequency, and contact and flight time, for the 0-5 m, 5-10 m, and 0-10 m intervals of a 10-m sprint

Variables	R	R^2	Significance
0-5 m Velocity			
0-10 m Step Length	0.535	0.286	p = 0.016
0-10 m Step Length, 0-10 m Contact Time	0.685	0.469	p = 0.006
5-10 m Velocity			
0-5 m Contact Time	0.506	0.256	p = 0.010
0-5 m Contact Time, 5-10 m Step Length	0.619	0.384	p = 0.005
0-5 m Contact Time, 5-10 m Step Length, 5-10 m Step Frequency	0.715	0.511	p = 0.002
0-10 m Velocity			
5-10 m Step Length	0.475	0.225	p = 0.006
5-10 m Step Length, 5-10 m Step Frequency	0.606	0.367	p = 0.001

The correlations between sprint velocity and step kinematics are presented in Table 3. All significant correlations ranged from moderate to large. Mean step length from the 0-5 m (ρ = 0.428, p = 0.033), 5-10 m (ρ = 0.500, p = 0.011), and 0-10 m (ρ = 0.459, p = 0.021) intervals significantly correlated with 0-5 m velocity. 5-10 m (ρ = 0.437, p = 0.029) and 0-10 m (ρ = 0.398, p = 0.048) step length correlated with 0-10 m velocity. Mean 0-5 m flight time had significant correlations with 0-5 m (ρ = 0.515, p = 0.008) and 0-10 m (ρ = 0.444, p = 0.026) velocity. 0-10 m flight time had a significant relationship with 0-5 m velocity (ρ = 0.406, p = 0.045). There were no significant correlations between sprint velocity and step frequency, nor were there significant correlations between sprint velocity and contact time.

DISCUSSION

This study analyzed the step kinematics (i.e. step length and frequency, contact and flight time) that predicted performance in a 10-m sprint for field sport athletes. The results indicated the importance of step length, in particular during acceleration. Step length in the 5-10 m and 0-10 m intervals predicted velocity over the 10-m testing distance, and longer step lengths were correlated with faster sprint performances. 0-5 m and 0-10 m contact time, and 5-10 m step frequency also predicted short sprint performance. Counter to the study hypothesis, no significant correlations were found between velocity, step frequency, and contact time. There were correlations between sprint velocity and flight time, although this may have been a function of the positive correlations between velocity and step length. The results of this study provide impetus to field sport and strength and conditioning coaches to focus upon step length development to enhance acceleration in their athletes.

Step length was a predictor for all intervals in the 10-m sprint (Table 2). Step length in the 0-10 m interval was predictive of 0-5 m velocity. Step length in the 5-10 m interval was predictive of both 5-10 m and 0-10 m velocity. Additionally, there were several moderate-to-large correlations between step length and sprint velocity (Table 3), with the significant relationships indicating that a longer step length was associated with faster sprint velocities. A longer step is representative of greater strength and power in the leg muscles, which is applied specific to the sprint step [1, 17]. This could also be linked to the effective production of force during support [3, 13]. Interestingly, Lockie et al. [17] found that different speed training protocols, including free sprinting, weights, plyometrics, and resisted sprinting, can all enhance step length in field sport athletes. Given the results of this study, which highlight the importance of step length for short sprint performance, this should be a focus for field sport and strength and conditioning coaches. If a field sport athlete can produce longer steps during acceleration, with no detriment to any other aspect of sprint technique, then short sprint performance should improve.

Table 3. Correlations between mean velocity and step length and frequency, and contact and flight time in the 0-5 meter (m), 5-10 m, and 0-10 m intervals in a 10-m sprint (Spearman's rho = ρ; significance = *p*; n = 25)

		0-5 m Velocity	5-10 m Velocity	0-10 m Velocity
0-5 m Step Length	ρ	0.428	0.169	0.352
	p	0.033*	0.420	0.084
5-10 m Step Length	ρ	0.500	0.365	0.437
	p	0.011*	0.073	0.029*
0-10 m Step Length	ρ	0.459	0.277	0.398
	p	0.021*	0.180	0.048*
0-5 m Step Frequency	ρ	-0.171	-0.002	-0.073
	p	0.415	0.993	0.730
5-10 m Step Frequency	ρ	-0.116	0.116	-0.009
	p	0.581	0.581	0.967
0-10 m Step Frequency	ρ	-0.165	0.032	-0.058
	p	0.431	0.878	0.782
0-5 m Contact Time	ρ	-0.324	-0.392	-0.395
	p	0.114	0.052	0.051
5-10 m Contact Time	ρ	-0.107	-0.187	-0.199
	p	0.612	0.372	0.341
0-10 m Contact Time	ρ	-0.295	-0.300	-0.364
	p	0.153	0.145	0.074
0-5 m Flight Time	ρ	0.515	0.351	0.444
	p	0.008*	0.087	0.026*
5-10 m Flight Time	ρ	0.289	0.169	0.270
	p	0.162	0.420	0.193
0-10 m Flight Time	ρ	0.406	0.190	0.346
	p	0.045*	0.362	0.091

* Significant ($p \leq 0.05$) relationship between the two variables

Previous research had illustrated the importance of step frequency for field sport athletes during short sprints [16, 22]. 5-10 m step frequency was a predictive variable for both 5-10 m and 0-10 m velocity. Increasing step frequency is especially important when transitioning to high velocities [14], and these results suggest this may also be the case during field sport acceleration after the first 5 m of a short sprint. However, there were no significant correlations between step frequency and velocity within any of the measured intervals (Table 3). This could be a function of the longer step lengths demonstrated by those subjects with faster velocities. As previous research had established a negative interaction between step length and frequency in that athletes with longer steps may also have a lower frequency of steps [12], then this may have also affected the results drawn from this study. As faster subjects tended to have greater step lengths during acceleration, this may have reduced the importance of step frequency in this particular sample group.

0-10 m contact time was a predictor for 0-5 m velocity, and 0-5 m contact time was a predictor for 5-10 m velocity (Table 2). Contact time, however, did not correlate with sprint velocity in any interval (Table 3). This was surprising, given that previous research had also shown that faster field sport athletes had lower contact times during early acceleration [22], and that lower contacts times were a differentiating factor in performance of elite sprinters [5, 19]. However, the production of longer steps may require more time in contact with the ground to generate the force necessary for propulsion [17]. As faster subjects from the current study tended to have longer step lengths, this may have affected the derivation of any significant correlations between sprint velocity and contact time. Nonetheless, field sport athletes should not ignore the potential impact that too long contact times may have upon sprint acceleration performance. Field sport and strength and conditioning coaches should ensure that the duration of ground support of their athletes remains in an optimal ‘window’ for efficient force generation for a short sprint, as this could affect step length, and by extension the resulting sprint velocity [29].

No flight time from any of the intervals predicted sprint velocity within a 10-m sprint (Table 2). Indeed, flight time has been found not to differentiate between good and poor acceleration in field sport athletes [22]. However, there were moderate-to-large correlations found between 0-5 m flight time and 0-5 m and 0-10 m velocity, and between the 0-10 m flight time and 0-5 m velocity (Table 3). The relationships indicated that longer flight times were associated with higher sprint velocities. This may have occurred as a result of the longer step lengths demonstrated by faster subjects. Longer steps tend to result in longer flight times [20, 27]. If faster subjects made longer steps during acceleration, then these subjects could also have had longer flights. This was particularly evident for 0-5 m velocity, where step length and flight time in both the 0-5 m and 0-10 m intervals correlated with velocity during the initial interval of the 10-m sprint (Table 3). Nonetheless, it is important for field sport athletes to ensure flight time is not too great, especially for those involved in contact sports such as Australian football, American football, rugby league, and rugby union. Players cannot change direction once they are airborne. If a player’s flight time is too great when running, this can affect their body positioning prior to collisions, and reduce their ability to move effectively and change direction in response to opponents during a match-play [30].

What must be acknowledged about the results drawn from this study is the degree of variation that remains unexplained in the predictive relationships for velocity in each of the intervals (Table 2). For the 0-5 m interval, the highest R^2 value was 0.469, which means that 53.1% of the variation in the predictive relationship remains unexplained. The highest R^2 value for the 5-10 m interval was 0.511, which means 48.9% of the variation in the predictive relationship remains unexplained. The highest unexplained variance was 63.3% for the 0-10 m interval, as the associated R^2 value equaled 0.367. Despite velocity in each interval establishing significant predictive relationships with particular step kinematics (Table 2), these data also provide evidence for the complex interaction between many different facets of technique that can contribute to short sprint performance in field sport athletes. This includes not only step kinematics, but also the joint range of motion and body positions adopted by athletes when sprinting, and the kinetics generated during stance [13, 18, 21, 22].

A limitation of this study is that more detailed kinematic data (i.e. joint ranges of motion and angular velocities), and kinetic data (i.e. vertical and horizontal forces and impulses) were not included in the multiple regression process. The inclusion of these data could have reduced the degree of unexplained variance following the multiple regression process, and added more detail to establishing the important technique requirements for field sport acceleration. Nevertheless, the results from this study still have merit and practical application. The focus of the study was on determining the relative importance of selected step kinematics for acceleration specific to field sports athletes, and the data emphasized the importance of step length. In order to enhance short sprint performance, field sport athletes should attempt to develop step length development such that they can maximize acceleration.

CONCLUSION AND PRACTICAL APPLICATION

The results of this study demonstrate the importance of step length for short sprint performance in field sport athletes, and confirm aspects of practical coaching theory for speed training. The practical applications are that field sport athletes should train for speed using exercises that emphasize power production; this could then translate to enhanced step length. Protocols emphasizing explosive movements specific to the sprint step (e.g. free, assisted and resisted sprinting, plyometrics), should be especially beneficial if incorporated into a field sport athletes’ conditioning program. However, the impact that step frequency, contact time and flight time can have upon short sprint performance should not be discounted. Step length should not be increased so that it adversely affects step frequency and the temporal aspects of sprint acceleration. Future research should determine whether certain speed training protocols or programs could concurrently improve step length, while also specifically developing the other kinematics associated with the sprint step so that short sprint performance is enhanced.

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