Factors That Differentiate Acceleration Ability in Field Sport Athletes

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Abstract

Lockie, RG, Murphy, AJ, Knight, TJ, and Janse de Jonge, XAK. Factors that differentiate acceleration ability in field sport athletes. *J Strength Cond Res* 25(10): 2704–2714, 2011–Speed and acceleration are essential for field sport athletes. However, the mechanical factors important for field sport acceleration have not been established in the scientific literature. The purpose of this study was to determine the biomechanical and performance factors that differentiate sprint acceleration ability in field sport athletes. Twenty men completed sprint tests for biomechanical analysis and tests of power, strength, and leg stiffness. The sprint intervals analyzed were 0–5, 5–10, and 0–10 m. The subjects were split into a faster and slower group based on 0- to 10-m velocity. A 1-way analysis of variance determined variables that significantly ($p \leq 0.05$) distinguished between faster and slower acceleration. All subject data were then pooled for a correlation analysis to determine factors contributing most to acceleration. The results showed that 0- to 5-m (~16% difference) and 0- to 10-m (~11% difference) contact times for the faster group were significantly lower. Times to peak vertical and horizontal force during ground contact were lower for the faster group. This was associated with the reduced support times achieved by faster accelerators and their ability to generate force quickly. Ground contact force profiles during initial acceleration are useful discriminators of sprint performance in field sport athletes. For the strength and power measures, the faster group demonstrated a 14% greater countermovement jump and 48% greater reactive strength index. Significant correlations were found between velocity (0–5, 5–10, and 0–10 m) and most strength and power measures. The novel finding of this study is that training programs directed toward improving field sport sprint acceleration should aim to reduce contact time and improve ground force efficiency. It is important that even during the short sprints required for field sports, practitioners focus on good technique with short contact times.

Key Words contact time, team sports, biomechanics, running speed, sprint

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Introduction

Sprinting speed is essential for many sports. An important component of speed is acceleration, which encompasses the ability to generate speed from a stationary or moving start. The importance of acceleration is most notable when examining performance in field sports, such as the various football codes (e.g., American football, soccer, rugby), lacrosse, and field hockey. The nature of these games does not often afford the athletes the conditions in which to reach their maximum velocity (40). For example, in sports such as rugby union (16) and soccer (3), the mean duration of a sprint during a game is approximately 2 seconds. After sprinting for 2 seconds, elite rugby union players reach a velocity of 6 $m \cdot s^{-1}$, which is approximately 70% of their maximum (17). Attaining a high sprint velocity as quickly as possible, especially over a very short duration or distance is important for successful field sport performance. Indeed, speed over short distances often delineates between players at different competition levels, in that more elite athletes tend to be faster (13). Field sport acceleration, however, has not been thoroughly researched in the current literature (15,32).

Training specificity is important for speed development, because research reports the existence of movement- and velocity-specific effects on the neuromuscular system (4). Therefore, when prescribing acceleration training programs for field sport athletes, consideration of the factors affecting performance, including the speed of the movement patterns used and optimal technique, must be appraised. To improve sprint performance, there must be an increase in one or both of the factors that produce horizontal velocity–step length and step frequency. For the purpose of this research, step length is the distance between alternating contacts of the left and right feet, which is half a running cycle. Stride length is the complete cycle, which is defined as the distance between successive contacts of the same foot (23). Step frequency is the rate that each step can be reproduced. In addition to step length and frequency, the components that directly affect these step characteristics, such as contact time and the force components of sprinting, need also be considered (38).

Based on the analysis of the first stride of a 15-m sprint, Murphy et al. (31) suggested that the ability to maintain a high stride frequency with low contact times is of utmost importance for effective field sport acceleration. However, whether this idea holds true past the first stride over the extended intervals of acceleration (i.e., 0–5 and 5–10 m) has not been determined. Contact time will be affected by the mechanics of force production during support. Previous research has suggested that the time taken to generate force during ground contact is of great consequence in the generation of maximum speed (38), but there is no research to suggest whether this is true for field sport acceleration. Clearly defining those technique factors that characterize good field sport acceleration is vitally important for coaches and practitioners to design training programs that will effectively target these parameters.

This is especially pertinent as evidenced by a survey of the strength and conditioning coaches of America's National Football League (18), there is a wide range of training techniques used to develop speed in field sports. These methods include resisted and assisted sprinting, plyometrics, and form running. Many of these protocols may be prescribed to athletes without scientific evidence on whether these will actually improve those factors most important for sprint acceleration in field sports. To determine the most ideal training method for improving acceleration on the field, we must first establish the variables that directly relate to effective acceleration performance in this specific population. The lack of research analyzing field sport acceleration has been previously acknowledged. Newman et al. (32) have posited that a greater understanding of initial acceleration ability in field sport athletes is required, whereas Cronin and Hansen (15) recognized that little research has analyzed the relationship between strength, power, and quickness during early (<5-m) acceleration. This is all despite the documented importance of the short sprints that occur in field sports (33).

Therefore, the purpose of this research was to determine the kinematic, kinetic, and performance-related variables that differentiate faster and slower acceleration in field sport athletes. It was hypothesized that athletes with better acceleration abilities will report greater values for factors such as step length and step frequency, lower contact times, generate more force during ground contact, and will be stronger and more powerful. Correlations will also be calculated between parameters significant to velocity during acceleration to ascertain their relative importance. The results of this study will inform coaches and practitioners about those technique variables most important for field sport acceleration. This information can then be used to drive the implementation of training programs for field sport athletes. Coaches and practitioners will know what they need to specifically target to improve acceleration and speed for these athletes.

Methods

Experimental Approach to the Problem

To analyze the distinguishing factors of effective acceleration, a cross-sectional analysis of field sport athletes was conducted. Based on 10-m time, the subjects were split into a faster and slower group. This allowed for the determination of which technique, leg stiffness, power, or strength variable(s) differentiated between the faster and slower acceleration in field sport athletes. Specifically, the aims of this study were to ascertain the key kinematic variables (step length, step frequency, contact time) for a field sport athlete over a 10-m sprint; identify the kinetic profile of the first and second contacts for a field sport athlete in a 5-m sprint; assess the leg musculotendinous stiffness, power, and strength properties of field sports athletes; and define which of those variables are important for fast acceleration. Those variables that differentiated between faster and slower field sport athletes were then correlated with selected performance variables (i.e., velocity and contact time) to determine the strength of their relationship to sprint acceleration.

Subjects

Twenty healthy men (age = 21.9 ± 2.9 years; mass = 80.5 ± 8.5 kg; height = 1.81 ± 0.07 m) were used as subjects for this study. The subjects were recruited if they (a) were currently active in a field sport, (b) had a strength training history (≥2 times·per week) extending over the previous 12 months, (c) were currently strength training (≥3 $h \cdot wk^{-1}$), and (d) 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 University of Technology, Sydney ethics committee. All subjects received a clear explanation of the study, including the risks and benefits of participation, and written informed consent was obtained before testing.

The sample size was determined by estimating the magnitude of the effect size for the 2 groups to be analyzed (faster and slower). Based on research that has examined acceleration performance for field sport athletes (26,31), it was assumed that the effect size for this study would be large (0.8). An 80% confidence level for rejection of the null hypothesis when comparing the 2 groups was desired. Therefore, power was set at 0.8 (25).

Procedures

Before data collection, the subject's age, height, and mass were recorded. The tests were conducted over 2 separate days, with at least 48 hours between each testing session. Day 1 consisted of 10-m sprint tests, 5-bound tests (5BT), countermovement jump (CMJ) tests, and 40-cm drop jump tests for calculation of the reactive strength index (RSI). Day 2 performance measures included hopping leg stiffness tests (bilateral and unilateral), 5-m sprint tests with kinetic analysis of the first and second contacts, and a 3 repetition maximum (3RM) squat. A standardized warm-up, consisting of 10 minutes of jogging, 10 minutes of dynamic stretching of the lower limbs, and progressive speed runs over the sprint testing distance (2 repetitions each at 60, 70, 80, and 90% of perceived maximum velocity), was used on both days.

Speed Analysis

On the first test day, each subject was required to complete 4 sprints over the 10-m testing distance. This distance is indicative of the initial acceleration phase that is of the utmost importance to field sport athletes (17,34). Rest periods of 2 minutes were allocated between sprint trials. Markers were positioned at 10 m to signify the finish. Subjects were allowed to start in their own time and were instructed to sprint through the finish line. A video camera (JVC© GR-DVL9800, Tokyo, Japan) was used to assess the selected ground contact variables, with a sample rate of 100 Hz. External light sources were provided by portable 500-W flood lights (Fairway Lighting©, Melbourne, Australia). Before all sprint testing, reflective tape was placed on the fifth metatarsal for the right foot and the first metatarsal for the left foot. These selected landmarks were determined through palpation, and permitted the calculation of step length, step frequency, and contact time.

The camera and stand was placed at a height of 0.79 m and was positioned lateral to the subject to allow a sagittal plane view of the movement. For the first 2 sprints, the high-speed camera recorded the 0- to 5-m interval. For the second 2 sprints, the camera was moved, and data were recorded for the 5- to 10-m interval. Two trials were used per interval, because this has been used previously in research analyzing sprint technique (9,26,36). The camera was positioned 8 m lateral to the subject's running plane and was placed at the 2.5-m mark for the filming of the 0- to 5-m interval and the 7.5-m mark for the 5- to 10-m interval. Markings on the floor ensured that the camera was placed in an identical position for each test for all subjects.

Recorded images were collected on a video cassette, and transferred onto an IBM-compatible computer via Studio Digital Video (version 1.1.0.15.), and were edited in Adobe Premiere 6.0. The edited file was then exported into custom software (DigiSport 2000, BBSportz version 0.5.2.01) for further analysis. The vertical and horizontal scaling of the video images recorded by the camera was checked using the methods outlined by Gruen (22). Before testing, a meter-long ruler was carried throughout the observation volume and imaged by the camera. These data were exported and analyzed within the custom software and ensured that the recorded images were calibrated and representative of the real-space coordinate system. Analysis was conducted on the 2 trials used for each interval, and the averages were used. For the mean step kinematic measurements, the total number of measures a subject had within an interval was used to calculate the average. Start and finish points of the movement phases were estimated visually from the video footage (7). Contact time was the period between touch-down and toe-off of the one foot during ground support. Step length was defined as the distance between toe-off of one foot, and touchdown (foot strike) of the opposing foot. For the purpose of this research, step frequency was calculated from the velocity and mean step lengths for each interval through the following formula: Step Frequency = Velocity·Mean Step Length per interval^{-1} (23).

The time taken for the sprints was measured by the use of a velocimeter (Onspot©, Wollongong, Australia). The velocimeter consisted of a stopwatch (Seiko©, Tokyo, Japan) and a nylon line attached to a reel, which allowed the line to unwind unimpeded when the subjects began their sprint. An optical sensor sent electrical impulses to the velocimeter's processor for every 0.1 m of linear line displacement. The velocimeter was placed on a 0.72-m-high table, 1.5 m behind the subject for each trial. The line was attached to the back of the subject's shorts. The stopwatch was activated with the first movement of the subject. The subjects were instructed not to hesitate at the start of their sprint, because this would falsely trigger the velocimeter. If a subject did hesitate and trigger the timer, the trial was disregarded, and another attempt was allowed after the requisite rest period. The recorded times for the 3 chosen intervals (0–5, 5–10, and 0–10 m) were then used to calculate velocity through the equation $v = st^{-1}$, where v is the velocity; s is the displacement of the runner; and t is the time taken for the sprint.

Lower-Limb Power Assessment

After the acceleration assessment in the first testing session, the subjects completed their lower-limb power assessment. Jump heights and length of bounds have been previously used as estimates of lower-limb power (28,36). For each separate power assessment, 3 trials were completed, 2 minutes of recovery time was allocated between each trial, and the average was used for analysis.

The 5BT was used to measure stretch–shorten cycle capacity in the horizontal plane. This test involved the subjects attempting to cover the greatest horizontal distance possible by performing a series of 5 forward bounds with alternate right and left foot contacts. Subjects were required to start with both feet parallel, before commencing with the 5 alternate leg bounds. They were allowed to choose which leg they preferred to perform the initial push-off with, and this take-off leg was used for all trials. The total distance covered was measured from the start line to the final position of the front of the landing foot on the fifth bound.

The CMJ was used to assess stretch-shortening capacity in the vertical plane. The CMJs were performed on a force plate (Onspot©). The data were sampled at 1,000 Hz, and recorded to an IBM-compatible computer via a National Instruments (DAQCard™-AI-16E-4) analog-to-digital converter. The CMJ has been related to superior performance during acceleration in track sprinting (8) and field sports (15), and was thus considered to be appropriate for this study. The subjects were instructed to jump for maximal height while keeping their hands placed on their hips, which limited contributions to the movement from the upper body. No restrictions were placed on the knee angle attained during the eccentric phase of the jump. However, subjects were instructed to maintain straight legs during the flight. The following formula was used to calculate jump height:

$$\text{Jump Height} = (1/2a[t/2]^2),$$

where a is the acceleration due to gravity (i.e., 9.8 m·s^{-2}), t is the total flight time.

Calculation of jump height using projectile motion equations has been used in previous research analyzing the CMJ (29,30).

A 40-cm drop jump was used to determine the RSI. The RSI assesses the subject's ability to produce force rapidly under high eccentric load. This height of 40 cm was chosen because it has been recommended as being optimal for training (6). Drop jump performance has also been related to short sprint speed (39) and was therefore assessed within this study. Similar to the CMJ, the drop jumps were performed on the aforementioned force plate. The starting position for the drop jump involved the subject standing upright on a 40-cm box. Subjects were then instructed to keep their hands on their hips throughout the jump to minimize any contributions from the upper body. Subjects were instructed to step off (not jump off) the box, and 'explode' up off the force plate, attempting to minimize contact time. Jump height and contact time were determined, and RSI was calculated using the following equation:

$$\text{RSI} = \text{JH} \cdot \text{CT}^{-1},$$

where JH is the jump height in meters [½ $at^2/2$] and CT is the length of the time in seconds the subject was in contact with the force plate after the drop (36).

Vertical Leg Stiffness

On the second day of testing, vertical leg stiffness was determined using a bilateral and unilateral (right and left legs) hopping test conducted on the force plate used for the jump tests. The subjects were instructed to hop at 2.2 Hz in time with a digital metronome (Seiko©, Tokyo, Japan). Previous research has reported that this cadence is the preferred frequency for hopping (19). The subjects were instructed to keep their hands on their hips throughout each trial to minimize any upper body contribution to each hop and ultimately vertical leg stiffness measurements. No shoes were worn by subjects during the hopping stiffness test, to negate any between-shoe variability. Trials lasted for approximately 10 seconds or until a steady hopping state was achieved. Feedback about technique was provided if required to aid the subject to achieve steady-state hopping. Once synchronization with the metronome was achieved, kinetic data from the force plate were collected for 5 seconds. Trials were accepted when hops were within 2% of the designated movement frequency (20). Stiffness was calculated as the ratio of the maximum ground reaction force (GRF), and the maximum change in length of the 'internal leg spring' (the muscles of the multijointed leg) occurring from the start of ground contact time, to the point where the muscles of the leg are maximally compressed (which occurs when the GRF is at its peak) (20). These values were then averaged to provide a vertical leg stiffness value, which was used for further analyses. This is shown mathematically as follows:

$$K = F/\Delta L,$$

where F is the the maximum GRF and ΔL is the maximum change of displacement of the leg spring.

As has been used in previous literature (10,20), ΔL was calculated by the double integration of the vertical acceleration of the center of mass of the subject as calculated from the vertical GRF. The final leg stiffness was made relative to body mass by the following equation:

$$\text{Relative Leg Stiffness} = K \cdot \text{BM}^{-1},$$

where K is the absolute leg stiffness and BM is the body mass.

Kinetic Acceleration Assessment

After the leg stiffness assessment, 5-m sprints were conducted over a different, fixed 3-dimensional force plate (Onspot©), which was embedded in a running platform. Two dimensions (horizontal and vertical) were used in this study. Data were sampled at 1,000 Hz and recorded to an IBM-compatible laptop via a National Instruments (DAQCard™-AI-16E-4) analog-to-digital converter. The subjects used the same starting leg as in the 10-m sprints. Force measurements were taken for the first 2 contacts, with a total of 4 trials. The first 2 sprints were used to measure the first contact; the second 2 sprints collected data for the second contact. A 2-minute recovery period was allotted between trials. As for the kinematic analysis, 2 trials were used for each ground contact in accordance with previous use of this methodology (9,26,36).

The measurements of the subject's first 2 step lengths were taken from the video recordings from the sprints on day 1 and used accordingly to adjust the subject's start position such that the appropriate contact was centered on the force plate. During the warm-up, the researcher observed the subject's technique, and if the subject did not contact the force plate cleanly, slight adjustments were made to the start line to ensure contact in subsequent trials. The subjects were discouraged from 'tracking' the force plate and instructed to sprint maximally as they normally would. If the force plate was either missed or not struck cleanly, the trial was disregarded and the subject completed another trial after a 2-minute rest period. Generally, not more than 3 attempts were needed before a successful trial was completed.

The data were analyzed using custom software (UTS Data Collection Software, version 1). In the vertical plane, the variables analyzed were as follows: maximum GRF (peak vertical force generated during ground contact); time to maximum GRF (TGRF; duration from initial ground contact until peak GRF); and the impulse generated in the vertical plane during ground contact (VI; total vertical force generated during support divided by total contact time [force$\cdot$time^{-1}]). In the horizontal plane, the variables analyzed were as follows: maximum braking force (BF; the peak antero-posterior force that opposed forward motion); time to BF (TBF; duration from initial ground contact until peak BF); maximum propulsive force (PF; peak antero-posterior force consistent with the direction of forward motion); time to PF (TPF; duration from time of BF until peak propulsive force); and the impulse generated during the propulsive phase (PI; total propulsive force generated divided by time period from BF until take-off [force$\cdot$time^{-1}]).

Strength Assessment

The 3RM squat was used as a measure of lower body strength and was conducted on a Smith machine (Life Fitness©, Artarmon, Australia). The warm-up consisted of 15–20 body mass–only squats followed by 10 repetitions at approximately 60–70% of the estimated 1RM. After a 3-minute rest interval, the subjects completed their first attempt at their 3RM. The weight was increased until the subject failed to complete 3 repetitions. To ensure a full recovery, rest intervals of 3 minutes were provided between each attempt. Generally, not more than 5 attempts were needed before the 3RM was reached. Bilateral strength exercises at heavier loads have been found to have high reliability (intraclass correlation coefficient [ICC] = 0.92) (5).

For the downphase of the squat, the subjects were instructed to descend until the tops of their thighs were parallel to the floor, before attempting to lift the bar. A length of non–weight-bearing wire, individually set for each subject, was tied across the Smith machine at the descent height to give the subjects an indication on the depth required for each squat (14). This was visually assessed by the investigator, and subjects were also given verbal cues on when they were to halt the downphase, and begin the up-phase, of the squat (15). No knee wraps, weightlifting belts, or other supportive garments were permitted. If the subject did not descend to the appropriate position, the trial was disregarded, and attempted again after the required rest period. Absolute strength was taken as the maximum load lifted for 3 repetitions. Relative strength was calculated according to the following equation:

$$\text{Relative Strength} = 3\text{RM} \cdot \text{BM}^{-1},$$

where 3RM is the maximum load lifted for 3 repetitions and BM is the body mass.

Statistical Analyses

After data collection and analysis, descriptive statistics were calculated for all results. Trial-to-trial reliability of variables within the study was assessed by ICCs calculated from a 2-way mixed method consistency model for single measures. These methods were based on reliability analyses conducted in previous research (27,35). An ICC > 0.8 was considered acceptable for reliability (37).

The subjects were then split into 2 groups–faster and slower–according to their 10-m velocity. This split served the purpose of dividing the subjects into 2 groups of differing sprint ability. A 1-way analysis of variance was used to determine whether there were significant differences in the dependent variables between the faster and slower groups. An alpha level of $p \leq 0.05$ was chosen as the criterion for significance. Effect sizes were calculated according to the methods of Cohen (12), where the difference between the means was divided by the pooled *SD*s. For the purpose of this research, 0.5–0.8 was considered a medium effect size and 0.8 and above a large effect size.

All data from both groups were then combined for Pearson's correlation analysis between the contact times and force–time components and between the velocity measures (0–5, 5–10, and 0–10 m) and the other variables. An alpha level of $p \leq 0.05$ was chosen as the criterion for significance. For the purpose of this study, a Pearson's r value <0.7 was considered low; 0.7–0.9 moderate; and ≥ 0.9 good for predicting relationships (37). All statistical analyses were computed using the Statistics Package for Social Sciences (Version 17.0).

Results

Velocity and Step Characteristics

The ICCs for 0- to 5-m, 5- to 10-m, and 0- to 10-m velocity were 0.94, 0.88, and 0.92, respectively. When the subjects were split into groups according to their 0- to 10-m velocity, there was a significant ($p \leq 0.05$) difference between the average velocities for the faster and slower groups for all intervals (Table 1). Each of these had large effect sizes. In the 0- to 5-m interval, the faster group had a 10% greater velocity; in the 5- to 10-m interval, there was a 6% velocity difference; and in the 0- to 10-m interval, the faster group's velocity was 9% greater.

In the 0- to 5-m and 0- to 10-m intervals, the ICC for mean step length (0.94 and 0.78, respectively) and frequency (0.91 and 0.84, respectively), were indicative of high reliability. Interestingly, there were no significant differences between the 2 groups for either any of the mean values of step length or step frequency (Table 1). This was also reflected in the effect sizes for these comparisons, in that the majority were relatively low. However, the average step frequency over the entire 10-m sprint tended to be higher for the faster group ($p = 0.09$). An effect size of 0.80 was calculated for this difference.

TABLE 1. Comparison of average velocity, SL, and SF between faster and slower field sport athletes during a 10-m sprint.*†

	Faster group (n = 10)	Slower group (n = 10)	p	ES
Age (y)	21.5 (±2.42)	22.2 (±3.33)	0.60	0.24
Body mass index	24.16 (±2.19)	24.56 (±2.89)	0.73	0.16
Velocity 0–5 m ($m \cdot s^{-1}$)	3.91 (±0.13)	3.56 (±0.10)	0.00‡	3.02
SL 0–5 m (m)	1.17 (±0.15)	1.16 (±0.14)	0.86	0.07
SF 0–5 m (Hz)	3.39 (±0.45)	3.11 (±0.36)	0.14	0.69
Velocity 5–10 m ($m \cdot s^{-1}$)	6.73 (±0.25)	6.32 (±0.23)	0.00‡	1.71
SL 5–10 m (m)	1.84 (±0.16)	1.81 (±0.16)	0.76	0.19
SF 5–10 m (Hz)	3.69 (±0.32)	3.51 (±0.33)	0.24	0.55
Velocity 0–10 m ($m \cdot s^{-1}$)	4.93 (±0.14)	4.53 (±0.10)	0.00‡	3.29
SL 0–10 m (m)	1.51 (±0.14)	1.49 (±0.13)	0.78	0.15
SF 0–10 m (Hz)	3.30 (±0.31)	3.07 (±0.26)	0.09	0.80

*ES = effect size; SL = step length; SF = step frequency.
†Mean (±*SD)* and corresponding p values and ES.
‡Significant ($p \leq 0.05$) difference between faster and slower groups.

Mean contact time in the 0- to 5-m (ICC = 0.83) and 5- to 10-m (ICC = 0.70) intervals had acceptable reliability in this study. When examining the contact times within the 0- to 5-m interval, the 5- to 10-m interval, and the 0- to 10-m interval (Figure 1), the faster group recorded lower ground contact times when compared with the slower group. Significant ($p \leq 0.05$) differences were recorded for the 0- to 5-m (16%; effect size = 1.18) and 0- to 10-m (11%; effect size = 1.00) intervals. Although the difference in average contact time in the 5- to 10-m interval was not significant ($p = 0.11$), it did have a large effect size of 1.00.

Ground Kinetics

No significant differences were found between the major kinetic measurements of the 5-m sprints for either the first or second step contacts (Table 2). There were no significant differences between the 2 groups in the time taken to reach peak forces in the vertical and horizontal planes. However, a trend emerged in the characteristics between the 2 groups. The time taken to reach the peaks of each of the 3 major forces measured–TGRF, TBF, and TPF–for both the first and second contacts tended to be lower in the faster group. For example, within the second contact, TBF approached significance ($p = 0.06$) and had a large effect size of 1.00, whereas TGRF had a large effect size of 6.32 (Table 2). Faster athletes tended to reach their peak force sooner than the slower athletes did, and this is commensurate with the fact that faster athletes had lower contact times.

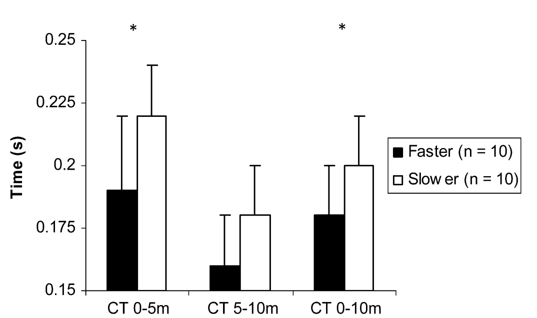

Figure 1. Comparison of contact times (CTs) (mean ± *SD*) for faster and slower groups in the 0- to 5-m, 5- to10-m, and 0- to 10-m intervals in a 10-m sprint. *Significant ($p \leq 0.05$) difference between faster and slower groups.

This is further evidenced when comparing sample force traces between typical subjects in the faster and slower groups. Figure 2 features the vertical (shown by F_{ver}) and horizontal (shown by F_{hor}) force traces from a subject from each testing group for both the first and second ground contacts. As reflected in Table 2, there are no great differences in the magnitude of forces. However, the faster subject produces the forces over a much shorter period of time. Ground contact efficiency was further investigated by correlating the force–time aspects of ground contact with contact time. All but one correlation between the contact times for each interval and the time taken to reach peak force in both the horizontal and vertical plane were significant ($p \leq 0.05$), with all correlations being positive (Table 3).

Power and Strength

Table 4 highlights the power, strength, and leg stiffness measures for this study. The ICCs for the 5BT, CMJ, and RSI were 0.98, 0.97, and 0.96, respectively. The difference in the 5BT was not significant ($p = 0.13$) but did have a moderate effect size of 0.74. The faster group had a significantly superior performance in the CMJ (vertical power), which was

Table 2. Ground kinetics for the faster and slower field sport athletes for the first (1) and second (2) contacts in a 5-m sprint.*†

	Faster group ($n = 10$)	Slower group ($n = 10$)	p	ES
GRF1 (N)	1,334.55 (±131.62)	1,397.25 (±290.89)	0.54	0.28
TGRF1 (s)	0.12 (±0.02)	0.13 (±0.03)	0.33	0.39
BF1 (N)	−853.70 (±322.61)	−889.81 (±239.93)	0.78	0.13
TBF1 (s)	0.13 (±0.03)	0.20 (±0.16)	0.22	0.61
PF1 (N)	6.64 (±150.49)	13.92 (±136.31)	0.91	0.05
TPF1 (s)	0.08 (±0.08)	0.08 (±0.16)	0.87	0.00
GRF2 (N)	1,435.90 (±169.79)	1,458.00 (±272.88)	0.82	0.10
TGRF2 (s)	0.01 (±0.01)	0.11 (±0.02)	0.13	6.32
BF2 (N)	−1,144.62 (±169.57)	−1,192.71 (±212.86)	0.58	0.25
TBF2 (s)	0.12 (±0.02)	0.14 (±0.02)	0.06	1.00
PF2 (N)	29.37 (±136.43)	73.26 (±190.40)	0.56	0.26
TPF2 (s)	0.07 (±0.07)	0.10 (±0.11)	0.39	0.33

*GRF = maximum ground reaction force; TGRF = time to maximum ground reaction force; BF = maximum braking force; TBF = time to maximum braking force; PF = maximum propulsive force; TPF = time to maximum propulsive force; ES = effect size.
†Mean (±*SD*) and corresponding p values and ES.

14% greater for the faster group (effect size = 1.05), and the RSI (reactive power), which was 48% greater (effect size = 1.61). The components of RSI, contact time, and jump height were also investigated. Individually, neither contact time nor jump height differentiated between the faster and slower groups. However, the difference in the jump height after the drop had a medium effect size of 0.68.

Force trace data from typical subjects in the faster and slower groups were produced to further illustrate the RSI results (Figure 3). The initial force peak is where the subject contacts the plate after landing from the 40-cm drop height. The section of the curve where force equals zero is when the

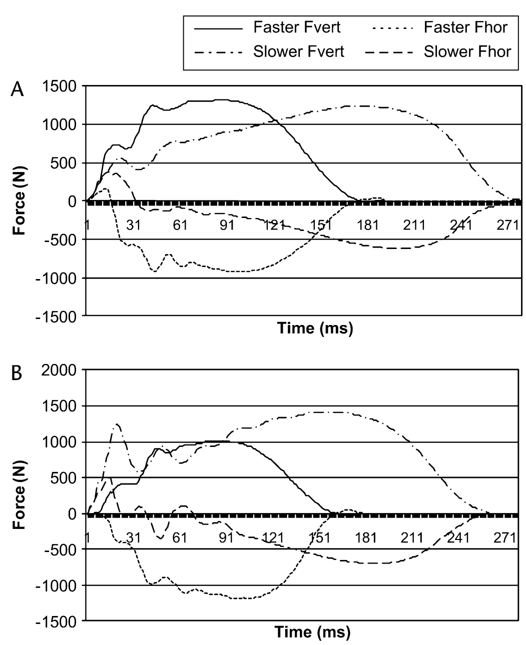

Figure 2. Sample force trace from a typical subject from the faster and slower field sport athlete groups for the first contact (A) and second contact (B) in a 5-m sprint.

Table 3. Correlations between mean CT in the 0- to 5-m, 5- to 10-m, and 0- to 10-m intervals and the force–time components for the first (1) and second (2) contacts in a 5-m sprint in field sport athletes.*

		Mean CT 0–5 m	Mean CT 5–10 m	Mean CT 0–10 m
TGRF1	r	0.59	0.71	0.68
	p	0.00†	0.00†	0.00†
TBF1	r	0.53	0.52	0.61
	p	0.01†	0.01†	0.00†
TPF1	r	−0.01	0.13	0.08
	p	0.48	0.29	0.36
TGRF2	r	0.51	0.76	0.67
	p	0.01†	0.00†	0.00†
TBF2	r	0.70	0.78	0.81
	p	0.00†	0.00†	0.00†
TPF2	r	0.48	0.39	0.51
	p	0.02†	0.05†	0.01†

*TGRF = time to maximum ground reaction force; TBF = time to maximum braking force; TPF = time to maximum propulsive force; r = Pearson correlation; p = significance; $n = 20$; CT = contact time.
†Significant ($p \leq 0.05$) relationship between variables.

Table 4. Five-bound test, CMJ, RSI, DJCT, and DJH, 3RM squat, and relative strength, and K for faster and slower field sport athletes.*†

	Faster group (n = 10)	Slower group (n = 10)	p	ES
5BT (m)	11.95 (±0.78)	11.32 (±0.92)	0.13	0.74
CMJ (m)	0.41 (±0.03)	0.36 (±0.06)	0.02‡	1.05
RSI (jump height·CT^{-1})	1.38 (±0.32)	0.93 (±0.23)	0.00‡	1.61
DJCT (s)	0.25 (±0.07)	0.29 (±0.08)	0.25	0.53
DJH (m)	0.33 (±0.06)	0.27 (±0.11)	0.17	0.68
3RM (kg)	119.78 (±27.79)	103.46 (±20.13)	0.15	0.67
Relative strength (3RM·BM^{-1})	1.52 (±0.33)	1.27 (±0.25)	0.07	0.85
Bilateral K (N·m·kg^{-1})	210.88 (±48.18)	193.20 (±24.54)	0.32	0.46
Left-leg K (N·m·kg^{-1})	156.08 (±18.03)	166.67 (±28.57)	0.34	0.44
Right-leg K (N·m·kg^{-1})	152.55 (±26.99)	164.59 (±23.78)	0.30	0.47

*5BT = 5-bound test; CMJ = countermovement jump; RSI = reactive strength index; DJCT = drop jump contact time; DJH = drop jump height; 3RM = 3 repetition maximum; ES = effect size; K = leg stiffness.
†Mean ± *SD* and corresponding p values and ES.
‡Significant ($p \leq 0.05$) difference between faster and slower groups.

subject is in flight during the jump. The force peak after this period is when the subject lands after the jump. The initial peak for the faster subject had a much shorter duration when compared to the slower subject, and the period of flight was also longer.

There was no difference in absolute strength, as measured by the 3RM squat, when comparing the 2 groups. However, when the 3RM squat was made relative to body mass, results revealed that the faster group tended to have greater relative strength (1.52 ± 0.33 vs. 1.27 ± 0.25 kg·BM^{-1}; $p = 0.07$). This disparity had an effect size of 0.85. The ICCs for bilateral, left-leg, and right-leg stiffness was 0.98, 0.97, and 0.96, respectively. There were no significant differences between the faster and slower groups for any of the leg stiffness measures (Table 4).

The 5BT, CMJ, 3RM, and relative strength all correlated to 0- to 5-m, 5- to 10-m, and 0- to 10-m velocity. The RSI correlated to 0- to 5-m and 0- to 10-m velocity (Table 5). All correlations were positive, indicating that a higher strength or power score was associated with a higher velocity. However, the strongest relationship (CMJ and Velocity 5–10 m; $r = 0.71$) only accounted for 50% of the common variance.

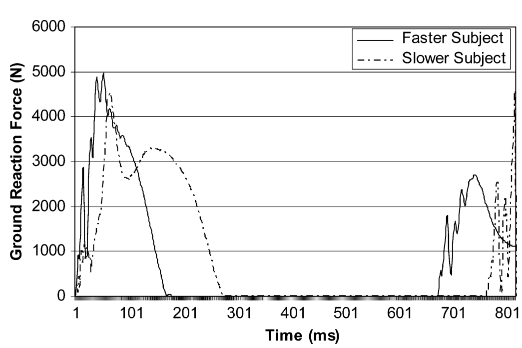

Figure 3. Sample force trace of drop jump performance from a typical subject from the faster and slower field sport athlete groups.

Table 5. Correlations between velocities for the 0- to 5-m, 5- to 10-m, and 0- to 10-m intervals and the 5BT, CMJ, RSI, DJCT, and DJH, 3RM squat, and relative strength in field sport athletes.*

		Velocity 0–5 m	Velocity 5–10 m	Velocity 0–10 m
5BT	r	0.48	0.62	0.57
	p	0.02†	0.00†	0.00†
CMJ	r	0.55	0.71	0.61
	p	0.01†	0.00†	0.00†
RSI	r	0.65	0.32	0.55
	p	0.00†	0.09	0.01†
DJCT	r	−0.13	0.14	−0.06
	p	0.30	0.28	0.39
DJH	r	0.43	0.39	0.40
	p	0.03†	0.04†	0.04†
3RM	r	0.43	0.60	0.47
	p	0.03†	0.00†	0.02†
Relative	r	0.50	0.66	0.56
strength	p	0.01†	0.00†	0.01†

*5BT = 5-bound test; CMJ = countermovement jump; RSI = reactive strength index; DJCT = drop jump contact time; DJH = drop jump height; 3RM = 3 repetition maximum; r = Pearson correlation; p = significance; n = 20.
†Significant ($p \leq 0.05$) relationship between variables.

Discussion

The ability to accelerate quickly is essential for field sport athletes. The actual factors important for field sport acceleration, however, have not been clearly established in the scientific literature. Therefore, the aim of this study was to investigate the factors that differentiate between relatively faster and slower sprinters from a sample of field sport athletes. The results from this study emphasize those variables that need to be targeted by a field sport athlete wishing to improve their acceleration performance.

The main finding from this study is that contact time is the major step characteristic that delineates faster and slower acceleration. This strongly relates to the findings of Weyand et al. (38), who reported that the time taken to generate force during ground support in sprinting is of great consequence to speed development in physically active subjects. However, the unique findings particular to field sport athletes from this study provide valuable insight into these athletes' speed characteristics. Contact time is a function of the force mechanics produced during support. When looking at the mean contact times within the 0- to 5-m interval and the 0- to 10-m interval (Figure 1), the faster group had significantly lower contact times for these 2 intervals. This current result builds on the work of Murphy et al. (31) on field sport athletes, who showed that during first and second contacts in a 15-m sprint faster athletes had significantly lower contact times than slower athletes ($p \leq 0.05$). Furthermore, in track sprint performance, the reduction of ground contact time has been shown to be a major differentiating factor in elite performance (11). Our findings show that by minimizing support time during sprinting, field sport athletes may also be able to increase their acceleration.

Previous research has established that stride frequency may be a defining factor between good and poor acceleration, in that faster field sport athletes can generate a higher stride frequency (31). Furthermore, contact time and stride frequency have been referred to as the 2 most important kinematic parameters for elite sprinters (11). Although there were no significant step frequency differences between the faster and slower groups, the mean step frequency for the 0- to 10-m interval did approach significance ($p = 0.09$), and had a large effect size (0.80) (Table 1). For field sport acceleration, a player who can accelerate faster will have lower contact times, and may also have a higher step frequency. The timing and magnitude of the kinetics produced during ground support will affect an athlete's ability to reduce contact time and possibly increase stride frequency.

There were no significant differences between the faster and slower groups for peak forces measured at impact for the first or second contacts of a 5-m sprint (Table 2). However, there was a trend toward the faster group having lower times to peak force for both contacts during early acceleration, especially in relation to GRF and BF (Table 4). Indeed, the difference in TBF2 between the faster and slower groups approached significance ($p = 0.06$), and had a large effect size (1.00), whereas the difference for TGRF2 had a large effect size (6.32). These results appear to be associated with the reduced ground contact times achieved by quicker accelerators and an ability to attenuate force in shorter periods of time. The positive correlations between contact time and the time to peak forces (Table 3), and the force traces shown in Figure 2, substantiate this finding. When analyzing Figure 2, it is shown that the faster subject reached their peak force more quickly, in both the vertical and horizontal directions for both the first and second ground contact. This is indicative of greater efficiency of force production. Kollias et al. (24) found similar results when comparing soccer players and nonfield sport athletes. In a vertical jump, soccer players, who would be expected to have good lower-limb power, were found to show a trend toward a higher rate of force development. The ability to develop and use force within a short duration appears to be an important factor in field sport acceleration.

The power and strength qualities of a field sport athlete would affect their ability to produce force quickly during acceleration. Although there was no significant difference between the 2 groups for the 5BT, the effect size for the difference was moderate (0.74), indicating that horizontal power generation may be a factor during field sport acceleration. The tests of vertical and reactive power (CMJ and RSI) did reveal significant differences between the slower and faster groups (Table 4). This supports the findings in track sprinting demonstrating a correlation between the CMJ and the acceleration phase of a 100-m sprint (8). In field sports, CMJ has been shown to be a delineating factor between American football players from higher and lower divisions (21). These results suggest that a more powerful field athlete, as measured by a maximal vertical jump, would be likely to have better acceleration ability.

Additionally, as evidenced by the higher RSI, good field sport accelerators may potentially be able to attenuate higher eccentric loads, and convert this into concentric force over a shorter period of time. Figure 3 (force traces of a drop jump from a typical faster and slower subject) provides some support for this suggestion. The faster subject attenuated the GRF over a shorter time period (indicated by the length of the initial force peak), before producing a greater jump height (indicated by the period of time where there was no force). The jump height difference, although not significant, did have a medium effect size (0.68). The RSI results may also help to explain the lower ground contact times attained by the athletes with better acceleration in the short sprints. These results are consistent with the findings of previous research, which have shown the tendency for field sport athletes from higher divisions to be more powerful than players from lower divisions (1,21).

There were no significant differences between the faster and slower groups for either bilateral or unilateral leg stiffness. Although stiffness has been related to the transition from acceleration to maximum velocity during a 100-m sprint (8), it may not be as important during short accelerations. Additionally, there were no differences between the 2 groups in the 3RM. Previous research has also shown a lack of correlation between 3RM strength and short sprint performance in rugby league players (2,15). However, the difference in relative strength, although not significant, had a large effect size (0.85). Baker and Nance (2) found that when the 3RM squat was related to body mass, a relationship was established with sprint performance. As such, this highlights the contribution of relative strength to acceleration. Purely absolute strength may not ultimately benefit short sprinting speed; strength relative to the athlete's body mass will be of greater value.

There were a number of significant correlations between velocity and the measures of power and strength (Table 5). However, it is important to note that even the highest correlation, which occurred between the CMJ and velocity in the 5- to 10-m interval ($r = 0.71$) still only accounted for 50% of the common variance. Although strength and power are contributing factors to acceleration, other factors (i.e., sprint kinematics and kinetics) will play a major role in final performance. Therefore, it is very important that when prescribing specific training programs for field sport acceleration, technique is not compromised when developing power and strength. This is a very important consequence that can be derived from this study. Football strength and conditioning coaches will often use an assortment of training protocols in an endeavor to improve running speed (18). Some of these protocols (e.g., plyometrics) will increase power (28). However, changes in power and strength must not come at the expense of sprint technique. Strength and conditioning coaches must always be focused on the technical adaptations they wish to incur (e.g., reduced contact time) when implementing sprint acceleration training programs.

The results from this study indicate that faster field sport acceleration features lower contact times and shorter times to peak forces during ground support. A higher stride frequency may also contribute. Faster field sport athletes tend to be more powerful, as shown by maximal jump tests, and have greater relative strength. Although measures of strength and power do correlate with sprinting velocity, the strength of these relationships indicates that the technical factors involved with sprinting must not be ignored. Training programs designed to enhance field sport acceleration should focus on reducing contact time and improving force efficiency during ground contact. Documenting those training protocols that provide these adaptations is an important area for future research.

Practical Applications

A specific training program for field sport acceleration should be targeted toward reducing contact time and time to peak force production during ground support. Improving stride frequency may also provide benefits. Programs that emphasize explosive power movements (e.g., plyometrics), or a high rate of movement speed (e.g., overspeed training) could provide these adaptations. These protocols would also have the advantage of training some of the specific physical capacities (i.e., horizontal, vertical, and reactive power) needed for effective field sport acceleration. It is evident, however, that future research is required to define specific technical, strength and power adaptations that results from typical speed training methods. In the meantime the results from this study show that strength and conditioning coaches should focus on improving ground contact mechanics to enhance field sport acceleration. If resources are available, practitioners may consider force plate analysis for their athletes to determine ground contact force profiles during initial acceleration. In conclusion, it is essential that strength and conditioning coaches do not lose sight of the importance of field sport athletes maintaining superior technique with short contact times during short sprints.

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