Characteristics of Sprint Performance in College Football Players

William F. Brechue,[1] Jerry L. Mayhew,[2,3] and Fontaine C. Piper[2,4]

[1]Center for Physical Development Excellence, Department of Physical Education, United States Military Academy, West Point, New York; [2]Human Performance Laboratory, Truman State University, Kirksville, Missouri; [3]Department of Physiology, A.T. Still University of Health Sciences, Kirksville, Missouri; and [4]Department of Anatomy, A.T. Still University of Health Sciences, Kirksville, Missouri

Abstract

Brechue, WF, Mayhew, JL, and Piper, FC. Characteristics of sprint performance in college football players. *J Strength Cond Res* 24(5): 1169–1178, 2010—To investigate sprinting strategy, acceleration and velocity patterns were determined in college football players ($n = 61$) during performance of a 9.1-, 36.6-, and 54.9-m sprints. Acceleration and velocity were determined at 9.1-m intervals during each sprint. Lower-body strength and power were evaluated by 1 repetition maximum (1-RM) squat, power clean, jerk, vertical jump, standing long jump, and standing triple jump. Sprint times averaged 1.78 ± 0.11 seconds (9.1 m), 5.18 ± 0.35 seconds (36.6 m), and 7.40 ± 0.53 seconds. Acceleration peaked at 9.1 m (2.96 ± 0.44 $m \cdot s^{-2}$), was held constant at 18.3 m (3.55 ± 0.0.94 $m \cdot s^{-2}$), and was negative at 27.4 m (-1.02 ± 0.72 $m \cdot s^{-2}$). Velocity peaked at 18.3 m (8.38 ± 0.65 $m \cdot s^{-1}$) and decreased slightly, but significantly at 27.4 m (7.55 ± 0.66 $m \cdot s^{-1}$), associated with the negative acceleration. Measures of lower-body strength were significantly related to acceleration, velocity, and sprint performance only when corrected for body mass. Lower-body strength/BM and power correlated highest with 36.6-m time ($rs = -0.55$ to -0.80) and with acceleration (strength $r = 0.67$–0.49; power $r = 0.73$–0.81) and velocity (strength $r = 0.68$–0.53; power $r = 0.74$–0.82) at 9.1 m. Sprint times and strength per body mass were significantly lower in lineman compared with linebackers-tight ends and backs. The acceleration and velocity patterns were the same for each position group, and differences in sprint time were determined by the magnitude of acceleration and velocity at 9.1 and 18.3 m. Sprint performance in football players is determined by a rapid increase in acceleration (through 18.3 m) and a high velocity maintained throughout the sprint and is independent of position played. The best sprint performances (independent of sprint distance) appear to be related to the highest initial acceleration (through 18.3 m) and highest attained and maintained velocity. Strength relative to body mass and power appears to impact initial acceleration and velocity (through 18.3 m) in contribution to sprint performance.

Key Words 40-yd sprint, body mass, acceleration, muscular strength, muscular power, performance

Introduction

The 40-yd sprint is clearly the most popular and central test for evaluating and comparing football players at any level of competition. It is the centerpiece of scouting combines held to evaluate college recruits and National Football League (NFL) prospects. The 40-yd sprint appears to be one of those mystical measurements that does not have a strong scientific basis for its existence. It is believed to have originated with legendary professional Coach Paul Brown who reasoned that 40 yd was about as far as a typical player would have to run on any given play. However, that very reasoning is being questioned today in light of player position specialization.

Although the 40-yd sprint has been shown to be a good predictor of on-field performance (4,14), its relevance to football has been questioned as the average football play requires considerably shorter sprints (5–20 yd) and may rely more on a player's ability to accelerate quickly and change direction than to maintain speed over a longer distance. Although sprint speed (straight-ahead speed) and agility (change-of-direction speed) are related, they are clearly different skills. The latter requires rapid, repetitive decelerations and accelerations over short distances apparently using different running technique (23,27) and includes perceptual skill as well. Regardless, it is the rapid acceleration that may be more important than linear speed, thus, achieving maximal acceleration and speed earlier (first steps to 5–10 yd) would be advantageous for sports performance (e.g., football). It has been suggested that the 40-yd sprint time is a poor predictor of initial acceleration because of its low correlation with 5-yd sprint time ($r = 0.41$) and thus may not be specific to the demands of most football positions (28). Further, 100-m sprint

Address correspondence to Dr. William F. Brechue, bill.brechue@usma.edu.

24(5)/1169–1178

Journal of Strength and Conditioning Research

specialists do not attain maximal velocity until 50–60 m. It has also been suggested that the biomechanical and physiological demands of various sprint distances require different training protocols (3,28). Thus, individuals testing with the 40-yd sprint must attain maximal velocity sooner (3) leading to the suggestion that there may be different strategies for maximal sprint performance depending upon the particular sport. Therefore, the purpose of this study was to evaluate sprint strategy used by college football players by quantifying the acceleration and velocity characteristics of sprint performance during 3 different sprint distances. In addition, measures of lower-body strength and leg power were used to explore the role of each in sprint acceleration and performance.

Methods

Experimental Approach to the Problem

The use of the 40-yd sprint to evaluate running speed in football players has been questioned recently. The demands of the game lend themselves more to obtaining quick acceleration over shorter distances. This has led to speculation that different acceleration strategies might be engaged in performing sprints of different distances. To determine if football players employ a different acceleration/velocity strategy to complete sprints of varying distance, acceleration and velocity were determined at 9.1-m intervals of a 9.1-, 36.6-, and 54.9-m sprints in NCAA Division II college football players ($n = 61$). Testing was performed as part of the team's regular testing cycle before spring practice and following the completion of the winter off-season training program. The teams won–lost record was 16–6 for the season before and after conducting this study and included a conference championship. All testing procedures were reviewed and approved by the University Human Subjects Review Board.

Subjects

Physical and performance characteristics of the subjects are shown in Table 1. The team was divided by playing position into lineman ($n = 23$), linebackers-tight ends (LB-TE) ($n = 9$), and backs (cornerbacks, receivers, quarterbacks, running backs, and outside linebackers; $n = 29$). Height was measured using a calibrated stadiometer. Body mass (BM) was measured using a calibrated balance scale. Body fat was determined using a bioelectric impedance device (Tanita Corp, Arlington Height, IL, USA).

Sprint Timing

Each player performed 2 trials of each sprint distance: 9.1-, 36.6-, and 54.9-m sprints. The order of testing was randomized by sprint distance with a minimum of 3 days between sprint trials. Two players ran simultaneously in a competitive environment for each sprint. Players were randomly assigned to a lane for the first sprint. After the first sprint, a minimum of 5 minutes' recovery was given before the player performed the second sprint in the other lane. Testing was performed on an indoor rubberized track. Players wore cotton shorts, T-shirt, and rubber-soled athletic shoes for all testing. No track spikes were allowed for testing. Sprints

Table 1. Physical characteristics of players.

	Team ($n = 61$)	Lineman ($n = 23$)	LB-TE ($n = 9$)	Backs ($n = 29$)
Age (y)	20.1 ± 1.4	19.8 ± 1.2	20.0 ± 1.4	20.3 ± 1.4
Height (cm)	183.8 ± 6.8	188.0 ± 5.2	185.5 ± 8.2	179.8 ± 5.1*
Weight (kg)	104.2 ± 20.7	125.0 ± 13.2†	107.5 ± 8.6‡	86.7 ± 9.0
Body fat (%)	19.6 ± 6.7	26.1 ± 4.5†	20.3 ± 3.4‡	13.9 ± 3.7*
Fat-free mass (kg)	83.7 ± 9.0	92.5 ± 5.0†	85.7 ± 6.9‡	74.6 ± 3.6*
Fat mass (kg)	20.6 ± 11.5	32.6 ± 9.3†	21.8 ± 4.4‡	12.1 ± 4.2*
STJ (cm)	723.9 ± 72.1	661.1 ± 61.5†	733.3 ± 27.7	768.6 ± 52.8
SLJ (cm)	252.2 ± 22.9	232.9 ± 21.8†	259.1 ± 11.9	264.2 ±16.0
VJ (cm)	65.8 ± 8.9	59.4 ± 27.4†	69.1 ± 4.8	69.3 ± 8.4
SQ(kg)	170.5 ± 28.2	177.7 ± 25.9	185.5 ± 25.5	160.5 ± 27.7*
SQ/BM	1.69 ± 0.33	1.46 ± 0.28†	1.74 ± 0.32	1.85 ± 0.28
PCLN (kg)	117.7 ± 13.2	119.1 ± 12.3	131.4 ± 12.7	111.8 ± 10.9*
PCLN/BM	1.17 ± 0.20	0.98 ± 0.15†	1.23 ± 0.15	1.29 ± 0.12
Jerk (kg)	121.8 ± 16.8	128.2 ± 15.9	131.8 ± 17.3	113.2 ± 13.6*
Jerk/BM	1.21 ± 0.21	1.06 ± 0.19†	1.23 ± 0.19	1.31 ± 0.16

STJ = standing triple jump; SLJ = standing long jump; VJ = vertical jump; SQ = squat; PCLN = power clean; BM = per body mass.

Mean ± *SD*. Lineman–offensive/defensive lineman, LB-TE–inside linebackers and tight ends, backs–quarterbacks, running backs, receivers, defensive backs, and outside linebackers.

*Backs different from LB/TE and lineman, $p < 0.05$.

†Lineman different from LB/TE and backs, $p \leq 0.05$.

‡LB-TE different from backs, $p \leq 0.05$.

TABLE 2. Overview of off-season run training program.

Day 1–speed development/agility
Wks 1–5 Speed ladder Dot drills Box jumps, kangaroo jumps Bounding–bounding, straight leg, single leg, etc. Stride development–step-high knees, goose step, glut kicks, etc. Arm exchange drills Sprint starts Fast feet drills–cone drills, short shuttles 10-yd sprints Wks 6–7–shift to conditioning emphasis Jog/jump rope (5 min) Dynamic flexibility complex* Speed development complex† 5 × 3-min condition stations (bags drill, box jumps, etc.) Wks 8–10 Same
Day 2–speed development conditioning
Wks 1–5 Speed development complex† Sprint shuttles, one-leg sprints, hop-to-sprint, jump-to-sprint, prone-to-sprint 40- to 60-yd sprints Wks 6–7 Jog/jump rope (5 min) Dynamic flexibility complex* Speed development complex† 5 × 3-min conditioning stations Wks 8–10 Dynamic flexibility complex* Wrestling ladders, tug-of-war, etc. "Grass drills" and conditioning stations in the wrestling room
Day 3–maximal effort sprints–jumps–shuttles
Same for all 10 wks Jog/jump rope (5 min) Dynamic flexibility complex* Speed development complex† Time 40-yd sprint × 2 trials; measure 1 jump (VJ, SLJ, and STJ), time 1 shuttle (3-cone, T-, 5–10–5, etc.)

*Dynamic flexibility complex–perform for 10 repetitions each: trunk rotations, lumber jacks, OVD side bends, around the world, A–P leg swings, lateral leg swings, and split jumps.

Perform next 8 exercises over 20 yd: toe-up walking, walking lunges, forward, walking lunges, lateral (switch at 10 yd), arm circles, side hops, backwards running, glut kicks, carioca.

†Speed development complex (20-yd drills): toe-up walking, high-knee running, side-glide with arm swings, backward run, skipping, straight-leg bounding, bounding, fast skipping, giant arm swings × 2 progressions, 2 × 20 yd ½-speed sprint, 2 × 20 yd ¾-speed sprint, and 2 × sprint starts at 100% speed for 10 yd.

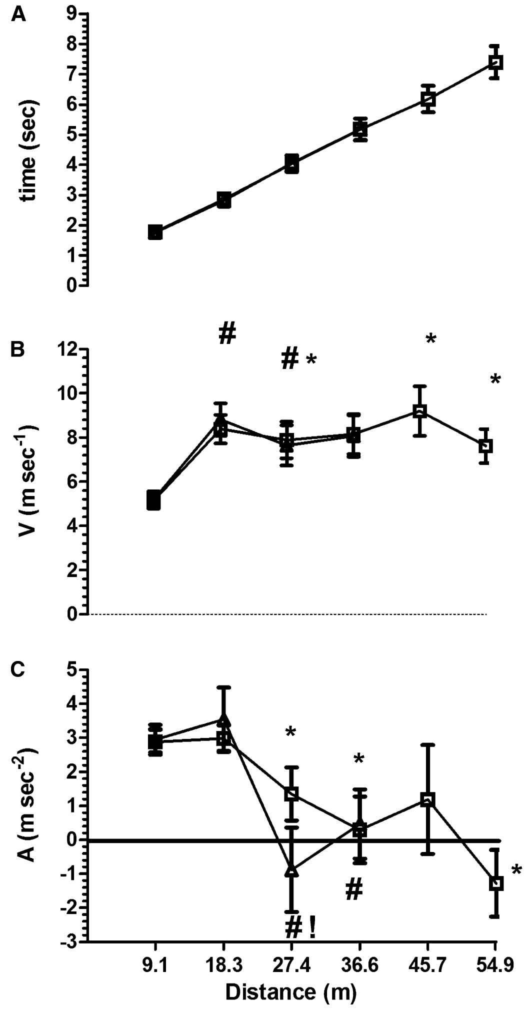

Figure 1. Acceleration/velocity characteristics of sprint performance. Values are mean ± *SD*. $n = 61$. X = 9.1-m sprint, Δ = 36.6-m sprint, and □ = 54.9-m sprint. (A) Time, (B) average velocity (V), and (C) average acceleration (A). #Statistical difference within the 36.6-m sprint, $p \leq 0.05$. *Statistical difference within the 54.9-m sprint, $p \leq 0.05$. !Statistical difference between sprint trials, $p \leq 0.05$.

commenced from a football stance and timers were placed at 9.1-m intervals covering the entire distance of the sprint. Sprints were hand timed by 2 experienced timers in each running lane (7). The faster of the 2 times for each sprint trial was recorded unless the 2 times differed by more than 0.08 seconds, after which the 2 times were averaged and recorded. The overall difference in the same trial time averaged 0.06 ± 0.04 seconds, intertester reliability $r = 0.96$ (9.1-m sprint), 0.05 ± 0.03 seconds, intertester reliability $r = 0.98$ (36.4-m sprint); 0.05 ± 0.04, intertester reliability $r = 0.96$ (54.9-m sprint). Average acceleration and velocity were calculated from 9.1-m interval times.

TABLE 3. Relationship between velocity and acceleration with 36.6-m sprint performance.

	Interval sprint times (s)			
	9.1 m 1.77 ± 0.14	18.3 m 2.82 ± 0.20	27.4 m 4.03 ± 0.26	36.6 m 5.18 ± 0.35
9.1 m *A*	−0.99*	−0.89*	−0.87*	−0.88*
9.1 m *V*	−0.99*	−0.91*	−0.87*	−0.87*
18.3 m *A*		−0.47*	−0.26†	−0.18
18.3 m *V*		−0.77*	−0.57*	−0.51*
27.4 m *A*			0.05	0.18
27.4 m *V*			−0.54*	−0.31†
36.6 m *A*				0.28†
36.6 m *V*				−0.75

Data are *r* values from Pearson product–moment correlation. $n = 61$. *V* = average velocity; *A* = average acceleration. 9.1, 18.3, 27.4, and 36.6 m are distance intervals during the 36.6-m sprint.
*Significant, $p \leq 0.01$.
†Significant, $p \leq 0.05$.

Muscular Strength and Power

Lower-body muscular strength was evaluated by determination of the 1-repetition maximum (1-RM) in the squat (SQ), power clean (PCLN), and jerk (JK) 1 week after sprint testing (7). All subjects were well accustomed to maximal strength testing. Squats were performed from the standing position, with the bar held high on the back of the shoulders. The SQ was judged successful if the subject squatted to a position where the hip was below the level of the knee and then returned to a full upright position. Judgment of the SQ was given after completion of the repetition, because no signal was given to the subject during the repetition regarding depth of SQ. Power cleans were preformed from the floor without the use of grip-assisting straps. A PCLN attempt was judged successful if the bar went from the floor to the shoulders in one continuous movement, and the bar was received with the hips above the level of the knee. The JK was judged according to Olympic-style competition rules. The bar was taken from the rack to the starting position. The bar had to travel from the shoulders to the full-extension overhead position in one motion. One-RM testing was performed by progressively incrementing load until the subject was unable to successfully complete the lift. The 1-RM was typically achieved in 3–5 maximal attempts. Over 4 years of testing, the test–retest correlations within any test cycle for all strength tests range from $r = 0.90$–0.96 with a minimum of 4 and maximum of 8 days between tests.

Leg power was assessed with the vertical jump (VJ), standing long jump (SLJ), and the standing triple jump (STJ). All jumps were initiated from a stationary standing position with a bent knee counter movement at the player's discretion. Vertical jump was assessed with a Vertec as the difference between jump height and standing reach height. Standing long jump and STJ were determined with a tape measure on a gymnasium floor. The best of 3 trials was used for analysis.

TABLE 4. Relationship between leg strength and power and acceleration/velocity characteristics and performance of the 36.6-m sprint.

	Intervals (m)								
	9.1		18.3		27.4		36.6		
	V	*A*	*V*	*A*	*V*	*A*	*V*	*A*	36.6-m time
STJ	0.74*	0.73*	0.56*	0.34†	0.24	−0.19	0.51*	0.17	−0.79*
SLJ	0.80*	0.79*	0.42*	0.11	0.37†	−0.05	0.44*	0.03	−0.80*
VJ	0.82*	0.81*	0.50*	0.20	0.22	−0.19	0.45*	0.13	−0.78*
SQ	−0.11	−0.12	−0.02	0.14	0.00	0.03	−0.16	−0.11	0.11
SQ/BM	0.53*	0.49*	0.50*	0.34†	0.12	−0.22	0.28	0.12	−0.53*
PCLN	−0.13	−0.26	−0.04	−0.05	0.02	0.08	−0.14	−0.09	0.07
PCLN/BM	0.68*	0.67*	0.58*	0.35†	0.15	−0.25	0.37†	0.16	−0.69*
Jerks	−0.19	−0.21	−0.19	−0.13	−0.16	0.00	−0.13	−0.02	0.22
Jerks/BM	0.54*	0.52*	0.46*	0.28†	0.05	−0.27	0.35†	0.20	−0.55*

STJ = standing triple jump; SLJ = standing long jump; VJ = vertical jump; SQ = squat; PCLN = power clean; "/BM" = per body mass.
Data are *r* values from Pearson product–moment correlation technique. $n = 61$. *V* = average velocity; *A* = average acceleration. 9.1, 18.3, 27.4, and 36.6 m are distance intervals during the 36.6-m sprint.
*Significant, $p \leq 0.01$.
†Significant, $p \leq 0.05$.

TABLE 5. Sprint performance by position group.

	Sprint interval (m)					
	9.1	18.3	27.4	36.6	45.7	56.9
9.1-m sprint						
Lineman ($n = 23$)	1.86*					
	0.11					
LB-TE ($n = 9$)	1.73					
	0.06					
Backs ($n = 29$)	1.73					
	0.08					
36.6-m sprint						
Lineman	1.89*	3.00*	4.26*	5.49*		
	0.12	0.17	0.23	0.30		
LB-TE	1.76	2.79	3.98	5.11		
	0.05	0.06	0.08	0.17		
Backs	1.69	2.68	3.86	4.96		
	0.09	0.11	0.15	0.21		
54.6-m sprint						
Lineman	1.87*	3.04*	4.28*	5.50*	6.59*	7.89*
	0.12	0.16	0.27	0.36	0.40	0.52
LB-TE	1.74	2.82	3.97	5.06	6.03	7.23
	0.05	0.11	0.16	0.18	0.23	0.24
Backs	1.71	2.75	3.87	4.96	5.91	7.06
	0.09	0.10	0.13	0.18	0.22	0.26

Mean ±*SD*. Lineman = offensive/defensive lineman; LB-TE = inside linebackers and tight ends; Backs = quarterbacks, running backs, receivers, defensive backs and outside linebackers.
*Lineman different from LB-TE and backs, $p \leq 0.05$.

The difference between the 3 trials was never greater than 4.82 cm (VJ), 19.6 cm (SLJ), or 46.3 cm (STJ).

Training Program

Players participated in a 12-week winter off-season training program designed in a linear periodization fashion. The training program consisted of 3 4-week training microcycles. The make-up of the microcycles was 3 weeks of training followed by 1 week of testing and recovery. Microcycles consisted of 4 training days per week, of which 2 days focused on leg strength and power and 2 days focused on upper-body strength and power. The lifts used were the squat, PCLN, power snatch, and JK (leg strength and power) and push press, bench press, and incline press (upper-body strength and power). Training intensity increased from week 1 to week 3. Individual lifts were performed for 4–8 sets with 1–5 repetitions per set, with a decreasing intensity and an increasing repetition pattern as follows: week 1–intensity 85/80% for 4/5 repetitions, week 2–intensity 90/85/80% for 2/4/5 repetitions, week 3–intensity 95/90/85/80% for 1/2/4/5 repetitions. The testing/recovery week consisted 1-RM testing on the first 2 days of the week and active recovery consisting of 4 sets per lift at 70% for 4 reps (first microcycle) and 80% for 2 reps (second and third microcycles) on the other 2 training days.

Auxiliary lifts were performed on each upper-body training day for 4 sets of 8 repetitions. Three to 4 exercises were performed in various combinations. The exercises included close-grip bench press, dumbbell press, bent-over rows, triceps extensions, biceps curls, parallel dips, pull-ups (pronated grip), and chin-ups (supine grip). Torso stability work was performed 2 times per week.

Running drills were performed 3 d wk^{-1} in 30-minute sessions with the following emphasis: day 1–agility, speed development drills, day 2–speed development drills, conditioning, and day 3–speed, agility, and jump testing. A summary of running drills is provided in Table 2.

Statistical Analyses

Data are presented as mean ± *SD*. Sprint performance (interval time, interval acceleration, and interval velocity) in the 9.1-, 36.6-, and 54.9-m sprints was evaluated using analysis of variance (ANOVA) with repeated measures. Analyses were performed by position group using one-way ANOVA to test for differences in sprint performance and lower-body strength/power among the groups. Pearson product–moment correlations were calculated to assess the relationship between variables. Significant F values were evaluated using the Newman–Keuls post hoc test. The alpha level was set to

0.05. Effect size (ES) was calculated as the difference between 2 means divided by the pooled *SD*. Statistical power for all comparisons ranged from 0.87 to 0.98.

Results

Acceleration and Velocity Characteristics of Sprint Performance

Average sprint times were 1.78 ± 0.11 seconds in the 9.1-m sprint, 5.18 ± 0.35 seconds in the 36.6-m sprint, and 7.40 + 0.53 seconds in the 54.9-m sprint (Figure 1A). Time, acceleration, and velocity were similar between the 9.1-m sprint and the 9.1-m interval of both the 36.6- and 54.9-m sprints (Figure 1). During the 36.6-m sprint, acceleration increased and peaked at 9.1 m and was maintained at the 18.3-m interval, decreased to a negative value at 27.4-m (ES = 1.70), but increased to a low positive value at 36.6-m (ES = 1.29; Figure 1C). Velocity increased at 9.1 m and peaked at 18.4 m (ES = 1.52; Figure 1B). There was a small but significant decrease in velocity at 27.4-m interval (ES = 1.25). Time, acceleration, and velocity were similar between the 9.1-m sprint and the 9.1-m intervals of both the 36.6- and 56.9-m sprints (Figure 1). During the 54.9-m sprint acceleration, peaked at the 9.1-m interval, was maintained at the 18.3-m interval, and decreased to a low positive value at 36.6-m interval (ES = 0.75; Figure 1C). Acceleration then increased at the 45.7-m interval (ES = 0.57) and decreased to a negative value at the 54.9-m interval (ES = 1.24). There were no differences in acceleration between the 36.6- and 54.9-m sprints at the 9.1-, 18.3-, and 36.6-m intervals. Velocity during the 54.9-m sprint was the same as observed for the 36.6-m sprint (Figure 1B). There was an increase and then a decrease in velocity at the sprint intervals beyond 36.6-m (ES = 0.83 and 1.17, respectively). In the 54.9-m sprint, there are 2 peaks that were not different from each other.

Relationships between Acceleration, Velocity, and Sprint Performance

Acceleration and velocity at the 9.1- and 18.3-m intervals were significantly negatively correlated with sprint interval times and the final 36.6-m sprint time (Table 3). Likewise, during the 54.9-m sprint, acceleration and velocity at the 9.1- and 18.3-m intervals were very highly negatively correlated (A: $r = -0.99$ to -0.87; V: $r = -0.99$ to -0.88) with each sprint interval time and the final 54.9-m sprint time. At all intervals beyond the initial (9.1-m) interval, acceleration and velocity become less well associated with sprint time.

Relationship between Physical Characteristics and Sprint Performance

Body mass was moderately significantly positively correlated with sprint interval times; 91.4-m ($r = 0.57$), 36.6-m ($r =$

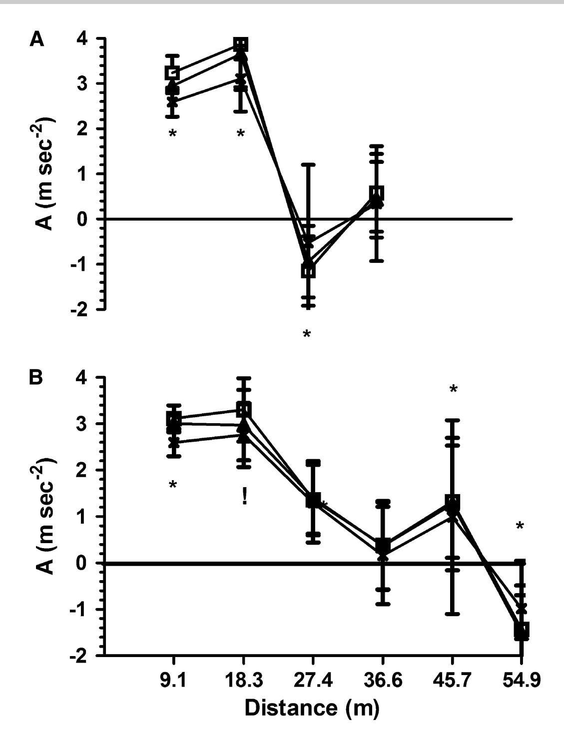

Figure 2. Acceleration characteristics of sprint performance by position groups. Values are mean ± *SD* of average velocity. *X* = lineman (*n* = 23), Δ = LB/TE (*n* = 9), and ■ = backs (*n* = 29). (A) = 36.6-m sprint and (B) = 54.9-m sprint. *Lineman statistically different from LB/TE and backs, $p \leq 0.05$. !Lineman statistically different from backs, $p \leq 0.05$.

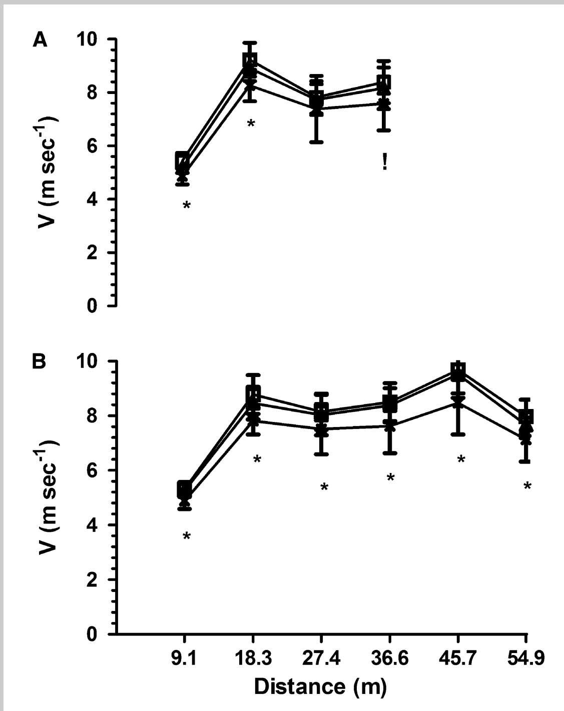

Figure 3. Velocity characteristics of sprint performance by position groups. Values are mean ± *SD* of average acceleration. *X* = lineman (*n* = 23), Δ = LB/TE (*n* = 9), and ■ = backs (*n* = 29). (A) = 36.6-m sprint and (B) = 54.9-m sprint. *Lineman statistically different from LB/TE and backs, $p \leq 0.05$. !Lineman statistically different from backs, $p \leq 0.05$.

0.70–0.74), and 54.9-m ($r = 0.53–0.56$) sprints. Body mass was negatively correlated with acceleration in the 9.1-m sprint ($r = -0.56$) and at the 9.1-m ($r = -0.67$) interval of the 36.6-m sprint and 18.3-m interval ($r = -0.57$) interval of the 54.9-m sprint. Similarly, there were moderate negative correlations between BM and velocity in the 9.1-m sprint ($r = -0.56$), and at the 9.1-m ($r = -0.68$) and 18.3-m ($r = -0.56$) intervals of the 36.6-m sprint, and the 18.3-m interval ($r = -0.56$) of the 54.9-m sprint.

Lower-body strength as measured by the SQ, PCLN, and JK was highly correlated with sprint time, acceleration, and velocity in the 36.6-m sprint only when expressed per kilogram BM (1-RM/BM; Table 4), with the highest correlations with acceleration and velocity observed at the 9.1-m interval. A similar pattern and range of r values were observed between strength/BM and the 9.1- and 54.9-m sprints; again, the highest correlations with acceleration and velocity being with the initial (9.1- and 18.3-m) intervals.

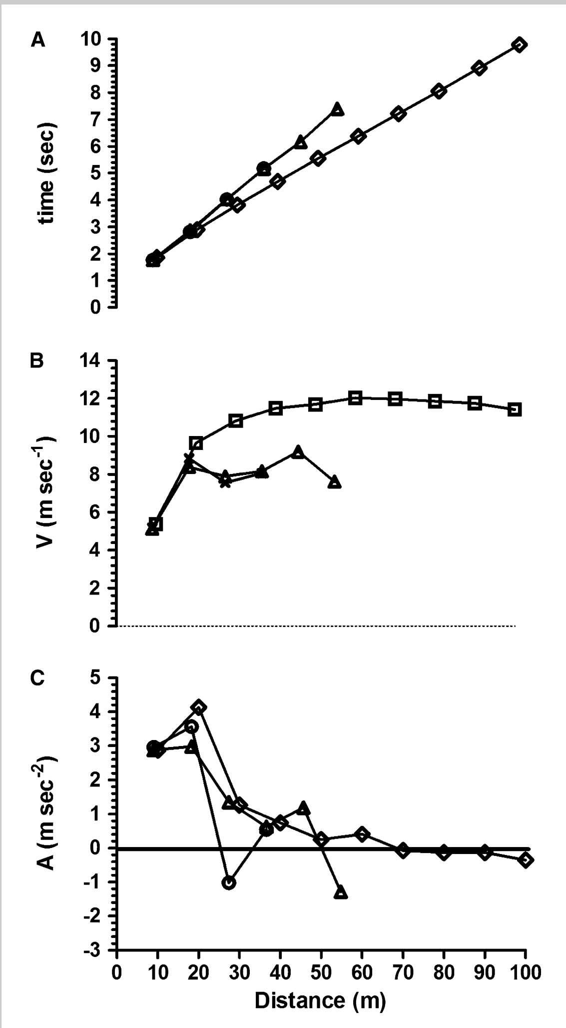

Figure 4. Comparison of acceleration and velocity characteristics of sprint performance of track and football. Values are means. (A) Interval times, (B) average velocity, and (C) average acceleration. O = football 36.6-m sprint, Δ = football 54.9-m sprint, ◇ = track 100-m sprint; data are the 5 fastest 100-m sprint performance ever recorded–data excerpted from speedendurance.com.

Power as measured by VJ, SLJ, and STJ was highly correlated with sprint time in the 9.1-m ($r = -0.84$ to -0.79), 36.6-m ($r = -0.80$ to -0.78; Table 4), and 54.9-m ($r = -0.78$ to -0.65) sprints. Like strength/BM, power had the highest correlations with acceleration and velocity in the 9.1-m ($r = -076$ to -0.68) and at the 9.1-m interval of the 36.6-m (Table 4) and 54.9-m (-0.83 to -0.71, $p < 0.01$) sprints. Velocity was highly correlated with leg power measures in the 9.1-m sprint ($r = 0.67–0.75$) and at the 9.1-m interval of the 36.6-m sprint (Table 4). Velocity correlations with leg power measures were moderate to weak at all intervals of the 54.9-m sprint ($r = 0.39–0.73$) with the highest correlation being with the 18.3-m interval (0.66–0.73).

Lineman had significantly greater BM, % fat, fat-free mass, and fat mass, while showing significantly lower VJ (ES = 1.25, 1.15, respectively), SLJ (ES = 1.18, 1.29, respectively), STJ (ES = 1.21, 1.40, respectively), and strength relative to BM for SQ (ES = 0.98, 1.2, respectively), PCLN (ES = 1.37, 1.53, respectively), and JK (ES = 0.95, 1.22, respectively) when compared with LB/TE and backs (Table 1). Lineman had significantly slower sprint times in the 9.1-, 36.6-, and 54.9-m sprints compared with LB/TE and backs (ES ranged from 1.08 to 1.52; Table 5). Acceleration (Figure 2) and velocity (Figure 3) patterns were similar between position groups, although lineman had significantly lower acceleration and velocity (ES ranged from 0.78 to 2.30). Analysis of covariance (ANCOVA) eliminated differences among the 3 position groups in the 9.1-m ($F = 3.2$, $p = 0.06$) and 36.6-m ($F = 3.06$, $p = 0.07$) sprints when the effect of BM was removed. Furthermore, the 9.1-m acceleration differences between groups were also eliminated when covaried with BM ($F = 2.8$, $p = 0.55$). Figure 4 shows the sprint splits and the acceleration and velocity patterns of the 100-m sprint using data are from six of the fastest 100-m sprint times ever recorded, including the most recent world record (data excerpted from 12th IAAF World Championship report) and two previous world record performances and a world record performance that was later nullified by a drug violation (data excerpted from speedendurance.com). Also shown in Figure 4 are data from the 36.6- and 54.9-m sprints in football players from the present study.

Discussion

There is little doubt that maximal sprint speed is a key physical quality for high-caliber sports performance. Sprint performance across athlete populations, to include football, basketball, baseball, rugby, lacrosse, tennis, etc., compares very closely for distances between 30 and 55 m (3,5, 9–11,14,15,21). The sprint times observed in the present study are in good agreement with those of the previous studies. In general, the acceleration patterns were similar among different sprint tests. Maximal acceleration was attained at 9.1 m and maintained through 18.3 m. Velocity peaked at 18.3 m and was maintained for the most part throughout the duration of the sprint. However, a reduction in velocity at 27 m was associated with a reduced (54.6-m sprint) or negative (36.6-m sprint) acceleration. A significant effect supported by the large EF. This pattern was consistent in all 3 sprint distances and was independent of position. The same acceleration and velocity patterns and positional independence have been observed in a preliminary study of players timed during the 2004 and 2005 NFL combines (22).

It makes sense that football players would display this general pattern of acceleration because they are trained with an emphasis of "getting off the ball" and "first step" dependence. Further, football is typically a game of short distance, short duration, and intermittent bursts of activity (17). However, most team sports involve intermittent maximal sprints occurring over short distances accelerating from either a stationary or moving start. The values of acceleration and velocity at 9.1 m compare favorably with previous reports in football (25,28), rugby (3,10,31), and other team sports (e.g., basketball, lacrosse, and tennis [25,30,31]). The acceleration and velocity values between 5 and 10 m are also similar among the various athlete populations where 5-m values were obtained (10,25).

In the present study, 36.6- and 54.9-m sprint performances were mostly highly associated with acceleration at 9.1 and 18.3 m and velocity at 18.3 m, in agreement with previous work (10,25,26) but in contrast to others (28). The correlations between 36.6-m sprint performance and acceleration at 27.4- and 36.6-m intervals were statistically significant but very low and of little physiological significance. Further, 36.6-m sprint performance was highly correlated with velocity at each distance interval except 27.4 m. Thus, the differences in sprint performance among the players in general and by position were almost entirely related to differences in acceleration and velocity at the 9.1- and 18.3-m intervals. This agrees with previous assertions that 10- or 20-m sprint times may be more appropriate for football evaluation (22,28). However, this assertion may be more true for lineman as backs and receivers typically run more than 20 yards on a play and may have to run at maximal speed for greater than 20-m more often. In the present study, this is the area where acceleration was negative and velocity was declining. Thus, improving sprint speed or enhancing overall longer duration sprint performance in these players may require focused training at distances beyond 36 m as has been suggested previously for rugby players (3) and may have some biomechanical basis (3,10).

The most readily accepted and familiar expression of sprint performance worldwide would likely be the 100-m sprint. Based on the present data, football players reach maximal velocity at 20 m, in contrast to track sprinters who attain maximal velocity between 50 and 60 m (19,24). This fact has been offered as an argument against the use of the 36.6 m as the primary measure of sprint performance in most sports. "However, the pattern of acceleration and velocity of the six fastest 100-m sprint times ever recorded in track and field is consistent with other 100-m results (19,24) and interestingly is not altered among aged sprinters (24). Importantly for the present discussion is the fact that the acceleration and velocity patterns are essentially the same as observed through all distances tested in football players (36.6- and 54.9-m)." The major and apparently most significant difference between track and football is magnitude. Football players had a second peak velocity at 45 m (of the 54.9-m sprint) that would correspond with the track sprinters peak at 50–60 m and suggests that they too reach peak velocity later in the longer duration sprints. However, it is important to note that this second peak followed a significant reduction in velocity at the 27-m interval and did not correlate with sprint performance. Thus, it would seem that this second peak can be viewed as an artifact of the reduced velocity and reflects the inability of football players to maintain velocity in longer sprints. Thus, it appears that athletes, independent of sport, invoke the same strategy for sprint performance; start fast and maintain velocity throughout the sprint (19). The best sprint performances appear to be associated with the greatest acceleration between 10 and 20 m and the highest attained and maintained velocity throughout the sprint regardless of level of performance, sport, or age (present data [24]). The apparent sport-specific difference in sprint performance appears to be related to training specificity rather than strategic differences. Sprint conditioning as related to each specific sport would alter the specific maintenance of velocity and the ultimate expression of sprint speed.

Sprinting performance can be impacted by body dimensions and composition, strength/power, and running technique. Height and longer limbs are associated with greater sprint performance (1,2,29). However, in the present study, the relationships between height and sprint time ($r = 0.42$–0.50) and acceleration/velocity (r -0.46 to -0.37) are minimal. This is likely because of the taller individuals being linemen, who had slower sprint times and significantly greater body mass. The negative impact of BM on sprint performance in this population is indicated by the high positive relationship with sprint time and particularly the negative relationship to 9.1- and 18.3-m acceleration/velocity. Further when statistically controlling for BM (ANCOVA) the player position differences in sprint time (9.1 and 36.6 m) were eliminated. Lineman also had a significantly greater % body fat, which has also been proposed to negatively impact sprint performance (1,2,11,28). However, in the present study,. an analysis of residuals (18) indicated that BM was the primary variable impacting sprint performance and fat (%fat or fat mass) was not an independent contributor; in agreement with previous assessments (11).

Sprinting requires high force generation (24), and thus a relationship between sprint performance and lower-body strength and power would be expected. Indeed increasing SQ strength is associated with increased sprint speed in physical education students (12,13,20), elite soccer players (30), and college football players (16). Various measures of lower-body strength (1-RM SQ, hang clean, isokinetic peak torque during hip extension or flexion, knee flexion, and plantar flexion) have been shown to be related to sprint performance, but the correlation coefficients are moderate to poor ($r = -0.30$ to -0.55 [2,6,8,11,21,25,31]) and explain less than 30% of performance variation. The best correlations between isokinetic hip and knee peak torque and sprint performance were observed at higher isokinetic velocities (25,26). Acceleration (10–20 m) is critical to sprint performance (discussed above) and has been shown to be related to hip extension and flexion peak torque; flexion torque being the better predictor (6).

In contrast, absolute measures of lower-body strength (1-RM or 3-RM SQ, 1-RM PCLN, 1-RM hang clean, 1-RM JK, knee extension flexion isokinetic torque) do not correlate with acceleration, velocity, or sprint performance (present data and [3,7,10]). However, when corrected for BM, the relationships between SQ, PCLN, and JK with sprint time and initial acceleration and velocity are significant (present data and [3]). The quality of the relationship between isokinetic torque and sprint performance may also be related to the expression of torque relative to BM because this resulted in the highest correlations, especially at the highest isokinetic speeds (25).

The important contribution of leg power to sprint performance is indicated by high correlations with 36.6-m sprint time in agreement with previous studies (1,10,25,28,30). It is worth noting that the highest correlations between strength and power measurements occurred with the first 9.1 m confirming the importance of quick acceleration in producing fast sprint times (28). Furthermore, lower-body strength measures should be expressed relative to BM to assess their contribution to producing this initial high acceleration. Thus, BM indirectly influences sprint performance (i.e., acceleration) through it association with the expression of muscular strength and power. This was confirmed using ANCOVA to remove differences in sprint performance among players when BM was controlled.

In conclusion, the best indicator of sprint performance appears to be the magnitude of the initial acceleration and velocity (9.1- to 18.3-m interval) and the maintenance of velocity throughout the sprint, independent of sprint distance. In football players, this pattern is consistent across all positions. Lower-body strength relative to BM and leg power appears to contribute specifically to initial acceleration and velocity and play a minimal role in maintaining sprint velocity. The apparent impact of BM on sprint performance appears to be directly related to lower-body strength relative to body mass.

Practical Applications

The focus of the present study was to evaluate acceleration/velocity patterns and linear speed in college football players. The 9.1 m (10-yd) and perhaps the 18.3 m (20-yd) sprints provide the best measure of 1-dimensional speed for individuals trained for football performance. To improve football skill, it requires "getting off the ball" confirming the idea that everything is in the start. To improve running speed (36.6-m sprint time) in football players, the focus should be getting a better start. Although this makes sense and certainly relates to playing the game of football, the present data suggest that in addition one should focus on the interval between 18.3 and 27.4 m, where acceleration is negative and velocity declines. The importance of the magnitude of these changes is supported by the strong indicators of EF. These changes may impede the general improvement in sprint speed and are independent of player position, height, body mass, or leg strength/power. Sprint training for defensive backs, running backs, and wide receivers who are more likely to sprint more than 20-yd on a more regular basis during a game would benefit from some sprint training between 20 and 60 yd when they would be typically decreasing acceleration and velocity. Furthermore, given the relationships between strength per BM and initial acceleration/velocity and ultimate sprint performance observed, here it appears that football players would benefit from training that focused directly on increasing maximal lower-body strength (1-RM), especially those with larger mass. This conclusion is supported the analysis controlling for BM (ANCOVA) and the magnitude of differences by group indicated by the large EF.

References

1. Abe, T, Brown, JB, and Brechue, WF. Architectural characteristics of muscle in black and white college football players. *Med Sci Sports Exerc* 31: 1448–1452, 1999.
2. Anderson, M, Gieck, J, Perrin, D, Weltman, A, Rutt, R, and Denger, C. The relationship among isometric, isotonic, and isokinetic concentric and eccentric quadriceps and hamstring force and three components of athletic performance *J Orthop Sports Phys Ther* 14: 114–120, 1991.
3. Baker, D and Nance, S. The relation between running speed and measures of strength and power in professional rugby league players. *J Strength Cond Res* 13: 230–235, 1999.
4. Barker, M, Wyatt, TJ, Johnson, RL, Stone, MH, Bryant, HSO, Poe, C, and Kent, M. Performance factors, psychological assessment, physical characteristics, and football playing ability. *J Strength Cond Res* 7: 224–233, 1993.
5. Berg, K and Latin, RW. Comparison of physical and performance characteristic of NCAA Division I basketball and football players. *J Strength Cond Res* 9: 22–26, 1995.
6. Blazevich, AJ and Jenkins, DG. Predicting sprint running times from isokinetic and squat lift tests: A regression analysis. *J Strength Cond Res* 12: 101–103, 1998.
7. Brechue, WF and Mayhew, JL. Equipment and running surface alter sprint performance of college football players. *J Strength Cond Res* 19: 821–825, 2005.
8. Chapman, AE and Caldwell, GE. Kinetic limitations of maximal sprinting speed. *J Biomech* 16: 79–83, 1983.
9. Coleman, AE and Lasky, LM. Assessing running speed and body composition in professional baseball players. *J Appl Sport Sci Res* 6: 207–213, 1992.
10. Cronin, JB and Hansen, KT. Strength and power predictors of sports speed. *J Strength Cond Res* 19: 349–357, 2005.
11. Davis, DS, Barnette, BJ, Kiger, JT, Mirasola, JJ, and Young, SM. Physical characteristics that predict functional performance in Division-I college football players. *J Strength Cond Res* 18: 115–120, 2004.

12. Deane, RS, Chow, JWC, Tillman, MD, and Fournier, KA. Effects of hip flexor training on sprint, shuttle run, and vertical jump performance. *J Strength Cond Res* 19: 615–621, 2005.
13. Dleecluse, C, Van Coppenelle, H, Willems, E, Van Leemputten, M, Diels, R, and Goris, M. *Med Sci Sport Exer* 27: 1203–1209, 1995.
14. Fry, AC and Kraemer, WJ. Physical performance characteristics of American collegiate football players. *J Appl Sports Sci* 5: 126–138, 1991.
15. Garstecki, MA, Latin, RW, and Cuppett, MM. Comparison of selected physical fitness and performance variables between NCAA Division-I and -II football players. *J Strength Cond Res* 18: 292–297, 2004.
16. Hoffman, JR, Cooper, J, Wendell, M, and Kang, J. Comparison of Olympic vs traditional weightlifting training programs in football players. *J Strength Cond Res* 18: 129–135, 2004.
17. Iosia, MF and Bishop, P. Analysis of exercise-to-rest ratios during a Division IA televised football competition. *J Strength Cond Res* 22: 332–340, 2008.
18. Kearns, CF, McKeever, KH, John-Adler, H, Abe, T, and Brechue, WF. Relationship between body composition, blood volume, and maximal oxygen uptake. *Equine Vet J.* Equine Exercise Physiology 6 (Suppl), 34: 485–490, 2003.
19. Korhonen, MT, Mero, A, and Suominen, H. Age-related differences in 100-m sprint performance in male and female master runners. *Med Sci Sports Exer* 35: 1419–1428, 2003.
20. Kotzamanidis, C, Chatzopoulos, D, Michailidis, C, Papaiakovou, G, and Patikas, D. The effect of a combined high-intensity strength and speed training program on the running and jumping ability of soccer players. *J Strength Cond Res* 18: 198–920, 2004.
21. Mann, R and Sprague, P. A kinetic analysis of the ground leg during sprint running. *Res Q Exer Sport* 51: 334–348, 1980.
22. Mayhew, JL, Williams, T, Piper, FC, and Brechue, WF. Comparison of incremental distances of the 40-yd dash in NFL combine participants. Presented at the 2008 National Strength and Conditioning Conference.
23. McClay, IS, Robinson, JR, Andriacchi, TP, Frederick, EC, Gross, T, and Martin, P. A profile of ground reaction forces in professional basketball. *J Appl Biomech* 10: 222–236, 1994.
24. Mero, A, Komi, PV, and Gregor, RJ. Biomechanics of sprint running: A review. *Sports Med* 13: 376–392, 1992.
25. Nesser, TW, Latin, RW, Berg, K, and Prentice, E. Physiological determinants of 40-meter sprint performance in young male athletes. *J Strength Cond Res* 10: 263–267, 1996.
26. Newman, MA, Tarpenning, KM, and Marino, FE. Relationship between isokinetic strength, single-sprint performance, and repeated-sprint ability in football players. *J Strength Cond Res* 18: 867–872, 2004.
27. Sayers, M. Running technique for field sport players. *Sports Coach* 23: 26–27, 2000.
28. Seiler, S, Taylor, M, Diana, R, Lyons, J, Newton, P, and Brown, B. Assessing anaerobic power in collegiate football players. *J Appl Sport Sci Res* 4: 9–15, 1990.
29. Tanner, JM. *The Physique of Olympic Athletes.* London: George Allen and Unwin, 1964.
30. Wisloff, U, Castagna, C, Helgerud, J, Jones, R, and Hoff, J. Strong *Br J Sports Med* 38: 285–288, 2004.
31. Young, WB, James, R, and Montgomery, I. Is muscle power related to running speed with change of direction? *J Sports Med Phys Fitness* 42: 282–288, 2002.