Dr. Gary A. Dudley
1952-2006

Quantification of Competitive Game Demands of NCAA Division I College Football Players Using Global Positioning Systems

Aaron D. Wellman,[1] Sam C. Coad,[1] Grant C. Goulet,[2] and Christopher P. McLellan[1]

[1]Faculty of Health Sciences and Medicine, Bond University, Queensland, Australia; and [2]School of Kinesiology, University of Michigan, Ann Arbor, Michigan

Abstract

Wellman, AD, Coad, SC, Goulet, GC, and McLellan, CP. Quantification of competitive game demands of NCAA Division I college football players using global positioning systems. *J Strength Cond Res* 30(1): 11–19, 2016—The aim of the present study was to examine the competitive physiological movement demands of National Collegiate Athletic Association (NCAA) Division I college football players using portable global positioning system (GPS) technology during games and to examine positional groups within offensive and defensive teams, to determine if a player's physiological requirements during games are influenced by playing position. Thirty-three NCAA Division I Football Bowl Subdivision football players were monitored using GPS receivers with integrated accelerometers (GPSports) during 12 regular season games throughout the 2014 season. Individual data sets ($n = 295$) from players were divided into offensive and defensive teams and subsequent position groups. Movement profile characteristics, including total, low-intensity, moderate-intensity, high-intensity, and sprint running distances (m), sprint counts, and acceleration and deceleration efforts, were assessed during games. A one-way ANOVA and post-hoc Bonferroni statistical analysis were used to determine differences in movement profiles between each position group within offensive and defensive teams. For both offensive and defensive teams, significant ($p \leq 0.05$) differences exist between positional groups for game physical performance requirements. The results of the present study identified that wide receivers and defensive backs completed significantly ($p \leq 0.05$) greater total distance, high-intensity running, sprint distance, and high-intensity acceleration and deceleration efforts than their respective offensive and defensive positional groups. Data from the present study provide novel quantification of position-specific physical demands of college football games and support the use of position-specific training in the preparation of NCAA Division I college football players for competition.

Key Words GPS, monitoring, American football

Address correspondence to Aaron D. Wellman, awellma1@nd.edu.

30(1)/11–19

Journal of Strength and Conditioning Research

Introduction

American football is a field-based team sport requiring high levels of muscular strength, power, speed, and agility and is characterized by intense collisions and repeated high-intensity movements (27). American football games are intermittent in nature involving short-duration high-intensity bouts of exercise which incorporate movements such as sprinting, backpedaling, accelerating, decelerating, and physical collisions, separated by transient periods of low-intensity recovery between plays (12). During the in-season period of competition, players competing in National Collegiate Athletic Association (NCAA) Division I college football are required to participate in 12 regular season games on a consecutive weekly basis. Few studies (12,26) have investigated the demands of NCAA Division I football games, and as such, the movement characteristics of competition in college football players remain ambiguous. Although research (12,26) has provided a rudimentary description of exercise to rest ratios encountered during NCAA Division I college football games, a more detailed assessment of position-specific movement demands during competition provides novel insight to improve our understanding of the demands of competition and enable increased scope for position-specific training and conditioning programs to optimize on-field performance.

The development of global positioning system (GPS) technology with integrated tri-axial accelerometers have allowed the physiological demands of training and competition in contact team sports to be quantified by tracking the movement of players (2,10,32). Improvements in GPS technology have subsequently resulted in enhancements in accuracy (13), and the validity and reliability of GPS to determine the movement demands of team sports is well established (6,14,15,30). The quantification of team-sport competition demands using GPS technology has been reported in sports similar in nature to American football, including rugby league (2,10,24), rugby sevens (11), Australian football league (AFL) (18,29,31), and rugby union (7,19). Further substantiating the use of GPS technology to accurately determine position-specific demands of team sports, Boyd et al. (4) demonstrated the capacity of GPS units with integrated accelerometry to differentiate between training drills and competitive games and to discriminate between players competing in elite and subelite team-sport competitions. Although GPS technology is widely used in team sports for analysis of game and training movement demands, current literature on the movement profile characteristics of American football players is limited (8).

DeMartini et al. (8) reported movement profile characteristics associated with pre-season training sessions in NCAA Division I college football by examining the physical demands of Division I college football players during 9 preseason practices over the course of 8 days, using GPS to evaluate total distance covered and running velocity characteristics. The main findings reported by DeMartini et al. (8) were that nonlinemen covered greater total distance and sprint distances than linemen, who covered greater distance at slower speeds. To date, ambiguity remains regarding the demands of in-season NCAA Division I college football games and team training activities (8).

In American football, each position group has distinct physiologic and biomechanical demands associated with specific technical and tactical requirements (16); however, uncertainty exists regarding the position-specific movement demands of NCAA football competition. Given the widespread inclusion of GPS technology in collegiate American football programs, a detailed assessment of competitive movement profile characteristics will provide sports performance specialists with quantified information on game demands. A more comprehensive understanding of the demands of NCAA football competition will augment our understanding of the position-specific movement demands of NCAA college football players and allow sport coaches to individualize training programs that replicate the demands of American football games.

The aim of the present study was (a) to examine the competitive physiological movement demands of NCAA Division I college football players using portable GPS technology during games and (b) to examine positional groups within offensive and defensive teams, to determine if a player's physiological requirements during games are influenced by the playing position. We hypothesized that there will be substantial positional differences in movement demands of NCAA Division I college football players during games. Data obtained will provide scope for performance coaches seeking to optimize position-specific training regimens.

Methods

Experimental Approach to the Problem

Portable GPS and integrated triaxial accelerometry technology was used in the present study to quantify the position-specific movement characteristics of NCAA Division I college football games. The GPS movement profile data were collected during 12 regular-season NCAA Division I college football games. All games were 60 minutes in duration, comprised of four 15-minute quarters, each followed by a brief recovery period, and played outdoors between the hours of 12:00 and 21:00 over a period of 12–13 weeks from September to November. All participants were required to participate in a minimum of 75% of the total offensive or defensive plays for the GPS data sets to be included in the present study. Each individual GPS data set was characterized as constituting either offensive or defensive team performance and, subsequently, divided into specific positional groups for the offense that included wide receivers (WRs), quarterbacks (QBs), running backs (RBs), tight ends (TEs), and offensive linemen (OL) and for the defense that included defensive backs (DBs), linebackers (LBs), defensive ends (DEs), and defensive tackles (DLs).

Subjects

Thirty-three NCAA Division I Football Bowl Subdivision football players (age 20.7 ± 1.0 years, age range was 18–22 years, height 188.6 ± 7.2 cm, and mass 106.7 ± 19.6 kg) participated in the present study. The heights and weights for each position group are expressed as mean ± *SD* and presented in Table 1. All subjects were collegiate athletes whom had been selected to participate in the football program 8 months before the commencement of the study. All participants in the present study took part in the teams' off-season physical development training program that included a full-body strength and power training program and specific skills and conditioning sessions designed to simulate the demands of NCAA Division I college football competition. The present study comprises statistical analysis of data collected as part of the day-to-day student athlete monitoring and testing

Table 1. Position group heights and weights expressed as mean ± *SD*.

Position	Height (cm)	Weight (kg)
Defensive tackle	191.0 ± 0.4	135.2 ± 0.3
Defensive end	193.4 ± 3.6	118.6 ± 5.8
Linebacker	186.3 ± 3.4	105.5 ± 2.5
Defensive back	182.8 ± 5.2	86.4 ± 6.1
Offensive line	196.8 ± 3.9	136.8 ± 5.0
Tight end	196.6 ± 1.1	115.0 ± 7.1
Running back	181.8 ± 2.0	97.8 ± 10.3
Quarterback	192.4 ± 2.3	93.0 ± 1.6
Wide receiver	185.6 ± 10.5	91.3 ± 12.4

procedures within the university's football program. Researchers were provided with deidentified GPS data sets from 12 regular season games for analysis. Deidentified data included participant playing position for the purposes of position-specific data analysis. Ethical approval was obtained from the university's human research ethics committee.

Procedures

Global Positioning System Units. The present study used commercially available GPS receivers (SPI HPU; GPSports, Canberra, Australia), which operated in a nondifferential mode at a sampling frequency of 15 Hz. The GPS receivers also contain integrated tri-axial accelerometers (IA), which operated at 100 Hz and assessed the frequency and magnitude of full-body acceleration ($m \cdot s^{-2}$) in 3 dimensions, namely, anterior-posterior, mediolateral, and vertical (17,23). Subjects had previously worn GPS receivers in outdoor training sessions that included football-specific running, and skill-related and game-simulated contact activities during a 3-week preseason training period. Prior to the commencement of each game, GPS receivers were placed outside for 15 minutes to acquire a satellite signal, after which, receivers were placed in a custom-designed pocket attached to the shoulder pads of the subjects. Shoulder pads were custom-fit for each individual, thereby minimizing movement of the pads during competition. The GPS receivers used in the present study (66 g; 74 × 42 × 16 mm) were positioned in the center of the upper back, slightly superior to the scapulae. Subjects were outfitted with the same GPS receiver for each of the 12 games. After the completion of games, GPS receivers were removed from the shoulder pads and subsequently downloaded to a computer for analysis using commercially available software (Team AMS; GPSports). The validity and reliability of GPS to measure distance and velocity during high-intensity exercise that characterizes contact and noncontact team sports have been reported (3,9,14,25). Johnston et al. (14) have demonstrated GPS receivers used in the present study to be valid for measuring total distance and average peak speed in a team-sport simulation circuit, with intraclass correlation values of interunit reliability reported to be 0.94 for high-speed running (14.00–19.99 $km \cdot h^{-1}$) distance, 0.81 for very-high-speed running (>20.00 $km \cdot h^{-1}$) distance, −0.20 for total distance, and −0.14 for peak speed.

Data provided from GPS receivers were assessed as movement profile variables including total, low-intensity, moderate-intensity, high-intensity, and sprint distances (m), maximal velocity achieved ($km \cdot h^{-1}$), and counts of sprint, acceleration and deceleration efforts. Classifications of parameters of movement profile variables are described below and presented in Table 2. Each of the GPS variables measured in the present study was calculated using commercially available software (Team AMS; GPSports).

Movement Profile Classification. Movement profile classifications have been described for game analysis in similar contact team sports (20–22,24); however, the classification profile used in the present study was devised for American football players. Each movement classification was coded as one of 4 speeds of locomotion (Table 2). Low-intensity movements, such as standing, walking, and light jogging, were considered to be 0–10 $km \cdot h^{-1}$; moderate-intensity movements, such as a cruising jog, were considered to be 10.1–16.0 $km \cdot h^{-1}$; high-intensity movements, such as fast jog or striding, were classified as 16.1–23.0 $km \cdot h^{-1}$; and sprinting or maximal effort movements were classified as exceeding 23.0 $km \cdot h^{-1}$. Short duration high-intensity movement efforts, or measures of acceleration and deceleration, were classified as 3 groups, specifically, moderate (1.5–2.5 $m \cdot s^{-2}$), high (2.6–3.5 $m \cdot s^{-2}$), and maximal (>3.5 $m \cdot s^{-2}$) and presented as a count of how many efforts an athlete undertook per game.

Table 2. Movement classification system.

	Movement classification
Speed of locomotion ($km \cdot h^{-1}$)	
0–10	Low-intensity
10.1–16	Moderate-intensity
16.1–23	High-intensity
>23.0	Sprinting/maximal effort
Acceleration and deceleration ($m \cdot s^{-2}$)	
1.5–2.5	Moderate
2.6–3.5	High
>3.5	Maximal

Statistical Analyses

All movement and variables from the present study were presented as descriptive statistics, mean ± *SD*. Hypothesis testing was conducted to determine any main effects for movement profile data between position groups on the offensive and defensive teams. A one-way ANOVA was used to determine positional group main effects. In the event homogeneity of variance assumption was violated, a Welch Robust Test of Equality was used to determine main effects between position groups. For all main effects detected by a one-way ANOVA, post-hoc Bonferroni tests were used. Alpha intervals for all hypothesis testing were set at $p \leq 0.05$ as the level of significance for statistical tests. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS for Windows, version 14.0; SPSS, Inc., Chicago, IL, USA).

Results

Offense

Significant ($p < 0.001$) main effects from ANOVA testing were reported for all movement profile variables measured in the

TABLE 3. Offense positional movement profiles.*

Movement variables	Wide receiver (WR)	Running back (RB)	Quarterback (QB)	Tight end (TE)	Offensive linemen (OL)
Running zone distances					
Total distance (m)	5,530.6 ± 996.5	3,140.6 ± 685.6†	3,751.9 ± 801.9†	3,574.2 ± 882.2†	3,652.4 ± 603.0†
Low intensity distance (m)	3,546.2 ± 756.2	2,291.3 ± 482.0†	3,661.5 ± 642.2‡	2,579.2 ± 663.8†§	2,885.4 ± 663.8†‡§
Moderate intensity distance (m)	1,530.9 ± 341.2	738.4 ± 247.2†	568.3 ± 147.8†	947.2 ± 155.5†‡§	913.2 ± 147.8†‡§
High intensity distance (m)	655.2 ± 196.3	303.1 ± 118.7†	138.1 ± 65.1†‡	336.5 ± 137.8†§	131.1 ± 65.7†‡‖
Sprinting distance (m)	315.8 ± 163.2	101.2 ± 71.7†	76.9 ± 46.0†	40.3 ± 47.4†	9.3 ± 11.3†‡
Average maximal speed ($km \cdot h^{-1}$)	31.5 ± 2.2	28.8 ± 2.5†	29.4 ± 8.5	25.3 ± 7.8†‡§	23.7 ± 2.8†‡§
High intensity movement efforts					
Sprint efforts (#)	12.7 ± 5.7	4.6 ± 3.1†	2.8 ± 1.9†	1.5 ± 1.6†‡	0.3 ± 0.5†‡
Moderate acceleration efforts (#)	62.2 ± 14.0	26.3 ± 11.2†	26.8 ± 9.1†	49.0 ± 19.7†‡§	46.7 ± 13.5†‡§
High intensity acceleration efforts (#)	38.2 ± 13.1	18.7 ± 7.7†	21.0 ± 7.8†	21.5 ± 14.3†	16.5 ± 5.9†
Maximal acceleration efforts (#)	21.9 ± 8.1	8.2 ± 4.9†	9.3 ± 5.9†	5.5 ± 4.1†	1.5 ± 1.6†‡§
Moderate deceleration efforts (#)	36.9 ± 14.0	15.6 ± 7.2†	22.2 ± 7.5†	22.0 ± 8.5†	25.1 ± 7.1†‡
High intensity deceleration efforts (#)	18.5 ± 13.1	7.9 ± 7.7†	9.7 ± 7.8†	9.3 ± 14.3†	8.3 ± 5.9†
Maximal deceleration efforts (#)	15.8 ± 5.4	6.4 ± 3.5†	6.3 ± 3.4†	4.7 ± 3.9†	6.6 ± 2.0†‡§

*Data are mean ± *SD*.
†Significantly different ($p \leq 0.05$) for WRs.
‡Significantly different ($p \leq 0.05$) to RBs.
§Significantly different ($p \leq 0.05$) to QBs.
‖Significantly different ($p \leq 0.05$) to TEs.

present study for the offensive position groups (Table 3). From post-hoc analysis of movement profile variables, total, moderate-intensity, high-intensity, and sprinting distances covered by the WR position was significantly ($p < 0.001$) greater in comparison to all other offensive position groups, including RB, QB, TE, and OL. Low-intensity distance covered by the WR position was also significantly ($p < 0.001$) greater for all offensive position groups apart from QB. The QB position group covered significantly ($p < 0.001$) more low-intensity distance than RB, TE, and OL positions. Moderate-intensity distances were significantly ($p \leq 0.05$) greater for RB and QB position groups than for TE and OL position groups. High-intensity distances were significantly ($p < 0.01$) greater for the RB and TE positions than for QB and OL positions. Sprinting distances were significantly ($p < 0.001$) greater for RB than for OL. The average maximal speed achieved by WR, RB, and QB positions was significantly ($p \leq 0.05$) greater than by TE and OL positions, whereas the average maximal speed achieved by the WR position group was significantly ($p \leq 0.05$) greater than by the RB position group.

For all high-intensity movement profile variables, including sprint efforts, moderate-intensity, high-intensity, maximal-intensity acceleration, and deceleration efforts, the WR position was involved in significantly ($p < 0.01$) more efforts than any other offensive position group. The QB and RB positions were involved in significantly ($p < 0.01$) more sprint efforts per game than the TE and OL positions. The TE and OL groups were involved in significantly ($p < 0.001$) more moderate acceleration efforts than the RB and QB positions; however, the OL position group had significantly ($p < 0.001$) less maximal acceleration efforts than QB and RB positions. The OL position was also involved in significantly ($p < 0.001$) more moderate deceleration efforts than the RB position, whereas for maximal deceleration efforts, the OL position was involved in significantly ($p \leq 0.05$) less moderate deceleration efforts than the RB and QB position groups.

Defense

Significant ($p < 0.001$) main effects from ANOVA testing were reported for all movement profile variables measured in the present study for defensive position groups team (Table 4). Post-hoc analysis of movement profile variables, including total, moderate-intensity, high-intensity, and sprinting distances covered, revealed that both the DB and LB positions covered significantly ($p \leq 0.05$) greater distances in all zones than the DE and DT positions during games. The only main effect reported for distance covered between the DB and LB position groups was for low-intensity distance covered, with the DB position covering significantly ($p \leq 0.05$) more distance than the LB position group. The DB position had the highest average maximal speed which was significantly ($p \leq 0.05$) greater than all other defensive positions. The average maximal speed of the LB position group was significantly ($p \leq 0.05$) greater than that of the

TABLE 4. Defense positional movement profiles.*

Movement variables	Defensive back (DB)	Defensive tackle (DT)	Defensive end (DE)	Linebacker (LB)
Running zone distances				
Total distance (m)	4,696.2 ± 1,114.8	3,013.0 ± 650.9†	3,276.6 ± 815.2†	4,145.4 ± 980.3‡§
Low intensity distance (m)	3,448.7 ± 923.0	2,499.5 ± 456.9†	2,662.8 ± 652.5†	2,989.1 ± 721.5†‡§
Moderate intensity distance (m)	926.1 ± 247.4	629.0 ± 249.0†	665.2 ± 224.0†	912.5 ± 271.4‡§
High intensity distance (m)	513.8 ± 155.5	158.6 ± 62.0†	226.0 ± 96.1†	435.0 ± 165.0‡§
Sprinting distance (m)	247.0 ± 113.1	7.7 ± 10.9†	29.2 ± 24.1†	196.7 ± 104.7‡§
Average maximal speed ($km\cdot h^{-1}$)	31.1 ± 1.9	23.5 ± 1.7†	26.1 ± 2.6†‡	29.6 ± 1.2†‡§
High intensity movement efforts				
Sprint efforts (#)	10.6 ± 4.3	0.4 ± 0.6†	1.4 ± 1.4†	8.0 ± 4.1†‡§
Moderate acceleration efforts (#)	45.1 ± 16.0	29.5 ± 9.9†	31.9 ± 11.2†	37.1 ± 14.4
High intensity acceleration efforts (#)	32.2 ± 11.4	15.4 ± 5.7†	20.0 ± 6.8†‡	26.4 ± 11.0†‡§
Maximal acceleration efforts (#)	20.9 ± 8.6	2.8 ± 2.2†	7.2 ± 4.6†	13.1 ± 6.2†‡§
Moderate deceleration efforts (#)	29.5 ± 11.5	19.5 ± 7.5†	22.7 ± 9.4†	23.7 ± 11.0
High intensity deceleration efforts (#)	19.4 ± 11.4	7.9 ± 5.7†	10.6 ± 6.8†	14.3 ± 11.0†‡
Maximal deceleration efforts (#)	14.0 ± 6.1	2.6 ± 2.0†	5.4 ± 2.9†	10.4 ± 5.1†‡§

*Data are mean ± *SD*.
†Significantly different ($p \leq 0.05$) for DBs.
‡Significantly different ($p \leq 0.05$) to DT.
§Significantly different ($p \leq 0.05$) to DE.

DE and DT positions, although significantly ($p \leq 0.05$) less than that of the DB position. The average maximal speed of the DE position was significantly ($p \leq 0.05$) greater than that of the DT position and significantly ($p \leq 0.05$) less than that of the DB and LB positions.

The DB position group was involved in significantly ($p \leq 0.05$) more sprint efforts, moderate-intensity, high-intensity, and maximal-intensity acceleration and deceleration efforts than the DE and DT positions groups. Apart from moderate acceleration and deceleration efforts and high-intensity deceleration efforts, the DB position group was involved in significantly ($p \leq 0.05$) more high-intensity movements than the LB position group. The LB position group was involved in significantly ($p \leq 0.05$) more sprint efforts, high- and maximal-intensity acceleration and deceleration efforts than the DE and DT positions. Last, the DE position group was involved in significantly ($p \leq 0.05$) more high-intensity acceleration efforts than the DT position group.

Discussion

The present study examined the competitive physiological movement demands of NCAA Division I college football players using portable GPS technology during games and assessed positional groups within offensive and defensive teams to determine if a player's physiological requirements during games are influenced by playing position. The results of the present study provide novel insight into the competitive demands experienced by NCAA Division I college football players and provide scope for the design of position-specific and game-specific physical conditioning strategies for coaches seeking to optimize training for the demands of competition. The results confirm our hypothesis that significant differences in movement profiles accompanying NCAA Division I college football games exist between playing positions. The most notable finding for physical characteristics of games in both offensive and defensive teams was the movement profiles of the WR, DB, and LB positions, with athletes in these 3 position groups covering more total distance at higher intensities than all other positions on their respective offensive and defensive teams.

The total distance covered by athletes in team-sport competition such as American football may be considered an overall reflection of running volume. The present study found a significant ($p < 0.001$) difference in total distance traveled between position groups within both the offensive and defensive teams. The WR position group covered more total distance per game than all other offensive groups. Similarly on defense, the DB and LB position groups covered greater total distance than the DT and DE position groups. The finding of the present study that the WR, DB, and LB position groups covered greater total distance is consistent with the work of DeMartini et al. (8) who found significant differences in the distance traveled between linemen (2,573 $\pm$ 489 m) and nonlineman (3,532 $\pm$ 943 m) during preseason training. However, the present study evaluated game data over the course of 12 games compared with DeMartini et al. (8) who evaluated data obtained during preseason training in the heat. The absence of published research in relation to the demands of NCAA Division I football games make comparisons with others problematic. Despite the absence of comparable studies, the present results indicate that the total distance covered for both linemen (3,314.0 m) and nonlinemen (4,141.3 m) during games is greater than the data reported by DeMartini et al. (8). From an observational perspective, results from the present study may be attributed to the increased distance from the line of scrimmage from which the WR, DB and LB position groups started plays. Beginning play further from the line of scrimmage gives athletes a larger area for movement, providing increased movement requirements during plays and further distances to travel between plays to huddle for brief tactical discussion related to subsequent play. Given WRs, DBs, and LBs covered greater total running distance throughout games than their offensive and defensive teammates, it is reasonable to suggest athletes in these positions may require modified running volumes in training to support recovery and adequately prepare them for the physical demands of subsequent competition.

In addition to differences in total distance covered by WRs, DBs, and LBs, the present study found significant ($p \leq 0.05$) differences in moderate-intensity, high-intensity, and sprint distances covered by WRs, DBs, and LBs compared with all other positions on their respective teams. The RBs and TEs covered significantly ($p \leq 0.05$) more high-intensity distance than OL. Similar observations in American football training were made by Demartini et al. (8) who reported nonlinemen covering significantly ($p < 0.001$) more high-intensity ($>16.0\ \text{km}\cdot\text{h}^{-1}$) distance for position drills, team drills, and total practice time than linemen in preseason training. Positional differences observed in the present study may be attributed to the position-specific requirements of games. Tactically, the primary responsibility of OL is to block defensive players, preventing opponents from tackling their own team's ball carrier. These movements are associated with short bursts of acceleration, deceleration, and change of direction, which most frequently occur within a few yards of the line of scrimmage, thereby limiting the distance traveled per play. Players in the DT and DE position groups characteristically accelerate short distances and perform rapid change of direction movements before engaging the opposing OL, followed by pursuing the ball carrier. The position-specific requirements of the OL, DT, and DE positions, requiring a static play initiation posture at or near the line of scrimmage at commencement of each play followed by contact, with an opponent positioned approximately 1 m apart, likely influences subsequent running distances. These distances are less than those covered by other positions on the offensive and defensive teams that require players to travel greater distances before engaging an opponent. The differences in high-intensity distance covered by TEs and

RBs, compared with that covered by OL, may be attributed to the more diverse requirements of these position groups, including blocking, running with the ball, and releasing on pass routes. The WR position group is required to repeatedly run passing routes at high velocities throughout the course of games, consequently accounting for significantly greater high-intensity distance and significantly more sprint efforts when compared with all other offensive positions. The DB position group is primarily responsible for defending WR on passing routes; however, they also provide secondary support on running plays. As the last line of defense, the DB position is often responsible to make tackles on long running or passing plays, which is indicated in the present study with greater high-intensity distance and more sprint efforts of DBs when compared to all other defensive positions.

In addition to the distance covered during play, the WRs and DBs cover more distance between plays as they are required to jog back to the line of scrimmage at the conclusion of plays, which may be a distance of 20–30 m to either huddle, or reassume their alignment for subsequent play, whereas OL, DTs, and DEs characteristically walk short distances during recovery between plays (26). The LB position is required to defend running plays in addition to covering WR, RB, and TE on passing plays which may account for similar movement characteristics to the DB position. The results of the present study highlight the unique movement demands of WR, DB, and LB position groups in comparison to other positions on their respective offensive and defensive teams and is potentially related to their proximity to the line of scrimmage at the initiation of play. Young et al. (32) reported greater running distance covered at high speed, along with moderate and high accelerations and decelerations to be associated with markers of muscle damage in collision team-sport players, and consequently, the monitoring and prudent adjustment of weekly training loads specifically for the WR, DB and LB positon groups, may reduce the likelihood of subsequent performance decrements associated with fatigue.

Research (1,19,24) in team sports using portable GPS technology indicates positional differences in movement characteristics during competition. No previous studies have reported the movement demands of NCAA Division I football competition; consequently, a lack of understanding exists regarding the demands of American football games. Investigations in team sports similar to American football, including rugby league, rugby union, and Australian rules football, indicate that significant differences exist in high-intensity movements, including acceleration and deceleration efforts (28,32), and maximal speed (5,24) between position groups. The present study found significant differences in maximal running speeds and maximal acceleration and deceleration efforts recorded from offensive position groups. The average maximal speed of WR position was significantly ($p \leq 0.05$) greater than all other offensive positions except QB. The average maximal speed of the RB and QB position groups was significantly ($p \leq 0.05$) greater than that of both the TE and OL position groups. The WR group had significantly ($p \leq 0.05$) more sprint, maximal acceleration, and maximal deceleration efforts than all other offensive position groups, presumably because of repeated route running requiring sprinting and frequent changes of direction.

Defensively, there were no significant differences between total, moderate-, or high-intensity distance covered between DB and LB position groups; however, significant ($p \leq 0.05$) differences were indicated for average maximal speed, sprint, maximal acceleration, and maximal deceleration efforts. The DB group had significantly ($p \leq 0.05$) more sprint, maximal acceleration, and maximal deceleration efforts than all other defensive positions, highlighting the specific high-intensity running requirements of this position during defensive play. The LB position group demonstrated significantly ($p \leq 0.05$) greater average maximal speeds, sprint, maximal acceleration, and maximal deceleration efforts than the DE and DT groups. Similar research (8) has not quantified high-intensity movement characteristics of individual position groups, making comparisons with the present study difficult.

The significant differences between the DB group when compared with the defense as a whole, and the LBs compared with DTs and DEs, highlight 3 distinct running profiles for the defensive team, requiring different forms of training to achieve optimal development. The starting positions on commencement of each play for the DB and LB groups afford larger areas to achieve higher maximal speeds, while the positional requirements of defending pass routes and pursuing ball carriers result in greater changes of direction for the DB and LB groups. The WR and DB position groups achieved significantly greater maximal speeds, sprint efforts, and maximal acceleration and deceleration efforts than their respective offensive and defensive counterparts throughout the course of games, indicating the need for positional specificity in speed training for NCAA Division I football players.

The results of the present study provide novel insight into position-specific physical demands of NCAA Division I football games and provide physical performance staff with quantified information, which can potentially be used to replicate the physical demands of games in training. The present study demonstrated appreciable differences in the positional movement demands of NCAA Division I college football games, emphasizing the need for position-specific training to adequately prepare players for the rigors of competition.

Practical Applications

The present study provided a novel analysis of the movement demands associated with NCAA Division I college football games. The results indicated significant differences in total running volume and high-intensity movement demands, most notably for the WR, DB, and LB position groups. Higher overall running loads were experienced for these 3 position groups, while greater high-intensity movement demands were required of the WR and DB groups. Data from the present study augments our understanding of the competitive demands experienced by NCAA Division I college football players and provide scope for the design of position-specific and game-specific physical conditioning strategies for coaches seeking to optimize training for the demands of competition.

Data from the present study support the use of position-specific training in the preparation of NCAA Division I college football players for competitive games. Maximizing performance and limiting the effects of fatigue are critical challenges for performance coaches, and as such, accounting for the physical demands associated with weekly training and games is imperative. Modifying weekly training loads of individuals within position groups involved in greater high-speed running volumes and a higher number of acceleration and deceleration efforts may mitigate fatigue, accelerate recovery, and improve subsequent performance. The WR, DB, and LB position groups are exposed to greater running volumes, faster running velocities, and a higher number of acceleration and deceleration efforts in games than their offensive and defensive counterparts and may benefit from carefully monitored and individualized training load prescriptions throughout the week. Additionally, while RB and TE groups do not accrue the total distance of the WR group during games, they are exposed to greater running volumes than the OL, which warrants individualized training load prescriptions based on the physical demands of competition. Clearly, performance coaches seeking to optimize physical performance characteristics associated with competition must differentiate training programs based upon position-specific movement demands.

Data obtained from the present study provide a better understanding of the demands of NCAA Division I football and provide a foundation from which to implement a systematic approach to the development of individual and position-specific training programs. Future studies should examine how coaches seeking to enhance competitive performance can manipulate individual and position-specific training programs to mitigate fatigue, enhance recovery, and optimize game-day performance.

Acknowledgments

No grant aid or manufacturer's aid was received in conjunction with the present study, and no conflicts of interest are declared. The results of this study do not constitute endorsement of the product by the authors of the National Strength and Conditioning Association.

References

1. Austin, DJ and Kelly, SJ. Positional differences in professional rugby league match play through the use of global positioning systems. *J Strength Cond Res* 27: 14–19, 2013.
2. Austin, DJ and Kelly, SJ. Professional rugby league positional match-play analysis through the use of global positioning system. *J Strength Cond Res* 28: 187–193, 2013.
3. Barbero-Álvarez, JC, Coutts, A, Granda, J, Barbero-Álvarez, V, and Castagna, C. The validity and reliability of a global positioning satellite system device to assess speed and repeated sprint ability (rsa) in athletes. *J Sci Med Sport* 13: 232–235, 2010.
4. Boyd, LJ, Ball, K, and Aughey, RJ. Quantifying external load in Australian football matches and training using accelerometers. *Int J Sports Physiol Perform* 8: 44–51, 2013.
5. Cahill, N, Lamb, K, Worsfold, P, Headey, R, and Murray, S. The movement characteristics of English premiership rugby union players. *J Sports Sci* 31: 229–237, 2013.
6. Coutts, AJ and Duffield, R. Validity and reliability of GPS devices for measuring movement demands of team sports. *J Sci Med Sport* 13: 133–135, 2010.
7. Cunniffe, B, Poctor, W, Baker, JS, and Davies, B. An evaluation of the physiological demands of elite rugby union using global positioning system tracking software. *J Strength Cond Res* 23: 1195–1203, 2009.
8. DeMartini, JK, Martschinske, JL, Casa, DJ, Lopez, RM, Ganio, MS, Walz, SM, and Coris, EE. Physical demands of National Collegiate Athletic Association division I football players during preseason training in the heat. *J Strength Cond Res* 25: 2935–2943, 2011.
9. Edgecomb, SJ and Norton, KI. Comparison of global positioning and computer-based tracking systems for measuring player movement distance during Australian football. *J Sci Med Sport* 9: 25–32, 2006.
10. Gabbett, TJ, Jenkins, DG, and Abernethy, B. Physical demands of professional rugby league training and competition using microtechnology. *J Sci Med Sport* 15: 80–86, 2011.
11. Granatelli, G, Gabbett, TJ, Briotti, G, Padulo, J, Buglione, A, D'Ottavio, S, and Ruscello, BM. Match analysis and temporal patterns of fatigue in rugby sevens. *J Strength Cond Res* 28: 728–734, 2014.
12. Iosia, MF and Bishop, PA. Analysis of exercise-to-rest ratios during division IA televised football competition. *J Strength Cond Res* 22: 332–340, 2008.
13. Johnston, RD, Gabbett, TJ, and Jenkins, DG. Applied sports science of rugby league. *Sports Med* 44: 1087–1100, 2014.
14. Johnston, RD, Watsford, ML, Kelly, SJ, Pine, MJ, and Spurrs, RW. Validity and interunit reliability of 10 hz and 15 hz units for assessing athlete movement demands. *J Strength Cond Res* 28: 1649–1655, 2014.
15. Johnston, RD, Watsord, ML, Pine, MJ, Spurrs, RW, Murphy, AJ, and Pruyn, EC. The validity and reliability of 5-hz global positioning system units to measure team sport movement demands. *J Strength Cond Res* 26: 758–765, 2012.
16. Kraemer, WJ and Gotschalk, LA. Physiology of American football. In: *Exercise and Sport Science.* W.E. Garrett and D.T. Kirkendall, eds. Philadelphia, PA: Lippincott, Williams & Wilkins, 2000. pp. 795–813.
17. Krasnoff, JB, Kohn, MA, Choy, FKK, Doyle, J, Johansen, K, and Painter, PL. Interunit and intraunit reliability of the RT3 triaxial accelerometer. *J Phys Act Health* 5: 527–538, 2008.
18. Loader, J, Montgomery, P, Williams, MD, Lorenzen, C, and Kemp, JG. Classifying training drills based on movement demands in Australian football. *Int J Sports Sci Coach* 7: 57–67, 2012.
19. McLellan, CP, Coad, S, Marsh, D, and Lieschke, M. Performance analysis of super-15 rugby match-play using portable micro-technology. *J Athl Enhanc* 2: 5, 2013.
20. McLellan, CP and Lovell, DI. Neuromuscular responses to impact and collision during elite rugby league match play. *J Strength Cond Res* 26: 1431–1440, 2012.
21. McLellan, CP and Lovell, DI. Performance analysis of professional, semiprofessional, and junior elite rugby league match-play using global positioning systems. *J Strength Cond Res* 27: 3266–3274, 2013.
22. McLellan, CP, Lovell, DI, and Gass, GC. Creatine kinase and endocrine responses of elite players pre, during, and post rugby league match play. *J Strength Cond Res* 24: 2908–2919, 2010.

23. McLellan, CP, Lovell, DI, and Gass, GC. Biochemical and endocrine responses to impact and collision during elite rugby league match play. *J Strength Cond Res* 25: 1553–1562, 2011.
24. McLellan, CP, Lovell, DI, and Gass, GC. Performance analysis of elite rugby league match play using global positioning systems. *J Strength Cond Res* 25: 1703–1710, 2011.
25. Petersen, C, Pyne, D, Portus, M, and Dawson, B. Validity and reliability of GPS units to monitor cricket-specific movement patterns. *Int J Sports Physiol Perform* 2: 381–393, 2009.
26. Rhea, MR, Hunter, RL, and Hunter, TJ. Competition modeling of American football: Observational data and implications for high school, collegiate, and professional player conditioning. *J Strength Cond Res* 20: 58–61, 2006.
27. Robbins, DW and Young, WB. Positional relationships between various sprint and jump abilities in elite American football players. *J Strength Cond Res* 26: 388–397, 2012.
28. Sirotic, AC, Knowles, H, Catterick, C, and Coutts, AJ. Positional match demands of professional rugby league competition. *J Strength Cond Res* 25: 3076–3087, 2011.
29. Sullivan, C, Bilsborough, JC, Cianciosi, M, Hocking, J, Cordy, J, and Coutts, AJ. Match score affects activity profile and skill performance in professional Australian football players. *J Sci Med Sport* 17: 326–331, 2014.
30. Varley, MC, Fairweather, IH, and Aughey, RJ. Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *J Sports Sci* 30: 121–127, 2012.
31. Wisbey, B, Montgomery, PG, Pyne, DB, and Rattray, B. Quantifying movement demands of AFL football using GPS tracking. *J Sci Med Sport* 13: 531–536, 2010.
32. Young, WB, Hepner, J, and Robbins, DW. Movement demands in Australian rules football as indicators of muscle damage. *J Strength Cond Res* 26: 492–496, 2012.