Global Positioning System Analysis of a High School Football Scrimmage

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Abstract

Gleason, BH, Sams, M, Salley, JT, Pustina, A, and Stone, MH. Global positioning system analysis of a high school football scrimmage. *J Strength Cond Res* 31(8): 2183–2188, 2017—The purpose of this study was to examine the physical demands of a high school American football scrimmage. Male high school football players ($N = 25$) participated in a spring scrimmage. Global positioning system data and game film were recorded throughout the entirety of the scrimmage to determine the total distance covered, the distance covered in different velocity bands, the number of accelerations and decelerations performed, and the work-to-rest ratio of the scrimmage. The athletes were divided into 2 groups: linemen (L) ($N = 7$) vs. nonlinemen (NL) ($N = 8$) for statistical analysis, and independent T-tests with Holm's sequential Bonferroni adjustment were used to determine differences in movement characteristics between the L and NL groups. Average play duration was 5.7 ± 2.1 seconds, whereas the rest interval was 33.4 ± 13.6 seconds between plays, for an overall exercise-to-rest ratio of 1:5.9. Total distance, standing and walking distance, running distance, striding distance, sprinting distance, and total high-speed running distance covered by NL was greater than L (statistically significant at $p \leq 0.05$). Distances traveled in each velocity band by position and by play are also included to provide context of our findings. Data from the present study add to the pool of support for the use of position-specific training in preparing high school football players for competition.

Key Words GPS tracking, American football, game demands

Introduction

Global positioning system (GPS)–based analysis of game play has been performed on several team sports to date, particularly within a variety of football codes (5,18). Despite several collegiate and professional American football teams performing regular GPS analysis as a quantitative measure of workloads in practices and games, only 2 GPS studies have previously been published; these evaluated the overall movement demands of Division I football (6,16). Two other studies have evaluated work and rest periods by recorded games at several levels of play (9,13). These 4 studies collectively have provided valuable information that may be used to design appropriate preparatory sport-specific training programs that best reflect movement demands and rest periods encountered during game play.

DeMartini et al. (6) documented preseason practices and scrimmages by 49 members of an National Collegiate Athletic Association (NCAA) Division I team. Not surprisingly, the authors noted different movement patterns between groups–nonlinemen (NL) traveled farther than linemen (L) during position drills (1,673 ± 420 m vs. 1231 ± 189 m; $p < 0.001$) and during team drills and scrimmaging (1,262 ± 626 vs. 915 ± 383 m; $p = 0.026$). Nonlinemen spent more time than L in higher velocity zones during position group drills and team drills. Similarly, Wellman et al. (16) reported GPS movement characteristics for 33 members of an NCAA Division I team during 12 regular season games. Statistically significant differences were found between position groups on offense and defense, with greater total running volumes observed in wide receiver, defensive back, and linebacker positions. Furthermore, wide receivers and defensive backs covered greater distances at high speeds ($>16.1\ km\cdot h^{-1}$). Linemen largely performed moderate acceleration and deceleration efforts (1.5–$2.5\ m\cdot s^{-2}$) with less distance covered.

In a detailed video analysis of an NCAA Division I football game, Iosia and Bishop (9) found that work-to rest ratios varied depending on the type of offense, with a hurry-up offense producing a 1:3 work-to-rest ratio and a slower offensive style producing a 1:10 ratio. On average, however, both Iosia and Bishop (9) and Rhea et al. (13) found average work-to-rest intervals of roughly 1:5–1:6 for teams ranging from high school to professional play.

Currently, no research has applied GPS technology to the high school level of play. Thus, the purpose of the present

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31(8)/2183–2188

Journal of Strength and Conditioning Research

study was (a) to observe the overall movement demands of high school football players in a scrimmage using GPS technology, (b) to examine the influence of position on movement demands, and (c) to confirm previous investigations of work-to-rest intervals in regard to hurry-up, no-huddle game play.

Methods

Experimental Approach to the Problem

In the present study, portable integrated GPS accelerometer units and video analysis were used to quantify the physical demands of a high school American football scrimmage. Data were collected during a spring scrimmage against an in-league opponent. For movement analysis, the athletes were divided into groups based on playing position. Activity and rest intervals were calculated by replaying video and measuring time spent during and between plays. Average total distances (TDs) covered and distances covered per play were calculated.

Subjects

Twenty-five male varsity high school football athletes (age: 16.9 ± 1.0 years; height: 1.8 ± 0.1 m; mass: 93.9 ± 22.0 kg) participated in this study. The athletes were grouped by playing position for descriptive analysis of positional demands. These position groups were further separated into 2 groups, L and NL, for statistical analysis because of the small sample analyzed; athletes included were either previous starters or athletes being groomed to play a major role in the upcoming season. Similar to DeMartini et al. (6), L included the positions of defensive end, defensive and offensive tackle, offensive guard, center, and tight end, whereas NL included the positions of linebacker, wide receiver, quarterback, and running back. These groups were determined based on information received from the coaching staff and subsequent video analysis. All athletes read and signed an informed consent explaining the risks and benefits of the study, and parent or guardian signatures were obtained for athletes younger than 18 years. The methods for this study were approved by the East Tennessee State University Institutional Review Board.

Procedures

Scrimmage. Data were collected during a spring scrimmage against an in-league opponent, officiated by league officials. Based on the agreements of the scrimmage, special teams play was not performed–only the opposing team kicked noncontact field goals following scores. As a result, only offensive and defensive plays were included in this study. Data were collected by researchers during the scrimmage from sideline GPS data recording software and video footage recorded from the stands.

Global Positioning System Data. Movement analysis was conducted with GPS units (Minimaxx S4; Catapult Innovations, Scoresby, VIC, Australia) sampling at a frequency of 10 Hz. The units also contained triaxial accelerometers, which sampled at 100 Hz and assessed the frequency and magnitude of full-body accelerations ($m \cdot s^{-2}$). The GPS units used in the present study have been previously investigated and were found to be valid and reliable in measurement of distances covered during sport-specific running (10). Previous study of distance accuracy with these units using runs of 15 and 30 m revealed typical error of 0.2 and 0.3 m, and small coefficients of variation of 1.3 and 0.7%, respectively (3).

Table 1. Velocity bands.

Velocity bands ($km \cdot h^{-1}$)	Description
0–7.2	Standing and walking
7.3–14.4	Jogging
14.5–19.8	Running
19.9–25.2	Fast running or striding
>25.2	Sprinting
>14.4	High-speed running

In accordance with manufacturer guidelines, the units were turned on approximately 10 minutes before the team warm-up, after which the units were placed in a harness underneath the athletes' shoulder pads. Plays were manually tagged in the GPS software's live mode via a "Start/Stop" button. After the completion of the scrimmage, the GPS units were removed from the harnesses and downloaded for analysis using manufacturer-provided software (Catapult Sprint v5.1.7; Catapult Innovations).

Assessed movement profile variables included TD and distance covered in arbitrarily defined velocity bands (m) (Table 1), distance covered in the 3 highest velocity bands (high-speed running: >14.4 $km \cdot h^{-1}$), and counts of total accelerations and decelerations. Similar to the velocity bands, acceleration bands categorized accelerations and decelerations as moderate (1–2.5 $m \cdot s^{-2}$), high (2.5–4 $m \cdot s^{-2}$), or maximal (>4 $m \cdot s^{-2}$) (Table 2). The velocity and acceleration bands were chosen as laboratory standards for male

Table 2. Acceleration bands.

Acceleration and deceleration bands ($m \cdot s^{-2}$)	Description
1.0–2.5	Moderate
2.6–4.0	High
>4.0	Maximal

Table 3. Linemen vs. nonlinemen velocity zone distance comparison.*†

Variable	Linemen	Nonlinemen	95% Confidence interval	Effect size (*d*)
Total distance (m)‡	1,686.4 ± 302.3	3,111.1 ± 891.5	590.9 to 2,178.7	1.94
Standing and walking distance (m)‡	981.7 ± 211.9	1,810.5 ± 532.4	327.1 to 1,279.5	1.86
Jogging distance (m)	434.9 ± 112.2	602.6 ± 199.3	−25.0 to 345.1	0.95
Running distance (m)‡	68.0 ± 42.9	268.5 ± 139.4	77.5 to 318.7	1.83
Fast run/striding distance (m)§	12.0 ± 16.7	152.4 ± 74.0	78.0 to 202.8	2.53
Sprinting distance (m)‡	1.0 ± 0.0	42.0 ± 27.3	19.2 to 64.8	2.10
High-speed running distance (m)‡	80.0 ± 55.7	462.9 ± 215.2	196.7 to 564.3	2.32

*Values are mean ± *SD*.
†95% confidence interval is the confidence interval of the difference between groups.
‡Statistically different ($p < 0.01$).
§Statistically different ($p < 0.001$).

team sport athletes based on manufacturer recommendations and previous research on soccer athletes (2,15).

Video Analysis. A video camera (Sony HDR-HC9; Sony Electronics, San Diego, CA, USA) was stationed in the stands approximately at the 50-yard line. The camera ran continuously for the duration of the scrimmage at a rate of 30 frames per second. Video analysis was carried out by a single researcher, with each play coded and timestamped as part of a game script. The game script was used to calculate work and rest intervals for each play and establish athletes' play-by-play involvement.

Global Positioning System Data Reduction. Despite the capabilities of the live mode software to automatically "bench" inactive players to avoid overreporting data for athletes not involved in a play, the pace of the scrimmage did not allow the researchers time to substitute athletes between plays. Instead, the game script developed through video analysis was used to determine athlete substitutions and manually adjust athlete involvement as needed. Plays in which an athlete did not participate were removed from the GPS report. Although all athletes' data were used for descriptive analysis of each position's distance covered per play, athletes who completed less than 50% of potential plays were excluded from statistical analysis to limit the data to starting offensive, defensive, and utility players, leaving 15 total athletes (7 L, 8 NL) for statistical analysis in the comparison between L and NL. Data from all participating players were reported and included in Table 5 to provide coaches context of movement demands according to position.

Statistical Analyses

Average play count and average distance covered in each velocity band were calculated for each position group for descriptive analysis of positional demands. The athletes were grouped into L vs. NL for statistical analysis. Means and *SD* were calculated for all measured variables. Independent-samples *T*-tests (using Welch's correction for unequal variances, when necessary) with Holm's sequential Bonferroni correction

Table 4. Linemen vs. nonlinemen acceleration-based effort comparison.*†

Variable	Linemen	Nonlinemen	95% Confidence interval	Effect size (*d*)
Accelerations				
Moderate acceleration efforts (#)	69.1 ± 16.4	63.3 ± 16.8	−24.5 to 12.7	0.35
High acceleration efforts (#)	21.0 ± 11.5	18.8 ± 8.7	−14.0 to 9.5	0.22
Maximal acceleration efforts (#)	9.0 ± 1.6	7.1 ± 3.4	−4.8 to 1.1	0.69
Decelerations				
Moderate deceleration efforts (#)	42.4 ± 4.6	75.5 ± 74.6	−29.3 to 95.5	0.60
High deceleration efforts (#)	15.4 ± 5.1	18.5 ± 14.7	−9.5 to 15.7	0.27
Maximal deceleration efforts (#)	5.3 ± 2.2	11.0 ± 11.0	−3.5 to 14.9	0.70

*Values are mean ± *SD*.
†95% confidence interval is the confidence interval of the difference between groups.

Table 5. Position-based velocity zone distances per play.*†

Position	Plays (#)	Standing and walking (m)	Jogging (m)	Running (m)	Striding (m)	Sprinting (m)	High-speed running (m)
OL	38 ± 19 (23–53)	21.6 ± 9.3 (14.2–29.0)	8.2 ± 2.7 (6.0–10.4)	0.9 ± 1.0 (0.2–1.7)	0.1 ± 0.3 (0–0.3)	0 ± 0 (0–0)	1.0 ± 1.2 (0.1–2.0)
QB‡	54	26.6 ± 16.5	5.6 ± 8.1	2.8 ± 3.8	2.4 ± 6.5	1.1 ± 5.0	6.3 ± 12.4
RB	16 ± 6 (9–23)	23.0 ± 7.5 (14.5–31.5)	12.5 ± 2.6 (9.6–15.4)	3.8 ± 3.3 (0–7.5)	1.8 ± 1.9 (0–4.0)	0.9 ± 0.8 (0–1.8)	6.4 ± 5.6 (0.1–12.8)
TE	21 ± 4 (15–27)	28.2 ± 1.5 (26.1–30.4)	7.2 ± 1.6 (4.9–9.5)	1.9 ± 1.2 (0.2–3.6)	0.4 ± 0.5 (0–1.1)	0 ± 0 (0–0)	2.3 ± 1.7 (0–4.7)
WR	26 ± 18 (13–39)	29.6 ± 4.8 (26.1–33.2)	12.2 ± 6.1 (7.7–16.7)	6.0 ± 3.7 (3.3–8.7)	2.5 ± 1.9 (1.0–3.9)	0.4 ± 0.5 (0–0.7)	8.8 ± 5.2 (5.0–12.6)
DL	29 ± 11 (20–38)	20.2 ± 5.0 (16.3–24.2)	9.4 ± 1.6 (8.1–10.7)	2.2 ± 1.6 (0.9–3.5)	0.7 ± 0.8 (0–1.3)	0 ± 0 (0–0)	2.9 ± 2.4 (0.9–4.8)
LB	22 ± 16 (7–38)	21.2 ± 6.8 (14.5–27.9)	10.3 ± 1.5 (8.9–11.8)	4.6 ± 1.2 (3.4–5.8)	1.4 ± 0.9 (0.5–2.3)	0.3 ± 0.7 (0–1.0)	6.3 ± 1.8 (4.5–8.1)
DB	31 ± 17 (17–44)	28.4 ± 4.1 (25.1–31.7)	11.2 ± 4.4 (7.7–14.7)	4.1 ± 2.0 (2.5–5.7)	2.5 ± 1.7 (1.1–3.9)	0.4 ± 0.5 (0–0.9)	7.0 ± 3.8 (4.0–10.1)

*OL = offensive line; QB = quarterback; RB = running back; TE = tight end; WR = wide receiver; DL = defensive line; LB = linebacker; DB = defensive back.
†Values are mean ± *SD* with associated 95% confidence intervals.
‡Quarterback values are presented as sum total for plays and mean ± *SD* only for other variables.

for statistically significant p-values (1) were used to determine the differences in the GPS variables described previously. Statistical significance was set at $p \leq 0.05$. Statistical analyses were performed using the statistical software R (version 3.2.4). The R package "effsize" (version 0.6.2) was used to calculate Cohen's d magnitudes of effect. Hopkins' descriptions of effect size (8) were used to describe the magnitudes of the differences.

Results

The distances traveled by L and NL are presented in Table 3, whereas total accelerations and decelerations are presented in Table 4. With the exception of jogging distance, statistically significant differences were observed between L and NL for distances traveled in each velocity band and for TD. These differences ranged from moderate to very large. There were no statistically significant differences between groups for the number of acceleration or deceleration efforts performed. Linemen completed an average of 54.9 ± 7.2 plays, whereas NL completed an average of 66.4 ± 15.1 plays with an average play duration of 5.7 ± 2.1 seconds, average rest intervals of 33.4 ± 13.6 seconds, and an overall exercise-to-rest ratio of 1:5.9 during drives.

Discussion

The purpose of this study was to quantify the physical demands imposed on high school American football players and typical work-to-rest intervals during a spring scrimmage. Furthermore, it was of primary interest to compare these demands between players of different positions. The main finding was that NL players covered more distance than L.

Both teams playing in the scrimmage ran offenses classified as spread, no-huddle, and 3–4 defenses. The team studied is from a 6A school (largest enrollment category in the state), whereas the opposing team is from a 5A school; both teams compete against each other in the same athletic conference. Our observations of play duration (5.7 ± 2.1 seconds) and rest intervals (33.4 ± 13.6 seconds) were similar to those of Rhea et al. (13), who reported average high school football play duration to be 5.6 ± 2.0 seconds and average rest interval to be 31.49 ± 8.78 seconds. Similarly, Iosia and Bishop (9) observed average collegiate play durations of 5.23 seconds and rest intervals of 36.09 seconds. The present findings should be interpreted with some caution because games are more multidimensional than scrimmages in terms of clock management and strategy. Furthermore, different styles of play may produce different movement profiles (e.g., wing-t offense, 4-2-5 defense), and specific situational packages may furthermore affect demands of play (e.g., goal line, special teams). It should be noted that the scrimmage concluded spring practice for both teams. Although the scrimmage was not a countable game, it is the researchers' impression that the level of play was similar in intensity to an in-season game.

Similar to DeMartini et al. (6), NL traveled greater distances than L in both TD and nearly all velocity bands, save jogging. These differences can likely be attributed to differing positional requirements between the 2 groups. Linemen are generally engaged with an opponent within a few yards of the line of scrimmage, whereas NL positions (such as wide receivers and running backs) are often required to cover far more distance and may make several changes of direction each play. High-speed running distance for both groups was lower than the values reported by Wellman et al. (16) for their highest 2 velocity bands, which have similar cutoff points to those used for high-speed running. Although further studies are needed in game settings to confirm these values, previous studies in sports such as soccer have shown that the level of play (12) affects the athletes' movement profiles. That is, as the athletes develop and reach progressively higher levels of performance, the physical requirements and intensity of the sport increase dramatically.

No statistically significant differences were found between groups for the number of accelerations and decelerations performed. These findings are in contrast to Wellman et al. (16), Sirotic et al. (14), and Young et al. (20), who demonstrated statistically significant differences in accelerations and decelerations between position groups in American football, rugby league, and Australian Rules football, respectively. Because of the combined nature of the present study, more nuanced differences may have been masked by the potentially high variability between the combined positions. For instance, Wellman et al. (16) demonstrated that defensive backs and wide receivers performed more accelerations and decelerations compared with other defensive and offensive positions, respectively. As such, future research should seek to increase the athlete pool studied to allow for position-specific comparisons instead of the L vs. NL comparison of the present study.

Practical Applications

The present study provided novel information in regards to the demands of high school football. The results indicated that a significant difference exists between L and NL players in terms of TD covered and distance covered at different velocities. In conjunction with research by Wellman et al. (16), these findings would suggest that coaches can optimize their training and conditioning strategies by training in a more position-specific manner. Accordingly, coaches are encouraged to view several resources that outline position-specific programming for off-season preparatory conditioning programs (7,17,19). A breakdown of distance traveled by position is provided in Table 5 to give coaches context of the material.

Although current GPS technology may be cost-prohibitive for the majority of high school teams, other forms of workload monitoring such as session rating of perceived exertion may be viable alternatives (4,11). Regardless of the monitoring tools used, resulting fatigue management may decrease the likelihood of injury and maintain or improve the athletes' performance, particularly for position groups with the greatest demands (16).

The present study highlights the valuable information that can be obtained from tools such as athlete-worn GPS units, which allow for objective analysis of competitive play and can aid in the development of sport-specific training programs for American football athletes. Importantly, this information can be published without divulging the coaching staff's tactics. Future research should aim to increase the athlete pool analyzed and should examine the athletes in game settings. This greater athlete pool will allow for more detailed analyses of position-specific performances and contrast game demands between levels of play. Analyses of play-by-play distances are necessary to design appropriate sport-specific conditioning programs for each position group. Furthermore, analyses examining the training leading up to games are needed. Such data will afford coaches a better understanding of how manipulation of training loads and intensities can best prepare their athletes for optimal game-day performance.

Acknowledgments

This study was made possible by financial support from the East Tennessee State University Center of Excellence for Sport Science and Coach Education. We thank the players and coaches of the Science Hill High School football program for their participation in the study. Also, we thank Dr. Satoshi Mizuguchi for his assistance with the IRB approval process.

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