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Quantifying in-season practice demands of NCAA division I college football using integrated GPS, accelerometer and HR monitors

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Abstract
Purpose: The aims of this study was to determine the physiological demand of practice in National Collegiate Athletic Association Division I football players through Global positioning system, accelerometers and Heart Rate monitoring across position groups.
Approach: Thirty players wore a portable integrated monitor unit for 10-weeks during the fall football season. They were divided into position groups and compared across different speeds zones, HR zones, accelerations, work variables and distance traveled at different speeds.
Results: For all of the speed and distance variables there was significant ($P<0.05$) differences between position groups with wide receivers, running backs and defensive backs, running at high speeds and covering more distance. For HR data there was no major significant differences between position groups. For work variables, quarterbacks had the smallest work to rest ratio, while wide receivers, running backs and defensive backs had the smallest ratios. Compared to game data, practice is performed at slow speeds but covers greater distances.
Conclusion: Overall, skilled positions in football run at high speeds and cover more ground than their counterparts and accelerate the most while heat rate data indicated that internal demands of practice are similar across position groups.

Keywords: Load, speed, distance, work

Introduction

American rules Football is a common sport in the United States of America and is slowly growing internationally. Traditionally, practice demands have been set by the coaches to optimize performance and prepare the players for games. There is very little research addressing the demands of practice and load placed on the player. Until recently, it has been extremely difficult to determine how much work/activity a player performs or goes through during a practice. The development of wearable technology and the use Global Positioning Systems (GPS) have allowed coaches and practitioners to monitor and analyze player training loads and activity during practices and games [1-4].

Due to the nature of college football and limited access to college football players, research is scarce at best. There is a handful of studies that address workload of games ranging from video analysis of work to rest ratios [5], competition modeling [6], and demands quantified by GPS [4, 7, 8]. Fewer studies have looked at the physiological demands of practice. Some of these studies have evaluated load measures derived from GPS and accelerometer data [9, 10] or preseason training addressing speed zones and load [11, 12]. With very little data on American football players, there is a need to address the physiological demands of Division I college football programs during practice.

Physiological demands of practice and performance in other sports are well documented [13]. The use of GPS and Heart Rate (HR) data are common in soccer [14], rugby [15], and Australian Rules football [16]. Common measurements include speed zones [4, 8, 11, 16, 17], workload [9, 17], and HR derived data [11, 17]. To date there is only one study that has analyzed physiological load in college football players using both HR and GPS data [11]. DeMartini *et al*. [11] evaluated profile characteristics of speed in five zones and address maximum and average HR in starters and nonstarters in different positions and team drills as well as total practice. This novel paper addressed different forms of practice (individual position drills or team drill) and kept the analysis in the general area of those variables. They failed to individualize the results or determine a workload value. Their manuscript, as insightful as it is, failed quantifying practice for individual position groups. The only other study to date that has practice demand in college athletes is Wellman *et al*. [12] who analyzed GPS and accelerometer data during training camp. They reported movement profiles by position and compared them to perceived levels of fatigue and soreness. Their two findings were that different positions have distinct movement demands and wellness measures were related to movement characteristics. Yet they failed to break up positons by speed zones which have been shown to be more insightful [18] then just high and low intensity distance. These two novel studies show the distinct difference in how movement demands can be quantified and analyzed in college football players.

Due to the nature of college football and the parameters in place set forth by the National collegiate Athletic Association (NCAA) [19], college practices vary substantially from team to team. DeMartini *et al*. [11], but were limited to team versus individual drills and lineman versus non-lineman. Their results concluded that non-lineman run more and have a higher HR than lineman, specifically in team versus individual drills. Non-lineman covered more distance during team drills and for total practice. Wellman *et al*. [12] as previously mentioned, looked at movement profiles of different positions during pre-season, but not during the season. In-season practice and fall camp schedules differ substantially, as loads tend to be higher in pre-season then in season [3], but only practice load have been reported not workload variables.

Overall, there is not enough research evaluating the physiological demand of a Division 1 football practice to determine if the demand at practice matches game requirements and whether different position groups experience different demands during practice. Therefore, the purpose of this study was to (a) determine the physiological demand of practice through GPS, accelerometer and HR monitoring, (b) compare the demands across position groups.

Materials and methods

Study Design

To examine practice parameters of NCAA Division I football players by position using GPS and HR monitors, thus gaining a better understanding of load during practice. GPS and HR was collected during normal practices of a Division 1 college football bowl subdivision team over a 10-week period (from August through October). In total, there were 550 measurable observations. Data was collected as part of a monitoring program in place to determine the wellbeing of the student athlete.

Participants

Data was gathered from 30 football players (age, 20.0 ± 1.0 years; mass 101.8kg: height 183.4 ± 9.2 cm). The players included two quarterbacks, three running backs (RB), six wide receivers (WR), five offensive lineman (OL), five defensive linemen (DL), five linebackers (LB), and four defensive backs (DB). They were no Tight Ends (TE) as the offense did not have a traditional TE position. The heights and weights for each position are presented in Table 1. All data and information met the University's Intuitional Review board's approval (IRB #2016-246). All data present was calculated from GPS, accelerometer and HR data.

Table 1: Position groups height and mass (mean ±SD)

Position	Height (cm)		Mass (kg)	
Quarterbacks (QB)	191.2	± 3.3	99.3	± 3.3
Running Backs (RB)	173.3	± 2.8	85.9	± 2.8
Wide Receiwr (WR)	180.4	± 9.3	85.3	± 8.5
Offensiw Line (OL)	194.7	± 3.5	135.6	± 7.8
Defensiw Backs (DB)	182.0	± 7.3	80.0	± 6.6
Linebackers (LB)	184.4	± 2.0	99.2	± 1.5
Defensiw Line (DL)	190.8	± 3.4	120.4	± 18.7

Procedure

Monitoring devices: GPS and HR data were taking together using a commercially available unit (Polar team Pro: Polar, Polar Electro Oy, Kempele, Finland) which had a sampling frequency for the GPS at 10 Hz, accelerometer at 200 Hz and 1000 Hz HR sensor. The Monitoring device (39 g, 36 × 68 × 13 mm) was a place around the chest with the sensor position across the xiphoid process. This monitor for HR has been shown to be a valid and reliable measure of HR [20]. GPS has been proven to be both reliable and valid in measuring distance and velocity during high intensity exercise [2], while acceleration data have been reliable and reliable when reporting bands of acceleration rather than absolute values [21].

Measurements

Heart Rate data

HRs were categorized into 6 HR zones, based off a volitional max test during summer training. HR zones where as follows: 0-60%, 60-70%, 70-80%, 80-90% 90-95% and 95-100% and have been used in previous monitoring literature [17]. Total HR exertion was calculated using Edwards internal training load method [22]. The percent HR reserve (% HR reserve) was calculated for each practice using the formula developed by Karvonen [23].

% HR Reserv = (exercise mean HR-resting HR) ÷ (HR max-Restisitng HR) × 100

Energy expenditure was derived from HR using the equation developed by Keytel *et al*. [24]. This equation has been shown to under estimate energy expenditure by 6-13% [25], but for general applications this is seen as acceptable.

Energy Expenditure = [(-55.0969 + (0.6309 x HR) + (0.1988 x weight) + (0.2017 x age))/4.184] x 60 x Time

HR max was recorded and average HR was calculated. Also reported is load and recovery values calculated by proprietary algorithms that where provided by Polar. These values are calculated based off of duration and intensity of the practice using time and HR data.

GPS Data

Frequency and Duration of running speed were broken down into the following speed zones: Standing and walking (0-6 $Km{\cdot}h^{-1}$), Jogging (6-12 $Km{\cdot}h^{-1}$), Cruising (12-14 $Km{\cdot}h^{-1}$), Striding (14-18 $Km{\cdot}h^{-1}$), High intensity Running (18-20 $Km{\cdot}h^{-1}$), and Sprinting (>20 $Km{\cdot}h^{-1}$). Data was also divided into Low intensity distance (0-14 $Km{\cdot}h^{-1}$), and high intensity distance (>14 $Km{\cdot}h^{-1}$). High and low intensity durations were then used to formulate a Work to Rest ratio [17]. From GPS Data Max speed and Number of Sprints (bursts over 20 $Km{\cdot}h^{-1}$), Total Distance was recorded, and average speed was calculated.

Acceleration data

Accelerations where broken down into deceleration and acceleration efforts. Each effort was classified into one of four categories: 0.5-0.99, 1-1.99, 2-2.99 and >3 $m \cdot s^{-2}$.

Statistical Analyses

All variables are presented in tables (2-4) as mean ± SD. A one-way ANOVA was used to analyze any main effect differences between position for each variable. If a main effect ($P \leq 0.05$) was detected a post hoc Bonferroni test was used. All statistical analyses were performed using Statistical Package for Social Science (IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY).

Results

HR Derived data (Table 2)

There was a significant ($P<0.001$) main effect of percent time spent in each HR zone. For 0-60% zone, the LB and QB groups were similar ($P>0.050$) and spent the most time in this zone, while the DB group spent the least amount of time in this zone ($P<0.001$). For 60-70% zone, the LB group spent the least amount of time in this zone, all others where similar ($P>0.050$). For 70-80% zone, the DB spent the least amount of time in this zone, all others where similar ($P>0.050$). For 80-90% zone, the DB, OL and WR groups had similar time spent in this zone ($P>0.160$), but spent more time ($P<0.001$) in this zone than the DL, QB, RB, and LB groups. For 90-95% and the 95-100% zones, there was no significant findings from the post-hoc analysis. For Polar calculated load the DB group recorded the highest load vales, and the LB group had the lowest values. For Polar recovery time there was no significant difference between positon groups.

Table 2: Percent (%) time spent in each HR zone & HR derived load and recovery

Percent time per HR zone (±SD)	Player Positions						
	QB	RB	WR	OL	DB	LB	DL
Zone 1: 0-60% HR max	82.07 ± 10.88*	78.81 ± 10.45	77.20 ± 10.52	73.70 ± 16.51	69.10 ± 13.10ϕ	83.81 ± 10.40*	75.96 ± 13.79
Zone 2: 60-70% HR max	10.69 ± 6.02	11.10 ± 4.79	11.41 ± 4.71	13.77 ± 6.93	13.30 ± 4.22	8.60 ± 4.33ϕ	13.84 ± 7.86
Zone 3: 70-80% HR max	5.45 ± 4.03	7.67 ± 4.59	8.06 ± 4.75	8.35 ± 6.11	12.46 ± 5.85*	5.82 ± 4.81	7.91 ± 5.39
Zone 4: 80-90% HR max	1.77 ± 2.63	2.36 ± 2.81	3.13 ± 3.92*	4.03 ± 5.74*	5.00 ± 5.02*	1.73 ± 2.54	2.14 ± 2.36
Zone 5: 90-95% HR max	0.02 ± 0.04	0.05 ± 0.12	0.19 ± 0.68	0.15 ± 0.47	0.13 ± 0.37	0.02 ± 0.06	0.13 ± 0.31
Zone 6: 95-100% HR max	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
Polar HR load (AU)	119.4 ± 67.0	128.84 ± 61.80	135.0 ± 55.2	111.1 ± 49.2	167.3 ± 84.1*	94.3 ± 51.9ϕ	123.2 ± 46.4
Polar Recovery (hours)	23.41 ± 29.8	19.04 ± 19.61	21.6 ± 25.8	41.7 ± 43.0	30.1 ± 26.5	16.8 ± 17.9	26.2 ± 22.1

Note: if there is was no significant (p>0.05) difference among position groups, they will have the same or no symbol.
*Significantly the highest (P<0.001)
ϕ Significantly the lowest(p<0.001)

Distance covered and time spent in speed zones (Table 3)

There was a significant ($P<0.001$) main effect for distances covered and time spent in each in speed zones. The QB, OL and DL groups significantly ($P<0.001$) spent the least amount of time in the speeds zones equal to or faster than Striding, yet the QB group covered the most distance walking while the OL and DL groups covered the least walking. The WR and RB groups significantly ($P<0.001$) covered the most distance and spent the most time in the faster speed zones (> 12 $km \cdot h^{-1}$). The DB group significantly ($P<0.001$) covered the most amount of distance and spend the most amount of time Jogging or Cruising, while spending the least amount of time walking. The LB group were similar across many variable, but spent most of their time in the Cruising speed zone.

Table 3: Distance (? MD covered and percentage of time spent in designated speed zone by position group

Distance (± SD) within speed zones	Player Positions						
	QB	RB	WR	OL	DB	LB	DL
Standing and Walking (0-6 km·h^{-1})	2736 ± 531*	2209 ± 451	2325 ± 649	1775 ± 335ϕ	2335 ± 509	2018 ± 440	1946 ± 430ϕ
Jogging (6-12 km·h^{-1})	1947 ± 556	1976 ± 485	1848 ± 533	1993 ± 498	2382 ± 700*	1798 ± 481	1824 ± 464
Cruising (12-14 km·h^{-1})	131 ± 52	276 ± 93*	300 ± 98*	163 ± 79	258 ± 108*	228 ± 104*	153 ± 88
Striding (14-18 km·h^{-1})	148 ± 79ϕ	401 ± 131*	405 ± 135*	132 ± 91ϕ	270 ± 127	216 ± 99	134 ± 93ϕ
High-intensity running (18-20 km·h^{-1})	40 ± 43ϕ	144 ± 57*	138 ± 65*	26 ± 31ϕ	68 ± 37	53 ± 30	29 ± 26ϕ
Sprinting (> 20 km·h^{-1})	54 ± 72	185 ± 78	231 ± 117*	28 ± 45ϕ	97 ± 73	72 ± 51	38 ± 49ϕ
Percent time per speed zone (±SD)							
Standing and Walking (0-6 km·h^{-1})	89.63 ± 4.22	88.81 ± 4.90	89.35 ± 6.15	88.84 ± 3.69	86.87 ± 4.39ϕ	90.26 ± 4.34	90.07 ± 4.56
Jogging (6-12 km·h^{-1})	9.50 ± 2.00ϕ	8.87 ± 1.92ϕ	8.22 ± 1.74ϕ	10.21 ± 1.80	11.42 ± 2.58*	8.33 ± 1.80ϕ	9.02 ± 1.74ϕ
Cruising (12-14 km·h^{-1})	0.37 ± 0.12	0.80 ± 0.29*	0.86 ± 0.25*	0.51 ± 0.23	0.76 ± 0.24*	0.67 ± 0.29*	0.45 ± 0.22
Striding (14-18 km·h^{-1})	0.34 ± 0.18ϕ	0.95 ± 0.33*	0.95 ± 0.30*	0.34 ± 0.21ϕ	0.66 ± 0.25	0.52 ± 0.20	0.33 ± 0.22ϕ
High-intensity running (18-20 km·h^{-1})	0.08 ± 0.08ϕ	0.28 ± 0.12*	0.26 ± 0.11*	0.06 ± 0.07ϕ	0.14 ± 0.07	0.10 ± 0.05	0.06 ± 0.05ϕ
Sprinting (> 20 km·h^{-1})	0.09 ± 0.10ϕ	0.30 ± 0.13*	0.36 ± 0.15*	0.05 ± 0.09ϕ	0.16 ± 0.10	0.12 ± 0.08	0.06 ± 0.08ϕ

Note: If there is was no significant (p>0.05) difference among position groups, they will have the same or no symbol.
*Significantly the most amount of distance or % time (P<0.001)
ϕ Significantly the least amount of distance or % time (P<0.001)

Important work variables (Table 4)
There was not a main effect for Total HR exertion (P=0.182), but there was a main effect for every other work variable (P>0.014). The QB group significantly (*P*<0.001) had the lowest work to rest ratio, while the WR, RB and DB had the highest ratios. The QB, DL and OL groups significantly (*P*<0.001) covered the least amount high intensity distance, while the RB and DB covered the most. The RB, and DB groups significantly (*P*<0.001) ran faster than any other group, and covered more distance at higher intensity and ran more sprints than any other group. The DB and LB groups were significantly (P=0.020) different for HR exertion per minute, but not different from any other position group. The DB groups significantly (*P*<0.001) coved more distance per minute than any other group, but was similar to the QB, RB, WR groups in total distance traveled. The DL group had one of the highest average HR (*P*<0.001), which were similar with the OL and DB groups, and shared the lowest max speed values with the OL group.

Table 4: Number of deceleration and acceleration efforts

Work Variable	Player Positions						
	QB	RB	WR	OL	DB	LB	DL
Total HR Exertion (AU)	20468 ± 5385	19823 ± 4714	20039 ± 4309	19478 ± 5027	19897 ± 4884	18455 ± 4776	19104 ± 4560
HR Exertion/min	215 ± 58	224 ± 68	224 ± 57	216 ± 75	241 ± 75*	202 ± 60ф	207 ± 60
Max HR (b·min^{-1})	184 ± 14	192 ± 19	195 ± 19	194 ± 20	192 ± 17	183 ± 18	195 ± 18
Average HR (b·min^{-1})	120 ± 11	119 ± 13	122 ± 10	129 ± 10*	128 ± 11*	115 ± 10	125 ± 10*
% HR Reserve	47 ± 8	45 ± 9	47 ± 9	50 ± 9	52 ± 9	44 ± 7	47 ± 8
Average work to rest ratio	1:34 ± 10ф	1:16 ± 5*	1:16 ± 6*	1:23 ± 6	1:16 ± 5*	1:20 ± 7	1:25 ± 7
Estimated Energy Expenditure (Kcals)	1625.3 ± 530.8	1530.7 ± 418.5	1595.6 ± 397.3	1677.4 ± 498.2	1638.1 ± 477.5	1407.3 ± 441.1	1575.8 ± 493.3
EE per minute of practice (Kcal/min)	9.6 ± 3.1	9.2 ± 2.5	9.8 ± 2.4	11.2 ± 3.3*	10.6 ± 3.1*	8.8 ± 2.8ф	10.4 ± 15.1*
Total Distance (m)	5057 ± 1110*	5192 ± 1002*	5246 ± 1345*	4118 ± 834	5410 ± 1317*	4386 ± 1022	4124 ± 923
Distance/Min	29.8 ± 6.5	31.1 ± 6.0	32.2 ± 8.3	27.5 ± 5.6ф	35.0 ± 8.5*	27.4 ± 6.4ф	27.3 ± 6.1ф
Total Time (Min)	170 ± 37	167 ± 42	163 ± 33	150 ± 38	155 ± 32	160 ± 37	151 ± 33
Low Intensity Distance: 0-14 km·h^{-1} (m)	4815 ± 1036	4462 ± 853	4472 ± 1133	3932 ± 790	4975 ± 1165	4044 ± 917	3923 ± 850
High Intensity Distance: >14 km·h^{-1} (m)	242 ± 166ф	730 ± 212*	774 ± 261*	187 ± 141ф	435 ± 209	341 ± 142	201 ± 141ф
Max Speed (km·h^{-1})	24.0 ± 2.5	26.4 ± 1.8*	27.4 ± 2.9*	22.5 ± 3.2ф	25.2 ± 2.2	24.8 ± 2.7	23.8 ± 5.4ф
# of Sprints (> 20 km·h^{-1})	9 ± 12	30 ± 12*	36 ± 17*	5 ± 7ф	16 ± 11	11 ± 8	6 ± 7ф
Average Speed (km·h^{-1})	5.4 ± 0.2ф	6.1 ± 0.3*	6.1 ± 0.45*	5.7 ± 0.3	5.9 ± 0.3	5.6 ± 0.3	5.6 ± 0.3

Note: if there is was no significant (p>0.05) difference among position groups, they will have the same or no symbol.
* Significantly the highest (P<0.001)
ф Significantly the lowest (p<0.001)

Deceleration and Acceleration efforts (Table 5)
There was a significant (*P*<0.001) main effect for every declaration and acceleration effort. The QB group had significant more decelerations greater than 2 m·s^{-2}. For declarations and accelerations of 0.05-0.99 m·s^{-2} all position groups where similar. For accelerations of 1.0-1.99 m·s^{-2} the DL group had the lowest amount of efforts (*P*<0.001), while every other groups were similar. For accelerations of 2.0-2.99 m·s^{-2} the RB and WR groups had significantly (P>0.43) more efforts than any other group. For acceleration over 3 m·s^{-2} the QB and LB position groups had the fewest efforts (*P*<0.034) than any other groups.

Table 5: Number of deceleration and acceleration efforts

Variable	Player Positions						
	QB	RB	WR	OL	DB	LB	DL
No. Decelerations > 3 m·s^{-2}	9.1 ± 15.1*	4.6 ± 3.3	5.1 ± 3.9	2.5 ± 2.6	4.6 ± 3.9	3.2 ± 3.6	3.1 ± 3.3
No. Decelerations 2.99-2 m·s^{-2}	32.5 ± 21.0*	16.5 ± 8.5	14.5 ± 8.1	12.3 ± 10.5	10.9 ± 10.5	8.1 ± 5.8	9.2 ± 7.8
No. Decelerations 1.99-1 m·s^{-2}	55.3 ± 24.6	76.3 ± 27.6*	66.8 ± 26.7*	55.2 ± 25.3	44.2 ± 23.2	58.8 ± 24.4	35.6 ± 15.3ф
No. Decelerations 0.99-0.5 m·s^{-2}	29.1 ± 13.4	42.8 ± 45.2	45.2 ± 20.9	38.3 ± 16.3	38.8 ± 17.1	39.8 ± 16.5	31.1 ± 11.2
No. Accelerations 0.05- 0.99 m·s^{-2}	24.4 ± 13.1	31.6 ± 13.4	28.9 ± 11.9	25.1 ± 18.8	27.4 ± 15.7	33.6 ± 16.9	22.9 ± 11.4
No. Accelerations 1- 1.99 m·s^{-2}	77.9 ± 40.6	81.2 ± 31.4	79.6 ± 35.7	63.7 ± 31.5	75.1 ± 34.3	68.6 ± 27.3	43.3 ± 14.9ф
No. Accelerations 2- 2.99 m·s^{-2}	23.4 ± 18.3	37.7 ± 18.8*	30.3 ± 14.8*	28.6 ± 18.8	21.7 ± 12.6	19.9 ± 11.4	19.8 ± 8.8
No. Accelerations > 3 m·s^{-2}	3.5 ± 9.1ф	11.0 ± 7.3	11.7 ± 8.1	11.9 ± 10.2	10.9 ± 10.7	5.9 ± 5.5ф	13.1 ± 10.6

Note: if there is was no significant (p>0.05) difference among position groups, they will have the same or no symbol.
*Significantly the highest (P<0.001)
ф Significantly the lowest (p<0.001)

Discussion
This study's aim was to examine the physiological load of NCAA Division 1 football practices using GPS, accelerometers and HR data. Data was analyzed by position, and values were compared to provide insight into different demand of each position. In general, your skilled positions (WR, DB, LB, and RB) covered more distance at practice, ran faster, and covered more distance in high intensity speeds. It

has been previously reported that non-lineman travel more distance then lineman [11, 12], our data showed similar trends, with lineman covering less distance than non-lineman. Difference in position groups was clearly outlined by Wellman *et al*. [12], that different positions move more, depending on how far they are away from the ball, and the nature of their position (i.e. most of offensive lineman's movement occurs at or near the line of scrimmage with very little down field running (pg. 2714). One difference that has not been addressed in previous literature are the special team's demands of football players. One explanation on why certain groups may run more could be there participation on special teams. It is very often made up of WR, DB, RB, and LB position groups. This excludes QB, OL, and DL, who typically are not on kickoff, kickoff return, punt and punt return. Very often these plays result in more distance travel as they are an attempt to change field position. This could help further explain why positions who are typically more on special teams may also show more distance traveled and load.

One interesting finding from our data is that lineman traveled 4,109 m and non-lineman covering 5,010 m which is greater than previously reported practice data [11, 12]. Differences in data could be contributed to pre-season vs in-season [3], practice style (tempo), duration of practice and size of practice facility [11, 12]. The current study practice lasted 160 ± 36 minutes was conducted in an up tempo short periods with high energy and very little down time, so players were constantly moving from one drill to the next, and to different parts of the practice facility.

There are some similarities between the current study and previous research [4, 11, 12]. The majority (90 %+) of distance covered were at speeds less than 15 $km \cdot h^{-1}$. Also, distance covered in high speeds (20+ $km \cdot h^{-1}$) was less than 5% of total distance covered [11, 12]. These similarities show a general trend that the majority of football practice is spent in slow speeds or low intensities with short burst of high speeds that do not contribute a lot to total load or distance traveled. This information leads to two conclusions. First, the aerobic system of football players is key as the majority of work done at practice appears to be lower intensity in nature, and second, high speeds are reached in practice by all groups (22-27 $km \cdot h^{-1}$) and the same requirement is equal if not higher in games [4]. Overall, football players need to have a strong aerobic base to maintain aerobic capacity for the duration of practice and games while still having the explosive strength to reach high levels of speed.

For more internal loads, HR data among groups were similar across all measures with the majority (~80%) of practice being spent in the 0-60% HR zones. This is the first study that has addressed HR zones in NCAA Division I football players, and evaluating with the average HR around 130 $b \cdot m^{-1}$, this is similar to previous data that reported average HR during practice [11]. The HR data would further indicate that the majority of practice is spent performing low intensity exercise. When addressing HR data, it appears that internal loads are similar across all position groups, with little difference between Heart Rate Exertion, max HR or % Heart Rate Reserve. This may indicate that internal loads are similar across position groups as fitness level, body type, and nature of the position seem to equate internally as measured by HR. DBs may be lighter, smaller, and in better aerobic shape than their DL counter parts who are larger, taller [26], and more adapted to short powerful bursts, rather than high speeds and long distances. HR data has been used to measure exercise intensity [27], yet the idea of whether HR can be used in sports with varying pace has mixed results with some saying it does [28], and others say it does not [29]. Yet, these studies are done in soccer players with little data on American Football players. With only one other study [11] measuring HR data during football practice and showing that team drills and position drills elicit different HR responses, the use of HR monitoring for intensity of practice or internal load needs further exploration.

One of the main reasons to monitor athletes is to determine training load. This can be done through high tech monitoring (GPS, RFID) [17] or Rate of Perceived Execution (RPE) based load scale [30]. The objective load derived from GPS have been created and calculated via the manufactures of the GPS device. These load metrics have been used to evaluate load in College football players [3, 9, 12]. Each GPS unit calculates load differently, some use an algorithm that used GPS data and accelerometer data. The Polar Team Pro system reports a load but as a measure of HR and intensity, the results of Polar load and recover values showed that the DB groups had the highest load and LB had the lowest. We also took an open and novel approach to address load based off of work variables used by Cunnifee *et al.* [17]. Variables of interest where HR exertion, percent HR reserve, work to rest ratios, estimated energy expended, number of sprints and distance traveled in lower or high intensities. When evaluating data based off of HR, it appears that all position groups displayed similar responses in HR exertion, HR reserve, and estimated energy demand. This research is the first of its kind in college football players, but it appears that HR may be similar in other sports that showed no difference in HR data among different positions in rugby Rugby [17] and soccer [31]. HR is usually an indicator of intensity, but needs to be broken down into periods or segments of practice to give a better indicator of intensity. HR as a whole might not be able to tell you the demands of an entire practice [11]. Addressing Work to rest ratio it appears that QBs have the lowest work to rest ratio. For every second they spend in high intensity of work (> 8 $km \cdot h^{-1}$), they spend 34 seconds lower intensity or rest (0-8 $km \cdot h^{-1}$). OL, DL, and LB position groups have similar ratios while the DB and WR groups have the Highest ratios (1:16). This crude way to measure work to rest is very dependent on position and is probably grounded in the amount of distance players move during and after each play. For example, OL may only move 5 m during a play as they may be restricted to downfield motion, but a WR may run a route that covers 40 m then have to jog back to the line of scrimmage. Further work needs to be done to determine if work to rest ratios may be an effective way to evaluate load in football players, however, it shows promise.

One of the more objective ideas of using GPS data is to determine if it mimics game demands. Since game data was not collected and there is limited published data on game demands, comparisons will be draw from Wellman *et al*. [4] work. This is purely observational; No statistics were run. (Table 6) For distance measures, total distance covered was greater in the practice measurements than in games. This is attributed to the nature of practice and distance moved within practice from different positions and area of practice field. This observation carried over into the distance traveled at low intensity. The greater amount of low intensity distance was covered during practice than in games. This relationship changes as intensity increases. In game situations more distance was covered in moderate to sprint intensities than in practice, accounting for a larger percentage of distance at higher speeds (23% game vs 13% practice at intensities > 10 km·h^{-1}). Average max speeds were greater for game data than practice data. Even though this is not a direct comparison of the same players under the same conditions, a general conclusion can be drawn. Practice may be performed at lower intensities, than during a game. This can be attributed to self-regulation of players as they know it is practice and overall intensity and stakes are not as high. This comparison could also be drawn by looking at Wellmen's work in both of their papers [4, 12]. Coaches would agree that practices even if the intent is to mimic game situations, practice will never truly be at the same intensity of a game. This should be taken into consideration when evaluating max speeds and distance traveled as a measurement of effort during practice.

Table 6: Game vs Practice Comparison

Table VI. Game vs Practice Comparison

Variable		Player Positions						
		QB	RB	WR	OL	DB	LB	DL
Total Distance (m)	G	3751	3140	**5530**	3652	4696	4145	3144
	P	**5057**	**5192**	5246	**4118**	**5410**	**4386**	**4124**
Low Intensity Distance (m)	G	3661	2291	3546	2885	3448	2989	2581
	P	**4684**	**4186**	**4172**	**3768**	**4717**	**3816**	**3771**
Moderate Intensity Distance (m)	G	**568**	**738**	**1530**	**913**	**926**	**912**	**647**
	P	279	677	705	295	528	444	286
High Intensity Distance (m)	G	**138**	**303**	**655**	**131**	**513**	**435**	**192**
	P	40	144	138	26	68	53	29
Sprint Distance (m)	G	**76**	**101**	**315**	**9**	**247**	**196**	**18**
	P	54	185	231	28	97	72	38
Average Max Speed (km·h^{-1})	G	**29**	**28**	**32**	**24**	**31**	**30**	**25**
	P	24	26	27	23	25	25	24

G= Game data derived from Wellman et al. 2016

P= Practice data from current study

Bold= Larger observed value

Conclusion

In conclusion, GPS, Accelerometer and HR data can be used to measure physiological demands of practice in NCAA division-1 football players. The data from this study and current literature has developed what a player's movement profile look like. The results from this study have confirmed the different demands placed on each position especially the DB and WR groups covered more distance and at higher intensity. What is novel about this study is the integration of all three ways to monitor performance. These results may guide further research as movement demands might be different among position groups, but the HR responses were similar, indicating that there is specific adaptation and physiological differences among position groups that yield similar responses. Lastly, practice demands and game demands are similar, yet the intensity level of games appears to be higher.

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Conflict of Interest

The authors report no conflict of interest and the results of the present study do not constitute endorsement of the product by the authors.

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