USING A GLOBAL POSITION SYSTEM TO TRACK

SELECTED PHYSICAL DEMANDS OF NCAA

DIVISION I FOOTBALL PLAYERS DURING GAMES

By

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PHYSICAL DEMANDS OF NCAA DIVISION I FOOTBALL

PLAYERS DURING GAMES

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PURPOSE: To compare differences in distance traveled, maximum velocity, accelerations, decelerations, and high intensity change of directions in Division I football players. METHODS: Twenty-one Division I football players, ages 18-24, wore global positioning system (GPSs) monitors during games to track selected variables of each athlete. Athletes were grouped by similarities in playing position in the following manner; wide receiver (WR) and defensive back (DB), and offensive linemen (OL) and defensive linemen (DL). Parameters measured were total distance covered, maximum velocity, total inertial movement analysis (IMA) (movements >3.5 m/s^2), distances traveled in deceleration and acceleration using two velocity categories for each (Deceleraton band 1=3-10m/s^2 Deceleration band 2=2-3m/s^2, Acceleration band 7=2 3m/s^2, and Acceleration band 8=3-10m/s^2). Inclusion criteria included that athletes must have participated in 70% of the total plays during the games selected. A Oneway ANOVA analysis with 95% confidence interval for means was used to determine differences ($p<.05$) among groups. Newman Keuls post hoc tests were used to determine mean differences. RESULTS: The results of The present study indicated that DBs scored significantly *(p<0.05)* higher in total distance covered, total IMA, deceleration and acceleration in both Band 1 and Band 2 than WRs. There was no significant difference between DBs and WRs in maximum velocity. DL scored significantly higher in maximum velocity, deceleration and acceleration Band 1 than OL. There were no significant differences between DL and OL in total distance covered, total IMA, and deceleration and acceleration Band 2. CONCLUSION: DBs and DL travel further, average higher maximum velocities, and accrue more high intensity, explosive movements throughout a game than WRs and OL.This study provides quantification of positional physical demands and comparisons of collegiate football games and could be used to develop position specific training programs to better prepare athletes for play.

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CHAPTER I

INTRODUCTION

Global positioning systems (GPS) tracking and the use of accelerometers in sports is a

relatively new concept. It was developed in the last 10-15 years and is gaining popularity. The

technology can be used to monitor many different aspects of various sports and many styles of

this technology are currently available. Most require the athlete to wear a small GPS monitor on

the upper part of their back, usually placed between the shoulder blades. This is accomplished

by placing the monitor in a pouch that has been sewn onto a shirt or in a custom made bra

provided by the company. The current forms of this technology are capable of accumulating a

substantial amount of data and to track many different types of parameters for coaches, trainers,

and exercise scientists to evaluate and to further develop training and game strategies for their

athletes and teams. Each GPS/accelerometer company has its own software that is capable of

collecting a variety of data which place the results into easy-to-read tables. However, it is up to

the coaches, trainers, and exercise scientists to analyze the data and to make decisions based

upon the information.

There have been a select number of studies involving GPS tracking and the use of

accelerometers in sports to measure overall stress, performance variables, and risk of injury

(Boyd et al., 2011; Cormack et al., 2013; Gabbett et al., 2012). However, validity and

reliability is of upmost importance when testing new technology. In a study involving the same technology that was used for this research, it was found that the devices showed high levels of reliability with a coefficient of variance (CV) of 1.9% in low and high intensity activity during field testing and it was concluded that the accelerometers could be applied to athletes to confidently assess changes in workload (Boyd et al., 2011). GPS devices have also been used to assess risk of injury. For example, Gabbett and associates (2012) found that the distance covered in mild, moderate, and maximum accelerations and velocities were related to risk factors for injuries (Gabbett et al., 2012). Position specific demands have also been recorded using GPS tracking. One such study focused on Division I football players during preseason practice. Not surprisingly, the main findings were that non-lineman covered more distance and obtained higher velocities than lineman during practice (Demartini et al., 2011).

Currently, little is known of the amount of work with respect to distance, velocities, and similar variables placed upon American collegiate football players at selected positions. While coaches feel they may have a good impression of the amount of work players are subjected to, physical and thermal injuries remain a concern. It becomes more difficult to evaluate the stress level of players during a competitive game. The goal of this study is to compare the distance traveled, top speed, acceleration variables, and similar GPS-tracking information between similar offensive and defensive positions to gain a better understanding of the demands placed on athletes during a game and throughout an entire season. Additionally, comparisons of the aforementioned variables will be made based on players positions both in practice and in games. With this new found understanding of workload on athletes, athletes and coaches can use better preparation methods for competitive play by implementing better practice and conditioning plans.

Hypothesis HO₁

There will be no difference in distance traveled (DT), maximum velocity (MV), total IMA, and the distance traveled in acceleration and deceleration bands between DBs and WRs. There will also be no difference in DT, MV, total IMA, and the distance traveled in acceleration and deceleration bands between DL and OL.

CHAPTER II

REVIEW OF LITERATURE

TRAINING LOAD & STRESS MEASUREMENTS

There are numerous factors that affect an athlete during games and practice. Calculating training load and overall stress on the body has been established for some time. However, the use of GPS microsensors with integrated accelerometers is becoming ever more popular as a new way to calculate load. This new technology was initially not widely accepted early due to poor reliability and validity when measuring total distances at a fast rate of speed (Cormack et al., 2010). However, these devices have the capability of measuring gross fatiguing movements such as impacts and high accelerations. Recently, upgrades in the technology have improved the reliability and validity which could have a lasting effect on how exercise scientists and coaches calculate work load. Boyd and Colleagues conducted a study to assess the reliability of the MinimaxX (Catapult Innovations. Scoresby, Victoria) accelerometer in the laboratory and in the field. They utilized the equipment with Australian football players (Boyd et al., 2011) and used Player Load to calculate accelerations and decelerations in three planes. For testing, 10

accelerometers were positioned on a custom-designed cradle and subjected to six 30 sec trials with a 2 min. interim period. Following three lab trials, monitors were placed on 10 athletes who underwent 180 minutes of team sport skills training involving high-intensity activities such as jumping and changing direction. Next, researchers moved to the dynamic testing of the accelerometers. For this part of the experiment, an Instron 8501 hydraulic shaker was used. Eight MinimaxX monitors were securely attached to the shaker and subjected to 10 trials of 10 seconds each. The lab testing was conducted to ensure validity and reliability of the devices before use in the field portion of the experiment. For the field portion of the experiment, data was collected during nine Victorian Football League matches over the 2009 pre- and premiership seasons. The results showed an acceptable level of validity and reliability both in the lab and on the field. The within-device reliability (CV 0.9 to 1.05%) and between-device reliability (CV 1.02 to 1.04%) were both superior to previous studies conducted on different brands of microsensors. Additional important data found from this study was that the devices remained stable over a long period of time, which in turn kept them from drifting from the baseline measurement. The devices also showed high levels of reliability in low and high intensity activity during the field test. The authors concluded that these accelerometers could be applied to athletes to assess changes and workload confidently.

Cormack and Colleagues (2013) conducted a study using seventeen elite Australian football players, participating in 22 matches, to test tri-axial accelerometers and the correlation between the microsensor's data and neuromuscular fatigue (NMF). The parameters measured were load per minute (LPM), high-speed-running (HSR), meters per minute at >15 km/h, and total distance relative to playing time (m/min). The results indicated NMF status affects how LPM is recorded in elite Australian Football players. In the fatigued state compared with the

nonfatigued state, there is an important reduction in the contribution of the vertical accelerometer vector to LPM. The researchers suggested that their findings demonstrated the value of using microsensors to monitor load per minute to calculate NMF. They also reported that player and activity profiles could benefit from the technology as well. The collection of data on individual players could possible allow threshold values for individual accelerometer vectors that may be used as an indicator of change in a player's movement during a match.

The ability to measure external load on an athlete and provide analysis and strategies for the best training regimen has also been a goal of strength and conditioning coaches. GPS sensors with integrated accelerometers have shown to be quite reliable in collecting data to calculate load. For instance, Boyd and Colleagues (Boyd et al., 2013) studied 40 Australian Football (AF) players. The first parameter used was Player Load 3D (PL3D), which was a calculation of all movements in 3 vectors (up and down, side to side, front to back) and the second parameter was Player Load slow (PLslow), which was all activities performed at low velocities (<2m/s). Twenty-four matches and 32 training sessions were analyzed and players were broken up into two groups, elite and sub-elite level. A major finding of this study was that "accelerometers detected differences in external load between activities (training drills and matches), playing positions, and from elite to sub-elite competition." The authors also found that the microsensors were capable of differentiating between low-velocity and high velocity activities, due to the fact that different outcomes occurred when reviewing the numbers. There was also a very strong correlation *(r=.94)* between the total distance that the athlete traveled and the measure of PL. This suggests that PL could be an accurate analysis of movement load in Australian Football matches when other methods are unavailable. The authors concluded from this study that using GPS sensors integrated with tri-axial accelerometers could be a

useful tool for comparing loads in practice and games. The authors also stated that "accelerometers have the potential to provide a supplementary measure of low-velocity external load that may be underestimated by current

time-motion-analysis methods."

Lovell, Sirotic, & Impellizzeri (Lovell et al, 2013) conducted a study that was the first of its kind to assess the relationship between external training load (TL) and Ratings of Perceived Exertion (RPE) using GPS microtechnology. They measured the external load parameters of distance, high speed running (HSR), Player Load, and impacts of thirty-two professional rugby league players from the same National Rugby League (NRL) club. They found significant within-individual correlations *(r=.82)* between RPE and other measures of load and intensity. Total distance covered and HSR were highly correlated with RPE, while intensity measures of m/min and HSR/min were moderately correlated. They suggested large correlations were seen between RPE and accelerometer measures of body load and impacts. Also, intensity measures of body load/min and impact/min showed moderate correlations with RPE. The findings from this study provide evidence to support not only RPE's validity, but also GPS/accelerometer validity as well. Finally they concluded that both internal and external factors influence RPE and both should be analyzed to provide the most accurate measurement of training load (Lovell et al., 2013).

In order for strength and conditioning coaches and sport coaches to effectively design a training program, they need a good understanding of the internal response that a training load will evoke in each athlete (Gallo et al., 2015, as cited in Gaudino et al., 2015). A well-known and proven way of calculating internal response is by studying an athlete's Rating of Perceived Exertion (RPE). Gaudino, Iaia, & Strudwick (Gaudino et al., 2015) conducted a study using

twenty-two soccer players from the English Premier League to determine the relationship between external load parameters and RPE during elite soccer training. Each player's RPE was collected individually in private 20 minutes after the session to ensure the perceived effort did not reflect the most recent exercise bout, but in fact the entire training session. The parameters derived from the GPS/accelerometers were total HSR (>14.4 km/h) and very HSR (>19.8 km/hr) running distance, HSR per minute, acceleration/deceleration activity, metabolic power, impacts, and body load (Player Load). The results showed significant within-individual correlations between RPE and external measures of training load. A moderate correlation was seen between the number of accelerations during the session and actual RPE. They concluded that speed, acceleration, and impacts were strong predictors of RPE in soccer. Thus, using these parameters could be a good tool for coaches and trainers to analyze workload.

The primary objective for strength and conditioning coaches and sport coaches is to develop a program that pushes the athletes to their maximal performance capabilities but minimizes the negative consequences of training such as overtraining and injury (Gabbett & Ullah, 2012). The objective is to find the perfect combination of overloading the stimulus, providing adequate recovery to promote strength and agility gains, and reduce the risk of injury and overtraining. In the past, measuring training load on the athletic field of play has been rather difficult and quite subjective. Gabbett and colleagues (2012) conducted the first study of its kind to use GPS and accelerometer derived data to document highly accurate running loads of elite rugby players to investigate a correlation between high training load and increased risk of soft-tissue injuries associated with overtraining. Thirty-four elite rugby players were measured during preseason and season matches. The parameters used for this study were total distance, HSR, accelerations, decelerations, velocity, and physical contact. A new form of measurement

that was used in this study but not in previous studies in this literature review was repeated high-intensity efforts (RHIEs). This was defined as three or more, high-acceleration, high-velocity, or contact efforts with less than 21 seconds recovery between efforts. The author's findings were significant. They found that the distance covered in mild, moderate, and maximum accelerations and velocities were relative to risk factors for injuries. Similarly, athletes who accumulated more distance in the lower acceleration and velocity bands were less likely to sustain a lower body soft-tissue injury, suggesting that reducing the amount of sprinting performed prior to team competition is beneficial. The authors also suggested that measuring tackling, collisions, and repeated efforts (RHIE) is an important contributor to possible injury risk and is believed to be imperative to quantify these activities relative to soft-tissue injuries. The results of this study show that the more an athlete runs at a very high velocity, the greater the risk of a lower body soft-tissue injury.

Calculating total daily energy expenditure (TDEE) allows strength and conditioning coaches to provide sound nutrition programming for athletes (Walker, McAinch, Sweeting, & Aughey, 2015). However, very little is known about how much training and games influence energy expenditure or contribution of these variables to TDEE. Walker and Colleagues suggested that GPS and inertial sensors (accelerometers) could provide a solution to measuring physical activity (PA), metabolic power, and energy expenditure in team-sport athletes. Walker and Colleagues conducted a study using 18 professional Australian football players in an attempt to develop an algorithm that uses microsensor derived data and oxygen uptake to measure energy expenditure during training and games and to also test the microsensor technology. The athlete's maximal aerobic power (VO2max) was determined by using an incremental exercise test completed on a motorized treadmill. The technology used was MiniMax and accelerometer data

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was used to calculate PlayerLoad (Catapult Innovations, Scoresby Australia) for each stage of the maximal test (Walker et al., 2015). PlayerLoad is a modified scaled vector magnitude and is a measure of total effort, relative to the rate of change in each of the three vectors divided by 100. It was determined that sagittal plane acceleration and deceleration are primary drivers of energy cost and that additional force is required to overcome acceleration. They concluded that tri-axial accelerometers provided a simple, non-invasive and productive method of estimating energy expenditure during contact sports. Also, PlayerLoad and calculated energy expenditure showed a positive correlation with the MiniMax metabolic power calculation, which suggests that inertial sensors and GPS are valuable methods that provide estimates of energy expenditure during contact sports.

Wellman, Coad, Goulet, and McLellan (2015) conducted a study that focused on the demands placed on athletes during NCAA Division I college football games. The purpose of the study was to record and examine the physiological movement demands of football players using GPS technology. The study used portable GPS with integrated tri-axial accelerometers to quantify the position-specific movement patterns. Thirty-three NCAA Division I Football Bowl Subdivision players participated in this study ranging from 18-22 years in age. The GPS monitors were placed in the center of the upper back, slightly superior to the scapulae, in accordance with previous studies in this review. Data recorded from GPS monitors were assessed as variables including total, low-intensity (0-10 km/h), moderate-intensity (10.1-16.0 km/h), high-intensity (16.1-23.0 km/h) , and sprint (>23.0 km/h) distances, maximal velocity (km/h), and counts of sprint, acceleration and deceleration efforts. Findings showed that the wide receiver (WR) position group traveled further distances in moderate, high, and sprint intensities than any other offensive position group, including running backs (RB), quarterbacks

(QB), tight ends (TE), and offensive lineman (OL). Out of all of the offensive position groups,

the OL traveled the shortest total distance in all of the intensity zones. However, the OL groups

were involved in significantly more moderate acceleration and deceleration efforts than the RB

and QB positions. For the defensive groups, the defensive backs (DB) and linebacker (LB)

positions covered significantly greater distances in all zones than the defensive end (DE) and

defensive tackle (DT) positions. Also, the average maximal speed was significantly greater in

the DB and LB groups than the DE and DT groups. The DB group was involved in

significantly more sprint efforts, moderate, high, and maximal acceleration and deceleration

efforts than the DE and DT groups. It was determined from the results of this study that the

design of position specific conditioning programs implemented by coaches could possibly be

beneficial. Given WRs, DBs, and LBs covered greater total running distance in games than

their teammates, it is reasonable to suggest athletes in these groups may require modified

conditioning volumes during training to help with recovery and better prepare them for the

demands of competition (Wellman et al., 2015).

A similar study was conducted using 49 NCAA Division I college football players to assess

their physical demands during preseason training in the heat (DeMartini, Martschinske, Casa,

Lopez, Ganio, Walz, and Coris, 2011). GPS monitors with tri-axial accelerometers were worn on

the upper back between the shoulder blades during preseason practices. Data were collected over

8 consecutive days. Total distance covered was significantly higher in nonlineman (NL) than

lineman (L) (3,532 ± 943 vs. 2,573 ± 489 m). Total distance covered was significantly higher in

starters (S) vs. nonstarters (NS) (1,222 ± 508 vs. 850 ± 525 m). The main findings from this study

were that NL covered more distance and obtained higher velocities than L. DeMartini and

colleagues (2011) concluded that data acquired using GPS technology can accurately assess specific components of athletic performance. This information could lead to improved conditioning practices to more closely resemble sport demands and enhance performance. Also, strength and conditioning professionals can use game data to determine proper exercises to mimic the volume and speed appropriate for conditioning sessions.

Performance Variables

In addition to overall stress placed on the athlete (Player Load), or the stress that collisions and impacts place on athletes, the validity of GPS devices with integrated accelerometers in reading performance variables such as sprinting is also important. Before this new technology was developed, infra-red timing gates were most commonly used to assess sprint performance (Waldron, Worsfold, Twist, & Lamb, 2011). Waldron and Colleagues tested the validity of GPS sprint times against timing gates. Nineteen elite male rugby players volunteered. Before testing the actual sprints, players were taken through a dynamic warm up and stretching routine by the squad coach to insure readiness for maximal efforts. The experiment consisted of only two sprints on a grass surface with three minutes of rest between each sprint. Validity was determined by comparing mean speed (km/h) at 10m, 20m, and 30m and moving speed between 10m and 20m measured by timing gates with values recorded using GPS monitors. The results showed significant differences in speed variables such as acceleration in 10m, 20m, and 30m measurements between GPS and timing gate values (Waldron et al., 2011). However, the researchers acknowledged it was possible that the custom algorithms integrated within the newer 5 Hz devices may account for the clear differences in the level of agreement between methods. Specifically the GPS devices integrated with accelerometer technology could possibly be used to calculate small variables in sprint performance.

Impact forces play an important role in overall load in many sports where running and change-of-direction movements are common because the impact forces can be caused by the force of the foot hitting the ground (Nigg & Liu, 1991). In order for measures from accelerometer data to be used, the accuracy and precision of GPS monitors integrated with accelerometer microsensors must be tested for its validity (Wundersitz et al., 2013). Wundersitz and colleagues (2013) conducted a study using seventeen team sport participants to compare accelerometer readings with Ground Reaction Force (GRF) values derived from a force plate to check the accuracy of accelerometer microsensors. A tri-axial accelerometer was used along with a digital video camcorder to identify impact events and infrared timing gates to determine running velocity to provide readings for force recordings. Trials included accelerating straight ahead until reaching a force plate, at which point the athlete either kept accelerating or attempted a hard change-of-direction, followed by a hard acceleration to the finish line. Upon completion of the first five trials, rest was given to the athlete before initiating a second round of five trials containing a different change-of-direction movement. The results showed that accelerometer data significantly overestimated force plate GRF for all running and change-of-direction drills. In addition, as the change-of-direction action became more severe or the athlete made a harder cut, the measurement error increased. The location of the accelerometer on the body could play a part in force readings. This flaw of measuring accelerometer force to indirectly estimate foot-strike impact force is that separation of the accelerometer unit from the individual, may amplify errors. The results showed that upper-body mounted accelerometers could play a role in measuring impact forces over time to provide information for exercise prescription. However, accelerometers worn on the upper body should not be used as an absolute measure of a single foot-strike impact force because they cannot provide high levels of

accuracy.

The advancements in microtechnology and player analysis have increased the knowledge of the overall physical abilities of an athlete and the stresses placed on the athlete (Sullivan, Bilsborough, Cianciosi, Hocking, Cordy, & Coutts, 2014). Sullivan and Colleagues state that it is now "common practice for most AFL players to wear microtechnology devices during matches to provide coaching staff with real-time feedback on physical activity profiles." A study was conducted to assess what physical and skill measures are associated with coaches' vision of performance and player rank. They used units containing 10-Hz GPS and 100-Hz accelerometers from Catapult Innovations to measure high speed running (HSR), total distance traveled, body load (Player Load), max velocity, frequency of sprints, and accelerations of forty professional Australian football players. The results revealed that what a coach perceives as good or productive as a player is due to skill-based characteristics. Distance traveled, body load (Player Load), max velocity, frequency of sprints, and accelerations of forty professional Australian football players. The results revealed that what a coach perceives as good efficiently as the high-caliber player. The authors made the conclusion that match activity profiles should not be used as an independent measure of the performance of the athlete. Profiles with data derived from GPS units integrated with accelerometers are believed to be good tools for the analysis of athletic ability and workload in athletes rather than calculating actual performances in games or matches. The purpose of this study is to compare the distance traveled and Player Load value of offensive players with the distance traveled and Player Load value of defensive players to gain a better understanding of the demands placed on athletes during a game and throughout an entire season. This will hopefully lead to better practice planning and injury prevention tactics.

Purpose

The purpose of this study was to investigate and compare the physical demands placed on Division I collegiate football players at selected positions during four conference games during the 2016 season using GPS monitoring. Specifically, comparisons among four different positions will be made on positional mean differences in total distance traveled, top speed, accelerations, decelerations, and total high intensity change of directions.

CHAPTER III

METHODS

Participants

An application was submitted to the Institutional Review Board (IRB) on January 24th, 2017 and approved after revisions on March 16th, 2017 to conduct this study. Twenty-One NCAA Division I collegiate football players between the ages of 18 and 24 were used for this study. The participants were based on playing position and status. Participants include offensive linemen (OL), wide receivers (WR), defensive linemen (DL), and defensive backs (DB), which includes cornerbacks and safeties. The participants were grouped by assumed similarities in activity as follows: wide receivers and defensive backs and offensive and defensive linemen. Only those designated as game starters were chosen in order to track relevant data each game. Games were chosen based on percentage of playing time. All subjects participating in this study played in at least 70% of the total snaps during the game.

Material

Optimeye S5 (Catapult Innovations of Australia) monitoring devices were used to track each athlete. These devices are equipped with a 10Hz GPS engine, and an accelerometer and gyroscope that both measure at 100Hz. Openfield, a software provided by Catapult, was used as an interface for managing the data after it was downloaded. Microsoft Excel was used to place the

data in a table and graph format.

Procedure

The GPS monitors were charged prior to each game. The monitors were charged on average for 30 minutes to an hour before alarms were set and the monitors were placed in each player's shoulder pads. Alarms allowed investigators to set the devices to turn on at a certain time prior to placing monitors in shoulder pads without manually turning each device on. To set the alarms, the monitors were docked in a computer friendly case that is capable of housing up to 30 monitors. To avoid confusion, two separate cases were used, one for defensive players and one for offensive players. The cases were plugged into a laptop using USB cables and the alarms were set using the software provided by Catapult Innovations. Times were set using standard military time. After the alarms were set, the cases were unplugged from the computer and taken into the team's locker room so that the monitors could be placed individually into each of the player shoulder pads. The monitors were placed on the posterior side of the pads and rested between the shoulder blades of the athlete. In order for the monitors to stay in place throughout the entire session, they were placed in mesh pouches that have a Velcro strap sewn on for increased stability. In no way did the monitor restrict the athlete's movement during athletic play. The monitors were strapped into the pads the night before the game. Upon completion of the game, the monitors were immediately taken off of the players and turned off manually in order to decrease download time. Once all of the monitors were retrieved, they were docked again in their respective cases and plugged into a laptop using a USB cable to begin downloading. The data was downloaded onto Catapult Innovation's software operating system, Openfield. Depending on how long the game lasted, the download took between 30 minutes to an hour. Upon completion of the download, the cases were unplugged from the laptop, closed,
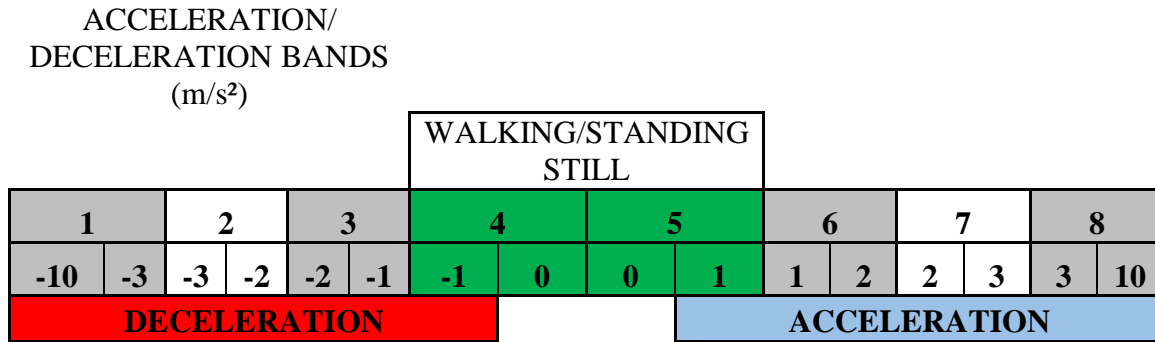
and stored away until the next game. Once all of the data was downloaded and in the operating

system, it was manually time stamped into quarters for that day's game. The data needed to be

time stamped in order to cut out unwanted "noise" in the data. This includes rest times, down

times between quarters of a game, and halftime of a game. For time stamping, standard military

time was used. Once the data was time stamped, the data was dropped into pre-made tables and

graphs that were designed manually prior to that particular session. For personal preference and

ease of use, the tables were saved and downloaded onto a Microsoft Excel document. The

numbers in this document were then copied and pasted into a Microsoft Excel template that was

manually made to fit the coach's preferences of how he/she wanted to report the data. The

numbers were copied and pasted next to their respective athlete.

Parameters Defined

For this study, seven parameters were used to measure stress and intensity. Distance

traveled (DT) (odometer) was measured in meters (m) and was used to determine the total

distance traveled by each athlete. Maximum velocity (MV) was measured in kilometers per

hour (kph) and is defined as the maximum speed that the athlete attained during that session. A

parameter developed by Catapult called Total Inertial Movement Analysis (Total IMA) was used

to measure the total number of times an athlete accelerated, decelerated, or changed direction at

high intensities, a speed greater than 3.5 m/s^2. Accelerations and decelerations were broken into

bands in order to track high intensity movements. Bands ranged one to eight, 1-4 being

decelerations and 5-8 being accelerations. In order to only analyze high intensity movements for

this study, only bands 1, 2, 7, and 8 were recorded. Band 1 consisted of decelerations between 3-

10 m/s^2 (D310). Band 2 consisted of decelerations between 2-3 m/s^2 (D23). Band 7 consisted of

accelerations between 2-3 m/s^2 (A23). Band 8 consisted of accelerations between 3-10 m/s^2

(A310). The average distance traveled by each position group in each band was recorded for this study. Figure 1 below further explains acceleration and deceleration bands.

Fig. 1

ACCELERATION/
DECELERATION BANDS
(m/s²)

				WALKING/STANDING STILL						
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**

-10	-3	-3	-2	-2	-1	-1	0	0	1	1	2	2	3	3	10

| DECELERATION	ACCELERATION

Statistical Analysis

For statistical analysis, IBM SPSS Statistical Analysis Software Version 22 was used. Descriptive statistics were used to attain the positional group means for each variable. This was followed by a Oneway ANOVA statistical analysis using a 95% confidence interval. Newman-Keuls post hoc tests were used to determine where the difference existed. An alpha level of $p<.05$ was used to determine significance.

CHAPTER IV

FINDINGS

Distance Traveled

Positional group means for odometer (distance traveled) are shown below in Figure 2. Not unexpectedly, DBs traveled significantly $(p<0.05)$ further than OL and DL, however; DBs also traveled significantly further than WRs (4,224 m vs. 3,132 m respectively). Consequently, DBs traveled 25% further than WRs. With respect to OL and DL, the DL group traveled significantly further than OL (3,638 m vs. 3,289 m). Therefore, the DL group traveled 9.6% further than the OL group. What appears somewhat surprising is that there was no significant difference in distance traveled between DL (3,638 m) and WR (3,132 m).

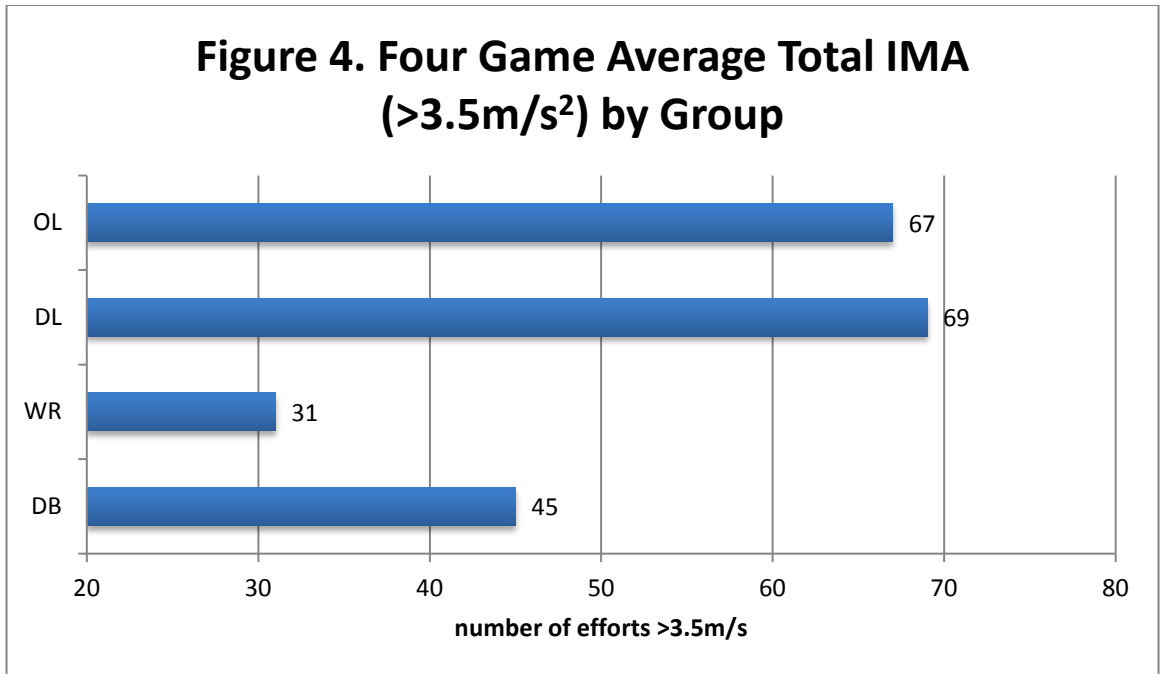**Figure 2. Four Game Average Distance Traveled (m) by Group**
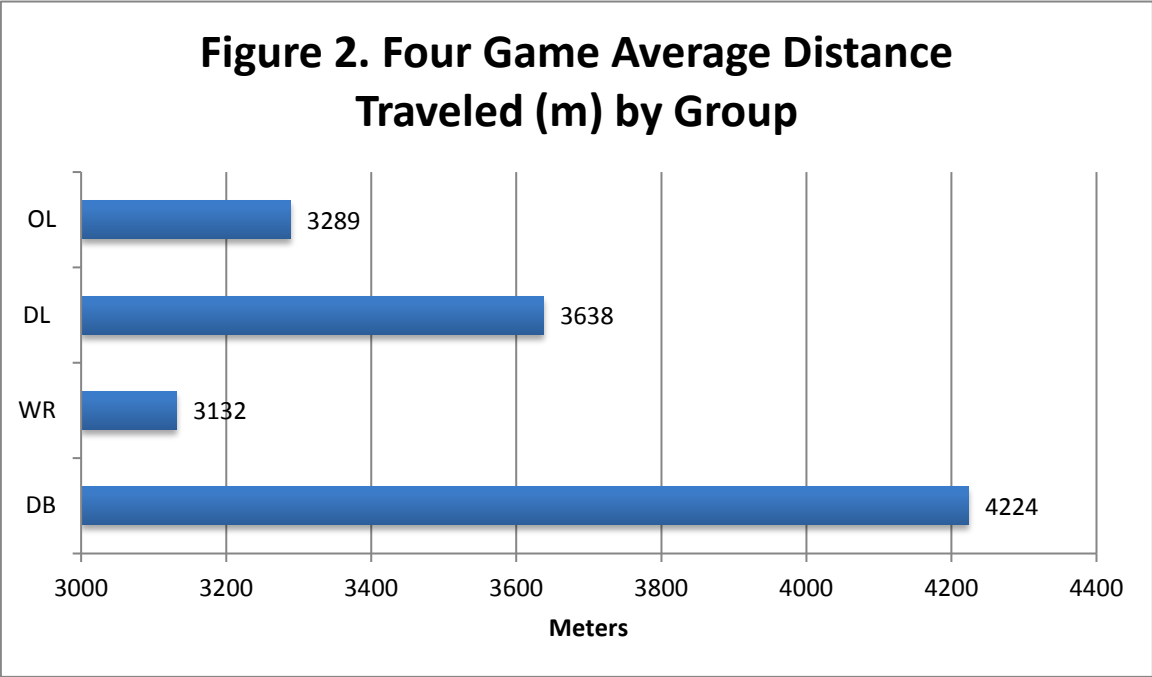
Maximum Velocity

Positional group means for maximum velocity are shown below in Figure 3. OL players demonstrated significantly *(p<0.05)* slower MV than DL (18.2 km/hr vs. 25.1 km/hr), WR (18.2 km/hr vs. 30.4 km/hr), and DB (18.2 km/hr vs. 31.1 km/hr). However, there was no significant difference in MV between DB and WR (31.1 km/hr vs. 30.4 km/hr).

Figure 3. Four Game Average Maximum Velocity (km/hr) By Group
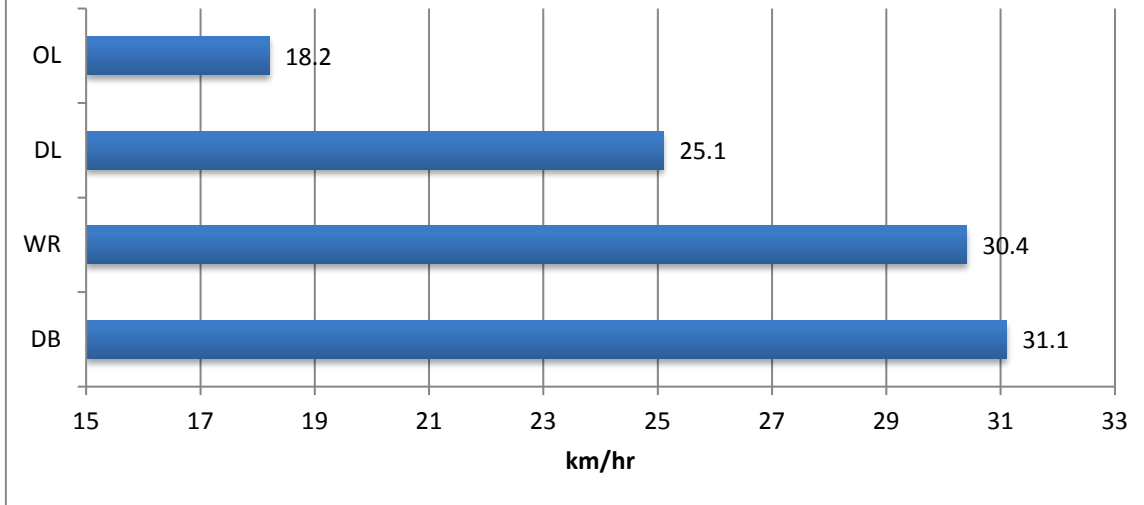
Total IMA

Positional group means for Total IMA are shown below in Figure 4. Both DBs and WRs scored significantly *(p<0.05)* lower for Total IMA compared to DL and OL. Similarly, DBs scored significantly lower than WR (45 vs. 31 respectively). There was no significant difference between OL and DL in Total IMA (67 vs. 69 respectively).

Figure 4. Four Game Average Total IMA ($>3.5 \text{m/s}^2$) by Group

| Group	Value
OL	67
DL	69
WR	31
DB	45

number of efforts >3.5m/s

Deceleration Band 1

Positional group means for distance traveled in Deceleration Band 1 are shown below in Figure 5. Both DBs and WRs scored significantly *(p<0.05)* higher when compared to DL and OL. There was no significant difference between OL and DL (0 m vs. 3 m respectively).

Figure 5. Four Game Average Distance Traveled In Deceleration Band 1 (3-10m/s^s) by Group

Group	meters
OL	0
DL	3
WR	11
DB	16
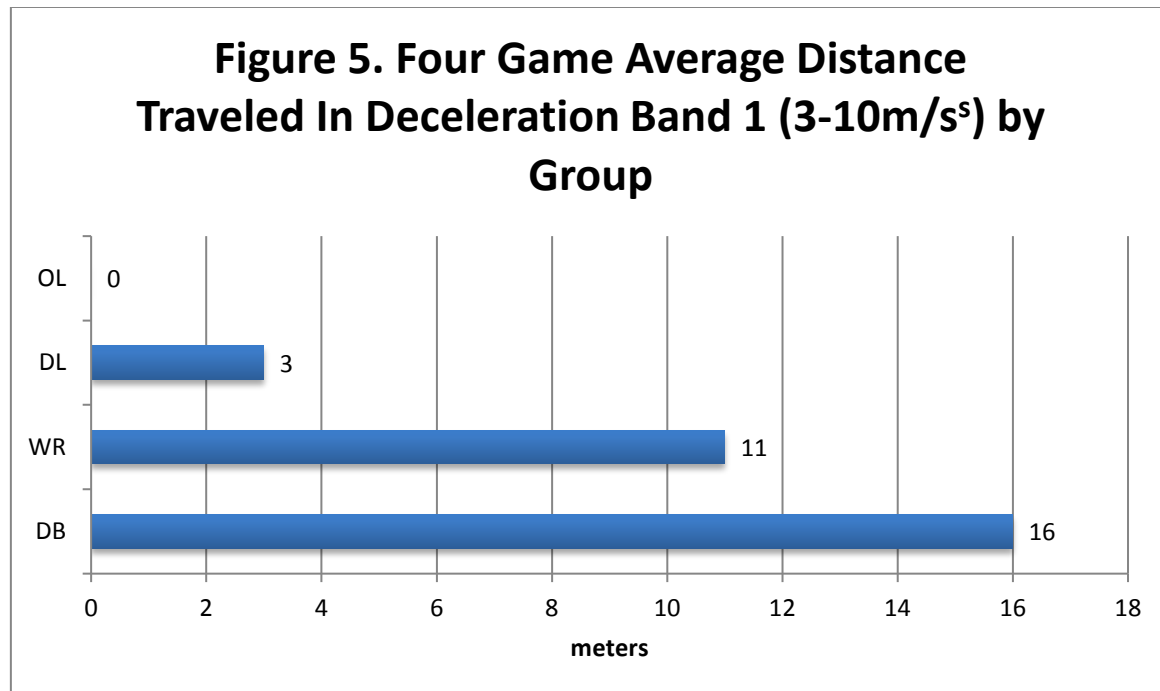
Deceleration Band 2

Positional group means for distance traveled in Deceleration Band 2 are shown below in Figure 6. DBs scored significantly *(p<0.05)* higher than DL (48 m vs. 18 m) WR (48 m vs. 36 m), and OL (48 m vs. 5 m). Similarly, DL scored significantly lower than WR (18 m vs. 36 m), but higher than OL (18 m vs. 5 m). WR scored significantly higher than OL (36 m vs. 5 m).
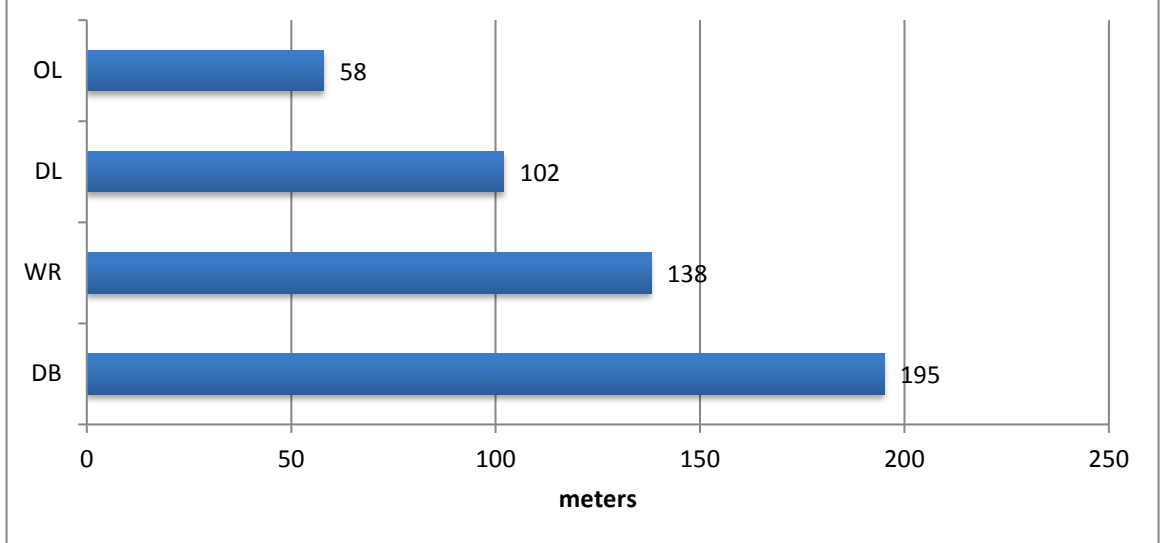
Figure 6. Four Game Average Distance Traveled In Deceleration Band 2 (2-3m/s²) by Group
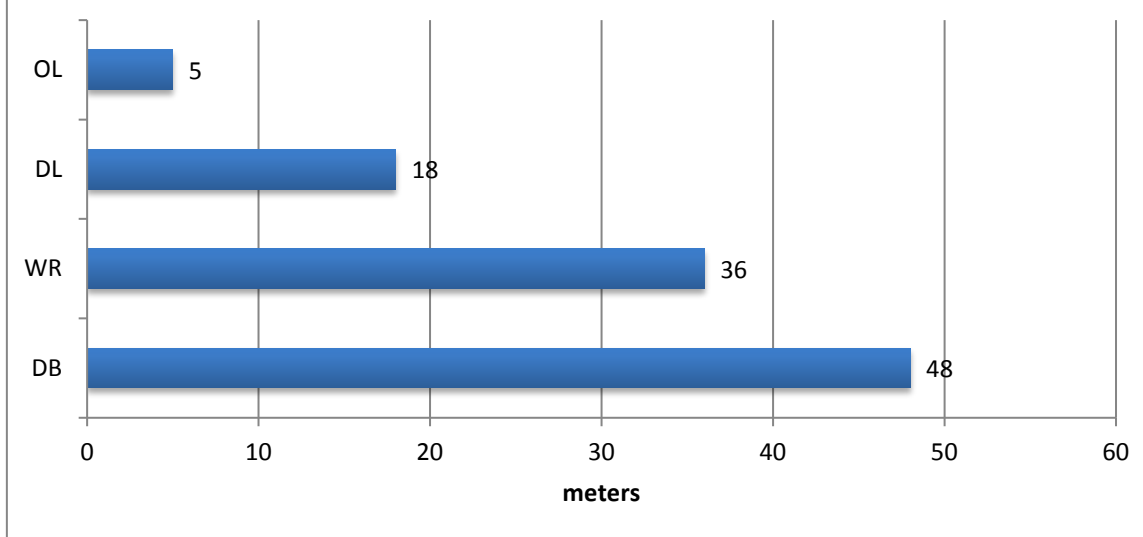
Acceleration Band 7

Positional group means of distance traveled in Acceleration Band 7 are shown below in Figure 7. DBs scored significantly *(p<0.05)* higher than DL (195 m vs. 102 m), WR (195 m vs. 138 m), and OL (195 m vs. 58 m). Similarly, DL scored significantly higher than OL (102 m vs. 58 m). WR scored significantly higher than OL (138 m vs. 58 m). There was no significant difference between DL and WRs (102 m vs. 138 m).

Figure 7. Four Game Average Distance Traveled In Acceleration Band 7 (2-3m/s²) by Group

Acceleration Band 8 (3-10 m/s²)

Positional group means for distance traveled in Acceleration Band 8 are shown below in Figure 8. Both DBs and WRs scored significantly *(p<0.05)* higher than DL and OL. DBs scored significantly lower than WRs (61 m vs. 111 m). There was no significant difference between OL and DL (2 m vs. 21 m).

Figure 8. Four Game Average Distance Traveled In Acceleration Band 8 (3-10m/s^2) by Group
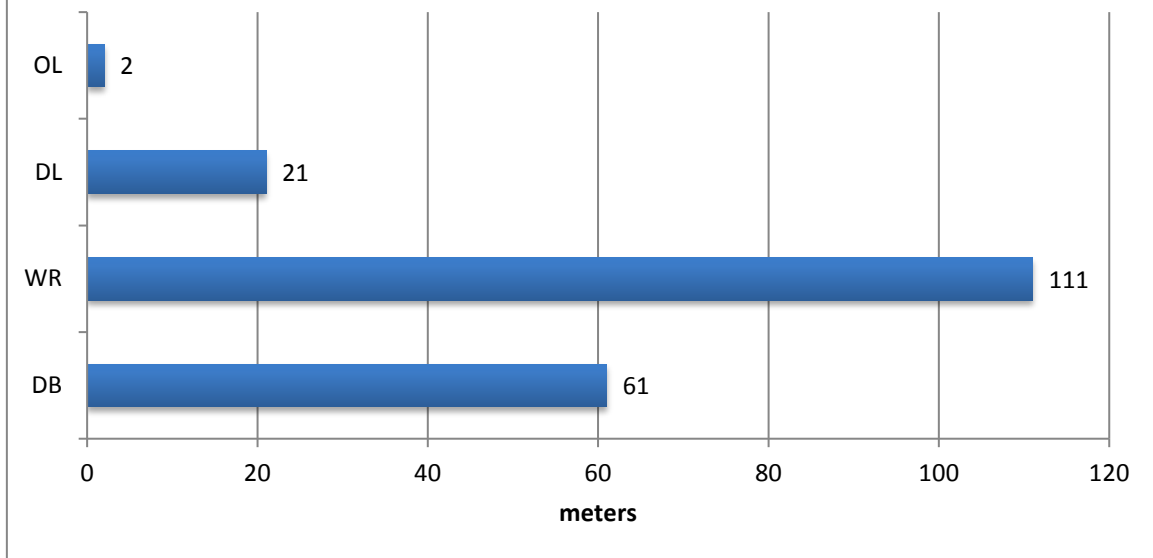
CHAPTER V

DISCUSSION

The purpose of this study was to compare selected movement variables related to intensity and stress in matched positional groups on an NCAA Division I football team during games. The goal was to identify the amount of stress each position is put through during a game and compare distances traveled and high intensity movement in order to possibly develop better exercise protocols and practice protocols that are more position specific to the demands of the position. In doing so, coaches, strength and conditioning professionals, and exercise scientists can put their athletes in a much better position to succeed during competitive play. College football today is full of many high-powered offenses that move at a fast rate. Most of which are no-huddle and are capable of scoring very quickly. Because of this, coaches and analysts alike discuss the disadvantages that lie on the defense's shoulders. They discuss fatigue of the defense playing a big factor in the success and failure of most football teams. Another goal of this study was to see if this is actually a factor. One could hypothesize that the offense is on the field, moving at a high rate of speed just like the defense, so fatigue should play a factor for them as well. Gaining a better understanding of exactly how far each positional group travels and how often they are exerting energy at a high level could be very beneficial to coaches and trainers.

Having this kind of information at hand could help them to evaluate their everyday practices in preparation for games to see if they are in fact giving their athletes the proper conditioning they need to compete at a high level.

Distance Traveled

This study revealed that the DB and DL groups both traveled further on average than the WR and OL groups. This finding contradicts a study conducted by Demartini and colleagues on distances traveled in practices by collegiate football players. Demartini found that non-lineman covered significantly greater distances than lineman during fall practices (Demartini et al., 2011). However, DBs were only significantly greater when compared to WR and OL. While failing to reach significance, the DL group actually traveled further than the WR group, (3,638 m vs. 3,133 m; $p = 0.26$). It would have been logical to assume that the DB and WR groups would travel further than OL and DL groups. However, it is interesting that the DBs did not travel significantly further than the DL group. It is also interesting that the DL group traveled further than the WR group. This may be because the WR group has a defined route for each play while the DL group is constantly chasing the ball after the snap, thereby accumulating more yards traveled during a game. Again it would be logical to assume that the DB and WR groups would travel a similar total distance throughout a game due to the fact that the DBs job is to cover the WR group. In this study however, this was not the case. One could argue that the distance traveled by the defensive position groups is directly affected by the style of offense they are competing against. For this reason, group means were taken for four games for this study in order to attain a more accurate measurement.

Maximum Velocity

This study's findings concerning MV are similar to previous studies conducted. Skill positions (DB and WR) attained significantly greater MV when compared to non-skill positions (DL and OL). Wellman and colleagues (2016) and Demartini and colleagues (2011) both recorded similar findings during competitive games and practices. Wellman's study found that skill players such as WR and DB groups attained higher velocities throughout a competitive game compared to DL and OL (Wellman et al., 2015). A similar study found that non-lineman traveled further distances at high velocities compared to lineman (Demartini et al., 2011). These findings are to be expected, however, finding significant differences when comparing similar position groups was something that was unexpected. In this study, DL attained significantly higher MV than the OL group (25.1 km/hr vs. 18.2 km/hr; p = .00). Again, this could be because DL are constantly chasing the ball after the snap while OL have a scripted step count or blocking scheme that limits their opportunities to get to open field and reach higher velocities.

Total IMA

When studying high intensity, explosive movements, WR and DB groups come to mind because they are the "skill" positions that reach the highest velocities throughout a game. However, this study investigated accelerations, decelerations, and high intensity change of directions, which do not necessarily correlate with velocity. Some interesting data was found when analyzing high intensity movements greater than 3.5 m/s^2. DL had accrued the most high intensity movements out of all of the positions measured with an average of 69 per game. OL accrued the second most with an average of 67 per game. Both of these positions were significantly greater when compared to the WR and DB groups. The reason for this finding

could be because the DL and OL positions require more high intensity steps and change of directions due to blocking schemes, maneuvering around a blocker, and constantly chasing the football after the snap. When comparing WR and DB groups, DB accrued significantly greater high intensity movements than the WR (45 vs. 31; p = .02). The same can be said regarding this finding as was said when comparing DL and OL to WR and DB. WR have a set route they will run every passing play. Also, depending on the style of offense, WR groups may run more vertical patterns down the field which require less change of directions and more linear speed. DB on the other hand, have to react to what the WR does, followed by possibly changing directions to make a tackle or break up a pass, which could be the reasoning behind their increase in high intensity movements. These findings differ considerably from another study of similar nature. Wellman and colleagues (2016) recorded maximal accelerations and decelerations of collegiate football players and found that DB and WR groups accrued significantly more of these movements than DL and OL groups. Style of offense, defense, and speed of play could all factor into the contradicting findings in this study.

Acceleration and Deceleration Bands

Deceleration and acceleration was measured as the total distance that was accrued by each athlete in each band. Deceleration Band 1 recordings showed that WR and DB groups both traveled significantly further decelerating at a rate of speed between 3-10 m/s^2 when compared to OL and DL groups. When comparing Total IMA, deceleration, and acceleration bands, the question might be, why did the OL and DL groups score higher numbers for Total IMA but lower in distances traveled throughout each band. This is because Total IMA was measured in total effort counts (#). Just because a certain athlete accrues a high number of effort counts does not mean that athlete is covering ground during those explosive movements. DL and OL groups

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scored higher Total IMA but lower explosive distances traveled because those positions spend most of their time in a condensed area on the field. There is not much distance being covered by either position even though they are moving their bodies explosively.

Findings for Deceleration Band 2 showed that all position groups were significantly different from each other. WR and DB groups traveled further distances than OL and DL groups (36 m & 48 m vs. 5 m & 18 m). DB traveled significantly further than all other positional groups while WR traveled significantly further than OL and DL. One difference from Deceleration Band 1 was that the DL traveled significantly further than OL (18 m vs. 5 m; $p = .03$). When comparing these findings to similar studies, it is difficult because other studies focused on effort counts for each band rather than distance traveled for each band. As stated earlier, effort counts and distances traveled do not necessarily go hand in hand.

Both acceleration bands that were recorded for this study showed much higher distances traveled when compared with deceleration bands for all position groups. For Acceleration Band 7, DB and WR groups again recorded the greatest distances with DB traveling significantly further the WR (195 m vs. 138 m; $p = .00$). DB, WR, and DL groups all traveled significantly further than the OL (195 m, 138 m, 102 m vs. 58 m; $p = .00, .00, .03$ respectively). From these findings it is clear that all positions throughout a game spend more time accelerating than decelerating. Specifically, OL and DL groups showed substantial increases from deceleration to acceleration, with OL still recording the least amount of yardage. The reason for the increase regarding the DL could be that when the ball is snapped, the goal of this position is to accelerate at a high rate of speed out of their 3-point stance in order to create angles and beat the OL off the ball to get to the quarterback or running back. In doing this, they accumulate high yardages accelerating. The job of the OL, on the other hand, is to stop, or decelerate, the DL from

penetrating and getting to the ball. Due to this factor, it is reasonable to assume that the OL will accelerate less than the DL.

Although distances traveled in Acceleration Band 8 were higher than both deceleration bands, there was a drop off of total yardage from Acceleration Band 7 to Band 8. This shows that the athletes spend more time accelerating at a moderate to high intensity. One difference found between the two acceleration bands was that the WR group traveled further than the DB group in Band 8 (111 m vs. 61 m) but traveled less in Band 7 (138 m vs. 195 m). Both of these differences were found to be significant. It is hard to say what could be the reasoning for this change. It could be that the WR group had more opportunities to get out into open space and accelerate to their top speed, which in turn would allow them to accrue more yardage in Acceleration Band 8. However, when analyzing max velocity, the DB group reached a higher average max velocity than the WR group. Therefore, it can be assumed that the DB group as a whole could be more explosive athletes that are able to reach their top speed faster (less distance required) when compared to the WR group, which needs more time (more distance required) to reach their top speeds.

Practical Application

Findings from this study could potentially have a lasting effect on how future strength and conditioning professionals, coaches, and trainers develop their training, conditioning, and practice schedules. At least one significant difference was found between positional groups in all of the parameters measured. Coaches can use this information to develop a training program that is more tailored to fit positional groups rather than a "one size fits all" program. It was found that defensive (DB & DL) position groups travel further, average higher top speeds, and accrue

more high intensity, explosive movements throughout a game. From a strength and conditioning perspective, a special focus should be placed upon developing a program for these select athletes. Taking into account their overall workload and amount of high intensity efforts throughout a competitive game and season, specialized plyometric, sprint training, and aerobic conditioning can be utilized to better prepare them for play. For offensive positions (WR and OL), over estimation of workload during games could be a causing factor for the overuse and soft tissue injuries that are prevalent in football. Mimicking their game workloads for practices and conditioning sessions could possibly reduce the amount of overuse and soft tissue injuries that these positions experience. On the contrary, football coaches can possibly prevent overuse injuries and fatigue by recruiting more athletes for specific positions that experience higher workload and more high intensity, explosive movements.

Future studies should focus on the style of play that the athletes experience to determine if this is a factor that affects parameters such as distance traveled and high intensity change of directions. Also, due to inadequate playing time, some positions were left out of this study. Future studies should place a focus on gathering data for all positional groups (linebackers, running backs, etc.) in order to gain a better understanding of the workload for each position on the field.

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