REVIEW ARTICLE

Sports Med. 1997 Apr; 23 (4): 247-260
0112-1642/97/0004-0247/$07.00/0

A Physiological Review of American Football

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Summary

American football has been one of the most popular sports in North America within the past century and has recently received support and increased participation from European nations. Two of the biggest concerns regarding participation in American football are the high incidence of injury and the physical demand for preparation. A basic understanding of the physiological systems utilised in the sport of football is necessary in order to develop optimal training programmes geared specifically for preparation as well as the requirements of individual field positions. Previously, it has been assumed that football relies primarily on an anaerobic source of energy for adenosine triphosphate (ATP) resynthesis with approximately 90% coming from the phosphocreatine (PCr) energy system. In lieu of research conducted specifically with football players, it appears that the energy contribution from the anaerobic glycolytic pathway in this sport has been underestimated. The elevated blood lactate levels observed in football players following game participation cast doubt on this hypothesis. Identifying position specific characteristics may also enhance the development of training programmes based on the requirements of the different positions. It appears that offensive and defensive linemen are generally larger, have higher levels of percent body fat and have greater absolute strength scores than all other positions. Offensive backs, defensive backs and wide receivers tend to display the lowest percentages of body fat, lower absolute strength scores, fastest times over 5, 10, 40 and 300m and the highest relative $\dot{V}O_{2max}$ values. Linebackers appeared to represent a transition group mid way between the backs and linemen for size, body composition, strength, speed and endurance as well as positional duties. Findings within the literature suggest that a lack of cardiovascular development of university and professional football players may prove to be a hindrance to performance with specific regards to thermal regulation. Additional aerobic conditioning as well as the reduction of percent body fat would not only enhance performance, but might play a key role in preventing injuries and allowing a smoother transition into life after football.

To the novice observer American football may appear to be a game dependent upon brute force and the ability to overpower opponents. However, this game heavily taxes the physiological systems of those who take part. American football, in fact, has been reported to combine the physical qualities of nearly all other sports – size, strength, power, speed, agility and endurance.[1] The psychological capabilities of an individual as well as the strategies and tactics of a team are of vital importance to success. Physical preparation, however, is the prime concern in developing athletes into football players. American football is unlike other sports in that the potential and incidence of injury are very high and participants must be optimally developed physically in order to withstand the constant physical contact and the physiological demands of the game.

The physical demands of the game include strength, speed, power, agility, flexibility, as well as aerobic and anaerobic endurance necessary. The objective of this review is to analyse the game of American football with regard to the different physical parameters previously stated. An analysis of the literature yields some interesting facts concerning the development of college and professional football players. It appears that throughout the literature, a trend concerning the lack of cardiovascular development in American football players is quite evident.[1-4] Furthermore, a relationship appears to exist between body composition (i.e. percent body fat) and its relation to physical performance in tests of strength, speed, and endurance.[3,5-8]

The physical requirements of American football will be discussed from 2 different viewpoints. Firstly, the basic characteristics of the sport and its elements will be examined with respect to the contribution of different biomotor abilities as well as the systems in which energy resynthesis takes place. Secondly, an analysis and grouping of the different positions into distinct categories will be addressed with respect to objective measures such as strength, speed, body composition and endurance. With this information established, the selection of certain physical characteristics that are most important to the development of football players can take place. Furthermore, certain physical characteristics that appear to have been neglected or have the potential for performance improvement can be determined.

It is through this in-depth review and compilation of the existing research that a systematic and scientific approach to football can be taken, which may enhance the performance of individuals and teams. By means of this, proper training parameters can be set according to the specific needs of the sport, which may consequently alter traditional methods used in the past.

1. Energy Systems

For muscular work the high energy compound ATP is required. When this chemical compound is broken down into its 2 constituent subunits, adenosine diphosphate (ADP) and an inorganic phosphate (Pi) molecule, energy is released and muscle contraction occurs.[9] In order to continue muscular work, these 2 molecules must be resynthesised so as to be broken down again for continued energy release. But this resynthesis requires energy in itself which is generally provided by 3 different metabolic pathways: the PCr system; anaerobic glycolysis; and the aerobic system.[9]

During the onset of high intensity exercise, ATP resynthesis occurs via the PCr system with the aid of the enzyme creatine kinase. This enzyme functions as a catalyst to the reaction between ADP and PCr resulting in the formation of ATP.[10] PCr is catalysed so that the liberated phosphate ion is donated to ADP to form ATP.[10,11] This is the most rapid method of supplying ATP to the muscles and is the primary system used for ATP resynthesis at the onset of exercise and during short term and high intensity work as seen in American football.[12,13] However, PCr is stored within the muscle fibre in limited amounts and the duration of maximal intensity exercise utilising this energy system has been reported to last approximately 1 to 10 seconds.[9]

The second anaerobic method by which ATP formation takes place during short term, high intensity exercise is through anaerobic glycolysis.[9,11,13] This system, along with the PCr system, resynthesises ATP for muscular contraction in the absence of oxygen. Also referred to as fast glycolysis, this system functions by breaking down blood glucose or muscle glycogen to form pyruvic acid, and eventually its reduced form, lactic acid, with the net formation of 2 or 3 ATP molecules.[14] Throughout this process, hydrogen ions (H^+) are liberated into solution and bind with the molecule nicotinamide adenine dinucleotide (NAD) to form the reducing equivalent NADH and H^+.[9] In the case of anaerobic glycolysis where oxygen is not adequately supplied to the working muscles, pyruvic acid accepts the hydrogen ions donated by NADH, thereby liberating that molecule so that further binding with H^+ may occur. Pyruvic acid then forms lactic acid and allows the continuation of glycolysis.[9] However, during intense exercise, large amounts of lactic acid are produced, which immediately dissociate and release H^+ that can adversely affect exercise performance. This increase in intracellular H^+ concentration reduces the ability of muscle cells to resynthesise ATP and also hinders the contractile process of muscle contraction.[9,11] This metabolic system is the principal one used in those events lasting from ≈30 sec to 2 min, such as a 400m race.[9,11] There is evidence that the anaerobic glycolytic pathway is stimulated much earlier following the onset of high intensity exercise.[13,15,16]

In the presence of oxygen, the glycolytic pathway is still active in the form of 'slow' or aerobic glycolysis.[14] In this case, the hydrogen ions that are liberated in solution are bound to NAD and flavin adenine dinucleotide (FAD) and transported to the mitochondria (in the electron transport chain) in order to resynthesise ATP. It appears that this system operates in conjunction with the aerobic or oxidative system, in which numerous ATP molecules are generated by the mitochondria.[11] Exercise activities that exceed ≈4 min duration, or those of a lower exercise intensity, tend to use the aerobic system as the primary source of ATP production.[9] It should be noted that the transfer between energy systems is a gradual one that occurs in a continuum and is a function of oxygen availability, exercise intensity and duration.

2. Energy Systems Utilised in Football

American football requires many physical qualities that appear to be independent of playing position. Such abilities include rapid acceleration, high running speed, good jumping ability, explosive force of muscles, speed endurance, strength endurance, power of the throw and deceleration.[1] The body must have certain qualities to perform these necessary abilities. Football players must have an aerobic capacity to provide power throughout a prolonged, intermittent duration and to recover quickly in short pauses. Maximum anaerobic power is also necessary to perform powerful movements and quick start acceleration. Groups of muscles must have the ability to provide stabilisation thereby contributing to maximal muscle force and explosive strength. Local muscular endurance is necessary to provide consistently repeated running at high speeds for long distances.[1]

American football can be classified as an acyclic sport that is composed of integral functions performed in one action.[17] For example, such functions including backpedalling, cutting and tackling are often performed in one integrated action during a given play. On the other hand, running is classified as a cyclic sport since the motor acts of running comprise cyclic, repetitive movements.[17]

With respect to the primary energy systems used in football, it appears that the PCr and lactic acid systems (anaerobic glycolysis) provide the bulk of energy production.[2,12,18] It has been suggested by Fox and Matthews[12] that the PCr system provides 90% of energy production in football whereas the lactic acid system contributes the remaining 10%. This contribution of the energy systems may hold true for football since it is a sport in which very short, highly intense bursts of energy (2 to 5 sec) are required, followed by brief periods of recovery lasting from 25 to 40 sec.[19] However, this ratio of the energy system contribution may be slightly elevated in light of more current research.

In a study conducted at the Canadian Football League (CFL) all-star game in 1979, Zapiec and Taylor[20] noted that athletes' playing time varied from 5 minutes and 42 seconds to 9 minutes and 48 seconds during a 2-hour and 19-minute game. In an earlier study carried out by Craig[19] that examined exposure time in professional football it was determined that maximal participation was 13.5 minutes. The shorts bursts of activity over such a prolonged period of time are indicative of a maximal or near maximal intermittent work regimen.[2] Lactate levels in the players examined by Zapiec and Taylor[20] increased 3- to 5-fold following completion of the game, although, blood glucose levels were not significantly affected. Similar findings were also reported by Smith and Jackson[21] who observed significantly higher blood lactate levels in college football players. Their results showed elevated blood lactate levels from a pregame value of 1.67 ml/L, to 4.39 and 5.08 ml/L at the half-time and postgame periods, respectively.[21]

It was also observed that the professional players in the Zapiec and Taylor[20] study had a higher relative area of fast twitch (FT) muscle fibres to slow twitch (ST) muscle fibres. An important point to note from this study is that the postgame muscle glycogen stains showed a reduction in content primarily in the FT fibres.[20] FT fibres are rich in glycogen and glycolytic enzymes thereby enabling these fibres to have a large anaerobic capacity.[9] Since FT fibres contract rapidly and develop more force than ST muscle fibres, it appears that the results reported by Zapiec and Taylor[20] support the notion that football is a strenuous intermittent type of exercise that relies on the PCr and lactic acid system for energy production.[9,11]

It has been established that PCr is restored rapidly following vigorous activity.[12,22,23] However, since the recovery period during football is very short (25 to 40 seconds), the amount of PCr replenishment that occurs may be less than optimal. In fact, it has been demonstrated that the time required to replenish intramuscular CP stores in recreational individuals following isolated quadriceps exercise may range from 55 to 90 seconds.[22] Repeated bouts of high intensity exercise incorporating brief periods of recovery suggest that football may rely more on the glycolytic pathway for its energy production that the 10% previously cited.[9] This finding is reinforced by the elevated lactate levels measured by Zapiec and Taylor.[20] However, it should be stressed that the PCr system may still be the primary system for ATP resynthesis. Based on the research cited, the 9/1 PCr to lactic acid system ratio may appear slightly elevated. Over the course of a football game, ATP resynthesis via anaerobic glycolysis may become a more important factor as a means for providing energy for work under conditions of PCr depletion and fatigue.[2,9]

3. Performance Measures

When an individual commences participation in football he must first acquire the basic skills necessary in order to be competitive. These skills include catching and throwing, backpedalling and changing direction, blocking and tackling. As the individual progresses from the high school level to university or professional football, he will very likely specialise at a particular position. Playing different positions in the sport places varying biomechanical and physiological demands on these individuals. The objective of the following section is to compare and contrast these physiological and biomechanical attributes and based on these findings, develop distinct categories of players. Such variations include body size, body composition, strength, speed and cardiovascular endurance. Since consistent data on quarterbacks and kickers is limited, these 2 positions will not be included in this analysis.

4. Size and Body Composition

Traditionally, coaches have used the criteria of size and maximum strength as the most important variables in selecting top potential football players. However, the element of size can be a very misleading factor when selecting players. With respect to football or other types of athletic skills, body composition plays a large role in successful performance. Body composition has been shown to be related to strength, speed and cardiovascular endurance in many studies conducted on university and professional football players.[7,8,24,25] In order to develop distinct groups of players by position based on objective data, size and body composition appear to have been some of the most obvious and consistent measures utilised.

Various studies conducted on football players have yielded from 2 to 5 categories of positions.[7,8,18,25,26] One of the consistent findings among these studies was that offensive and defensive linemen had statistically similar sizes as did the offensive backs, receivers and defensive backs. The linemen were taller and heavier than the backs in each of these studies. It appears that the linemen and backs represent opposite ends of the spectrum with linebackers midway between, thus yielding at least 3 categories of players.[2,7,8,27] With reference to body composition in percent fat and lean bodyweight, similar results were also found. The linemen exhibited higher values for percent fat and lean bodyweight than the backs, who statistically displayed significantly lower values.[2,5,7,8,24,27] Linebackers once again appeared to display values midway between these 2 groups, although in some of these studies, linebackers showed more similarities to backs while in other studies they had more in common with linemen (table I). This trend indicates the uniqueness of the linebacker position and therefore establishes these players as a distinct group.[28] In fact, Wilmore et al.[8] observed that professional linebackers were similar in size and body composition to world-class discus throwers as reported by Fahey et al.[29] Based on previous findings, it may be suggested that the recommended optimal percent body fat for college football players is as follows: defensive backs 10, offensive backs 12, linebackers 13, defensive linemen 15, and offensive linemen 17%.[6]

5. Strength

Strength training has been the cornerstone of football player development within the last 20 to 30 years. Strength can be defined as the maximum force that can be generated by a muscle or group of muscles against a resistance.[11,17] Very often when evaluating football players, the 1 repetition maximum (1 RM) is used. This method refers to the maximum amount of weight that can be lifted during 1 complete dynamic repetition of a particular movement.[9] The most commonly utilised exercises are the bench press, the squat and the power clean, with the bench press being a test to evaluate upper body strength, the squat used to assess lower body strength and the power clean to test overall strength and explosive power.[28] Studies that utilised dynamic methods have produced strength norms and averages for the National Collegiate Athletic Association (NCAA) division I, II, and III university football players. It has been found in these studies that linemen (offensive and defensive) have significantly higher absolute strength values than backs.[28,30,31] These findings also demonstrate a tendency for linebackers to fall midway between the linemen and backs, which is consistent with respective size and body composition values. In a study that examined a number of performance variables in division 1-AA football players, Barker et al.[32] found that offensive and defensive backs had statistically lower values for a

Table I. Body composition values and sizes of university and professional American football players

Study	Type	n	Height (cm)	Weight (kg)	Body fat (%)	Lean body mass (kg)
Wickkiser & Kelly[6]	University					
	DB	15	178.3	77.3	11.5	68.4
	OB & WR	15	179.7	79.8	12.4	69.6
	LB	7	180.1	87.2	13.4	75.4
	OL & TE	13	186	99.2	19.1	79.8
	DL	15	186.6	97.8	18.5	79.3
Wilmore & Haskell[7]	Professional					
	DB	4	184.4	85	7.7	78.4
	OB & WR	10	184.2	91.8	8.3	84.1
	LB	6	189.7	107.6	18.5	87.7
	OL & TE	12	193.5	113.2	15.5	95.4
	DL	12	192.2	120.6	18.7	97.7
Smith & Byrd[3]	University					
	DB	4	183.7	80.4	9.6	72.7
	OB	5	181.5	183.1	13.8	71.6
	OL	11	189.2	97.9	14.6	83.5
	DL & LB	7	188.8	99.9	14.3	85.6
Wilmore et al.[8]	Professional					
	DB	26	182.5	84.8	9.6	76.5
	OB & WR	40	183.8	90.7	9.4	81.9
	LB	28	188.6	102.2	14	87.6
	OL & TE	38	193	112.6	15.6	94.7
	DL	32	192.4	117.1	18.2	95.8
Burke et al.[24]	College					
	Backs	20	181.4	85.5	13	74.4
	Linemen	33	187.3	101.6	21.8	79.5
White et al.[5]	College					
	DB	8	178.9	77.6	7.3	72
	OB	17	179.5	81.8	11.5	72.2
	LB	6	181.8	90.2	11.6	79.6
	OL	13	185.9	99.7	14.8	84.7
	DL	14	183.1	96.6	13.2	83.5
Gleim[2]	Professional	51				
	DB & WR		173.4	83.6	5.7	
	OB		183	90.7	9.6	
	LB & TE		189.2	103.8	12.5	
	OL & DL		191.2	117.6	17	
Housh et al.[26]	University					
	DB	14	172	83		
	OB & WR	14	172.4	81.2		
	OL	13	174.8	110.2		
	DL	14	173.8	100.1		
Seiler et al.[27]	University					
	Backs	17		83.6	9.7	
	Linebackers	11		99.3	12.5	
	Linemen	13		117	16.5	

Abbreviations: DB = defensive back; DL = defensive lineman; LB = linebacker; n = sample size; OB = offensive back; OL = offensive lineman; TE = tight-end; WR = wide receiver.

1-RM lift in the squat exercise than defensive linemen. However, when strength was evaluated as the number of repetitions performed at a percentage of each player's respective 1-RM (70 and 90%), no differences existed between any of the positions. Black and Roundy[33] demonstrated the consistent trend with respect to absolute strength as division 1-A defensive linemen and offensive guards displayed higher mean values for the bench press and back squat as compared with cornerbacks and wide receivers. As depicted in table II, there also appears to be a difference in strength levels between NCAA division I and division II college football players. Division I football players displayed statistically greater values for bench press and power clean strength than both division II and III players. Division II players were also found to have statistically greater bench press strength values than division III players.[31]

With respect to relative strength, which is the ratio between an athlete's absolute strength and his bodyweight, division II backs exhibited higher values that those of the linemen.[30] Similar differences in relative strength in division I-AA were also observed by Barker et al.,[32] who found that offensive backs and linebackers displayed higher values than offensive linemen. Contrary to these findings, Olson and Hunter[28] have shown that in division I football players, linemen exhibited the highest values for relative strength. The greater relative strength values obtained by the linemen in the Olson and Hunter[28] study have been attributed to differences in the intensity and type of training regimen, variable emphasis on strength training or to genetic selection. Furthermore, because human muscle has been shown to generate a constant (specific) tension of approximately 30 N/cm^2 of muscle cross-section, the muscular mass of the linemen is likely to be higher than that of players in other positions.[34-38]

In a study conducted on National Football League (NFL) players by Wilmore et al.,[8] a similar trend appeared between backs and linemen with respect to absolute strength. Offensive and defensive linemen were stronger than offensive backs, receivers, and defensive backs with respect to the standing press, the curl and the bench press.[8] Linebackers in this study, however, had similar strength values to those of the linemen and in fact, exhibited a higher average value for the bench press than did either offensive or defensive linemen. The linebackers also demonstrated higher average strength values for the standing press than the offensive linemen. Higher values of percent body fat observed in the linemen as compared with the linebackers may have played a significant and detrimental role in dynamic strength performance.[8] Although this explanation is purely speculative, a lower level of percent body fat may have the potential for improving the efficiency of movement ultimately enhancing muscular activation and, therefore, strength performance.

Another method that is used when assessing strength levels in football players is through isokinetic dynamometry, which evaluates muscle force against accommodating resistance at a predetermined angular velocity.[39] A study that examined division II football players found similar results to the previous findings of Mayhew et al.[26,30] Using a Cybex II dynamometer, distinct differences were found between linemen and backs in regards to quadriceps and hamstring peak torque with linemen tending to be stronger than backs.[26] However, when peak torque was determined per kilogram of bodyweight, backs demonstrated higher values than the linemen.[26]

Although it seems evident that a greater magnitude of strength is required to play the position of offensive or defensive lineman, the literature appears to support the notion that higher levels of body fat represent a factor limiting performance as shown by the lack of positional differences in relative strength. Although linemen seem to display higher values for lean body mass (table I), the specific tension generated by skeletal muscle suggests that these players should demonstrate greater relative strength scores than backs. However, this does not appear to be the case. Further support for the adverse effects of excessive body fat are presented later in this review. Football is not just a game of size and strength but also of speed and power. The examination of speed and the role of cardiovascular endurance may help to delineate this observed trend in grouping football players.

6. Speed and Anaerobic Power

Speed can be defined as the capacity to travel or move quickly from one point to another, whereas

Table II. Mean strength scores (kg) for university and professional American football players

Study	Type	Bench press	Squat	Power clean	Standing press	Curl
Mayhew et al.[30]	University, Division I					
	WR	122.9	168	108.9		
	OB	115.7	188.5	116.1		
	DB	132.2	174.2	112.9		
	LB	151.9	197.6	122.7		
	OL	162.2	216.8	127.5		
	DL	159.7	207.5	127.3		
Olson & Hunter[28]	University, Division II					
	Backs	114.8	165.6	102.1		
	Linemen	126.5	178.7	108.4		
Wilmore et al.[8]	Professional					
	DB	125.1			81.9	60.1
	OB & WR	129.2			91.9	70.6
	LB	155.6			97.4	78.8
	OL & TE	151			96.9	80.5
	DL	147.6			101.5	85.8
Black & Roundy[33]	University, Division 1A					
	Cornerback	132.8 ± 18.8	189.6 ± 27.9			
	WR	122.8 ± 19.4	178.1 ± 25			
	DL	167 ± 23.2	231 ± 8.13			
	OL	167.6 ± 29.4	227.1 ± 38.5			
Barker et al.[32]	University, Division 1AA					
	OB		148.3 ± 17.7			
	DB		141.5 ± 24.8			
	OL		171.4 ± 30.2			
	DL		188.1 ± 39.7			
	LB		169.4 ± 19.5			
Fry & Kraemer[31]	University					
	Division I	136.9 ± 25.8	192.8 ± 37.6	123 ± 17.9		
	Division II	135.2 ± 25.5	182.5 ± 34.4	116.5 ± 17.3		
	Division III	128.6 ± 23.2	176.9 ± 32.4	113 ± 16.5		

Abbreviations: DB = defensive back; DL = defensive lineman; LB = linebacker; WR = wide receiver; OB = offensive back; OL = offensive lineman.

power can be defined as mechanical work performed per unit of time.[9,11,40] Since the predominant energy pathways utilised in football are the PCr and anaerobic glycolytic systems, the 40yd (36m) dash has been used as the standard test of football speed. However, the applicability of this test has been questioned since there are few times a player actually runs 40yd during a game.[25] A study by Crews and Meadors[25] on 48 university football players revealed high positive relationships between 5 (4.5m) and 40yd run times and between 15 (13.5m) and 40yd run times. Therefore, it was concluded that performance in a 40yd run is representative of how fast a player can move at 5 and 15yd and was therefore deemed to be an appropriate test of football speed. However, Seiler et al.[27] found low to moderate relationships between the mean running velocity after 5yd and the mean running velocity in the final 35yd of a 40yd dash in division I college football players. These results subsequently led to the conclusion that the 40yd run may not be an accurate predictor of initial running velocity.[27] The confounding results in these studies indicate the necessity of utilising sport-specific as well as position-specific field tests that are more accurately related to football performance.

Studies carried out of 40yd dash times of professional and university football players have yielded results that have grouped players into the categories previously suggested (table III).[2,28,30,33]

When examining division I college football players, wide receivers, offensive backs and defensive backs displayed the fastest times over 40yd with defensive and offensive linemen having the slowest times.[28,33] Linebackers, once again, tended to fall midway between these 2 groups. This trend was also evident from an evaluation of 51 professional NFL players by Gliem,[2] who found that defensive backs and wide receivers had the fastest times followed in order by offensive backs, linebackers and tight ends, and finally offensive and defensive linemen. Mayhew et al.[30] also observed this trend as division II backs demonstrated faster times over 40yd than linemen. More recently, however, Barker et al.[32] utilised a number of different running tests to evaluate positional group differences: the 5, 10 and 300yd shuttle run tests. Their results revealed that offensive linemen displayed slower times over 5 and 10yd as well as the 300yd shuttle run than offensive backs, defensive backs and linebackers. Defensive linemen also displayed slower times during the 300yd shuttle run than the offensive backs but did not display statistically different times than the backs for the 5 and 10yd shuttle runs.[32] Black and Roundy[33] also found this trend with respect to the 40yd dash, as offensive and defensive linemen displayed slower times than cornerbacks and wide receivers. Comparisons in 40yd run times have demonstrated differences between division I, II and III college football players.[31] Fry and Kraemer[31] reported that division I and II football players displayed faster run times over 40yd than their division III counterparts. Similar to the highest strength values observed in division I players over division II and III players, it appears that a continuum from division I to III exists regarding athletic fitness and performance. Such a trend may be attributed to superior player selection and recruitment as well as variable advancements in training.

The assessment of power in American football players has often been accomplished by the standing vertical jump test or the use of a power index. The ability to jump higher has been observed to be significantly greater for offensive and defensive backs as opposed to offensive linemen.[32] Furthermore, offensive linemen were found to have lower values for vertical displacement than linebackers.[32] These findings appear to be consistent with those of Black and Roundy[33] who also found higher vertical jump values for defensive backs and wide receivers as opposed to linemen. Barker et al.[32] attempted to explain the observed differences in vertical jump power between the offensive linemen and backs based on the following factors: i) the offensive linemen had the highest percent body fat of any other position thereby reducing jumping efficiency; and (ii) the offensive linemen demonstrated the lowest relative strength scores. Results obtained by Mayhew et al.[41] lend support to these notions as significant negative correlations were observed between percent body fat and anaerobic power corrected for bodyweight in college

Table III. Mean 40yd (36.6m) dash times (sec) for university and professional American football players

Study	Type	40yd dash time (sec)
Gleim[2]	Professional	
	DB, WR	4.58 ± 0.12
	OB	4.81 ± 0.21
	LB, TE	4.93 ± 0.14
	OL, DL	5.08 ± 0.21
Olson, Hunter[28]	University, Division 1	
	WR	4.60
	OB	4.63
	DB	4.64
	LB	4.78
	OL	4.98
	DL	5.08
Mayhew et al.[30]	University, Division II	
	Backs	4.91 ± 0.22
	Linemen	5.22 ± 0.26
Black & Roundy[33]	University division 1A	
	Cornerback	4.48 ± 0.12
	WR	4.46 ± 0.11
	DL	4.99 ± 0.19
	OL	5.08 ± 0.15
Fry, Kraemer[31]	University	
	Division I	4.88 ± 0.27
	Division II	4.92 ± 0.26
	Division III	4.96 ± 0.27

Abbreviations: DB = defensive back; DL = defensive lineman; LB = linebacker; OB = offensive back; OL = offensive lineman; TE = tight-end; WR = wide receiver.

players. Furthermore, significant positive correlation coefficients were also demonstrated between percent body fat and agility, 10 and 40yd dash times.[41] Seiler et al.[27] continued to observe this trend as backs generally had greater values for anaerobic power corrected for bodyweight, as obtained through the Wingate and Margaria-Kalamen tests, than linebackers and linemen. Although the linemen observed by Seiler et al.[27] generated the highest absolute power indices of the 3 groups of players, their values appeared consistently lower than backs and linebackers when corrected for bodyweight. Since power production over repeated plays during the duration of a football game may be the key factor for successful performance on the offensive line, drastic improvements for this variable may be possible through changes in body composition.

7. Cardiovascular Endurance

Endurance can be generally defined as the capacity to perform a type of activity which involves many muscle groups and systems for a prolonged period of time.[17] The most common method of measuring cardiorespiratory function in athletes is an incremental treadmill test that measures the rate of oxygen consumption ($\dot{V}O_2$) This measure can be defined as the functional capacity of the cardiorespiratory system to deliver blood to the working muscles during maximal and supramaximal (>100% $\dot{V}O_{2max}$) work while maintaining mean arterial blood pressure.[9]

It appears that football players generally do not have a well developed cardiovascular system as compared to athletes in other sports.[7,8] In fact, with specific reference to $\dot{V}O_{2max}$, university and professional football players demonstrate similar values to those of age-matched controls.[2,18,28] Since football is an anaerobic-type sport, the role of cardiovascular development has not been emphasised in training programmes for these players. It may be for this reason that there does not appear to be a distinct trend between groups of players as far as $\dot{V}O_{2max}$ is concerned although backs tended to have higher relative values than linemen (table IV). These differences in $\dot{V}O_{2max}$ may explain similar findings by Barker et al.[32] who demonstrated that offensive and defensive backs had faster times over a 1.5 mile (3.2km) run test than offensive and defensive linemen, and linebackers. These observations reflect differences in the aerobic capacity between the different groups of players as well as demonstrating a trend among the linemen who displayed higher values of percent body fat. However, in addition to aerobic cardiorespiratory function, physiological fitness as measured through blood lactate analyses has lacked documentation within the literature and may therefore be an important factor in demonstrating adaptive characteristics in American football as well as examining relationships with performance. Subsequent sections of this review will attempt to associate findings regarding size, body composition, strength, speed and endurance with performance requirements of different positions.

8. Positional Requirements

Based on measurements of size, body composition, strength, speed and endurance, 3 distinct groups of football players may be established: (i) offensive and defensive linemen; (ii) defensive backs, offensive backs and wide receivers; and (iii) linebackers and tight-ends. The position of tight-end may also represent a transitional group along with linebackers, although they have been grouped with either the offensive backs, the offensive linemen or the linebackers. Since the position of tight-end requires the player to make blocks on defensive linemen as well as to run down field to catch passes as a receiver, it would seem justifiable to place these players in a category with the linebackers as a transitional group between backs and linemen.

The results of the different physical parameters previously cited appear to be representative of the requirements for different positions. For example, success while playing the offensive and defensive line depends on the ability to execute the movements of charging, blocking and tackling with greater force and greater speed of execution.[42,43] Moreover, linemen must have a high degree of in-

Table IV. Endurance capacity ($\dot{V}O_{2max}$) of university and professional American football players

Study	Type	N	L/min	ml/kg/min
Wilmore & Haskell[7]	Professional			
	DB	2	4.5	54.5
	OB, WR	2	5.1	52.4
	LB	3	5.4	51.1
	OL, TE	4	6.2	52.6
	DL	4	5.6	43.5
Wilmore et al.[8]	Professional			
	DB	25	4.5 ± 0.4	53.1 ± 6.2
	OB, WR	39	4.7 ± 0.5	52.2 ± 5.0
	LB	28	5.3 ± 0.6	52.1 ± 4.9
	OL, TE	35	5.6 ± 0.8	49.9 ± 6.6
	DL	27	5.3 ± 0.6	44.9 ± 5.4
Smith & Byrd[3]	University			
	DB	4	4.77 ± 0.30	59.3 ± 1.00
	OB	5	5.00 ± 0.37	60.2 ± 4.27
	OL	11	5.44 ± 0.60	55.9 ± 7.41
	DL, LB	7	5.28 ± 0.68	53.2 ± 7.32

Abbreviations: DB = defensive back; DL = defensive lineman; LB = linebacker; OB = offensive back; OL = offensive lineman; TE = tight end; WR = wide receiver.

stantaneous strength and, in the case of the defensive lineman, be able to move quickly, hit the offensive opponent with considerable impact and then be able to move away quickly to the point of action.[7,43] These facts clearly demonstrate that playing football, especially at the line position, is dependent upon power which is related to maximum strength. Since maximum strength is one component that should be developed in all football players, it should be combined with the element of speed in order to produce a greater degree of power, particularly in the case of the lineman.

The positions of offensive back, defensive back, and wide receiver have been characterised as those having the lowest values for size and strength, a low percentage of body fat, yet demonstrating the fastest times over 40yd. With respect to the position of defensive back, quick, agile movements are required as well as a great deal of manouverability and speed in order to cover wide receivers.[3,7] These necessary qualities of the defensive back may offer an explanation as to why these players have one of the lowest percentages of body fat, since excessive levels of body fat may be detrimental to playing this position. Receivers and offensive backs also require a great deal of speed and finesse. As a result, strength development may not have been emphasised for these players. However, the lower relative absolute strength scores that appear to be characteristic of defensive backs and receivers suggest that this is one area of development that may need to be improved, since strength enhancement in the proper manner can increase power as long as a relatively low percentage of body fat is maintained.

The position of linebacker has been described as the core position of the defence aimed primarily at tackling the ball-carrier should they get past the line of scrimmage. Linebackers are also responsible for covering tight-ends and offensive backs running downfield to receive passes. Therefore, it appears evident as to why those who play the linebacker position have size, strength and speed values that fall midway between those of the backs and the linemen. These players are required to perform duties similar to those of the defensive linemen and defensive backs. As a result, an equal development of power, strength, speed, endurance and agility is optimal for linebackers since their duties range from contacting offensive linemen and tackling running backs to running downfield to cover receivers and tight ends.

The 3 distinct groups of players that have been established in this review can be used to develop a training programme for a football team keeping in mind the predominant energy systems and the characteristics of each position. Although more differences exist between specialty positions (e.g. a wide receiver spends more time catching footballs then a defensive back), dividing players into the 3 groups may be beneficial when the objectives are to develop strength, speed and endurance. However, when designing such a programme based on these findings, 2 factors that should receive more consideration are body composition and cardiovascular fitness. In the past, these 2 aspects of training have been somewhat neglected. What appears to be uncertain at the present time, however, is whether improvement in these 2 areas can facilitate better performance.

9. Performance Improvement

The utilisation of tests designed to assess percent body fat and physiological fitness have been a necessary tool for many football coaches as a means of monitoring the physical state of an athlete. For example, 3 300lb (135kg) offensive linemen for a professional team reported early to summer camp in 1988 specifically for a weight loss and conditioning programme developed by the team's management.[44] University football coaches, also should be aware of the negative effects of a high percent body fat. Excessive body fat has been associated with a reduction in speed, power and endurance.[45] Significant negative correlations have been found between percent body fat and 40yd run times.[7,25] Crews and Meadors[25] observed that if players' weights were higher than their optimal playing weight, they tended to display slower reaction times and slower run times at 5, 15, and 40yd. Further evidence of this finding can also be based on individual case information as well. Wilmore and Haskell[7] examined 2 cases: a 271lb (22.5% fat) defensive tackle and a 235lb (18.8% fat) running back who played for a professional team. After these 2 players were convinced to lower their playing weights, the defensive tackle dropped his weight to 258lb (13.9% fat) and the running back dropped to 216lb (11.5% fat). Each player had what he and his coaches felt was his best year in professional football while playing at this new reduced weight.[7]

Another factor that may enhance the performance of football players is the development of cardiovascular fitness. It has been demonstrated that the majority of game injuries occur in the second and fourth quarters, which are the latter portions of the 2 halves.[44,46,47] Players that demonstrate a reduced ability to utilise oxygen during recovery may increase the likelihood of fatigue toward the later stages of a game and therefore increase their risk of injury.[8] Therefore, with a better developed cardiovascular system, players may be better able to maintain a higher performance level throughout a game with relatively less effort, resulting in better play.[8] More specifically, endurance training has been shown to increase the capacity of the muscle to extract oxygen, which is believed to be primarily due to an increase in capillary density and secondarily to the increase in the myoglobin concentration and mitochondria number.[11,48] Subsequently the body has a better ability to utilise oxygen to carry out muscular work which results in less PCr depletion and less lactate and hydrogen ion formation.[9] Further evidence presented by Takahashi et al.[22] found that endurance trained runners had a significantly greater ability to resynthesise intramuscular PCr following severe and exhausting quadriceps exercise than untrained individuals. The combination of improved substrate resynthesis and lactic acidosis buffering would allow the football player to more efficiently utilise PCr as a rapid and immediate source for ATP production during game situations. Furthermore, during practice, less accumulation of lactic acid during submaximal drills would occur as a result of a faster rise in oxygen uptake.[9] Another benefit that a well developed cardiovascular system may provide occurs during summer football practices where thermal load can potentially burden a players' physiological system. Since the principal role of aerobic conditioning on the heart is to augment its ability to function as a volume pump, a resulting increase in cutaneous blood flow enhances the removal of internal heat which may reduce the chance of acute heat stress.[2,49] As a result of these adaptations, incorporating aerobic training may help prevent injuries, improve performance, decrease the chance of fatal nontraumatic collapse, and condition the athlete to lead a healthier life after retirement.[2]

10. Conclusion

Research into the literature has yielded some very interesting and useful information regarding American football. Firstly, American football can be classified as an intermittent type sport that primarily utilises the PCr system for its energy supply with secondary involvement of anaerobic glycolysis. In addition to this, 3 basic groups of players exist on a typical football team: (i) offensive and defensive linemen; (ii) offensive backs, defensive backs and wide receivers; and (iii) linebackers and tight ends. Based on parameters such as size, body composition, strength, speed and endurance while excluding some position-specific variables such as catching or throwing, an optimal training programme can be developed for each group of players in order to improve their performance. However, more attention should be directed towards the elements of body composition and cardiovascular endurance since development in these 2 areas may improve performance for the reasons previously cited. In addition, the improvement of body composition with a decline of excessive weight may reduce the risk of coronary artery disease, hypertension, stroke and diabetes.[50] Aerobic conditioning assists with the problem of excessive weight since cardiovascular training increases the utilisation of free fatty acids for energy production.[9] Not only may an increased emphasis in these areas help to improve performance, but it may also assist one to live a more healthy lifestyle after football.

Acknowledgements

This paper is dedicated to the memory of Edgar R. Nowalkoski, MSc, ATC, CAT (C).

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