COMPARING THE PHYSIOLOGICAL CHARACTERISTICS OF HIGH SCHOOL FOOTBALL PLAYERS BASED ON AGE AND POSITION PLAYED

THESIS

Presented to the Graduate Council of
Texas State University-San Marcos
in Partial Fulfillment
of the Requirements

for the Degree

Master of EDUCATION

by

Randy James Kaiser, B.E.S.S.

San Marcos, Texas
May 2004

ACKNOWLEDGEMENTS

I would like to begin by thanking my future wife, Kristi Dodson, for showing me how to use the "find" command in Microsoft Word. I would also like to thank Harve Latson, Greg Miller, Carolyn Clay, Kathy Sharp, Eric Schmidt, Roger Bartels and all other volunteers that donated their time to assist me in completing this paper.

I am very thankful for the members of my thesis committee. My deep appreciation to Dr. Pankey for the opportunities he has given me, Dr. Price for his unlimited statistical knowledge, and Dr. Ransone for his football expertise. And finally, I would like to thank Dr. Lisa Lloyd for her wisdom, patience, and dedication to this project.

This manuscript was submitted on May 6, 2004.

TABLE OF CONTENTS

LIST OF TABLES

COMPARING THE PHYSIOLOGICAL CHARACTERISTICS OF HIGH SCHOOL FOOTBALL PLAYERS BASED ON AGE AND POSITION PLAYED

CHAPTER I

INTRODUCTION TO THE STUDY

A common goal of successful football programs at any level is to identify football players who possess a high level of football playing ability (FPA) (3, 11, 13, 20, 27, 32). FPA is a construct made up of many different skills and is not always easily identified (32). Research, however, has clearly indicated that the football players with a high level of FPA on a team possess a great degree of one or more of the following: speed, strength, leanness, power, or agility (3, 6, 9, 10, 11, 14, 15, 27, 32). These physical attributes can be quickly and easily measured through objective performance tests (OPT) (3, 6, 9, 10, 11, 13, 14, 15, 20, 22, 24, 27, 32, 39). Performance on OPT, therefore, can be used to predict FPA. Although the development of OPT to accurately predict FPA by position and level of play is in its infancy, studies have clearly identified a relationships between FPA (as determined by starting status, coaches rank, draft position, or team ranking) and performance on such OPT as body size and composition (3, 10, 11, 14, 27), 1-repetition maximum (RM) bench press (9, 10, 18, 32), 225-lb bench press (27), the vertical jump (VJ) (6, 9, 10, 15, 18, 27, 32), SLJ (27), the 10-yard sprint (27), the 40-yard sprint (10, 11, 15, 27), and the 20-yard shuttle (15, 27, 32). Using a battery of OPT can, therefore, be important in assisting coaches in predicting player's FPA, identifying player's strengths and weaknesses for the development of individualized training programs, identify the position(s) for which a player is best suited, and determining a player's level of readiness to play (3, 6, 10, 11, 27, 32, 39). Indeed, the use of OPT shows promise, however, only limited descriptive information exists addressing the value in using OPT to evaluate football players at the high school level (22, 39). Therefore, the purposes of this study were to measure the body size and composition, muscular strength, speed, agility, and leg power of 14 to 19 year old high school football players and to compare the performance on OPT by position and age.

CHAPTER II

METHODS

Subjects

During spring and summer of 2003 and spring of 2004, 60 volunteers, recruited from eight area high school football programs in Central Texas, were tested. After a detailed description of the procedures was provided, written consent was obtained from a parent/guardian and written assent was obtained from the football players under the age of 18. The University's Institutional Review Board has approved this study.

Instrumentation

A calibrated physician scale (Detecto Scale Co., Jericho, NY) was used to obtain height and weight, and Lange calipers (Cambridge, MD) were used to measure skinfold thickness. A Vertec™ (Sports Imports, Columbus, OH) was used to measure VJ and a SLJ mat (Sports Books

Publisher, Toronto, Canada) was used to measure SLJ. A barbell weight bench was used to measure muscular strength. Timing gates (Brower Timing Systems Speedtrap 2, Draper, UT) and electronic stop-watches (Accusplit 601X, Cranston, RI) were used to measure speed and agility. All test administrators were trained on how to use the equipment prior to the assessment of the football players.

Test Procedures

Anthropometrics. All anthropometric measurements were taken prior to performance testing. Height and weight were measured with the football players in exercise clothes but without shoes. Body composition was assessed using a three-site (triceps, abdomen, and thigh) sum of skinfold protocol (20). Body size and composition measurements were taken by an experienced test administrator, previously trained according to the ACSM standards for body composition assessment (2).

Anaerobic power. Vertical leg power was assessed using the VJ protocol as described by the National Strength and Conditioning Association (NSCA) (5). Briefly, standing reach was established by having the athlete stand side-on to the apparatus reaching with his dominant hand and displacing as many vanes as possible while his feet remained flat on the ground. Then, the athlete jumped as high as possible using an arm swing and a counter movement. At the peak of his jump, he moves as many vanes as possible. VJ was recorded to the nearest 0.5 in. The athlete's best of 3 trials was used for data analysis.

Horizontal leg power was assessed using SLJ. The athlete stood behind a marked line, with feet comfortably apart. Then, he jumped forward as far as possible (a counter movement and arm swing were allowed immediately prior to take off). The athlete's best of 3 trials was recorded to the nearest 0.5 in.

Upper Body Strength. Upper body muscular strength was measured using a bench press repetition-to-fatigue test. The athlete performed the bench press with one of two absolute loads. Football players that were 14-16 years of age lifted 155 pounds and football players 17-19 years of age lifted 185 pounds. After performing a warm-up set, the athlete was given at least 3 minutes to rest prior to performing the actual test. The athlete lied down on the bench with his feet flat on the ground, with hands grasping the bar slightly wider then shoulder width apart. A satisfactory lift entailed that the athlete pushed the bar vertically to the point where the elbows were fully extended and then, in a controlled manner, lowered the barbell to the chest, without resting it on the chest. The athlete was required to maintain a continuous motion throughout the entire lift or the repetition did not count. Each athlete was given one attempt and the highest number of repetitions completed at the designated weight was recorded.

Speed. The 40-yd sprint was used to assess speed. The test was administered on a flat grassy surface, and thus, the football players were allowed to use football cleats. The start and finish were marked by two cones as well as by a 1-inch painted line. Starting position was a 3-point stance with the front foot up to the starting line, without any body part crossing the line. Once the subject was ready to begin the test, he placed his hand on the starting pad of the electronic timer and was asked to pause for at least 2 seconds in order for the timer to set. After the electronic timer was set (confirmed by one beep), the subject proceeded with the sprint when he was ready. Three timers using stop watches and one electronic timer recorded the time to the nearest 0.01 second. The stopwatches were started on the athlete's first movement and were stopped as the athlete's torso crossed the finish line. Hand-timers were asked to begin and stop the hand-help stopwatches with their index fingers. The best electronic time and the best average hand time of two trials were used for data analysis.

Agility. The pro-agility run, also known as the 20-yd shuttle run, was used to assess agility. The test was administered on a flat grassy surface, and thus, the football players were allowed to use football cleats. Starting position was a 2-point stance straddling the 5-yard line marking the starting and finishing lines. Once athlete was ready to begin the test, he placed his foot on the starting pad of the electronic timer and was asked to pause for at least 2 seconds in order for the timer to set. After the electronic timer was set (confirmed by a constant beep), the athlete pivoted and sprinted as fast as he could to his left to the 10-yd line, touching the line with his hand. Then, the athlete reversed direction and ran to the goal line, touching the line with his hand and completed the test by sprinting back through the electronic timing gate. Three timers using stop watches and one electronic timer recorded the time to the nearest 0.01 second. The stopwatches were started on the athlete's first movement and were stopped as the athlete's torso crossed the finish line. Hand-timers were asked to begin and stop the hand-help stopwatches with their index fingers. The best electronic time and the best average hand time of two trials were used for data analysis.

Statistical Analysis

To determine the physiological characteristics of high school football players based on age and position played, sixty high school football players (n = 60) were recruited from various Texas high school football programs. They were measured for height, body mass, body composition, muscular power, muscular strength, speed and agility. Descriptive statistics (mean ± standard deviation) were calculated for each variable and compared to previously reported descriptive statistics of college and professional football players. One-way

ANOVA was used to determine any differences between age groups and positions played.

CHAPTER III

RESULTS

There were 60 male high school football players that participated in the study. After data screening for positions played, many football players were found to play multiple positions. Because this is a common occurrence in high school football, some football players were used in two or three positions. After data screening for age grouping, the final sample included 60 males (1 in the 13-year old group, 7 in the 14-year old group, 12 in the 15-year old group, 16 in the 16-year old group, 22 in the 17-year old group, and 2 in the 18-year old group).

Table 1 reports the descriptive statistics for the football players' physical characteristics according to position. Table 2 reports the descriptive statistics for the football players' performance on selected OPT according to position. One-way ANOVA did reveal significant differences between positions played, however due to the nature of the each position, the differences between backs (i.e., quarterbacks, running backs, wide receivers, defensive backs) and linemen (i.e., offensive linemen and defensive linemen) are expected. For example, using the Bonferroni adjustment, post-hoc tests revealed that offensive linemen (OL) were heavier, had a higher percentage of body fat (%BF), had a lower VJ score, and were slower than both the wide receivers (WR) and defensive backs (DB). Defensive linemen (DL) however, were only found to be heavier and have a higher BF than the DB. All other significant differences are described in Table 1 and 2.

Table 1
Descriptive Statistics (mean ± SD) for Body Size and Composition in High School Football Players According to Position

Variables	(N)	Height (in)	Weight (lb)	Body Fat (%)
Total	59	67.98 ± 3.14	184.77 ± 38.37	12.05 ± 7.57
QB	6	68.21 ± 5.05	151.92 ± 13.57 [a]	7.49 ± 2.37 [e]
RB	4	67.75 ± 1.17	165.88 ± 26.55	6.91 ± 5.08 [f]
FB	6	66.83 ± 2.58	193.29 ± 21.18	17.41 ± 6.57
WR	9	68.36 ± 2.96	157.06 ± 14.25 [b]	4.96 ± 1.46 [b,g] (n=8)
TE	7	69.61 ± 1.97	186.86 ± 28.82	9.58 ± 3.23
OL	15	68.90 ± 3.00	213.08 ± 45.72 [a,b,c]	17.24 ± 8.12 [b,c]
DL	9	67.69 ± 2.97	210.69 ± 34.76 [d]	19.57 ± 8.04 [d,e,f,g]
DE	8	70.06 ± 1.41	198.16 ± 30.47	12.39 ± 6.67
LB	10	65.45 ± 2.73	173.38 ± 25.96	12.03 ± 5.97
DB	9	67.53 ± 3.15	155.47 ± 12.43 [c,d]	5.85 ± 1.86 [c,d]

[a] Significant differences were observed between QB and OL ($p < .05$) [d] Significant differences were observed between DL and DB ($p < .05$) [g] Significant differences were observed between WR and DL ($p < .05$)
[b] Significant differences were observed between WR and OL ($p < .05$) [e] Significant differences were observed between QB and DL ($p < .05$)
[c] Significant differences were observed between OL and DB ($p < .05$) [f] Significant differences were observed between RB and DL ($p < .05$)

Table 2

Descriptive Statistics (mean ± SD) for High School Football Players Grouped by Position

Variables	(N)	Standing Long Jump (in)	Vertical Jump (in)	20-yd Shuttle (electronic)	20-yd Shuttle (hand)	40-yd Sprint (electronic)	40-yd Sprint (hand)
Total	59	89.10 ± 12.77	20.53 ± 4.98	5.07 ± 0.58	5.19 ± 0.56	5.56 ± 0.55	5.35 ± 0.57
QB	6	89.92 ± 10.63	20.17 ± 3.19	5.17 ± 0.45 (n=5)	5.28 ± 0.48 (n=5)	5.63 ± 0.46 (n=5)	5.46 ± 0.45 (n=5)
RB	4	97.66 ± 9.33	23.25 ± 5.61	4.98 ± 0.52	5.12 ± 0.49	5.14 ± 0.34	4.96 ± 0.42
FB	6	82.67 ± 14.22	18.17 ± 6.22	5.20 ± 0.66 (n=5)	5.28 ± 0.56 (n=5)	5.73 ± 0.79 (n=5)	5.51 ± 0.85 (n=5)
WR	9	100.28 ± 9.64 [a,b] (n=8)	24.75 ± 4.99 [a] (n=8)	4.84 ± 0.68 (n=8)	4.97 ± 0.63 (n=8)	5.14 ± 0.27 [a] (n=8)	4.90 ± 0.27 [a] (n=8)
TE	7	94.73 ± 10.94	23.29 ± 4.30	4.67 ± 0.46 [e]	4.83 ± 0.46 [e]	5.35 ± 0.48	5.17 ± 0.47
OL	15	80.94 ± 12.08 [a] (n=13)	17.39 ± 4.05 [a,d] (n=14)	5.62 ± 0.44 [e] (n=8)	5.75 ± 0.49 [e] (n=8)	5.95 ± 0.61 [a,d] (n=13)	5.75 ± 0.63 [a,d] (n=13)
DL	9	82.51 ± 13.83 [b,c] (n=8)	18.88 ± 5.52 (n=8)	5.33 ± 0.56 (n=7)	5.45 ± 0.51 (n=7)	5.87 ± 0.69 (n=8)	5.68 ± 0.66 (n=8)
DE	8	93.69 ± 7.77 (n=7)	21.81 ± 3.01	4.88 ± 0.48	4.99 ± 0.49	5.42 ± 0.30	5.23 ± 0.35
LB	10	83.34 ± 14.91 (n=9)	18.44 ± 4.25 (n=9)	5.19 ± 0.44 (n=7)	5.29 ± 0.40 (n=7)	5.67 ± 0.50 (n=7)	5.41 ± 0.54 (n=7)
DB	9	98.04 ± 6.68 [c]	23.94 ± 3.49 [d]	4.99 ± 0.43 (n=8)	5.06 ± 0.39 (n=8)	5.19 ± 0.24 [d]	4.92 ± 0.27 [d]

[a] Significant differences were observed between WR and OL ($p < .05$) [c] Significant differences were observed between DL and DB ($p < .05$) [e] Significant differences were observed between TE and OL ($p < .05$)
[b] Significant differences were observed between WR and DL ($p < .05$) [d] Significant differences were observed between OL and DB ($p < .05$)

Table 3 reports the descriptive statistics for the football players' physical characteristics according to age. One-way ANOVA revealed no significant differences between height and age, weight and age, and %BF age at $p > .05$. Table 4 reports the descriptive statistics for the football players' performance on selected OPT according to age. Significant differences were found for both SLJ and VJ between the following age groups: 14 and 15 year olds, 14 and 16 year olds, 14 and 17 year olds. In addition, significant differences were found for electronic times for the 20-yd shuttle between 14 and 17 year olds, for the average hand-held 20-yd shuttle times between 14 and 16 years old as well as 14 and 17 year olds, for the mean electronic and hand-held 40-yd sprint times and the following 14 and 15 year olds, 14 and 16 year olds, and 14 and 17 year olds ($p < .05$).

Table 3

Descriptive Statistics (mean ± SD) for High School Football Players Grouped by Age

Variables	(N)	Height (in)	Weight (lbs)	Body Fat (%)
Age 13	1	65.50	182.00	24.19
Age 14	7	66.14 ± 3.30	168.07 ± 28.67	16.21 ± 8.50
Age 15	12	67.21 ± 4.01	170.65 ± 41.44	11.28 ± 10.00
Age 16	16	68.23± 3.12	184.36 ± 32.95	10.57 ± 5.98
Age 17	22	68.83 ± 2.43	197.26± 39.92	11.47 ± 6.59
Age 18	2	69.00 ± 3.54	195.25 ± 72.48	16.58 (n=1)

Table 4

Descriptive Statistics (mean ± SD) for High School Football Players Grouped by Age.

Variables	(N)	Standing Long Jump (in)	Vertical Jump (in)	20-yd Shuttle (electronic)	20-yd Shuttle (hand)	40-yd Sprint (electronic)	40-yd Sprint (hand)	Bench Press (reps-to-fatigue)
Age 13	1	64.50	10.50	6.10	6.07	7.13	7.02	-
Age 14	7	69.33 ± 11.10 [a,b,c] (n=6)	13.83 ± 3.88 [a,b,c] (n=6)	5.78 ± 0.43 [c] (n=5)	5.92 ± 0.49 [b,c] (n=5)	6.48 ± 0.67 [a,b,c] (n=5)	6.29 ± 0.65 [a,b,c] (n=5)	2.00 ± 4.47 [a,b] (n=5)
Age 15	12	89.36 ± 9.78 [a] (n=11)	20.14 ± 4.25 [a] (n=11)	5.10 ± 0.56 (n=9)	5.23 ± 0.55 (n=9)	5.53 ± 0.33 [a] (n=9)	5.33 ± 0.37 [a] (n=9)	8.38 ± 7.05 [a] (n=8)
Age 16	16	91.86 ± 9.20 [b] (n=15)	21.78 ± 3.79 [b]	5.05 ± 0.61 (n=13)	5.14 ± 0.55 [b] (n=13)	5.46 ± 0.32 [b] (n=15)	5.21 ± 0.34 [b] (n=15)	12.00 ± 6.70 [b] (n=10)
Age 17	22	93.14 ± 11.31 [c]	22.07 ± 4.72 [c]	4.83 ± 0.42 [c] (n=19)	4.96 ± 0.40 [c] (n=19)	5.36 ± 0.41 [c]	5.17 ± 0.45 [c]	12.08 ± 7.48 (n=13)
Age 18	2	99.00	21.00	-	-	5.34 (n=1)	5.28 (n=1)	14.00 (n=1)

Note: The 14, 15, and 16 year old group used 155 lbs for the bench press. The 17 and 18 year old group used 185 lbs for the bench press.

[a] Significant differences were observed between 14 and 15-year-old football players ($p < .05$).

[b] Significant differences were observed between 14 and 16-year-old football players ($p < .05$).

[c] Significant differences were observed between 14 and 17-year-old football players ($p < .05$).

Using the Bonferroni adjustment, post-hoc tests revealed that the 14-year old group, on average had a 22% lower SLJ score than the 15-year old group, a 25% lower SLJ score than the 16-year old group and a 26% lower SLJ score than the 17-year old group. In addition, the 14 year-old group on average, had a 31% lower VJ score than the 15-year old group, a 37% lower VJ score than both the 16 and 17-year old group. The 14-year old group on average had a 16% lower 20-yd shuttle electronic time than the 17-year old group, a 13% lower 20-yd shuttle hand time than the 16-year old group and a 16% lower 20-yd shuttle hand time than the 17-year old group, had a 15% lower 40-yd sprint electronic time than the 15-year old group. Additionally, the 14-year old group on average, had a 16% lower 40-yd sprint electronic time than the 16-year old group, a 17% lower 40-yd sprint electronic time than the 17-year old group, a 15% lower 40-yd sprint hand time than the 15-year old group, a 17% lower 40-yd sprint hand time than the 16-year old group, and a 18% lower 40-yd sprint hand time than the 17-year old group. Finally, the 14-year old group on average performed 76% less repetitions than the 15-yr old group and 83% less repetitions than the 16-yr old group in the bench press repetitions to fatigue test. No comparison could be made between the 14-year old group and both the 17 and 18-year old group due to differences in weight lifted.

CHAPTER IV

DISCUSSION

Performance variables (body size and composition, anaerobic power, muscular strength, speed, and agility) have been shown to be key factors in predicting the success of collegiate and professional football players (3, 6, 9, 10, 11, 14, 18, 27, 32, 33, 41). Measuring performance variables to predict FPA may be accomplished by OPT (3, 6, 9, 10, 11, 14, 27, 32, 33, 41). Despite the lack of research identifying a relationship between performance variables and FPA at the high school level, collegiate and professional studies have allowed for the speculation that the football players performing the highest on OPT at any level of play have the greatest FPA (3, 6, 9, 10, 11, 14, 18, 27, 32, 33, 41). This study has measured the before mentioned performance variables in 60 high school football players.

Body Composition. Compared to the football players in Williford et al. (39) the high school football players in this study were 4% shorter, 7% lighter and had 7% less body fat (BF). Compared to the football players in Kollias et al. (22), the high school football players in this study were 7% shorter, 7% lighter and had

22% less BF. In addition, when compared to collegiate and professional studies the findings of the present study support the two previous high school studies (22, 39) in that high school football players are lighter and had less FFM than collegiate and professional football players (8, 9, 11, 13, 17, 19, 24, 28, 31, 34, 35, 37, 38, 40). Although there is a clear distinction between the weight and FFM of high school football players and both collegiate and professional football players, no clear distinction in height, weight, or BF could be made between four different age groups of high school football players. Due to the differences in position groupings (i.e., case weighting) between this study and the previous high school studies, no comparisons based on positions will be made.

Anaerobic Power. In this study, the high school football players had an 8% lower VJ score than the high school football players in Williford et al. (39). The findings in this study also confirm the previous high school study (39) in that high school football players have a lower VJ than both collegiate and professional football players (6, 9, 19, 23, 27, 32, 36). Further evidence from the present study revealed that 14-year old high school football players may have a significantly lower VJ and SLJ score than 15, 16, and 17 year old high school football players.

Upper body muscular strength. Due to the fact that no other study at the high school level has implemented a repetition-to-fatigue bench press, no comparisons can be made to previous studies. In the present study, 14-yr old football players seem to be significantly weaker than both 15 and 16-yr old football players.

Speed and Agility. Due to the lack of research at the high school level, the agility results of the present study can only be compared to studies at the collegiate and professional level. Comparisons at the high school level based on age revealed that 14-year old high school football players are physically slower in the 40-yd sprint (electronic and hand time) than 15, 16, and 17 year old high school football players, less agile in the 20-yd shuttle (electronic) than 17 year old high school football players, and less agile in the 20-yd shuttle (hand time) than 16 and 17 year old high school football players. The 40-yd sprint results of the current high school study are comparable to that of a previous high school study (39). This re-affirms that high school football players are usually 5-7% slower than collegiate and professional football players.

Summary and Conclusions. Participation in high school football has grown over the past decade. Despite the increase in participation little research has been dedicated to football at the high school level. Although there is minimal research on high school football players, this study along with the two previous high school studies have began to describe performance variables at the high school level. The overall findings of the current study seem to suggest that age 14 may be a critical year in terms of development and future success. For example, the gains made during the transition from age 14-15 may have a larger training impact than previously thought. This information may also assist high school football coaches in identifying young football players' strengths and weaknesses for the development of more personalized training programs. This may ensure that the young football athlete has the best opportunity to develop appropriately and maximize future success. Future studies are warranted that include a larger high school football sample to allow for normative standards to be created based on age and positioned played. Furthermore, research at the high school level employing the concept of FPA (i.e., starters vs. nonstarters) is needed to identify whether elite high school players can be identified by the same performance variables used to identify collegiate and professional football players.

REFERENCES

1. ADAMS, G. (1998). *Exercise Physiology Lab Manual.* Indiana: McGraw-Hill.
2. American College of Sports Medicine. *Guidelines for Exercise and Testing and Prescription* (6th ed.). Philadelphia: Lippincott Williams & Wilkins, 2000.
3. ARNOLD, J.A., B. BROWN, R.P. MICHELI, & T.P. COKER. Anatomical and physiologic characteristics to predict football ability. *Am. J. Sport Med. 8*(2):119-122. 1976.
4. ARTHUR, M., & B. BAILEY. *Complete conditioning for football.* Illinois: Human Kinetics. 1998.
5. BAECHLE, T. *Essentials of strength training and conditioning: national strength and conditioning association*. Illinois: Human Kinetics. 1994.
6. BARKER, M., T.J. WYATT, R.L. JOHNSON, M.H. STONE, H.S. O'BRYANT, C. POE, & M. KENT. Performance factors, psychological assessment, physical characteristics, and football playing ability. *J. Strength Cond. Res.* 7(4):224-233. 1993.
7. BECKENHOLDT, S.E., & J.L. MAYHEW. Specificity among anaerobic power tests in male athlete. *Journal of Sports Medicine*. 23:326-332. 1983.

8. BEHNKE, A.R. JR., B.G. FEEN, & W.C. WELTHAM. The specific gravity of healthy men. *J. Amer. Med. Assoc.* 118:495-501. 1957.

9. BERG, K., R.W. LATIN, & T. BAECHLE. Physical and performance characteristics of NCAA division I football players. *Res. Q. Exercise Sport. 61*(4):395-401. 1990.

10. BLACK, W., AND E. ROUNDY. Comparisons of size, strength, speed, and power in NCAA Division 1-A football players. *J. Strength and Cond. Res. 8(2):* 80-85. 1994.

11. BURKE, E.J., E. WINSLOW, & W.V. STRUBE. Measures of body composition and performance in major college football players. *J. Sport Med. Phys. Fit. 20:* 173-179. 1980.

12. CHAPMAN, P., J.WHITEHEAD, & R. BINKERT. The 225-lb reps-to-fatigue test as a submaximal estimate of 1-rm bench press performance in college football players. *J. Strength and Cond. Res. 12*(4):258-261. 1998.

13. COSTILL, D.L., W.M. HOFFMAN, F. KEHOE, S.J. MILLER, & W.C. MYERS. Maximum anaerobic power among college football players. *J. Sport Med. Phys. Fit. 8*:103-106. 1968.

14. DANIEL, M.L., B.S. BROWN, & D. GORMAN. Strength and anthropometric characteristics of selected offensive and defensive university level football players. *Percept motor skill. 59*(1):127-130. 1984.

15. DAVIS, A.T. An analysis of the ingredients of a winning football team. *J. Sport Med. Phys. Fit. 12*:201-206. 1972.

16. DAVIS, D.S., B.J. BARNETTE, J.T. KIGER, J.J. MIRASOLA, & S.M. YOUNG. Physical characteristics that predict functional performance in division I college football players. *J. Strength and Cond. Res. 18*(1):115-120. 2004.

17. FORSYTH, H.L., W.E. SINNING. The anthropometric estimation of body density and lean body weight of male athletes. *Medicine and Science for Sports*. 5:174-180. 1973.

18. FRY, A.C., & W.J. KRAEMER. Physical performance characteristics of american collegiate football players. *Journal of Applied Sports Science Research.* 5(3): 126-138. 1991.

19. GETTMAN, L.R., & M.L. POLLOCK. What makes a superstar? A physiological profile. *Physician Sportsmed.* 5:64-68. 1977.

20. JACKSON, A.S., M.L. POLLOCK, & A. WARD. Generalized equations for predicting body density of women. *Med. Sci. Sports & Exerc.* 12:175-182. 1980.

21. JACKSON, A., & R. FRANKIEWICZ. The relationship of basic motor performance abilities to success in football. Proceedings, 39th annual convention, Southern District AAHPER, Jackson, Miss. 1973.

22. KOLLIAS, J., E.R. BUSKIRK, E.T. HOWLEY, & J.T. LOOMIS. Cardiorespiratory and body composition measurements of a select group of high school football players. *Res Quart.* 43:472-478. 1972.

23. MAYHEW, J.L., T. MCCORMICK, & B. LEVY. Strength norms for ncaa division II college football players. *National Strength and Conditioning Association Journal.* 9:67-69. 1987.

24. MAYHEW, J.L., F.C. PIPER, T.M. SCHWEGLER, & T.E. BALL. Contributions of speed, agility, and body composition to anaerobic power measurements in college football players. *J. Appl. Sports Sci. Res.* 3(4):101-106. 1991.

25. MAYHEW, J.L., J.L. PRINSTER, J.S. WARE, D.L. ZIMMER, J.R. ARABAS, & M.G. BEMBEN. Muscular endurance repetitions to predict bench press strength in men of different training levels. *J. Sport Med. Phys. Fit.* 35:108-113. 1995.

26. MAYHEW, J.L., J.S. WARE, M.G. BEMBEN, B. WILT, T. WARD, B. FARRIS, J. JURASZEK, & J. SLOVAK. The nfl-225 test as a measure of bench press strength in college football players. *J. Strength Cond. Res.* 13(2):130-134. 1999.

27. MCGEE, K.J., & L.E. BURKETT. The national football league combine: a reliable predictor of draft status? *J. Strength Cond. Res.* 17(1):6-11. 2003.

28. NOVAK, L.P., R.E. HYATT, & J.F. ALEXANDER. Body composition and physiologic function of athletes. *J. Amer. Med. Assoc.* 205:714-720. 1968.

29. OLSON, J.R., & G.R. HUNTER. A comparison of 1974 and 1984 player sizes, and maximal strength and speed efforts for division I ncaa universities. *Strength Cond.* 6(6):26 - 28. 1985.

30. PRATT, M. Strength, flexibility, and maturity in adolescent athletes. *Am. J. Dis. Child.* 143(5):859-862. 1989.

31. ROBERTSON, R.J., B.D. EPLEY, K.D. ROSE, F.M. ROYER, G.F. SULLIVAN, P.J. SCHNEIDER. Evaluation of a year-round football conditioning program. *Athletic Training.* 10(10):78-83. 1975.

32. SAWYER, D.T., J.Z. OSTARELLO, E.A. SUESS, & M. DEMPSEY. Relationship between football playing ability and selected performance measures. *J. Strength Cond. Res.* 16(4):611-616. 2002.

33. SHIELDS, C.L. JR., F.E. WITNEY, & V.D. ZOMAR. Exercise performance of professional football players. *Am. J. Sport Med.* 12(6):455-459. 1984.

34. SMITH, D.P, & R.J. BYRD. Body composition, pulmonary function and maximal oxygen consumption of college football players. *J. Sport Med. Phys. Fit.* 16:301-308. 1976.

35. SMITH, J.F., & R.E. MANSFIELD. Body composition prediction in university football players. *Med. Sci. Sport Exer.* 16:398-405. 1984.

36. WADE, G. Tests and measurements: Meeting the standards of professional football. *National Strength and Conditioning Association Journal.* 4:23. 1982.

37. WHITE, J., J.L. MAYHEW, & F.C. PIPER. Prediction of body composition in college football players. *Sports Medicine and Physical Fitness.* 20:317-324. 1980.

38. WICKKISER, J.D., & J.M. KELLY. The body composition of a college football team. *Medicine and Science in Sports.* 7:199-202. 1975.

39. WILLIFORD, H. N., J. KIRKPATRICK, M. SCHARFF-OLSON, D. L. BLESSING, & N.Z. WANG. Physical and performance characteristics of successful high school football players. *Am. J. Sport Med.* 22(6):859-862. 1994.

40. WILMORE, J.H., AND W.L. HASKELL. Body composition and endurance capacity of professional football players. *J. of Appl. Physiol.* 33:564-567. 1972.

41. WILMORE, J. H., R. B. PARR, W. L. HASKELL, D. L. COSTILL, L. J. MILBURN, & R. K. KERLAN. Football pros' strength - and CV weakness - charted. *Physician SportsMed.* 5:45-54. 1976.

APPENDIX A

REVIEW OF LITERATURE

Review of Literature

Performance variables such as body size and composition, anaerobic power, muscular strength, speed, and agility, have been shown to be key factors in the successful performance of collegiate and professional football players (3, 6, 9, 10, 11, 14, 18, 27, 32, 33, 41). After an extensive search of the literature, however, no quantitative research surfaced addressing the relationship between performance variables and FPA of high school football players. Despite this lack of research, studies addressing the variables associated with performance of collegiate and professional football players (3, 6, 9, 11, 14, 18, 27, 32, 33, 41) allow for speculation that the highest performing football players at any level of play (i.e., high school, college, or professional) have the greatest FPA, and are often those who possess the greatest quickness, agility, strength, power and lean body mass, or any combination of these.

Measuring performance variables to allow for the prediction of FPA is often accomplished by means of objective performance tests (OPT) (3, 6, 9, 10, 11, 14, 27, 32, 33, 41). Although the development of OPT to accurately predict FPA by position and level of play is in its infancy, studies have clearly identified a relationship between FPA (as determined by starting status, coaches rank, or draft position) and performance on such OPT as body size and composition (3, 10, 11, 14, 27, 32, 33), the 1-repetition maximum (RM) bench press (9, 27, 32), the

VJ (6, 9, 14, 18, 27, 32), the 40-yard sprint (9, 11, 27), the 20-yard sprint (27, 32), the 10-yard sprint (27, 32), and the pro-agility (27, 32). Furthermore, differences in VJ and 1-RM bench press between ranked and unranked NCAA Division-I college football teams have also been demonstrated (9).

Indeed, research suggests that: (a) excellence on a battery of OPT may translate into football success (3, 6, 9, 10, 11, 14, 18, 27, 32, 33, 41), and (b) improvement on OPT may result in enhanced FPA (32). However, only limited descriptive information exists addressing the value in using OPT to characterize a player's FPA at the high school level (22, 39). The following review will discuss the relevant literature identifying specific OPT that have shown to be most effective in predicting position-based FPA of high school players, and compare the differences in performance on OPT among high school, college and professional football players. This could assist high school coaches to more accurately: (a) identify the best football player for each starting position; (b) identify each player's strengths and weaknesses for the development of individualized training programs; (c) identify the position(s) for which a player is best suited; and (d) determine a player's level of readiness to play.

Body Size and Composition

FPA is highly correlated with body size and composition (3, 10, 11, 14, 27, 32, 33). The aspects of body size and composition most associated with athletic success appear to be height (3, 27, 32), body weight (3, 27), fat-free mass (11), and %BF (14). For instance, Sawyer et al. (32) demonstrated a relationship between FPA (determined by the average of coaches' ranking) and height for a group of NCAA Division I-A defensive players (r= 0.52). In a study of 326 collegiate football players attending the 2000 National Football League combine, McGee and Burkett (27) found that height and weight were among the best predictors of success for both offensive and defensive linemen, as well as for linebackers. In addition, Burke et al. (11) identified lean weight as one of the most important variables contributing to the classification of 67 Division I-A football players as starter, player (i.e., did not start but participated in more than one game) and non-player. In short, Burke et al. (11) determined that starters (i.e., players with highest FPA) had greater lean body mass when compared to non-starters and non-players. In a similar study of 43 collegiate football players, Daniel et al. (14) showed that either %BF or selected skinfold sites were essential in predicting FPA success at various positions. For example, the FPA of defensive linemen can be predicted reliably from %BF, chin and cheek skinfolds, and VJ. Based on these studies, evaluating body size and composition is important for predicting FPA.

Level of Play. From review of the literature, a relationship between level of play and both body size and composition appears to exist (22, 39). Table 1 summarizes the mean body size and composition of football players at three different levels of play. From comparison of mean values for body size and composition, high school players assessed by Kollias et al. (22) tended to: (a) weigh less than collegiate and professional players in 14 of the 16 studies that reported mean body weight (8, 9, 11, 13, 19, 24, 27, 28, 31, 32, 34, 35, 37, 40), (b) have less fat-free mass than collegiate and professional players in 12 of the 14 studies that reported mean fat-free mass (8, 9, 11, 13, 19, 24, 28, 31, 34, 35, 37, 40), and (c) have greater relative %BF than collegiate and professional players in 12 of the 14 studies that reported %BF (8, 9, 13, 17, 19, 24, 28, 31, 34, 35, 37, 38,). When considering the studies to which the high school players were lighter, had less fat-free mass, and had greater %BF, the sample of high school players in Kollias et al. (22), on average: (1) were 1 to 15% lighter than collegiate players and 2 to 18% lighter than professional players; (2) had 3 to 18% less fat-free mass than collegiate players and 8 to 17% less fat-free mass than professional players; and (3) had 3 to 50% greater relative %BF than collegiate players and 31 to 54% greater relative %BF than professional players. However, comparing the average height of the sample of high school football players in Kollias et al. (22) to the average heights of the college and professional players reported in the studies listed in Table 1 (8, 9, 11, 13, 24, 27, 28, 31, 32, 34, 35, 37, 38, 40), reveals no clear relationship between level of play and height.

Table 5

Means of Body Size and Composition of High School, Collegiate, and Professional Football Players

	N	Age	Height (cm)	Weight (kg)	FFM (kg)	%BF
High School						
Williford et al. (1994)	18	16.2	180.6	89.1	77.1	12.9
Kollias et al. (1972)	27	17.8	185.0	89.0	75.3	15.4
College						
Sawyer et al. (2002)	40	19.5	186.1	101.8		
Berg et al. (1990)	880		187.1	104.1	91.3*	12.3*
Mayhew et al. (1989)	53	20.3	182.7	90.8	79.6	11.9
Smith and Mansfield (1984)	68		187.4	98.5	85.9	12.8
Burke and Winslow (1980)	53		185.2	95.1	77.7	18.3
White et al. (1980)	58	19.9	182.0	89.7	78.5	12.1
Smith and Byrd (1976)	27		186.8	93.1	80.3	13.7
Wickkiser and Kelly (1975)	65		182.5	88.0	74.0	15.0
Robertson et al. (1975)	20		186.9	94.4	81.0	14.2
Forsyth and Sinning (1973)	11			82.4	70.8	14.1
Novak et al. (1968)	16	20.3	185.0	96.4	82.6	13.8
Costill et al. (1968)	72	21.0	179.0	92.6	83.1	10.3
Professional						
McGee et al. (2003)	326		186.4	109.1		
Gettman and Pollock (1977)	53			101.8	89.1	11.8
Wilmore and Haskell (1972)	44		190.2	107.0	90.9	16.2
Behnke et al. (1957)	25	25.2	183.0	91.2	81.7	10.0

Note. FFM = Fat-free body mass; %BF = percent body fat.
*N=632

The relationships between level of play and both total body weight and fat-free mass have been confirmed in a more recent study by Williford et al (39). From comparison of the mean body size and composition of football players reported in Table 5, high school players assessed by Williford et al. (39), on average, tended to: (1) weigh less than collegiate and professional players in 14 of the 16 studies that reported mean body weight (8, 9, 11, 13, 19, 24, 27, 28, 31, 32, 34, 35, 37, 40), and (2) have less fat-free mass than collegiate and professional players in 12 of the 14 studies that reported mean fat-free mass (8, 9, 11, 13, 19, 24, 28, 31, 34, 35, 37, 40). Unlike Kollias et al. (22), the 18 high school football players assessed by Williford et al. (39) tended to be shorter when compared to the collegiate and professional players in 13 of the 14 studies that reported mean height (8, 9, 11, 24, 27, 28, 31, 32, 34, 35, 37, 38, 40). When considering the studies to which the high school players were lighter, had less fat-free mass, and were shorter, the sample of high school players in Williford et al. (1994), on average: (1) were 1 to 14% lighter than collegiate players and 2 to 18% lighter than professional players; (2) had 1 to 16% less fat-free mass than collegiate players and 6 to 15% less fat-free mass than professional players, and (3) were 1 to 3% shorter than collegiate players and 1 to 5 % shorter than professional players. Also, in contrast to Kollias et al. (22), when comparing the average %BF of the sample of high school football players in Williford et al. (39) to the average %BF of collegiate and professional football players reported in the studies listed in Table 5 (8, 9, 11, 13, 17, 19, 24, 28, 31, 34, 35, 37, 38, 40), no clear relationship between level of play and %BF emerges.

From comparison of the mean heights, weights, fat-free masses, and percent body fats of high school football players to mean heights, weights, fat-free masses, and percent body fats of collegiate and professional football players, total body weight and fat-free mass appear to be key factors in distinguishing high school level of play from both collegiate and professional levels of play. Such factors may be useful in predicting a player's readiness to compete at the next level.

Position. Research on high school and collegiate football players has shown that body size and composition vary not only with level of play, but also by position (6, 9, 11, 22, 32, 38, 39, 40) Table 6 summarizes the mean body size and composition of offensive and defensive collegiate football players. Overall, the collegiate offensive players were heavier, had more fat-free mass, and had greater relative body fat than the collegiate defensive players (9, 32, 38). From comparison of mean values for body size and composition, the offensive players were 2 to 6% heavier, had 1 to 3% more fat-free mass, and had 8 to 10% greater relative body fat than the defensive players. However, there was no apparent difference in height between offensive and defensive collegiate players.

Table 6

Means of Body Size and Composition of Collegiate Offensive and Defensive Players

	OFFENSE					DEFENSE				
	N	Weight (kg)	Height (cm)	FFM (kg)	%BF	N	Weight (kg)	Height (cm)	FFM (kg)	%BF
Sawyer et al. (2002)	21	104.8	186.7			19	98.68	185.4		
Berg et al. (1990)	440	106.7	187.5	92.9	12.9	440	101.5	186.7	89.7	11.6
Wickkiser et al. (1975)	28	89.5	182.9	75.4	15.8	37	87.4	181.7	74.7	14.5

Note. FFM = Fat-free body mass; %BF = percent body fat.

Table 7 indicates the mean body size and composition of both high school and collegiate backs (e.g., running backs, defensive backs and ends, quarterbacks, and wide receivers) and linemen (e.g., offensive linemen, defensive linemen, and linebackers). Overall, at all three levels of play, linemen tended to weigh more, have greater fat-free mass, and have greater relative body fat than backs (6, 11, 22, 32, 38, 40). From comparison of mean values for body size and composition, the high school linemen were 15 to 19% heavier, had 10 to 12% greater fat-free mass, and had 28 to 48% greater relative body fat than the high school backs (22, 39). Similarly, when compared to collegiate backs, collegiate linemen were 19 to 32% heavier, had 7 to 21% greater fat-free mass, and had 47 to 68% more relative body fat (6, 11, 38). Finally, when compared to professional backs, professional linemen were 28% heavier, had 15% greater fat-free mass, and had 115% more relative body fat (40). With regard to height, there was virtually no difference between high school linemen and high school backs; however, collegiate linemen were 3-4% taller than collegiate backs (6, 11, 38) and professional linemen were 4% taller than professional linemen (40).

Table 7

Means of Body Size and Composition of High School and College Backs and Linemen

	BACKS					LINEMEN				
	(N)	Weight (kg)	Height (cm)	FFM (kg)	%BF	(N)	Weight (kg)	Height (cm)	FFM (kg)	%BF
<u>High School</u>										
Williford et al. (1994)	8	80.5	180.1	72.1	10.2	10	96	180.9	81.1	15.1
Kollias et al. (1972)	15	83.3	183	71.9	13.7	12	96	187	79.1	17.6
<u>College</u>										
Barker et al. (1993)	24	81.6	176.9	70.3	13.9	35	107.4	184.1	85.3	20.5
Burke et al. (1980)	20	85.5	181.4	74.4	13.0	33	101.6	187.3	79.5	21.8
Wickkiser et al. (1975)	30	78.6	179	69.0	12.0	35	96.2	185.1	78.3	17.7
<u>Professional</u>										
Willmore et al. (1972)	14	89.9	184.3	82.5	8.1	30	115.0	192.5	94.8	17.4

Note. FFM = Fat-free body mass; %BF = percent body fat.

Finally, Shields et al. (33) compared the body size and composition among four groups of professional football players (group 1: linemen; group 2: tight ends and linebackers; group 3: quarterbacks, running backs and kickers; and group 4: defensive backs and wide receivers). The average heights of each group were 193.3, 190.5, 184.7, and 181.9 cm, respectively. The average body weights were 117.7, 104.5, 94.1, and 85 kg, respectively. Average %BF was 17.4, 13.0, 12.1, and 8.1 percent, respectively. Average lean body mass was 96.8, 90.9, 82.7, 78.2 kg, respectively. Results showed that subjects in group 1 were the tallest, heaviest, had the greatest %BF, and the greatest lean body mass. Subjects in Group 2 were shorter, lighter, had less %BF, and lower lean body weight than those in Group 1. Subjects in Group 3 were shorter, lighter, had less %BF, and lower lean body weight than those in Group 2. And finally, subjects in Group 4 were shorter, lighter, had less %BF, and lower lean body weight than those in Group 3. Based on this study, at the professional level, linemen are expected to be the tallest, to weigh the most, and to have the greatest %BF on a team.

From review of previous research (9, 11, 22, 32, 33, 38, 39), total body weight, fat-free mass, and %BF appear to be key factors in distinguishing among position at the high school level. However, height does not distinguish seem to be a factor until higher levels of play. Therefore, at the college level total body weight, fat-free, mass, and %BF may be useful in determining the best-suited player for each position.

Conclusion and Discussion. There are two high school studies documenting the body size and composition of high school football players (22, 39). Because these studies are limited by small sample sizes (i.e., neither sample size was larger than 27), results cannot be generalized to all high school football players. In addition, since the physiological data reported by Kollias et al. (22) was collected in the early 1970's, results may be outdated, and therefore, not generalizable to current high school football players. Today's football players are believed to be considerably taller and heavier than football players from the 1970's (9, 11, 27, 28, 29, 31, 32). For instance, in a study by Olson and Hunter (29), 1983-84 collegiate offensive linemen were on average 2.9 cm (1.1 inches) taller and 9.6 kg (21.1 kg) heavier than 1973-1974 collegiate offensive linemen. Consequently, using results from older studies to characterize current football players' body size and composition may be misleading. Nevertheless, from review of the cross-sectional studies highlighted in this article, it may be postulated that: (a) high school football players tend to have less total body weight and fat-free mass than collegiate and professional football players; and (b) position played is related to total body weight, fat-free mass, and %BF, but not to height. Therefore, accurately assessing total body weight, fat-free mass, and percent body weight may assist coaches in determining player's level of readiness as well as the best-suited player for each position.

Anaerobic Power

FPA is highly correlated with anaerobic power (6, 9, 10, 14, 18, 27, 32). Anaerobic power is the ability of a muscle to exert a high force while contracting at a high-speed (5). Tests to measure anaerobic power are short in duration, performed at maximal movement speeds and produce very high power outputs. The most common test to assess anaerobic power is the VJ (1, 4, 5, 7, 39). Fry and Kraemer (18) found significant differences in VJ between starters and nonstarters across 3 NCAA Divisions, as well as within a specific team. In addition, Sawyer et al. (32) showed that VJ was significantly related to FPA (i.e., based on the rankings of 4 collegiate coaches) for the offensive group (r=.50), the defensive group (r=.64), and for three position groups (Offensive linemen (OL)-Defensive linemen (DL), r=.75, Wide receiver (WR)-Defensive back (DB), r=.73, Running back (RB)-Tight-end (TE)-Linebacker (LB), r=.74). Based on previous studies, VJ provides some indication of FPA and should be used when assessing FPA.

Level of Play. From review of the literature, VJ appears to increase as level of play increases (6, 9, 19, 23, 27, 32, 36, 39). Table 8 summarizes the mean VJ scores of high school, collegiate, and professional football players. On average, high school football players' VJ scores were 5% to 23% lower than collegiate players and 22 to 31% lower than professional players (9, 19, 23, 27, 32, 36, 39). Therefore, based on the studies reported in Table 4, VJ should also be considered a key factor in distinguishing among the three levels of play. In addition to other key performance tests, the VJ test may assist coaches in predicting a player's readiness to compete.

Table 8

Vertical Jump Scores (cm) of High School, Collegiate, and Professional Football Players

	N	Mean ± SD
High School		
Williford et al. (1994)	18	56.8 ± 9.6
College		
Sawyer et al. (2002)	70	73.7 ± 10.0
Barker et al. (1993)	59	61
Berg et al. (1990)	837	73.6 ± 9.5
Mayhew et al. (1987)		59.8
Professional		
McGee et al. (2003)	326	82.0 ± 9.4
Gettman et al. (1987)		73.4
Wade (1982)		72.9

Position. Limited research has also demonstrated that VJ not only varies with level of play, but also by position (9, 32). In a study of 837 collegiate football players, the mean VJ scores for the offensive and defensive players were 72.4 cm and 74.9 cm, respectively (9). In a more recent study involving a much smaller sample (n=40), the mean VJ scores for the offensive and defensive players were 72.4 cm and 75.1 cm, respectively (32). From comparison of the mean values for VJ, the defensive players jumped 3 to 4% higher than the offensive players (9, 32). Furthermore, Sawyer et al. (32) compared the differences in VJ scores among three groups of positions: (1) RB-TE-LB, (2) WR-DB, and (3) OL-DL. Mean VJ scores were 78.8, 77.4, and 69.7 cm, respectively. The RB-TE-LB group jumped 2% higher than the WR-DB group and 13% higher than the OL-DL group. In contrast, for the same grouping of players in the study Berg et al. (9), the VJ scores for the RB-TE-LB, WR-DB, and OL-DL groups were 76.7, 79.7, and 68.2 cm, respectively. The WR-DB group had a 4% higher VJ than the RB-TE-LB group and a 17% higher VJ than the OL-DL group. Based on these two studies, the OL-DL group, on average, is expected to have the lowest VJ scores among RB-TE-LB, WR-DB, and OL-DL groups of collegiate players. However, there is no clear difference between the VJ ability of RB-TE-LB and WR-DB groups of collegiate players.

At the high school level, Williford et al. (39) compared the VJ scores of 8 backs (WR, RB, QB) and 10 linemen (LB, DL, OL). The VJ scores for the backs and linemen were 61 (± 12.1) cm and 53.6 (± 5.3) cm, respectively. The backs were found to have a 14% higher VJ than the linemen. Similar to body size and composition, VJ varies by position at both high school and collegiate levels. Therefore, assessing VJ, along with body size and composition, may prove helpful in determining the best-suited player for each position.

Conclusions and Discussions. There has only been one high school study documenting the VJ scores of high school football players (39). Because this study is limited by a small sample size (n = 18), results cannot be generalized to all high school football players. Despite little research at the high school level, some trends do emerge: (a) high school football players tend to have lower VJ scores than collegiate and professional football players; and (b) when positions are grouped by similar abilities, high school linemen are expected to have lower VJ scores than high school backs. Therefore, the VJ test should also be administered when determining a player's readiness to compete and in predicting the best-suited player for each position.

Muscular Strength

FPA is also related to on muscular strength (5, 6, 9, 11, 27). Muscular strength is the amount of force a muscle or muscle group can exert in one maximal effort (5). The 1-repetition maximum (1-RM) bench press and the squat have become the most widely used methods to measure upper and lower body strength, respectively (4, 5, 9, 12, 26, 32, 39). Although determining the relationship between muscular strength and FPA is in its infancy, Sawyer et al. (32) has shown that the 1-RM bench press is significantly correlated to FPA in defensive players (r= 0.48). In addition, Berg et al. (9) demonstrated that mean bench press 1-RM scores were significantly higher in a sample of top 20 NCAA Division 1 teams versus non-top 20 NCAA Division 1 teams. Furthermore, Barker et al. (6) demonstrated that the average 1-RM squat for NCAA Division 1AA starters was significantly higher than the average 1-RM squat for NCAA Division 1AA nonstarters.

Although the 1-RM tests of muscular strength show promise in predicting FPA, many consider the 1-RM a dangerous and impractical test of muscular strength (12, 25, 26). Due to safety concerns and time considerations, a procedure involving repetitions-to-failure to predict muscular strength is gaining greater acceptance (12, 25 26, 27). Although the repetitions-to-failure test exhibits varying degrees of under and overestimation of actual 1-RM performance, preliminary research suggests a moderate to high correlation between 1-RM strength and the number of repetitions completed with absolute loads (r = 0.74 to 0.93) (12, 26). This indicates that individuals exhibiting greater levels of muscular endurance are expected to also have greater levels of muscular strength. Though a relationship between 1-RM strength and repetitions-to-failure has been identified, little descriptive data exists. Therefore, in order to compare the muscular strength of high school, college, and professional players, studies measuring strength with the 1-RM method are reviewed in this article.

Level of Play. Strength, particularly lower body strength, seems to increase markedly with age and maturational level (30). Because of a heightened awareness of the role that physical maturation plays on sports performance, maturity status is often considered in predicting sports performance (30). Much of the predictive value of maturation level lies in its association with body weight and lean body mass, which are also highly correlated with increased strength (30). Maturational level is usually assessed by the Tanner staging criteria (30). Although, Pratt et al. (30) showed that maturational status has a moderate correlation ($r = 0.53$) with lower body strength, assessment with Tanner's criteria can be somewhat impractical. Because Pratt et al. (30) also found a correlation between age and lower body strength ($r = 0.42$), it is acceptable to evaluate strength relative to age, or in the case of this article, to level of play.

Williford et al. (39) reported that as level of competition increases, 1-RM bench press scores increase. Table 9 summarizes the mean 1-RM bench press scores of high school and collegiate football players. When compared to previous research on Division 1-A collegiate football players, the mean 1-RM bench press scores for high school football players (39) were 11 to 20% lower than NCAA

Division I (9, 10, 26, 32). In contrast, when comparing the average 1-RM bench press scores of high school football players in Williford et al. (39) to the average 1-RM bench press scores of NCAA Division II collegiate football players reported in the studies listed in Table 5 (Mayhew 1989, 25, 26), no clear relationship between level of play and 1-RM bench press scores emerges. Therefore, 1-RM bench press maybe another useful test in determining if a player is ready to compete at the NCAA Division I level.

Table 9

Mean Bench Press Scores (kg) of High School and Division I and II Collegiate Football Players

	N	Mean ± SD
High School		
Williford et al. (1994)	18	125.6 ± 33.3
College: Division II		
Mayhew et al. (1999)	41	135.1 ± 16.8
Mayhew et al. (1995)	51	126.0
Mayhew et al. (1989)	54	126.1 ± 21.9
College Division I		
Sawyer et al. (2002)	40	141.0 ± 22.6
Mayhew et al. (1999)	52	140.4 ± 24.2
Black and Roundy (1994)	963	140.8 ± 20.5
Berg et al. (1990)	860	157.6 ± 25.6

Position. A difference in strength has also been shown to vary among position played (32, 39). In Sawyer et al. (32), the average 1-RM bench press scores for a sample of offensive and defensive players were 139.8(± 22.4) kg and 142.2(± 20.6) kg, respectively. The defensive players were on average 2% stronger than offensive players. In contrast, an earlier study (9) demonstrated that the average 1-RM bench press scores for a sample of offensive and defensive players were not significantly different (i.e., 157.9 ± 26.6 kg versus 157.4 ± 24.6 kg). This evidence suggests that upper body muscular strength cannot distinguish between offensive and defensive players.

When positions requiring similar physical attributes are grouped together and then compared to a different group of positions, differences in strength between groups of positions emerge. For instance, in a study comparing average 1-RM bench press scores of Defensive Tackles and Offensive Guards to Cornerbacks and Wide Receivers, the Defensive Tackle-Offensive Guard Group had 31% greater upper body strength than the Cornerback-Wide Receiver Group (i.e., 167.3 ± 26.2 kg versus 127.4 ± 19.1 kg). More comprehensive research at the collegiate and high school level has confirmed that bench press scores vary among positions requiring similar physical attributes (9, 32). Sawyer et al. (32) found that the average bench press scores for RB-TE-LB, OL-DL, and WR-DB were 140.1(±31.5) kg, 167.3(± 14.5) kg, and 129.0(±13.2) kg, respectively. The OL-

DL is 19% stronger than the RB-TE-LB group and 30% stronger than the WR-DB group. When using the same groups, these same findings are supported by previous research (9). For instance, in Berg et al (9), the average bench press scores for RB-TE-LB, OL-DL, and WR-DB groups were 156.6(±20.3) kg, 173.3(± 21.5), and 137.0(±17.3) kg, respectively. The OL-DL group was 11% stronger than the RB-TE-LB group and 30% stronger than the WR-DB group.

At the high school level, Williford et al. (39) compared the bench press scores of 8 high school backs (including backs, receivers, and quarterbacks) and 10 high school linemen (including centers, guards, tackles, and linebackers). The mean bench press scores of the high school backs and linemen were 106.0(±17.7) kg and 141.6 (±35.5) kg, respectively. On average, Williford et al. (39) found that high school linemen were 34% stronger than high school backs (WR, RB, and QB).

Conclusions and Discussion. There is only one study describing the upper body muscular strength of high school football players (39). Because this study is limited by a small sample size (i.e., n = 18), results cannot be generalized to all high school football players. Nevertheless, evidence from this study (39) as well as studies on collegiate players (9, 10, 24, 25, 26, 32) suggest that: (a) high school football players tend to have less upper body muscular strength than Division I collegiate football players; and (b) when positions are grouped according to similar attributes, high school backs tend to have less upper body muscular strength than high school linemen. Despite some trends emerging, there is not enough evidence to accurately characterize the relationship between upper body strength and position played at the high school level. Because research indicates that upper body muscular strength may be a good indicator of readiness to play at the next level as well as success at a particular position, more research is warranted to further characterize the relationship between a high football player's upper body muscular strength and both position.

Speed and Agility

Speed is defined as the time it takes to cover a fixed distance and is represented by displacement per unit of time (5). The test that is commonly used to measure speed is the 40-yd dash (1, 5). Agility is defined as the ability to stop, start, and change direction rapidly, in a controlled manner (5). The test most commonly used to measure the agility of football players is the pro-agility run, also known as the 20-yd shuttle run (27, 32). As previously stated, FPA is also related to both speed and agility (11, 22, 27, 32). For example, a study of 40 collegiate football players found both speed (i.e., 20 yds) and agility (i.e., pro-agility run) to be significantly related to FPA within the running back, tight end, and linebacker group ($r = 0.63$ and $r = 0.74$, respectively) and only speed (i.e., 20 yds) to be significantly related to FPA within the wide receiver and defensive back group (r =0.58) (32). Although agility has been shown to be an important predictor of FPA among collegiate players (11, 21, 27, 32), currently there is no descriptive data on results from agility tests at the high school level. Therefore, this article is limited to the review of studies on speed.

Level of Play. Recent studies demonstrate that high school football players are slower than collegiate and professional football players (9, 27, 39). Table 10 describes the mean 40-yd sprint times of high school, college, and professional football players (9, 27, 39). On average, high school football players were 6% slower than collegiate football players and 5% slower than professional football players (9, 27, 39).

Table 10

Mean 40-yd Sprint Scores (sec) of High School, Collegiate, and Professional Football Players

	(N)	Mean ± SD
High School		
Williford et al. (1994)	18	5.13
College		
Berg et al. (1990)	829	4.81 ± 0.26
Professional		
McGee et al. (2003)	326	4.87 ± 0.31

Position. More comprehensive research at the collegiate and high school level has confirmed that 40-yd sprint times vary based upon individual position played. At the collegiate level, Berg et al. (9) found that defensive players ran the 40-yard sprint 2% faster than offensive players (4.76±0.20 s versus 4.86±0.31 s, respectively). Further research by Sawyer et al. (32) found that ran defensive collegiate football players run the 20-yard sprint 3% faster than defensive collegiate players (2.9±0.15 versus 2.98±0.14s).

Although times from sprints may not clearly assist in distinguishing between offensive and defensive players, they do differentiate among different groups of positions. For instance, in Sawyer et al. (32), the WR-DB group was only 2% faster in the 20-yard sprint than the RE-TE-LB group (2.84±0.12 s versus 2.91±0.09 s), but was 8% faster in the 20-yard sprint than the OL-DL group (2.84±0.12 s versus 3.10±0.15 s). Using the same groups, these results are supported by previous research. For instance, in Berg et al. (1990), the WR-DB group was only 2% faster in the 40-yard sprint than the RE-TE-LB group (4.59±0.13 s versus 4.68±0.14 s), but was 9% faster in the 40-yard sprint than the OL-DL group (4.59±0.13 s versus 5.04±0.20 s).

Using a broader category, sprint times for players also vary at the high school level. Williford et al. (39) found that backs were 9% faster in the 40-yard sprint than linemen (4.8±0.2 s versus 5.3±0.3 s).

Summary and Conclusion. There has been only one study describing the 40-yd sprint times and no studies describing pro-agility run times of high school football players (39). Because Williford et al. (39) is limited by a small sample size (i.e., N = 18), results cannot be generalized to all high school football players. Nevertheless evidence does suggest that: (a) high school football players tend to be slower than collegiate and professional football players;(b) when positions are grouped by offensive and defensive categories, the offensive group tends to be slower than the defensive group in the 40-yd sprint and the pro-agility run; (c) and when positions are group by similar abilities, the high school linemen are expected to be slower than high school backs. Despite some trends, emerging there is not enough evidence at the high school level to evaluate speed and agility according to level of play and individual position played. More research is warranted to determine if relationships exist between a high school football player's speed and both level of play and individual position played and as well as a high school football player's agility and both level of play and individual position played.

Summary and Conclusions

With the continued growth in American football, more people are becoming interested about the physical attributes of high school football players and their relationship with overall FPA. Research has clearly identified specific attributes (i.e., body composition, anaerobic power, strength, speed and agility) associated with the success of college and professional football players. However research characterizing the performance of these variables at the high school level is limited. Regardless, test batteries characterizing body composition, anaerobic power, strength, speed and agility have been developed to assist coaches, trainers and researchers in predicting and improving FPA. Therefore, there is a need to further describe the performance of high school football players on OPT and develop normative standards in order to (a) compare each athlete's performance to other players of similar age and position played; (b) identify strengths and weaknesses in order to devise more individualized training programs; and (c) determine the level of readiness to compete at a higher level.

APPENDIX B

INFORMED CONSENT

Statement of Informed Consent

You are invited to participate in a study investigating the physiological characteristics of high school football players. In other words, we are trying to compare athletic abilities for high school football athletes based on age and position played. I am a graduate student and a graduate teaching assistant at Texas State University in San Marcos, in the Health, Physical Education, and Recreation Department. I am performing this study to fulfill my master's thesis requirement. I hope to compare and contrast the results of this study to past and future studies in order to identify common football playing abilities based on age and position played. You have volunteered as a possible participant in this study because your high school football team was chosen to be an experimental group. You will be one of 200 athletes chosen to participate in this study.

1. Purpose and Explanation of the Test

If you decide to participate, testing will include a battery of health and fitness tests including: height, weight, 3-site sum of skinfold, vertical jump, bench press repetitions to fatigue, broad jump, 20-yd shuttle run, and 40-yd sprint.

2. Attendant Risks and Discomforts

There are minimal risks to young, healthy male athletes participating in exercise testing. The effort required during this study is less than or equal to the physical efforts required of you during an actual football practice or game. However, it is important to be aware that the potential risks associated with exercise include muscle soreness, temporary breathlessness, minimal bouts of fatigue, and knee or ankle injury. **If you have had a previous knee injury and have been cleared**

to play, we invite you to participate in our study, but we will not allow you to perform the standing broad jump. The investigators are experienced and have conducted numerous exercise tests. In addition, emergency equipment will be brought to each site and is available at all times.

3. Use of Medical Records

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. Your confidentiality is important to us. For future data analysis, your name will be replaced with a number that can only be traced back to you by myself or by Dr. Lisa Lloyd, Lab Director at Texas State.

If you have any questions, please feel free to ask me now. If you have any additional questions later, feel free to contact me, Randy Kaiser (512) 245-1973, or the chair of my thesis, Dr. Lisa Lloyd, (512) 245-8358, and we will be happy to answer them.

You will be offered a copy of this form to keep.

Your decision whether or not to participate in this study will not prejudice your future relations with Texas State University or with me. If you decide to participate, you are free to discontinue participation at any time without prejudice.

Your signature indicates that you have read the information provided above and have decided to participate. If you are younger than 18 years of age, then you will need to have your parents read and sign the informed consent also.

I have read this form, and I understand the test procedures, risks, discomforts, and benefits of the study that I am about to participate in. Knowing these risks and discomforts, and having had an opportunity to ask questions that have been answered to my satisfaction, I consent to participate in this study.

Signature of Participant	Date	Age
Signature of Parent/Guardian	Date	
Signature of Investigator	Date	

APPENDIX C

RAW DATA

						SLJ	VJ	Bench Press		20-yard Shuttle		40-yd Sprint	
	Position	Age	Height (in)	Weight (lb)	%BF	in	IN	lb	reps	Electronic	Hand	Electronic	Hand
1	RB	16	69.25	203	14.09	93.5	22	155	17	5.66	5.77	5.14	5.17
2	WR	15	67	162	6.02	83.5	17.5	155	11	6.02	6.07	5.67	5.46
3	OL/DL	16	70.25	178.5	5.97	84.5	19	155	13	5.72	5.79	5.71	5.5
4	OL/DL	18	71.5	246.5	16.58	99	21	185	14	0	0	5.34	5.28
5	CB/WR	17	69.25	152	4.90	105	28.5	185	2	5.03	5.17	5	4.69
6	LB/FB	17	68	193.25	13.58	86.5	18.5	185	10	5.42	5.5	5.48	5.21
7	LB/FB	17	68	217.5	12.61	90.5	22.5	185	21	5 02	5.05	5.31	5
8	TE/DE	17	70.25	219	12.75	104.5	23.5	185	16	4.81	4.95	5.05	4.92
9	DL	17	63.5	197.5	21.05	79	15	185	17	5.37	5.46	5.69	5.62
10	TE/DE	17	69.5	178	6.71	96.5	21	185	9	4.85	4.9	5.15	5.01
11	QB	15	60.25	138	5.86	100	24	155	7	0	0	0	0
12	OL	15	76	285	28.38	77.5	15.5	155	20	5.58	5.83	6	5.9
13	DB	14	71.25	172	8.84	88	20	155	10	5.38	5.48	5.55	5.37
14		17	68.5	169	10.05	88	18	185	5	4.73	4.92	5.59	5.32
15	QB/WR/DB	16	73	167	6.44	99.5	19.5	155	7	5.29	5.33	5.41	5.1
16	LB/QB/TE	14	66.5	134	10.35	72.5	16	155	0	5.56	5.76	6.39	6.2
17	OL	14	68.5	226	26.06	72	12	155	0	6.42	6.68	6.68	6.58
18	OL/DL	14	64.5	153	20.84	55.5	9	155	0	6.02	6.11	7.42	7.15
19	FB	13	65.5	182	24.19	64.5	10.5	155	0	6.1	6.07	7.13	7.02
20	FB/LB	14	63	169.5	26.91	65	11.5	155	0	0	0	0	0
21	OL/DL	15	64.5	206.5	34.33	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	QB	15	69.25	150	6.18	82.5	17.5	155	1	5.3	5.36	5.72	5.59
23	OL	15	69.25	165	7.57	80	17	155	2	5.31	5.31	5.54	5.42
24	DE	15	70	176.25	13.84	92	22.5	155	3	5.15	5.31	5.68	5.41
25	FB/LB	15	66	177.5	11.06	94.5	19.5	155	17	5.18	5.22	5.47	5.19
26	OL/DE	16	68	169	9.89	0	18	155	2	5.45	5.54	5.77	5.55
27	DL	16	67	266.5	27.94	74	15.5	155	23	5.47	5.52	6.25	6.08
28	QB	17	66.25	161.5	10.68	92.5	20.5	185	8	5.31	5.49	5.3	5.25
29	OL/DL	16	68	196.5	17.87	92	22	155	19	5.47	5.66	5.53	5.46
30	DE	17	71	230	24.30	79	17	185	2	5.57	5.71	5.86	5.89
31	CB/WR	17	65.5	156	5.09	100	24.5	185	7	5.18	5.38	5.13	4.92

	Position	Age	Height (in)	Weight (lb)	%BF	SLJ in	VJ IN	Bench Press lb	reps	20-yard Shuttle Electronic	Hand	40-yd Sprint Electronic	Hand
32	DE	17	70	244	17.85	96 5	23	0	0	4.53	4.52	5.28	5
33	WR	17	71	160	3.54	95.25	23.5	0	0	4 78	4.81	5.08	4.94
34	CB/RB	17	68	165	2.25	106.3	30	0	0	5 07	4.96	4.93	4.65
35	TE	17	70 75	187	4.98	96	23	0	0	4.56	4.76	5.19	5
36	RB/CB	17	66.5	154	4.98	104 33	24.5	0	0	4.42	4.6	4.88	4 57
37	WR	18	66.5	144	#DIV/0!	0		0	0	0	0	0	0
38	WR	15	65	131	2.84	109	29.5	0	0	4 25	4.36	4.82	4.64
39	CB	16	64.5	135	5.97	94.88	23	0	0	5.33	5.16	5.33	5 06
40	DE	15	69	164	2.52	96	23.5	0	0	4.37	4.49	5.28	4 93
41	LB	14	67.5	167	5.76	0	0	0	0	0	0	0	0
42	TE	16	68.25	174	7.53	97.25	23.5	0	0	4.42	4.54	5.34	5.09
43	OL	16	70	190	9.06	94 88	22	0	0	0	0	5 31	4.92
44	OL	17	68	215	14.20	87	17.5	0	0	0	0	5 7	5.53
45	OL	16	67.75	192	11.17	88 98	18 5	0	0	0	0	0	0
46	OL	17	72 25	323	21.57	67.72	15.5	0	0	0	0	6.57	6.46
47	DB	16	63.5	138 5	7.22	89.37	22.5	0	0	0	0	5.4	5 12
48	OL	17	65.5	219	19.74	72	13.5	0	0	0	0	6.05	5.83
49	LB	14	61 75	155	14.72	62 99	14.5	0	0	5 5	5 57	6.36	6.16
50	LB	15	63	151	10.46	81.5	18.5	0	0	0	0	0	0
51	QB	17	74	161	5.45	92 5	23.5	0	0	4 38	4 47	5.32	5.18
52	LB	16	62	162	8.35	86.61	19	0	0	5.34	5 37	5 55	5.27
53	WR	16	71 75	181.75	3.90	115	32	185	12	3.94	4.28	4.98	4.71
54	TE	17	69.3	211	13.50	105	30	185	17	4.22	4.45	4.98	4.83
55	LB	17	68.75	207	6.50	110	26	185	26	4.28	4 54	5.13	4.86
56	FB/DT	17	70.5	220	16.14	95	26 5	185	17	4 28	4 55	5.28	5.13
57	DB/WR	16	66.25	159.75	6 96	95	23	185	3	4 25	4.37	5 05	4 76
58	TE/DE	16	72 75	205	11.27	91 34	26	185	11	4 28	4 46	5.32	5.14
59	RB	15	67 25	141.5	6 33	86 5	16.5	155	6	4.78	5.13	5.62	5 45
60	OL/DL	16	69.5	231.25	15 40	81 1	23	185	13	5	5 09	5.77	5 21

VITA

I, Randy Kaiser, was born in Victoria, Texas, September 1978, to Debra and Wayne Kaiser. After graduating from Yoakum High School in 1997, I began my college career at Southern Methodist University (SMU). After one semester in Dallas, I transferred to Southwest Texas State University (now Texas State University - San Marcos). During my undergraduate work I became interested in the exercise sport science field. I began helping professors as a research assistant and received my bachelor's degree in Exercise and Sports Science.

After receiving my bachelor's degree, I received a position as a graduate assistant and decided to enter the master's program at Texas State University-San Marcos. During the past two years of my graduate studies, I became a certified health and fitness instructor with the American College of Sports Medicine (ACSM), a member of the American College of Sports Medicine (national and regional), an instructor, and above all a professional.

Permanent Address: 927 Lakefront Ave, New Braunfels, TX 78130

This thesis was typed by Randy James Kaiser.