Longitudinal Morphological and Performance Profiles for American, NCAA Division I Football Players

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Abstract

Jacobson, BH, Conchola, EC, Glass, RG, and Thompson BJ. Longitudinal morphological and performance profiles for American, NCAA division I football players. *J Strength Cond Res* 27(9): 2347–2354, 2013—The aim of this study was to determine the changes in anthropomorphism and performance over a 4-year eligibility career of American football players. A total of 92 offensive and defensive linemen and 64 skill (wide receivers and defensive backs) player observations were included in the analysis. Data from preseason testing over a 7-year period were compiled, sorted, and analyzed by players' year in school. Assessments of strength included 1 repetition maximum bench press, squat, power clean, and a 225-lb maximum repetition muscle endurance test. Power and speed measures included vertical jump (VJ) and 40-yd (36.6-m) sprint. All strength measures improved significantly ($p < 0.05$) over the years of training. Skill players demonstrated a significant increase in power between years 1 and 2 but at no other time. Linemen did not demonstrate significant changes in VJ. Speed did not change significantly for either group over the 4 years of training. These data provide a theoretically predictable 4-year rate of change in anthropometric, strength, and power variables for Division I football players. By having a longitudinal assessment of expected physical improvement, it may be possible for strength training personnel to determine those who may need additional attention in an area to more closely improve as expected. Additionally, it is suggested that elite athletes may possess genetically superior attributes and therefore, when selecting athletes, particular attention should be paid to the selection of those who have previously demonstrated superior speed and power.

Key Words strength, speed, power, sport

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Introduction

American football players enter large National Collegiate Athletic Association (NCAA) Division I (Div1) programs and are met with sophisticated physical training protocols designed by professionals in the field of strength and conditioning. This emphasis on strength, power, agility, flexibility, speed, and endurance has resulted in the construction of multimillion-dollar training facilities and the hiring of expert personnel. In addition to an emphasis on the physical aspects, many universities employ nutritionists and psychologists to develop individuals to their potential. Because success in the sport is dependent primarily on physical variables, much of the training outside the sport-specific practices include protocols designed to enhance those physical attributes deemed important in the sport. In part, resulting from sophisticated training, present athletes are stronger, faster, and more powerful than those of the past. For example, in a comparison of physical performance characteristics by Div I offensive and defensive linemen (OL/DL) for the years of 1987 and 2000, Secora et al. (30) concluded that the 2000 OL were significantly ($p \leq 0.01$) more powerful (vertical jump [VJ]) but not stronger (bench press, squat, power clean) than those from the 1987 teams. Furthermore, the authors concluded that the 2000 defensive line players were significantly more powerful and stronger than the 1987 players. Garstecki et al. (8) compared Div I and II football players and found that Div I OL were significantly ($p \leq 0.01$) stronger (bench press, squat, power clean), faster (40 yd), and more powerful (VJ) than Div II players. Defensive linemen at Div I schools were similarly physically superior with the exception of the 40-yd sprint in which the authors found no significant difference. Although genetic predisposition cannot be discounted nor accurately measured, the addition of state-of-the-art training protocols, certified training professionals, biomechanically precise training equipment, and monitored nutrition presumably play important roles in the reason why current football players are physically superior to those of the past.

Assessment of the efficacy of the training and the consequential physical development are measured regularly throughout the year as part of the strength and conditioning program, via various strength, speed, and agility assessments (13).

Research supports that such training result in the improvement of the aforementioned variables, thereby contributing to greater physical performance (23,29). Typically, measures of strength and power include but are not limited to bench press, squat, power clean, and VJ, and measures of speed include the 40-yd sprint, which may be simultaneously timed at 10 or 20 yd. Testing of these variables to track improvement usually occurs at predetermined times over the course of a year. Over the period of a year, 4 training phases are common, each with specific training objectives and include in-season (August to December), off-season (January to March), spring training (March to April), and summer session (May to August). The 2 off-season phases (spring and summer) are typically designed to increase strength, agility, and flexibility while the in-season and spring training phases attempt to maintain what has been achieved during the off-season.

With respect to strength, power, and speed changes within the phases, Moore and Fry (25) found that some of the improvements generated at one stage of training diminished in other stages. For instance, over a 15-week period inclusive of (a) 4 weeks of concentrated strength training, (b) 5 weeks of strength training and intense conditioning, and (c) 30 days of spring training measures of squat, power clean, agility, and VJ increased after the initial 4 weeks of weight training, but sprint speed did not. However, all performance variables digressed to baseline after the end of spring training. Hoffman and Kang (14) tested Div III football players on the first day of summer camp (pre) and the last week of regular season (post) and found improvements in squat but no change in bench press between pre- and posttests.

Most studies that have attempted to ascertain physical improvements in football players have either been cross-sectional studies or limited to only one year (1,13,14,16). Only a few studies have provided longitudinal data on the physical development of college football players over the 4–5 years of eligible participation. In one study, Stodden and Galitski (31) examined the longitudinal effect of a college strength/conditioning program incorporating speed, strength, and agility drills over a 4-year period and concluded that the greatest number of significant improvements occurred during the first year of training with inconsistent improvements among the various tests between years 2 and 4. They found bench press to improve significantly over all 4 years in all groups. Miller et al. (24) collected data including body mass, body fat, power clean, bench press, squat, VJ, and sprint times on Div I football players at different phases from 1993 to 1998 and found that body mass was positively associated with increases in bench press and squat and that body fat was negatively related to performance in the 20- and 40-yd sprint. Additionally, the authors suggested that the greatest adaptation period for strength gains is in the early stages of players' college career.

To date, little information exists that provides professionals a means by comparing expected anthropometric and physical gains with actual gains. It is axiomatic that as the players mature and train they will ultimately improve in many areas. It would benefit the area of player development to have information specific to average expected improvement from year 1 to year 4 in a player's career to better determine the appropriate types of individual intervention needed to eliminate below average progress. By obtaining accurate longitudinal data on progress, professionals in the field will be able to compare assessment data for each individual with such standards. Although it is well known that physical properties will improve with training and maturity, the normal extent of improvement over time has yet to be fully determined. The purpose of this study was to determine the impact of a strength and conditioning program on the anthropometric characteristics and physical performance changes in NCAA Div I football players over their collegiate careers. Therefore, data on incoming freshmen players were longitudinally tracked to assess changes in performance variables over a 4-year period.

Methods

Experimental Approach to the Problem

Currently, little data exist that can be used as a measuring device for comparing expected physical progress with actual progress. To obtain average anthropometric and physical changes over a 4-year playing career, we examined players from their first (freshman) assessments to the fourth (senior) preseason (August) testing session over a 7-year period. Theoretically, August is the time when the athletes reach their competitive preseason peak both in strength and speed. Other testing sessions were available, but because of inherent changes in the times the athletes were tested (i.e., post off-season, post spring training, and post season), it was decided that the most consistent data would be found after the summer training sessions. Summer conditioning included 4 days of 1-hour weight training per week with an additional 45 minutes devoted to speed, agility, and conditioning. The full summer training period extended approximately 9 weeks. Freshmen were tested on arrival on campus without the benefit of organized summer training. Weight training consisted primarily of free weights (i.e., barbells and dumbbells) with ancillary lifts consisting of pulley apparatus' and lever-like machines. As has been done in previous studies (24), we divided players into groups by positions because players in selected positions are distinctly different in anthropometrics and selected performance variables. The positions were OL and DL and skill players–wide receivers and defensive backs (WR/DB).

Subjects

Approval was granted by the University's Institutional Review Board for use of human subjects in Research and the Athletic Department to access and statistically analyze preexisting data collected by the strength and conditioning staff over a 7-year period (2005–2011). For those players who entered in 2010, only 3 years of data were available. Subjects' age ranged from 18 to 24. A total of 92 linemen and

64 skill player observations were included in the analysis. For both linemen and skill players, the number of participants was 48 freshmen, 45 sophomores, 35 juniors, and 28 seniors. Junior college transfers were eliminated from the study because they were not true freshmen entering into the program. Similar to Stodden and Galitski (31), players with documented injuries resulting in restrictive training and rehabilitations for over 30 days within the last year were not included.

Procedure

Data were used from the August testing session each season spanning 7 years of player participation. As each freshman class was tested, their data were added to all previous freshman results and each year of participation was combined for each. The August phase of testing was used for this study because, theoretically, this reflects the time that each athlete reports in optimal playing condition. Additionally, because it has been suggested that some conditioning variables increase while some decrease depending on the time of testing (25), we believed that greater accuracy would be had by eliminating the time-sensitive confounding variables. To eliminate athletes from the study who had sustained injures that interfered with training, the investigators conducted extensive interviews with the strength and conditioning staff and the athletic trainers to determine what injuries the players had sustained and when they had occurred so that data representing rehabilitation values could be scrubbed. Redshirt players were grouped by academic status rather than by eligibility status, thus providing accurate time frames equal to those not redshirted. Data were grouped by year (freshman, sophomore, junior, senior) of participation and included height, weight, percent body fat, 1 repetition maximum (RM) bench press, National Football League (NFL) 225-lb (102.1-kg) bench press maximum repetition (Max Rep), 1 RM power clean, 1RM squat, VJ, and 40-yd sprint.

Strength training periodization was designed as a 6-week cycle beginning at the end of the football season lasting to spring training (winter) and in an 8-week cycle from the end of the regular academic year up to preseason practice in August (summer). Frequency of training was 4 $d \cdot wk^{-1}$: Mondays, Tuesdays, Thursdays, and Fridays. Initial strength training consisted of high repetitions, low resistance for the first 2 weeks; mid-range repetitions, mid-range resistance for the following 2 to 3 weeks; and low repetitions, high resistance for the remaining time. Speed and agility remained training varied in activity but changed minimally in frequency and duration during the cycle. Initial aerobic training was not highly emphasized but increased as the cycle progressed.

In-season weight training consisted of 3 days per week: Sunday, Tuesday, and Thursday. Sundays were primarily a "flush" day with emphasis on high repetitions and low volume. Tuesdays included Olympic lifts and heavier weight, and Thursdays included lighter weights with higher repetition for core and upper body only.

Assessment included anthropometric measures of body mass, height, and percent body fat. Strength assessment included bench press, squat, and power clean; muscle endurance involved the number of 225-lb bench press repetitions; power included the VJ; and speed assessment used a 40-yd sprint. Strength measures were assessed on separate days from power and speed measures, so as to not compromise on data. For strength, bench press and power clean were tested before squat, and the 225 lb repetition test was conducted on power and speed testing day.

Body fat was measured using a BOD POD (Cosmed USA, Inc, Chicago, IL, USA). As recommended by the manufacturer, players wore only tight fitting shorts and a swim cap on entering the BOD POD, and the operation of the BOD POD followed manufacturer's recommendations (3).

For all strength assessments, players first warmed up with 2 sets of 40–66% of the estimated maximum and, subsequently, were given 3–4 attempts to establish a 1RM. Rest between sets was approximately 5 minutes. Weight consisted of Olympic-style bars and weights in British equivalents. Technique was strictly monitored as described by Hoffman et al. (12,15). The NFL 225-lb Max Rep test consisted of completing as many full bench press repetitions as possible. No partial repetitions were recorded for any of the strength measures.

Vertical jump was measured using a Vertec (Sports Imports, Columbus, OH, USA). Distance was calculated by subtracting the standing reach height from the jump height, and jumps were performed with counter movement. Players were given 3 attempts with 3-minute rest intervals, and the highest jump was used for analysis. To determine power, VJ was converted to Watts using the formula suggested by Harman et al. (11). Speed was measured using the standard 40-yd (26.6-m) sprint and was assessed with electronic timers. Timing was initiated by the player's first move from a 3-point stance and terminated with contact with a photoelectric beam.

Statistical Analyses

Repeated measures analyses of variance were used to compare anthropometric and performance variables over time. All significant F ratios were subsequently analyzed using a Newman-Keuls post hoc test. Additionally, associations between variables were analyzed using bivariate correlations. A criterion alpha level of $p < 0.05$ was used to determine statistical significance.

Results

Results of this study provide a clearer picture of Div I football physical progress over a player's career. In general, strength increased significantly over time for both linemen and skill positions, however, measures of maximum power and speed did not. Percent body fat decreased significantly in linemen but not in skill positions, primarily because first-year linemen tended to report overfat, whereas skill players reported in a very lean condition.

Table 1. Progression of selected physiological variables over a 4-year competitive period of football linemen.*

Linemen, $N = 34$	Year 1, Mean (SD), $N = 29$	Year 2, Mean (SD), $N = 26$	Gain 1–2	Year 3, Mean (SD), $N = 20$	Gain 2–3	Year 4, Mean (SD), $N = 17$	Gain 3–4	Total gain %
Weight (kg)	128.7 (12.7)[a]	131.2 (10.8)[a]	1.9%	131.9 (8.5)[a]	0.5%	132.4 (8.2)	0.4%	2.9
Height (cm)	190.8 (4.8)	191.8 (4.2)	0.5%	192.3 (4.2)	0.2%	192.5 (4.5)	0.1%	0.9
Fat (%)	22.5 (6.7)[a]	19.0 (7.0)	−15.6%	19.7 (6.2)[a]	3.6%	20.6 (5.5)[a]	4.6%	−8.4
Bench press (kg)	159.3 (23.6)	171.2 (17.9)[a]	7.7%	181.8 (18.7)[a,b]	6.2%	187.7 (19.0)[a,b]	3.3%	17.8
225-lb Bench (Rep)	15.8 (6.4)	19.0 (5.0)	20.3%	23.8 (5.0)[a,b]	25.3%	26.5 (5.5)[a,b]	11.3%	67.7
Squat (kg)	210.0 (33.8)	242.8 (32.4)[a]	15.6%	258.6 (26.8)[a,b]	6.5%	267.6 (33.6)[a,b]	3.3%	27.4
Power clean (kg)	127.2 (14.3)	135.4 (12.2)[a,b]	6.5%	140.0 (12.5)[a,b]	3.4%	147.6 (8.6)[a]	5.4%	16.0
Vertical jump (cm)	65.5 (7.1)	64.8 (7.6)	−1.1%	67.1 (7.9)	3.6%	67.3 (6.6)	0.3%%	2.4
Vertical jump (Watts)	10,509.7 (1,139.1)	10,556.3 (1,234.1)	0.4%	10,723.9 (1,264.4)	1.5%	10,741.9 (1,057.9)	0.2%	2.2
40-yd Sprint (s)	5.36 (0.23)	5.29 (0.23)	−1.3%	5.17 (0.22)	−2.3%	5.17 (0.19)	0%	−2.7

*Superscipt letters "a" and "b" indicate significant differences ($p < 0.05$) among years.

Offensive and Defensive Linemen

Linemen body mass averaged 128.7 kg the first year and increased progressively each year with the fourth year players being significantly ($p = <0.039$) heavier (132.4 kg) than those in years 1–3. No significant weight differences were noted among years 1–3 (Table 1). No significant changes in height were noted when comparing first (191.05 cm) through the fourth years (192.55 cm). While weight increased slightly each year, the linemen became significantly leaner ($p = 0.03$) from year 1 to year 2. First year linemen averaged 22.5% fat, and fourth year linemen averaged 20.6% representing a 8.4% decrease (Table 1).

Concerning the 1 RM bench press, first year means were significantly ($p = 0.002$–0.0002) less than years 2 through 4, and the mean for year 2 was significantly less than for years 3 and 4. The largest gain occurred between year 1 and year 2 (11.9 kg, 7.5%). The improvement from year 1 (159.3 kg) to year 4 (187.7 kg) represented a 28.4 kg (17.8%) gain. Significant improvements were also recorded for the NFL 225-lb Max Rep test between year 1 and years 3 ($p = 0.04$) and 4 ($p = 0.01$) and between year 2 and year 4 ($p = 0.04$) (Table 1). Positive correlations between body mass and 1RM bench press ($r = 0.72$) and body mass and the NFL 225 lb ($r = 0.73$) assessments were noted.

There was significant improvement in 1RM squat ($p = 0.0013$–0.0003) between year 1 (210.0 kg) and all the following years (second: 242.8 kg, third: 258.6 kg, and fourth: 267.6 kg), and the squat mean for year 2 was significantly less than for year 4. The largest gain in squat occurred between year 1 and 2 (32.8 kg, 15.6%). The total improvement from the first to fourth years was 57.6 kg or 27.4%, which represented a significant ($p = 0.0003$) increase. There was significant increase in 1RM power clean between year 1 and the subsequent 3 years ($p < 0.013$ to $p = 0.0002$) with the largest gain occurring between year 1 and year 2 (8.2 kg, 6.5%). Additionally, year 2 was significantly different from year 4 ($p = 0.0002$). Linemen averaged 127.2 kg the first year and 147.6 kg the fourth year, representing a 16.0% gain.

With respect to maximum power output, VJ distances increased slightly but not significantly ($p = 0.26$) from year 1 (65.6 cm) to year 4 (67.1 cm), representing a 1.6-cm or 2.3% gain. Similarly, VJ power (Watts) increased at minimal levels over the 4-year period (2.2%) ($p = 0.26$–0.91). For the 40-yd sprint, times improved minimally each year, however, no significant ($p = 0.40$) improvement was noted. Averages for year 1 and 4 were 5.36 and 5.17 seconds, respectively. There was a negative correlation between body mass and the VJ ($r = -0.62$) and the 40-yd sprint ($r = -0.59$).

Wide Receivers and Defensive Backs

Wide receivers' and defensive backs' body mass averaged 79.7 kg the first year and increased significantly from year 1 to years 2–4 ($p = 0.002$–0.0002) with no significant

Table 2. Progression of selected physiological variables over a 4-year competitive period of football wide receivers and defensive backs.*

WR/DB, $N = 39$	Year 1, Mean (SD), $N = 19$	Year 2, Mean (SD), $N = 19$	Gain 1–2	Year 3, Mean (SD), $N = 15$	Gain 2–3	Year 4, Mean (SD), $N = 11$	Gain 3–4	Total gain %
Weight (kg)	79.7 (7.5)	85.8 (8.8)[a]	7.7%	84.6 (8.5)[a]	−1.4%	86.9 (5.7)[a]	2.7%	9.0
Height (cm)	180.8 (6.9)	181.2 (6.4)	0.2%	182.1 (5.1)	0.5%	183.3 (4.8)	0.7%	1.4
Fat (%)	8.4 (4.3)	7.9 (3.6)	−6.0%	7.7 (3.8)	−2.5%	8.1 (3.8)	9.0%	−3.6
Bench press (kg)	105.5 (17.6)	125.8 (15.2)[a]	19.2%	135.5 (17.7)[a]	7.7%	141.5 (7.7)[a]	4.4%	34.1
225-lb Bench (Rep)	4.1 (4.2)	8.9 (4.5)[a]	117.1%	11.5 (3.8)[a,b]	28.8%	12.0 (2.9)[a,b]	4.7%	192.7
Squat (kg)	155.2 (28.0)	180.0 (26.2)[a]	15.8%	196.5 (21.6)[a,b]	9.1%	205.5 (16.2)[a,b]	4.6%	32.4
Power clean (kg)	102.8 (15.5)	119.6 (13.0)[a]	16.3%	129.1 (12.5)[a,b]	8%	130.0 (12.3)[a,b]	1.0%	26.5
Vertical jump (cm)	83.1 (5.8)	86.9 (6.6)[a]	4.6%	88.9 (6.4)[a]	2.3%	89.9 (6.1)[a]	1.1%	8.2
Vertical jump (Watts)	9,835.1 (686.4)	10,289.9 (755.4)[a]	4.6%	10,370.5 (746.5)	0.8%	10,515.2 (712.7)	1.4%	6.9
40-yd Sprint (s)	4.58 (0.16)	4.53 (0.11)	−1.1%	4.53 (0.16)	0%	4.50 (0.10)	−0.7%	−1.7

*Superscipt letters "a" and "b" indicate significant differences from that playing year, $p < 0.05$.

differences among years 2–4. No significant changes in height were noted when comparing first (183.06 cm) and fourth (187.8 cm) years. Body mass changed little from years 2 through 4, and body composition reflected similar nonsignificant changes ($p = 0.39–0.98$) (Table 2).

For the 1RM bench press, the WRs/DBs increased significantly ($p = 0.0002$) from year 1 to year 2 and from year 2 to year 3 ($p = 0.008$), but not from year 3 to year 4 ($p = 0.10$). Bench press averaged 105.5 kg in year 1 to 141.5 kg in year 4, representing a 36.0-kg or 34.4% gain. For the NFL 225-lb Max Rep test, significant ($p < 0.01$) improvements were seen between year 1 and year 3 and year 3 and 4 (4.1 reps vs. 8.9 and 11.5 reps) and between year 2 and 4 (Table 2). In the 1RM squat, WR/DBs improved significantly ($p = 0.019$) from year 1 to year 2 and from year 1 to years 3 ($p = 0.01$) and 4 ($p = 0.01$). Also, significant gains were recorded between year 2 and year 4 (14.2%). Significant improvement for the power clean ($p < 0.001$) was noted from year 1 to year 2, but no additional significant changes occurred ($p = 0.039$). Continued improvement was noted from year 1 to year 4 with a total gain of 27.2 kg or 26.5% (Table 2).

Over the course of 4 years, VJ height increased from 83.1 to 89.1 cm (Table 2), but the only significant difference was between year 1 and the following years ($p = 0.015–0.001$), indicating a minimal lack of improvement for years 2 through 4. Vertical jump power (Watts) reflected a significant increase between years 1 and 2 but failed to change significantly thereafter. The 40-yd times improved slightly but not significantly from year 1 (4.58 seconds) to year 4 (4.50 seconds) (Table 2). A negative correlation existed between body mass ($r = -0.12$) and VJ and speed ($r = -0.52$).

Discussion

Recruiting the best football player is not always a guarantee that he will excel similarly in the college arena. It is axiomatic that young athletes just entering college are still maturing physically. No clear rubric can predict the age at which an individual reaches his/her maximum physical potential because of the undeniable factors that genetics plays in individual maturity potential in addition to the individual's personal commitment and drive. These results provide an updated rubric of average improvement in the physical realm over a typical eligibility span of elite NCAA Div I football players.

In the present study, minimal changes occurred for linemen in body mass and height over the 4 years of training, however, they became significantly leaner after the first year. Wide receiver/defensive backs reported lean

(<9%) and remained lean, but gained significant body mass, particularly between year 1 and year 2. For several decades, body mass for linemen has increased significantly and systematically, whereas WR/DB have largely remained the same (17). Lineman in 1960 and 1990 averaged about 91 and 123 kg, respectively (2). Comparable heights and weights were considerably greater for linemen in the present study than heights and weights recorded in past studies. For instance, mean height and weight for the USC OL and DL in 1993 was 189.7 and 109.5 kg, respectively (22). We found that freshmen reported to camp with an average body mass of128.7 kg, not significantly different from second or third year players; however, they carried significantly more fat than second year players. With respect to body composition, these results support an earlier contention that college linemen are likely to be too fat, whereas "skill" players are appropriately lean (2). In the present study, linemen tended to fall in the "overweight" category for male players between the ages of 20 and 40 (19–25%) years, and WR/DB fell in the "healthy" range (8–19%). Similarly, Mathews and Wagner (21), in a 2005 study involving Div I football players found that OL and DL averaged 27.6 and 22.1% fat, respectively, concluding that OL were obese based on body fat more than 25%. Kaiser et al. (19), in a study of freshman Div I football players found that OL reported at an average of 22.3% fat in comparison to WR and DBs who averaged 10.7 and 10.5%, respectively. Another study by Noel et al. (26) found that Div I linemen averaged more than 25% for body fat and that the fat was largely centered in the abdominal region, noting that abdominal fat carries strong relationship to ischemic heart disease and stroke. Two studies (4,5) found that Div I football players diagnosed with metabolic syndrome (MetSyn) were all obese making them more at risk for insulin resistance than leaner players. Players in speed-related positions and linemen have been found to have a 14 and 46% higher MetSyn, respectively, than average college males (4,5). The excessive proportion of body mass and fat of linemen increases the susceptibility of heat-related injuries (10) because of higher core temperatures in comparison to leaner players (6). Also, sweat rates are higher in linemen (10) than in backs making dehydration a possible issue.

In concert with the conclusions drawn by Hunter et al. (16) and Stodden and Galitski (31), the largest gains in strength occurred between a player's first and second years. For linemen, the gains from year 1 to year 2 were squat: 15.6%, bench press: 7.7%, 225 Max Rep, and power clean: 6.5% with the one exception for linemen occurring in the NFL Max Rep test, where the increase from years 1 to 2 was 20.3%, and the increase from years 2 to 3 was 23.8%. For WR/DBs, the largest gains from years 1 to 2 were 225 NFL Max Rep test: 192.7%, bench press: 19.2%, power clean: 16.3%, and squat: 15.8%. A large range between individuals was noted in the WR/DBs. This was because some players were unable to complete one full repetition of 225 lbs the first year, and therefore, averages of "0" were recorded, and the players were tested with less weight.

For both linemen and WR/DB, the greatest gains over the 4-year period occurred in the NFL 225 lb Max Rep test. Linemen increased 67%, while WR/DBs increased 192.7%. Additionally, large gains were found in squat, bench press, and power clean for both groups. Offensive linemen outperformed DL in areas of strength (i.e., bench press, squat, and NFL 225 Max Reps), whereas the DL group outperformed the OL group in areas requiring speed and power (i.e., power clean, VJ, and 40-yd sprint). These data support the suggestion that OL have greater absolute strength and are slower than DL, and DL are quicker and have greater power than OL (20). The requirements of the 2 positions (offense vs. defense) largely determine the physique of the players. For instance, offensive line play requires large bodies to shield the passer or to wall-off the defender in a predetermined manner, seldom requiring the players to move further than a few yards. In contrast, DL largely react on the ball and must be quicker and more agile, typically moving several yards each play. WR/DBs registered larger increases in the strength assessments after 4 years than linemen. It is likely that WR/DB were less intensely involved in strength training before entering college because these players depend, in a large part, on speed.

The variables reflecting power changed little in either of the 2 groups with the exception of the improvement generated by the WR/DBs between years 1 and 2 in the VJ (+3.8 cm, 4.6%). The linemen increased power by only 1.7%, whereas the WR/DBs increased more than 6%. Based on the Peak Power (Watts) formula generated by Harman et al. (11), WR/DBs demonstrated a significant surge in power between years 1 and 2 but not thereafter and linemen did not significantly increase in power over the 4 years of training. In 1991, Fry and Kraemer (7) reported NCAA Div I average performance characteristics. The sample included all positions except quarterback and kicker and found the following averages: 1 RM bench press = 319 ± 58 lb (144 kg); 1 RM squat = 425 ± 85 lb (192 kg); 1 RM power clean = 271 ± 39 lb (122 kg); VJ = 28.6 ± 3.6 in (72 cm); 40-yd sprint = 4.88 ± 3.6 seconds. In comparing results to the combined linemen and WR/CBs averages in the present study, the averages exceeded the results found by Fry and Kraemer, except for the 40-yd sprint.

Research suggests that with the exception of reducing fat weight, significant increases in speed are difficult to achieve. One recent study (27) concluded that a 6-week program, including 3 times per week sessions of training, was ineffective in increasing speed. Studies that suggest significant improvement in speed following training have shown minimal changes. For example, one study found significant improvement in the 5-m and 10-m sprints of 0.04 (2.8%) and 0.08 seconds (3.9%) after selected training (18). While these values constituted significant improvement, the meaningfulness of these small actual gains in comparison to the large strength gains may be negligible in a practical sense. It is generally agreed on that athletes who excel in either endurance or speed possess higher proportions of the type of muscle fibers that lend themselves to the activity. Little evidence exists to support a significant morphing of type I muscle fibers as a consequence of training, thereby resulting in significantly faster sprint times. These data suggest that speed cannot be significantly improved in elite athletes over 4 years of training. In the present study, speed improvement in linemen was only 2.7% and in WR/DBs was 1.7%. The larger change in linemen was positively correlated with a reduction in fat.

To predict success in college football, coaches need to be able to assume what potential increases in physiological variables can be expected. Although speed and power are largely a contribution of genetics, it is felt that strength is the variable that can be improved significantly. With respect to genetic predisposition, recent discovery of performing enhancing polymorphism within the angiotensin-converting enzyme (ACE) in the DNA sequence seems to be a natural genetic variation in elite athletes (28). The ACE contains 2 alleles associated with human performance with one allele specific to endurance and the other associated with muscular gains and power (9). Indeed, more than 200 genes have documented genetic variants, which affect physical and physiological performance such as muscle blood flow, muscle structure, O_2 transport, lactate turnover, and energy production (28).

Practical Applications

These results reflect the average changes that may be expected from year to year in each variable over the players' 4-year career. However, these averages can only be theoretically anticipated if the incoming players are within a reasonable distance from the first year means noted in this study. Additionally, based on the first year variance found for many of the variables, a large range of strength exists among freshmen, which potentially could increase or reduce the expected increases in individual athletes. Using these results, strength and conditioning personnel may compare the progress of their players and to adjust training based on such comparisons. While these data may serve as a general estimate of what may be expected in terms of physical potential increases, the variability of training programs, genetic makeup, and personal motivation are additional factors that can compromise on outcomes.

Training, diet, and psychological factors contribute to athletic success, but genetics may also play a significant role in separating elite athletes from the also-rans. In conclusion, these data provide a means with which to gauge what strength increases can be generally expected from Div I recruited linemen and "speed" players. While, maximal voluntary strength output and upper-body muscle endurance can be significantly increased over years of appropriate training, the variables constituting maximum power output and speed do not exhibit similar changes in 4 years of high-level training. It is noteworthy to mention that recruited players should already possess superior power and speed because these variables are particularly difficult to positively alter in 4 years of training at the college level.

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