

Dietary, Anthropometric, Blood-Lipid, and Performance Patterns of American College Football Players During 8 Weeks of Training

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Purpose: The purpose of this study was to determine the dietary, anthropometric, blood-lipid, and performance patterns of university-level American football players attempting to increase body mass during 8 wk of training. **Methods:** Three-day diet records, body composition (DEXA scan), blood lipids, and performance measures were collected in redshirt football players ($N = 15$, age 18.5 ± 0.6 yr) early season and after 8 wk of in-season training. **Results:** There was an increase ($p < .05$) from early-season to postseason testing for reported energy (+45%), carbohydrate (+82%), and protein (+29%) intakes and no change in the intake of fat. Fat intake was 41% of energy at the early-season test and 32% of energy at the postseason test. Increases ($p < .05$ for all) in performance measures, lean mass (70.5 ± 7.7 – 71.8 ± 7.7 kg), fat mass (15.9 ± 6.2 – 17.3 ± 6.8 kg), plasma total cholesterol (193.5 ± 32.4 – 222.6 ± 40.0 mg/dl), and low-density lipoproteins (LDL; 92.7 ± 32.7 – 124.5 ± 34.7 mg/dl) were measured. No changes were measured in triglycerides, very-low-density lipoproteins, or high-density lipoproteins. **Conclusion:** Increases in strength, power, speed, total body mass, muscle mass, and fat mass were measured. Cholesterol and LDL levels increased during the study to levels associated with higher risk for cardiovascular disease. It is possible that this is a temporary phenomenon, but it is cause for concern and an indication that dietary education to promote weight gain in a manner less likely to adversely affect the lipid profile is warranted.

Keywords: protein, lean body mass, cholesterol

Players of American football face a number of nutritional challenges. To gain weight, many of these athletes consume as much food as possible without receiving nutritional counseling from a qualified source (Cole et al., 2005; Duellman, Lukaszuk, Prawitz, & Brandenburg, 2008; Froiland, Koszewski, Hingst, & Kopecky, 2004; Jonnalagadda, Rosenbloom, & Skinner, 2001; Juzwiak & Ancona-Lopez, 2004; Kaiser et al., 2008). The long-term consequences of their eating habits are overlooked to meet the short-term goal of weight gain, athletic performance, and the ability to play at the college level (Applegate & Grivetti, 1997; Cole et al., 2005; Harp & Hecht, 2005; Jonnalagadda et al., 2001; Rankin, 2002). Coaches and teammates in the athletic community encourage the use of protein supplementation to support the development of lean body mass, strength, speed, and skill (Phillips, 2004).

Many individuals are unclear as to what their nutrition requirements are, and this may lead to unhealthy and or unnecessary dietary practices (Bovill, Tharion, & Lieberman, 2003). The current recommendations for

athletes training at moderate to high intensities for up to 3 hr/day are for at least 6–10 g of carbohydrate per kilogram of body mass per day ($\text{g} \cdot \text{kg}^{-1} \cdot \text{day}^{-1}$), no more than 20–35% of calories from fat, and no more than 10% of the total daily caloric intake from saturated fat (Burke, Hawley, Wong, & Jeukendrup, 2011; Rodriguez, DiMarco, & Langley, 2009). The protein requirements for athletes in strength and power sports are within the range of 1.4 – $1.8 \text{ g} \cdot \text{kg}^{-1} \cdot \text{day}^{-1}$ (Lemon, 1995; Lemon, Tarnopolsky, MacDougall, & Atkinson, 1992; Tarnopolsky et al., 1992; Tarnopolsky, MacDougall, & Atkinson, 1988). This requirement is roughly twice the recommended dietary allowance for the average individual, and many athletes have turned to protein supplements to meet or exceed this need (Applegate & Grivetti, 1997). Supplements are expensive and may or may not be needed to meet dietary recommendations. Furthermore, American football players, particularly incoming freshmen, are encouraged to increase their weight and lean body mass. These athletes may focus on calories rather than nutrients, which may favor a higher fat intake. In addition, freshmen athletes generally live on campus and are limited to the food choices offered by campus food service. Their diets are often low in fruits and vegetables and high in fatty food choices and simple carbohydrates (Cole et al., 2005; Jonnalagadda et al., 2001).

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More research is needed to identify the dietary practices of college football players, as well as the potential positive and negative effects of these practices. The purpose of this study was to determine the dietary, anthropometric, blood-lipid, and performance patterns of college American football players attempting to increase body mass during 8 weeks of training.

Methods

Participants

Students who volunteered for this investigation were incoming redshirt football players, 18–20 years of age, at Montana State University, an NCAA Division I American football program. Redshirt football players train, practice, and suit up with the team, but they do not play in games. Most of the participants had general lifting experience but were inexperienced in the Olympic and power-lifting techniques employed by the strength and conditioning staff. No exclusion criteria were developed for this study, as all NCAA athletes are required to complete yearly athletic physicals to screen for possible health risks. All participants in this study were informed of the risks of participation and gave written informed consent. Seventeen participants enrolled, and 15 completed the investigation. One subject chose to discontinue participation in the football program, while another did not wish to continue with the study after the initial 1-day diet record. The study was approved by the Human Subjects Committee at Montana State University.

Study Design

A pretest–posttest experimental design was used during this 8-week study. Performance outcomes (exercise testing and strength assessment), blood lipids, anthropometrics, and dietary intake were assessed. Participants completed two 3-day diet records, two strength and power assessments (administered by the university's strength and conditioning coaches), two blood-lipid profiles, and two dual-energy X-ray absorptiometry (DEXA) scans. All variables were collected between Weeks 2 and 4 for the early-season measurement and again between Weeks 11 and 12 for the postseason measures.

Estimated caloric, hydration, and protein requirements (1.6–1.8 g/kg) were determined for participants. Estimated caloric requirements were determined using the Cunningham formula, with an activity factor of 2.0–2.4. The Cunningham formula was used to estimate energy needs, as it takes into account lean body mass (Cunningham, 1980). According to the *Manual of Clinical Dietetics* (Dietitians of Canada & American Dietetic Association, 2000), an activity factor of 2.0–2.4 is used for individuals completing strenuous work or highly active leisure activities.

Strength and Conditioning (8-Week Program)

As part of their participation in the football program at Montana State University, athletes who participated in this investigation took part in football-team practices and completed strength and conditioning training and assessments. Strength and conditioning workouts were three times per week (Wednesdays and Fridays at 6 a.m. and Sundays at 1 p.m.). The progression of strength and conditioning training began in the developmental stage where athletes learned basic body control and techniques for strength training. Once these techniques were mastered, athletes entered the transitional phase where more complex exercises were done and submaximal efforts were incorporated into the workouts. If an athlete excelled in the transitional phase, the coaching staff developed an advanced program for that athlete to maintain complex body control while introducing maximal-effort lifting techniques. The exercises incorporated in the training program included, but were not limited to, cleans (power and hang), squats (various modifications), back jerk, bench press (flat, incline, dumbbell), pull-ups, rows (various modifications), biceps curls, shoulder press, shoulder raises, dips, back extensions, shrugs, triceps extensions, and gluteal ham raises.

Exercise Testing and Strength Assessment

Strength and skill assessments took place during Weeks 3–4 and Week 11. Testing measures included five-repetition-maximum of the bench, squat, and clean to test strength and power gains. The 10-yd (~9-m) dash was used to test speed, and the vertical jump was used to test power. All physical performance testing was completed by the strength and conditioning program coaches as a regular component of their program, and the results of their assessments were shared with the investigators of this study.

Blood-Lipid Analysis

Fasting blood samples were obtained in Weeks 3–4 and 11–12. They were collected between 7:30 and 9:30 a.m. after participants had rested for 10 min after their arrival at the Nutrition Research Laboratory. Blood was collected from an antecubital vein into evacuated tubes using a standard venipuncture technique. Samples were obtained in a vacuum tube without additive for analysis of blood lipids. The tubes without additive were allowed to clot. Blood was separated using a refrigerated 21000 Marathon centrifuge (Fisher Scientific, Pittsburgh, PA). Samples were stored at –80 °C until analysis. All samples from a given subject were analyzed at the same time and in the same assay run for a given analysis to limit variability in tests.

Serum low-density lipoprotein (LDL), high-density lipoprotein (HDL), total cholesterol, and triglyceride concentrations were measured in duplicate by standard

laboratory techniques using a VitrosDT60 Ektachem analyzer (Eastman Kodak Co., Rochester, NY) and the procedures described by Lie, Schmitz, Pierre, and Gochman (1976). LDL cholesterol concentrations were estimated using the Friedewald equation (Friedewald et al. 1972).

Anthropometric and Body-Composition Measurements

Nonfasting anthropometric measurements (height and weight) were taken during Week 1 of training. Body-composition measurements were collected by DEXA (Hologic Delphi W DEXA scanner with the GDR System Software Version 11.1 for use with Microsoft Windows) by the same certified radiology technologist during Weeks 2–3 and Weeks 11–12. The technician modified each participant's body position with the use of a foot restraint and foam blocks. The test–retest coefficient of variation for this specific DEXA machine was not available. Owing to coordination of scheduling for the DEXA scanning facility and the training and class schedules of the participants, time of day and food and beverage intake were not controlled. Data from the DEXA scan included bone mineral content, fat, lean mass, lean plus bone mineral content, and total mass. All results were provided in grams and by body region. Regions included left and right arms and legs, trunk, and head.

Dietary Assessment

Incoming freshmen and redshirt athletes live on campus and consume meals through the university food service in the dining halls. Three meals are provided by food service each day. Three-day diet records were developed to coincide with what food service was serving for breakfast, lunch, and dinner during the specified dates to increase ease of usability for study participants. Food records provided a list of all food and beverages available at mealtimes. In addition, the portion size of the serving implement used to serve each food was included. For example, hash browns were served for breakfast in a 1/2-cup serving-size ladle. Participants would check off if they had consumed this food and how many scoops they received, each being 1/2 cup. All participants received training on how to accurately measure portion sizes and complete a 3-day diet record. Diet-record training included education on the various-sized serving spoons and ladles used by the campus food service department. Additional space was provided on diet records for meals and snacks consumed outside of the dining halls. This was done to make recording of food intake easier for participants and to increase the likelihood of full reporting. Two 3-day diet records were collected by the same researcher (R.K.). Incomplete or unclear diet records were flagged, and athletes were immediately contacted to clarify the provided information. Two additional researchers (D.L. and L.K.K.) were responsible for entering data into the nutrient-analysis program. Diet records were analyzed using the dietary-analysis program Nutritionist Pro (ver-

sion 4.1.0, Axxya Systems, Stafford, TX). The food service department offered the research team the nutritional content of the foods they served on these occasions. With this information, the research team was able to add the individual food items into the Nutritionist Pro database for dietary analysis.

Statistical Analysis

Descriptive data are given as means and standard deviations. Paired *t* tests were used to compare early-season and postseason measurements. Statistical significance was set at $p = .05$.

Results

Subject Description and Anthropometric Data

Participants ($N = 15$) were 18.5 ± 0.6 years of age, 187.3 ± 6.9 cm tall, and 93.8 ± 15.3 kg in mass. Body-mass index (BMI) was 26.6 ± 3.4 kg/m².

Dietary Intake

All but 1 participant completed both early-season and postseason 3-day diet records. The nutritional content of the diet records is presented in Table 1. There was a significant increase ($p < .05$) from early season to postseason for reported energy (+ 45%), carbohydrate (+ 82%), and protein (+ 29%) intakes and no change in the intake of fat. Fat intake was 41% of energy at the early-season test and 32% of energy at the postseason test.

Estimated energy requirements for each subject compared with their actual early-season and postseason energy intake are presented in Figure 1. A comparison of the estimated protein requirements versus protein intake early season and postseason is presented in Figure 2. The average amount of protein consumed was 1.8 g/kg of body weight at both early-season and postseason time points. The estimated amount of protein consumed ranged from 0.9 to 2.8 g/kg during the preliminary diet record and from 0.9 to 2.9 g/kg in the postseason diet record. Individually, 9 of the 15 participants consumed at least 1.6 g/kg of protein. The 6 subjects consuming less than 1.6 g/kg of protein tended to weigh less than those consuming 1.6 g/kg of protein or more. The amount of fat consumed per day ranged from 122 to 193 g in the preliminary diet record and from 136 to 260 g in the postseason diet record.

Performance Measures

Performance variables are presented in Table 2. Two subjects were excluded from the analysis due to a sport-related injury and an inability to complete the testing protocol correctly. Overall, there was a significant improvement ($p < .05$) in vertical-jump, hang-clean, back-squat, and bench-press performance.

Table 1 Dietary Composition of Participants (N = 14) Based on 3-Day Diet Records Collected Early Season and Postseason, M ± SD

Dietary component	
Energy (kcal)	
early season	3,518 ± 849
postseason	5,115 ± 2,391*
Carbohydrates (g/day)	
early season	353 ± 118
postseason	643 ± 414*
Protein (g/day)	
early season	169 ± 52
postseason	217 ± 91*
Total fat (g/day)	
early season	160 ± 45
postseason	178 ± 60
Cholesterol (mg/day)	
early season	757 ± 333
postseason	1,004 ± 504
Dietary fiber (g/day)	
early season	19 ± 8
postseason	18 ± 8

*p < .05 compared with early-season training.

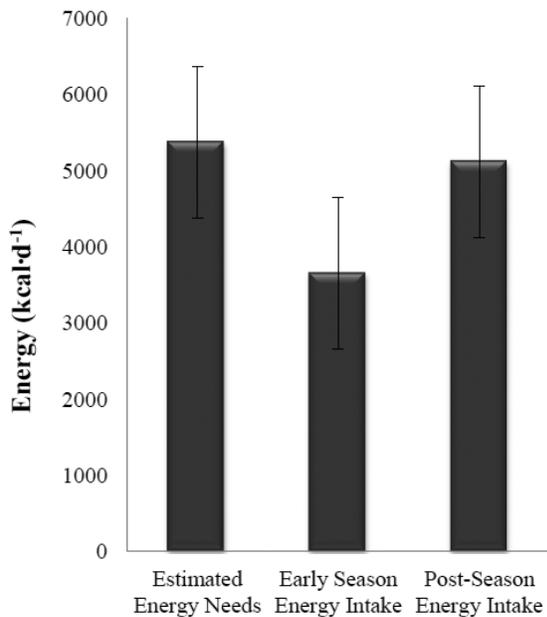


Figure 1 — Estimated energy requirements compared with estimated intakes from early-season and postseason 3-day diet records, M ± SD.

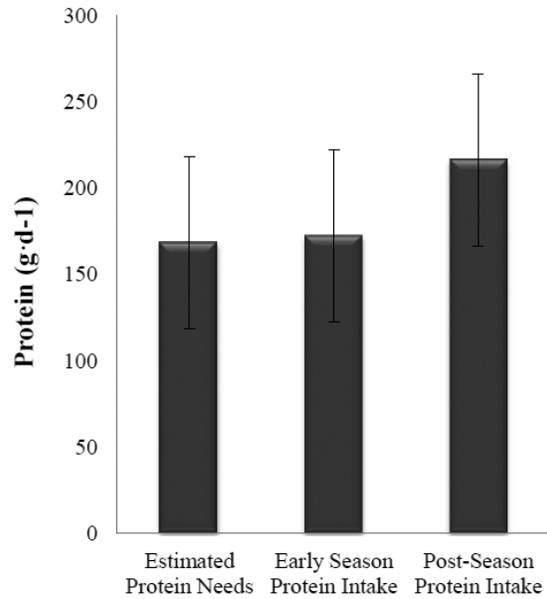


Figure 2 — Estimated protein requirements compared with estimated intakes from early-season and postseason 3-day diet records, M ± SD.

Table 2 Early-Season and Postseason Performance Measures (N = 13), M ± SD

Performance measure	
Vertical jump (cm)	
early season	66.0 ± 8.1
postseason	68.8 ± 7.4*
10-yd (~9-m) spring (s)	
early season	1.86 ± 0.08
postseason	1.85 ± 0.07
Hang clean (kg)	
early season	228.3 ± 19.0
postseason	245.9 ± 15.4*
Back squat (kg)	
early season	351.1 ± 26.9
postseason	382.0 ± 37.5*
Bench press (kg)	
early season	112.1 ± 12.9
postseason	117.4 ± 14.3*

*p < .05 compared with early-season training.

Table 3 Early-Season and Postseason Mass Measures From Dual-Energy X-Ray Absorptiometry (N = 15), M ± SD

Mass measure	
Total-body mass (kg)	
early season	96 ± 13
postseason	99 ± 14*
Right-arm fat mass (g)	
early season	877 ± 304
postseason	992 ± 343*
Right-arm lean mass (g)	
early season	4,859 ± 583
postseason	5,213 ± 579*
Trunk fat mass (g)	
early season	7,665 ± 3,353
postseason	8,540 ± 3,852*
Trunk lean mass (g)	
early season	35,344 ± 4,265
postseason	36,159 ± 4,406*
Right-leg fat mass (g)	
early season	3,066 ± 1,216
postseason	3,225 ± 1,215
Right-leg lean mass (g)	
early season	12,544 ± 1,294
postseason	12,748 ± 1,399
Total fat (g)	
early season	15,877 ± 6,197
postseason	17,262 ± 6,776*
Total lean mass (g)	
early season	70,478 ± 7,741
postseason	71,758 ± 7,703*

* $p < .05$ compared with early-season training.

Body Composition

All subjects completed two DEXA scans, and changes in lean and fat mass between early season and postseason are presented in Table 3. For the sake of brevity, values are given for the right arm and leg only; however, changes were similar between arms. There were significant increases ($p < .05$) in total body mass, arm fat and lean mass, trunk fat and lean mass, and total fat and lean mass.

Blood-Lipid Profile

Fasting blood-lipid concentrations are presented in Table 4. One subject did not participate in the blood draw. There was a significant increase ($p < .05$) in total cholesterol

Table 4 Early-Season and Postseason Blood Lipids (N = 14), mg/dl, M ± SD

Lipid measure	
Cholesterol	
early season	193.5 ± 32.4
postseason	222.6 ± 40.0*
Low-density lipoproteins	
early season	92.7 ± 32.7
postseason	124.5 ± 34.7*
Triglycerides	
early season	164.0 ± 88.3
postseason	149.1 ± 33.9
Very-low-density lipoproteins	
early season	32.8 ± 17.7
postseason	29.7 ± 6.8
High-density lipoproteins	
early season	68.0 ± 16.2
postseason	68.3 ± 14.3

* $p < .05$ compared with early-season training.

and LDL cholesterol measures, while no changes were measured in triglycerides, very-LDL cholesterol, and HDL cholesterol.

Discussion

The key findings of this investigation were that the group showed improvements in the tested performance measurements and gained both lean and fat body mass. Increases in total cholesterol and LDL cholesterol were also measured.

Dietary intakes reported by participants were below the estimated requirements for total energy but adequate for estimated protein intake for nearly all players. A 3-day diet record was used to collect the average intake over time. A 3-day diet record was selected versus a 24-hr recall, as a 24-hr recall relies on an individual's memory rather than recording food intake as it occurs. A 7-day diet recall has limitations, in that "the validity of the collected information decreases in the later days of a 7-day recording period in contrast to collected information in the earlier days" (Thompson & Subar, 2008, p. 3). It has been established in previous research that NCAA American football athletes underreport their energy and macronutrient intake on self-reported dietary records (Cole et al., 2005). The estimated average energy requirements ranged between 4,475 and 5,370 kcal/day. Average reported energy intake was 3,647 kcal (range 3,021–5,281 kcal) during the early-season collection and 5,115 kcal (range 2,412–11,816 kcal) during the postseason data collection. Average reported protein intake was 1.8 g/kg

per day. Within the 8-week study, participants increased body mass from 96 kg early season to 99 kg postseason. Thus, there is evidence that participants exceeded their caloric needs.

Incoming American redshirt football athletes often find themselves away from home for the first time. They have greater access to high-calorie, high-fat foods and are encouraged to gain weight to enhance performance with the football program. The reported increase in energy intake over the course of the study could be related to increased comfort with the 3-day diet records from early-season to postseason data collection. In addition, increased energy intake may be temporary while these athletes attempt to increase their lean body mass while adapting to the university level of play.

American football athletes have been identified as an at-risk population for cardiovascular disease (CVD; Kaiser et al., 2008), elevated blood pressure, and sleep-disordered breathing (Harp & Hecht, 2005) due to their increased body mass and size. The philosophy of “bigger is better” has become commonplace in the sport of football. Noel, VanHeest, Zanetas, and Rodgers (2003) suggest there is a point where increasing body mass will no longer increase lean muscle mass but, rather, will increase body fat. The diminished fat-free mass will ultimately decrease performance levels while putting these athletes at a higher risk for developing health problems such as obesity, diabetes, and cardiovascular disease later in life. An increase in muscle mass improves overall performance by enhancing strength, power, and speed. According to Buell et al. (2008), many athletes are indifferent to the composition of the weight gained and often experience increased abdominal adipose tissue. It was also noted that the overall body size increased as the NCAA level of play increased from Division III schools to Division I. The average range of body fat in men 20–29 years of age is 14–19%. Individuals with less than 12% body fat are above average in proportion of lean body mass, and those with greater than 20% body fat are below average in proportion of lean body mass (American College of Sports Medicine, 2000). This group increased both lean and fat mass during the study but had proportionally greater increases in fat mass. Percent body fat increased from 17% to 18% from early-season to postseason measure. Athletes involved in this study fell within the average range of percent body fat. While recent research suggests that the results of this study may have been more accurately determined if we had been able to make the determinations in the fasted state (Nana, Slater, Hopkins, & Burke, 2012), participants gained about 3 kg of body mass on average, and the direction of the change measured via DEXA scans is consistent with caloric excess resulting in gains of both fat and lean mass.

Harley, Hind, and O’hara (2011) observed a significant increase in body fat of about 1% and a significant decrease in lean body mass of 1–2% with no significant change in body mass in 20 English Super League rugby players with the use of three DEXA scans over the course of a 7-month season. They hypothesized that these

changes could be related to positive energy balance and a decrease in intensity of training midseason. The athletes in the current study gained fat and a modest amount of lean mass during the 8 weeks between measurements, and our findings are comparable in magnitude. While the duration of our study was shorter, the 3-kg gain in total body mass, the estimated 1-kg increase in lean body mass, and the increases in strength measured from early to postseason suggest that the dietary practices of the athletes in our study appear to have been sufficient for the maintenance, and perhaps augmentation, of muscle mass during the course of a competitive season. To promote lean body mass and improve performance, it was recommended that weight-control practices of nutrition education and strength and conditioning programming be improved.

Today’s football athletes have a greater body mass than players of the past. Kaiser et al. (2008) suggest that the increase in body mass has a high correlation with rule changes observed in the sport. Rules that have encouraged an increase in body size include the restriction of below-the-waist blocking techniques. Thus, offensive linemen have been expected to gain mass to make up for restricted techniques. The average BMI for participants in this study was greater than 26 kg/m². At this measurement, all included athletes would be considered overweight or at increased risk of disease (American College of Sports Medicine, 2000). The use of the BMI measurement is not recommended for football players, or athletic individuals, due to their increased lean body mass. However, Baron, Hein, Lehman, and Gersic (2012) found that retired professional National Football League players with a playing-time BMI ≥ 30 kg/m² had 2 times the risk of CVD mortality.

Total percent of dietary calories from fat was 30–54% for early-season and 20–51% for postseason diet records. The high proportion of fat, high cholesterol intake, and low fiber intake reported by participants is consistent with high dietary intake of meat and cheese and other dairy products. Research related to diets rich in total fat, saturated fat, cholesterol, and trans fats shows an increased risk of CVD (Flock & Kris-Etherton, 2011). LDL increased significantly in the group, with an average rise from near optimal (92.7 ± 32.7 mg/dl; 11 of 14 [79%]) to near/above optimal (124.5 ± 34.7 mg/dl; 12 of 14 [86%]); National Cholesterol Education Program, 2002). Similarly, the mean postseason total cholesterol concentration (222.6 ± 40.0 mg/dl; 11 of 14 [79%]) falls within the borderline-high total cholesterol classification range. Individuals in an overfed state will experience changes in their blood-lipid profile. After only 6 days of overfeeding with isocaloric diets containing long-chain triglycerides, medium-chain triglycerides, or fish oil, Hill et al. (1990) observed changes in fasting triglycerides, plasma LDL, and HDL levels. Thus, the increase in cholesterol and LDL is likely to be a function of overfeeding to gain weight in this population of athletes and may be a temporary response. Triglyceride levels decreased in both groups, but changes were not significant. HDL

cholesterol levels for both groups were within the high-HDL category at both early-season and postseason measures. No significant changes were found for the HDL measurement. HDL scavenges excess cholesterol, which can help decrease the risk of coronary artery disease. The high level of HDL in the athletes in our study may provide a buffer against the negative effects of the rise in cholesterol. Furthermore, as HDL levels rise, lipoprotein lipase activity increases, as does the insulin receptor sensitivity. The increase in lipoprotein lipase activity and insulin receptor sensitivity leads to an increase in the breakdown of triglycerides (Brooks, Fahey, & Baldwin, 2005). Alcohol intake could be a factor in weight gain and changes in specific lipids. However, this research did not ask participants provide information related to alcohol intake, as they were underage. Underage drinking is illegal and could result in suspension from an American NCAA football team.

There were several limitations to this research. It is limited by the small population and convenience sampling. As previously discussed, the self-reported 3-day diet records were not completed without error. Due to three researchers' working with the food records, interrater reliability could be a factor in data outcomes. In addition, this research collected general nutrition information (calories, protein, fat) versus looking at changes of types of foods chosen over time. The study length was 8 weeks. This length of time cannot account for changes that would occur over a longer period. The test-retest coefficient of variation for the DEXA machine used in this study was not made available to the researchers. A standardized protocol was not implemented for body-composition measurements. According to Nana et al. (2012), DEXA results are affected by daily activities and food and beverage intake. To minimize the likelihood of error, it is recommended that technicians follow a standardized protocol with participants in a fasted state.

In conclusion, the university-level, redshirted, freshman American football players participating in this investigation showed significant improvements in strength, power, and speed. They increased their total body mass, muscle mass, and fat mass over time. Athletes consuming a high-calorie, high-fat diet experienced increased body fat and an elevated blood-lipid profile. It is possible that this is a temporary phenomenon, but it is cause for concern and an indication that dietary education to promote weight gain in a manner less likely to adversely affect the lipid profile is warranted. A long-term high-calorie, high-fat diet may increase the risk of developing CVD later in life. Due to high fat consumption in these subjects, it is recommended that they receive further nutrition education to decrease their risk of long-term health consequences.

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