Physical Health, Nutrition Knowledge, Food Consumption, and Quality of Life in Female Collegiate Runners

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Abstract

Collegiate athletes undergo a pre-participation examination, but it often does not analyze dietary habits, nutrition knowledge, or quality of life. The purpose of this study was to assess these factors in female collegiate runners. Twenty-eight track and field and cross country runners from a Division II University completed this study. Blood pressure, body composition, and fasting blood glucose and lipids were measured. Participants also completed the Diet History Questionnaire (DHQIII) food frequency questionnaire (FFQ), Nutrition for Sport Knowledge Questionnaire (NSKQ), and the World Health Organization Quality of Life survey (WHO QOL-BREF). Fifty-seven percent of athletes' fasting glucose was over 100mg/dL, 7.4% had LDL >100 mg/dL, 13% had triglycerides >150 mg/dL, and 50% had HDL <50 mg/dL. Overall nutrition knowledge was poor. The FFQ indicated that 67.9% of athletes did not meet the recommended vegetable intake and 89% did not meet the recommend grain intake. Twenty-seven percent of athletes met estimated energy needs, 10.7% consumed 6-10 g/kg of carbohydrate (often recommended for athletes training 2-3 hours per day), 64.3% consumed at least 1.2 g/kg of protein (often recommended for endurance athletes), and 46% met the RDA for iron. The mean WHO QOL-BREF scores (out of 100) were 60.4 ±11.85 for physical health, 66.0±9.33 for psychological well-being, 79.9±16.73 for social relationships, and 81.4±11.81 for their environment. This research demonstrated inadequate nutrition knowledge among female athletes, possibly contributing to a poor diet as evidenced by high fasting blood glucose and low carbohydrate and protein intake. This may contribute to the low perception of physical and psychological health, possibly due to relative energy deficiency in sport (RED-S).

Background

Collegiate athletes are required to undergo a pre-participation examination (PPE) prior to participating in sport to determine whether they have conditions that could increase risk of health consequences and ensure safe participation in sport (Conley et al., 2014). However, the thoroughness of the PPE is dependent on the university and often does not assess nutrition knowledge, food consumption, or quality of life. Recent literature has revealed cardiovascular risk factors in young adult athletes in addition to a high prevalence of low energy availability (LEA), particularly in track and field and endurance athletes (D'Ascenzi et al., 2018, Melin, Heikura, Tenforde, & Mountjoy, 2018). Thus, more extensive screenings may be warranted to assess health risk factors and make the coaching staff more aware of the health of individuals and teams.

Physical health

It is widely accepted that regular physical activity is an effective way to maintain physical health, namely to reduce cardiovascular risk factors such as hypertension, hyperglycemia, hyperlipidemia, and improve body composition. Because of athletes' regular engagement in exercise, they are often assumed to have very low risk for cardiovascular disease (CVD), yet there is some evidence to the contrary. In fact, recent research has demonstrated that even athletes can demonstrate common CVD risk factors (D'Ascenzi et al., 2018).

Blood pressure.

There is a known association between higher systolic (SBP) and diastolic blood pressure (DBP) and increased risk of CVD (Guideline for the prevention, 2018). Normal blood pressure is <120mmHg SBP and <80 mmHg DBP. Elevated blood pressure is 120-129 mmHg SBP and

<80mmHg DBP. Hypertension stage 1 is 130-139mmHg SBP and 80-89mmHg DBP while stage 2 is >140mmHg SBP and >90mmHg DBP. While regular physical activity is a known strategy to decrease hypertension, some athletes have demonstrated elevated blood pressure despite engaging regularly in exercise (Borchers et al., 2009, D'Ascenzi et al., 2018).

Borchers et al. (2009) assessed a team of Division 1 collegiate football players to estimate the prevalence of metabolic syndrome, insulin resistance, and other risk factors. There were 90 athletes in the study with an average age of 20.1 ± 1.61 years. Assessments included family history, resting blood pressure, a fasting blood sample to measure lipids and glucose, anthropometrics, and body composition. The average systolic blood pressure was 126.70 ± 12.49 mmHg while the average diastolic pressure was 70.24 ± 8.55 mmHg. However, 44.4% of athletes were found to have a systolic blood pressure greater than 130 mmHg and 3.3% were found to have a diastolic blood pressure greater than 85 mmHg. These results are concerning as almost half of the sample demonstrated higher than normal blood pressure. Studies such as this one have called into question the CVD risk of athletes.

D'Ascenzi et al. (2018) analyzed the cardiovascular risk factors in 1,058 asymptomatic Olympic athletes with an average age of 24 ± 6 years, representing a broad spectrum of sports, including long distance runners. Athletes were divided by age into adolescent athletes (15-20 years), young adult athletes (21-29) years, and older adult athletes (30-45 years). The average age was 24 ± 6 years. In this sample, adolescent athletes' average blood pressure was 111 ± 12 mmHg systolic and 69 ± 8 mmHg diastolic. Young adults' average blood pressure was 114 ± 12 mmHg systolic and 73 ± 8 mmHg diastolic. Older adults' average blood pressure was 116 ± 11 mmHg systolic and 74 ± 9 mmHg diastolic. Hypertension was found in 40 of the athletes, which was 3.8% of the sample.

Lipids.

Another strong risk factor for CVD is hyperlipidemia, which refers to elevated cholesterol, elevated triglycerides (TG), or both. Hyperlipidemia is also based on the concentrations of the low-density (LDL) and high-density (HDL) lipoproteins. Classification is shown in Table 1 below (Nelson, 2012, p. 211). As with blood pressure, regular physical activity is a known way to improve lipid profiles. However, some athletes have demonstrated elevated lipids, causing concern for their CVD risk (Borchers et al., 2009, D'Ascenzi et al., 2018).

Table 1
Classification of Hyperlipidemias

LDL Cholesterol	
<100	Optimal
100-129	Near or above optimal
130-159	Borderline high
160-189	High
≥190	Very high
Total Cholesterol	
<200	Desirable
200-239	Borderline high
≥240	High
HDL Cholesterol	
<40	Low
≥60	High
Triglycerides	
<150	Normal
150-199	Borderline high
200-499	High
≥500	Very high

In Borchers et al.s' 2009 sample of 90 Division I football players, the average fasting cholesterol was 161.87 ± 25.78 mg/dl. The average HDL was 39.36 ± 8.97 mg/dl, LDL was 106.08 ± 23.95 mg/dl, and TG was 82.56 ± 46.34 mg/dl. However, nine percent of the athletes had total cholesterol >200 mg/dl, LDL <100 mg/dl, 49.4% of athletes surveyed had LDL between 100-160 mg/dl and 4.5% had LDL >160 mg/dl.

In D'Ascenzi et al.'s (2018) sample of Olympic athletes, 32% of the population had dyslipidemia (abnormal lipids). The average total cholesterol was 171 ± 33 mg/dl for adolescent athletes, 182 ± 34 mg/dl for young adults, and 191 ± 34 mg/dl for older adults. The average HDL was 64 ± 17 mg/dl for adolescent athletes, 66 ± 16 mg/dl for young adults, and 59 ± 15 mg/dl for older adults. The average LDL was 95 ± 27mg/dl for adolescent athletes, 103 ± 28 mg/dl for young adults, and 116 ± 31 mg/dl for older adults. The average TG was 69 ± 31 mg/dl for adolescent athletes, 77 ± 37 mg/dl for young adults, and 86 ± 41 mg/dl for older adults. They found that despite their participation in sport, as the athletes aged, lipids increased, indicating that sport participation may not eliminate the trend towards elevated LDL and triglycerides with increasing age.

Glucose.

Elevated blood glucose, also known as hyperglycemia, is another CVD risk factor. Normal fasting glucose is < 100 mg/dl; impaired fasting glucose, often referred to as pre-diabetes is 100-125 mg/dl, and the diabetic range is ≥ 126 mg/dl (American Diabetes Association, 2010). Insulin sensitivity is known to improve with regular physical activity, indicating that athletes should have good blood glucose control and demonstrate normal fasting blood glucose (Thomas, Pretty, Desaive, & Chase, 2016). Current research indicates that not all athletes have normal blood glucose (Thomas et al., 2016, Borchers et al., 2009). However, few samples have been tested.

The Olympic athletes from the research by D'Ascenzi et al. (2018) had an average fasting glucose of 93 ± 7 mg/dl for adolescent athletes, 93 ± 7 mg/dl for young adults, and 95 ± 9 mg/dl for older adults. Hyperglycemia was found in 3 athletes, 0.3% of the sample. In the sample of football athletes studied by Borchers et al. (2009), average fasting glucose was 85.50 ± 5.98 mg/dl, with 1.1% of the sample being above 100 mg/dl. This sample was also tested for insulin resistance using fasting insulin and the quantitative insulin sensitivity check index (QUICKI) calculations. Average fasting insulin was 9.01 ± 5.74 mg/dl with 15.7% demonstrating fasting insulin >15 μIU.mL. Insulin resistance was prevalent in 21% of the sample.

Thomas, Pretty, Desaive, and Chase (2016) analyzed the blood glucose of sub-elite athletes for 6 days using continuous glucose monitoring (CGM) devices, which are primarily used in diabetic individuals to aid in glucose regulation. Ten athletes who engaged in >6 hours of endurance activities per week wore the devices for 6 days in addition to reporting all meals and snacks and recording all exercise. The researchers wanted to see if the athletes achieved optimal glucose levels as defined by the World Health Organization during free living despite carbohydrate rich-diets and post-exercise hyperglycemia typical of athletes. Three of the 10 athletes demonstrated elevated fasting blood glucose within the pre-diabetes range. After accounting for blood glucose after meals, 4 of the 10 athletes spent more than 70% of time outside of optimal blood glucose levels. The two athletes that participated in the greatest volume of exercise demonstrated the most efficient glucose uptake.

Body composition.

Optimal ranges of body fat are sport, gender, and athlete specific (Jeukendrup & Gleeson, 2010). While there are no body fat standards for athletes, in weight-bearing activities such as running, a lower body weight and high power-to-weight ratio is desirable. However, having too low of overall body fat mass can be of concern. For men, essential body fat is about 3% and for women it is about 12%. For women, a very low body fat or a rapid decrease can compromise menstrual function (Mountjoy et al., 2014). This has been associated with LEA and relative energy deficiency in sport (RED-S). The presence of secondary amenorrhea, which is the absence of three consecutive cycles post-menarche, is estimated to be as high as 65% in female collegiate long-distance runners (Mountjoy et al., 2014). Thus, this population could benefit from body composition assessment as a preventative measure. The average body fat range for female sprinters is 12-20% and 10-15% for female distance runners (Jeukendrup & Gleeson, 2010). In comparison, the classifications for the general female population are as follows: athletic 8-15%, good 16-23%, acceptable 24-30%, overweight 31-36% and obese >37% (Jeukendrup & Gleeson, 2010).

One of the measures in a study by Webber et al. (2015) to assess diet quality in athletes was body composition. Their sample contained 138 male and female collegiate athletes from a variety of sports. Body composition was measured using air displacement plethysmography with the BodPod. The average body fat percentage was 11.1 ± 3.9% for males and 24.1 ± 4.5% for females.

Shriver, Betts, and Wollenberg (2013) also analyzed the body composition of collegiate athletes in a study that also assessed diet quality in female athletes. The sample contained 52

Division I female athletes from a university in the Midwest of the United States with an average age of 20 ± 1.5 years. The sample represented soccer, basketball, crosscountry as well as track and field. Body composition was determined using a whole-body scan performed by dual-energy x-ray absorptiometry (DEXA). The mean body fat percentage was 19.5 ± 3.7%. The research did not specify whether body composition varied by sport.

Nutrition

The joint position statement from the American College of Sports Medicine, Academy of Nutrition and Dietetics, and Dietitians of Canada is that "the performance of, and recovery from, sporting activities are enhanced by well-chosen nutrition strategies" (Thomas, Erdman, & Burke, 2016, p.501). The negative outcomes on health and performance when an athlete does not consume proper nutrients are well documented. The International Olympic Committee (IOC) describes that the underlying issue of RED-S is inadequate energy to support sporting activities, homeostasis, health, and activities of daily living (Mountjoy et al., 2014). When athletes have LEA, body systems are forced to decrease energy expenditure which can result in disruption of the function of, but not limited to, metabolic rate, menstrual function, bone health, immunity, protein synthesis, and cardiovascular health. RED-S can compromise health and performance in the short term as well as in the long term. For this reason, it is imperative that athletes consume a well-balanced, nutrient dense diet that can support their level of training. To prevent RED-S and other nutrition related injuries, there are sport specific recommendations in the joint position statement that can optimize performance and health (Thomas et al. 2016).

Adequate carbohydrate intake in athletes ensures that athletes are able to maintain blood sugar during exercise as well as replace glycogen stores post-exercise (Thomas et al. 2016).

Recommendations are individual and are dependent on various factors, including the type, intensity, and duration of exercise. For athletes in low intensity, skill-based training, the recommendation is to consume 3-5 grams of carbohydrate per kilogram of body weight per day (g/kg/day) of carbohydrates. Recommendations for those in a moderate-intensity program, exercising approximately one hour per day are 5-7 g/kg/d. A high-intensity program, performing moderate to high intensity exercise for 1-3 hours per day may necessitate 6-10 g/kg/d while a very high intensity program, with moderate to high intensity exercise for 4-5 or more hours per day may require 8-12 g/kg/d. Protein recommendations range from 1.2-2.0 g/kg/d, depending on the type of exercise. Adequate protein intake is necessary to support tissue recovery and increase metabolic adaptations to exercise.

Although the importance of a well-balanced diet is clear and the recommendations are available, athletes have reported consuming poor diets lacking in proper nutrients (Thomas et al. 2016, Webber et al., 2015, Hinton, Sanford, Davidson, Yakushko, and Beck 2004 2004, Shriver et al., 2013). Some have speculated that athletes simply lack the nutrition knowledge to be able to make appropriate decisions. For this reason, nutrition knowledge in athletes has been studied, but there is a lack of high quality studies on this topic (Spronk, Heaney, Prvan, & O'Conner, 2015).

Food consumption.

Webber et al. (2015) assessed the diet quality of 138 collegiate athletes. They used the Block 2005 food frequency questionnaire to find what the athletes ate, and then calculated a diet quality score using the Healthy Eating Index 2005. The sports assessed included gymnastics, swimming, diving, basketball, and volleyball. The males' average diet quality score was 47.7 ±

7.9 and the females was 53.1 ± 8.6 out of 100. They found that females reported consuming fewer than the recommended calories (1866.9 ± 976.8) while males reported consuming more than the recommended calories (3615.8 ± 2238.4). There was no difference found between the lean sports (gymnastics, swimming, and diving) and ball sports (soccer, basketball, and volleyball). Overall they found that the athletes' diets were high in sodium, solid fats, alcohol, and added sugars but low in fruits and fiber.

Hinton, Sanford, Davidson, Yakushko, and Beck (2004) analyzed the nutrient intake and dietary behaviors of both male and female collegiate athletes. In the sample of 345 athletes from a Division I university, 252 completed the food frequency questionnaire. The researchers decided to use the Youth Assessment Questionnaire because college students' diets typically resemble adolescents more closely than adults. The macronutrients and micronutrients were compared to the daily recommended intake (DRI) and recommended dietary allowance (RDA); however, this would be a conservative estimate because these were not designed for athletic populations. Thus, to evaluate the macronutrients they would also use the joint position statement for comparison. Females consumed an average of 2141 kcal while males consumed 2447 kcal. Of the females, only 19% consumed adequate carbohydrate of at least 6 g/kg of body weight and 32% consumed at least 1.5 g/kg of protein. Twenty-five percent of the females reported restricting carbohydrates and fats to decrease their weight. Of the male athletes, 10% consumed adequate carbohydrate of at least 6 g/kg of body weight and 19% consumed at least 1.5 g/kg of protein.

Shriver et al. (2013) also analyzed the diets of 52 Division I collegiate female athletes. The researchers used a 24-hour recall to familiarize the athletes with recording their diets, and then the athletes kept a 3-day food log consisting of 2 weekdays and 1 weekend day. The females had their body composition tested with a DEXA scan and had their resting metabolic rate (RMR) calculated using the Cunningham equation, which is based upon fat-free mass. The researchers then found an estimation of the athletes' total energy needs by multiplying by a physical activity factor based on a physical activity log. They found that the average calories consumed was 1939 ± 604. The distribution of calories was within range according to the recommended macronutrient distribution range with 53% of total calories from carbohydrate, 16% from protein, and 31% from fat. However, when compared to the athletes' estimated needs, 91% did not meet their energy needs, 74% did not consume at least 5 g/kg of body weight carbohydrate, and 50% did not consume at least 1.2 g/kg of body weight of protein.

Previous research has demonstrated that female collegiate athletes do not consume enough calories to meet the recommended ranges for their activity level. In addition, when carbohydrate and protein consumption is compared to the recommended ranges for athletes, many athletes fail to consume adequate amounts of these macronutrients. These findings are disconcerting in light of the negative outcomes on health and performance when athletes have LEA. The present study will analyze the food consumption of female athletes using a food frequency questionnaire.

Nutrition knowledge.

A study was conducted by Zawila, Steib, and Hoogenboom (2003) to assess the nutrition knowledge and attitudes toward nutrition of female collegiate cross country runners. Their sample included 60 female cross country runners from universities in Illinois and Michigan. There were six schools involved in the research, three from each state representing Division I, II, and III. The nutrition knowledge questionnaire that the researchers developed used questions from questionnaires created by Barr et al and included 76 true/false and Likert scale questions covering a variety of nutrition topics and seven open-ended questions to assess athletes' attitudes toward nutrition. Questions where fewer than 35% of athletes answered correctly were related to glycemic index, sources of muscle energy, nutrients and performance, and diet requirements for distance runners versus sprinters. The majority of athletes agreed that no more than 15% of calories should be provided by fat, a value below the lower end of the Acceptable Macronutrient Distribution Range, indicating that the majority of the runners did not understand how much fat was necessary in the diet. Athletes understood the importance of calcium in the body but underestimated how much was needed. However, they demonstrated a positive attitude towards nutrition education, and therefore it was suggested that they would benefit from an education program.

Torres-McGehee et al. (2012) analyzed the nutrition knowledge of athletes, coaches, strengths and conditioning specialists, and athletic trainers. The sample consisted of 185 athletes, 131 coaches, 71 strength and conditioning specialists, and 192 athletic trainers from a variety of sports at Division I, II, and III schools across the United States. The research team developed their own questionnaire consisting of 20 equally weighted questions. The participants' nutrition knowledge was tested in four domains: micronutrients and macronutrients, supplements and performance, weight management and eating disorders, and hydration. A score of 75% or better was considered adequate. The average score for athletes was 54.9 ± 13.5%, demonstrating inadequate nutrition knowledge. The micronutrient and macronutrient section had the lowest average scores for all groups while the weight management and eating disorder section had the second lowest scores. By assessing the coaching team as well as the athletes, the researchers concluded that not only did the athletes have poor nutrition knowledge, but team coaches, athletic trainers, and strength and conditioning coaches also had inadequate nutrition knowledge. The authors indicated that their questionnaire contains different questions than other questionnaires and to take caution with comparisons to other research.

Andrews, Wojcik, Boyd, and Bowers (2016) conducted a study of the nutrition knowledge of 123 student athletes at a Division I university in the Southeastern United States utilizing the same questionnaire developed by Torres-McGehee et al. (2012). Athletic teams assessed included baseball, men's and women's tennis, men's and women's track and field, men's soccer, and softball. With adequate nutrition knowledge defined as obtaining a 75% or better on the questionnaire, the overall nutrition knowledge was inadequate with an average score of 56.9 ± 14.3% and only 12 student-athletes demonstrated adequate nutrition knowledge, similar to the findings of Torres-McGehee et al (2012). The study also compared the results between gender, upperclassmen and lowerclassmen, and sports team. No differences were found among any of the groups. This study did not report performance in specific domains.

Spronk, Kullen, Burdon, and O'Conner (2014) did a systematic review to indicate the relationship between nutrition knowledge and dietary intake. There were 29 total articles that qualified to be in the review, 22 of them from community populations and seven from athletic populations. While they found a positive, weak association between diet quality and nutrition knowledge in their review, they also indicated that there were not consistent questionnaires and measures used in the studies to assess nutrition knowledge or dietary intake. This inconsistency made comparison difficult. In addition, many of the studies, particularly those in athletic populations were old, conducted between 1990 and 1995. Overall, the review found a lack of high quality studies assessing nutrition knowledge and dietary intake.

Trakman, Forsyth, Hoye, and Belski (2017) recognized the need for consistency among nutrition knowledge questionnaires in athletics. They created a questionnaire and validated it using classical test theory and Rasch analysis. The final questionnaire contains 89 items divided into 6 unidimensional subsections. These subsections are weight management (n=13 questions), macronutrients (n=30 questions), micronutrients (n=13 questions), sports nutrition (n=13 questions), supplements (n=12 questions), and alcohol (n=8 questions). The questionnaire was designed to be generalizable to any sport and applicable in any culture.

Trakman, Forsyth, Middleton, and Hoye (2018) then used the newly validated questionnaire to assess the nutrition knowledge of Australian football players. The sample consisted of 99 male elite and non-elite athletes aged 17-25. The Nutrition for Sport Knowledge Questionnaire (NSKQ) was used. The mean score for elite athletes was 45.4 ± 14.7% and 50.9 ± 11.0% for non-elite athletes. Scores less than 49% are considered poor, 50-64% are average, 65-75% are good and >75% are excellent. The elite athletes scored poorly in weight management, micronutrient, sports nutrition, and supplements. Non-elite athletes scored poorly in sports nutrition and supplements. Both elite and non-elite athletes could improve their nutrition knowledge.

Research done in the past has indicated that athletes lack nutrition knowledge (Zawila et al., 2003, Torres-McGehee et al., 2012, Andrews et al., 2016, Trakman et al. 2018). More specifically, when questionnaires report subcategories revealing specific areas in which athletes lack nutrition knowledge, weight management and recommendations for micronutrients are commonly less understood (Zawila et al., 2003, Torres-McGehee et al., 2012, Trakman et al. 2018). However, many of the older studies used different questionnaires, limiting the ability to compare them. With the newly validated NSKQ, researchers can now gather more consistent data and explore knowledge of specific nutrition subcategories. The purpose of assessing nutrition knowledge in this study is to contribute to the lack of data utilizing the NSKQ and gather more information about which specific categories of nutrition athletes lack knowledge.

Quality of Life

Quality of life has been defined as an “individual’s perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns” (Hawthorne, Herman, & Murphy, 2006, p. 38). In response to a broadening focus in health to assess health beyond the traditional measures, the World Health Organization developed a cross-cultural quality of life survey (WHOQOL-BREF, 1996). The survey includes four domains: physical health, psychological, social relationships, and environment. The physical health domain includes questions concerning activities of daily living, energy and fatigue, mobility, and sleep and rest. The psychological domain assesses body image and appearance, self-esteem, and thinking, learning, memory, and concentration. The social relationships domain questions personal relationships, social support, and sexual activity. Finally, the environment domain assesses financial resources, freedom, physical safety, security, transportation, home environment, physical environment, and participation in recreation and leisure activities. The World Health Organization Quality of Life, Brief (WHOQOL-BREF) is a validated shortened version of the 100 item questionnaire. It contains only 26 items, yet assesses all of the same domains and generates a similar result. The score is out of 100, with a higher score indicating a higher quality of life.

Recognizing a lack of normative data for the WHOQOL-BREF, Hawthorne et al. (2006) conducted a study in Victoria, Australia with 396 participants to establish normal values for age and gender. It should be noted that the sample sizes were relatively small for the younger age groups. Females aged 20-29 (n=30) scored 83.6 ± 11.3 in the physical health domain, 69.7 ± 17.9 in the psychological domain, 75.6 ± 15.3 in the social relationships domain, and 72.7 ± 15.6 in the environment domain.

Correia et al. (2017) assessed the quality of life specifically in athletes. Their sample contained 32 female Brazilian volleyball players with an average age of 22.5 ± 3.48 years. The participants were considered elite and each had competed in the University Sports National League. The answered the WHOQOL-BREF in addition to an Academic-Sports Questionnaire developed by the researchers that questioned topics related to student-athletes. The scores for their WHOQOL-BREF were 69.75 ± 14.3 in the physical health domain, 72.79 ± 11.8 in the psychological domain, 78.40 ± 14.8 in the social relationships domain, and 59.5 ± 14.5 in the environment domain. These scores were compared to the scores of a random female population from Brazil. When compared to the general population, the athlete scores were higher, especially in the physical, psychological and social domains.

Assessing quality of life can give coaching staff an idea as to what is going on with an athlete beyond performance and physical testing. As the focus of health among the general public broadens to include quality of life assessment, it is important to consider monitoring this parameter in athletic populations as well. Assessing physical health can give insight into an athlete's perception of their energy, fatigue, and sleep quality, while assessing their psychological health can reveal body image issues and poor self-esteem. Results from assessments such as the WHOQOL-BREF can reveal risk factors for developing RED-S. Given that LEA and RED-S can have psychological implications in addition to physical, assessing the quality of life in athletes can be highly beneficial. The use of the WHOQOL-BREF in the present study is to assess quality of life in collegiate runners to better understand athlete perception of their health in addition to physical testing. It also could reveal whether there are areas in which athletes have higher or lower scores, providing insight on areas that need improvement for targeted intervention.

Given that athletes still sometimes present with abnormal lipid, glycemic, and blood pressure values and that athletes often consume insufficient energy for their energy expenditure, the present study sought to assess the health of PLNU's track and cross country runners. In recent years PLNU's runners have suffered high incidence of injuries, including stress fractures. Therefore, the purpose of this study was to assess the physical health, nutrition knowledge, food consumption, and quality of life of the track and field and cross country athletes at PLNU.

Methods

Participants

The study was reviewed and approved by the university's institutional review board prior to any subject recruitment and data collection, and the study is in compliance with the Declaration of Helsinski as revised in 1983. Participants were Division II female runners. Researchers attended cross country and track and field practices and team meetings to recruit participants by explaining the purpose of the study and detailing what participation would entail. Participation was voluntary. Participants were scheduled for an individual laboratory visit in which they signed a written informed consent document and had any questions answered prior to data collection. There were a total of 28 participants, 13 cross country runners and 15 track and field athletes.

Procedures and Research Instruments

Participants were informed to refrain from exercise for at least 24 hours before the appointment, to fast after 10:00 pm the night before the appointment, and to abstain from food or water consumption the morning of the appointment. After researchers obtained the participants' informed consent, they measured resting blood pressure while the participant was still seated using a sphygmomanometer and stethoscope. Researchers then pricked the participants' finger to obtain a small blood sample. Blood glucose was measured using the OneTouch *Ultra 2* Blood Glucose Monitor and lipids were measured using the Alere Cholestech LDX. Researchers then took anthropometric measurements including height, weight, and body composition and calculated body mass index. Height was measured using a wall-mounted stadiometer. Body weight was measured using the electronic scale from the BodPod. Body composition was measured with air displacement plethysmography with the BodPod (Model 2007A, Cosmed USA, Concord, California). Participants were instructed to wear either an athletic swimsuit or spandex and a sports bra per the manufacturer's instructions. They removed all other clothing and any jewelry and their hair was tied up underneath a swim cap. Body composition was determined by the BodPod using the Siri equation. Resting metabolic rate (RMR) was also estimated by the BodPod using the Cunningham equation. Participants self-reported their physical activity level, which researchers entered into the BodPod to estimate total energy expenditure (TEE).

Once physical testing procedures were completed, participants remained in the laboratory and responded to three self-administered questionnaires. The WHOQOL-BREF questionnaire was administered on paper. This questionnaire contains 26 questions assessing the quality of life in 4 domains: physical health, psychological, social relationships, and environment. Each domain was manually scored as instructed by the WHO. The scores were converted to a score out of 100 using tables provided by the WHO. A higher score indicates a higher quality of life (WHOQOL-BREF, 1996).

The NSKQ is a validated questionnaire to assess both general and sport-specific nutrition knowledge in six domains: weight management, macronutrients, micronutrients, sports nutrition, supplements, and alcohol (Trakman et. al, 2017). This questionnaire was self-administered and scored online in Qualtrics.com. The score report provided an overall raw score as well as raw scores for each of the domains. Additionally, the report converted raw scores into percentages out of 100.

The third questionnaire was the National Institute of Health's Diet History Questionnaire III (DHQIII). This food frequency questionnaire assessed the types and frequency of food eaten over the past month using a database developed from a compilation of 24-hour recall data from the National Health and Nutrition Examination Surveys (NHANES) (National Cancer Institute, n.d.). This questionnaire was also self-administered online. The website generated a report for each participant estimating the daily intake of nutrients based on the food consumption reported. Researchers recorded the average calories consumed, grams of carbohydrate and protein consumed, as well as the percent of the diet made up of carbohydrate, protein, fat, and saturated fat, and the amounts of vitamin B12 and iron consumed. Additionally, the report indicated how many servings were in the following food groups: fruit, vegetables, grains, protein foods, and dairy.

Each participant performed moderate to vigorous intensity training for 1-3 hours per day, thus the carbohydrate recommendation is 6-10g/kg of body weight (Thomas et al., 2016). Researchers calculated this goal individually for each participant based on body weight. The minimum protein recommendation of 1.2 g/kg was also calculated individually based on body weight. The grams of carbohydrate and protein consumed were compared to both a recommendation given by the DHQIII and sport specific recommendation.

Fat free mass (FFM) in kilograms was calculated by the BodPod. Researchers divided calories consumed by FFM to calculate how many calories per kilogram of FFM per day (kcal/kg FFM/day) the athletes were consuming. This value was compared to recommended energy availability defined by kcal/kg FFM/day to determine whether the athletes had low energy availability.

Data Analysis

Data were assessed for normality, then mean and standard deviations for each variable were calculated. Independent t-tests were conducted to compare sprinters and jumpers with distance runners. Since there were no significant group differences except for diastolic blood pressure, data are presented together.

Results

Results of the anthropometric measurements are shown in Table 2. Blood pressure, lipid and glucose results are summarized in Table 3.

Table 2
Participant anthropometrics

	Sample Size, N	Mean (SD)	Recommended Values	N out of recommended range
Height (cm)	28	165.4 (6.87)	n/a	n/a
Weight (kg)	28	60.1 (5.06)	n/a	n/a
Body mass index (BMI)	28	21.98 (1.79)	18.5-24.9	3
Body fat percent(%)				
Distance Runners	12	22.7% (8.84)	10-15%*	12
Sprinters/Jumpers	15	21.3% (4.13)	12-20%*	9

*Jeukendrup & Gleeson, (2010)

Table 3
Physiological Health Markers*

	Sample Size, N	Mean (SD)	Recommended values	N out of recommended range
Resting systolic blood pressure (mmHg)	28	103.9 (9.97)	<120*	0
Resting diastolic blood pressure (mmHg)	28	59.5 (7.39)	<80*	0
Blood glucose (mg/dL)	28	100.8 (9.01)	<100**	16
Total cholesterol (mg/dL)	28	142.6 (23.64)	<200 §	0
Low-density lipoprotein (LDL) (mg/dL)	23	74.96 (21.93)	<100 §	4
High-density lipoprotein (HDL) (mg/dl)	28	49.5 (10.76)	>50 §	14
Triglycerides (mg/dL)	23	99.8 (78.56)	<150 §	3
TC:HDL	28	2.95 (.45)	≥3.5	3

*Guideline for the prevention (2018)
**American Diabetes Association (2010)
§ Nelson (2013)

Results of the NSKQ are displayed in Table 4. The overall nutrition knowledge score is considered poor based upon standards developed in the validation of the questionnaire (Trakman et al., 2017). Scores are average in the alcohol, macronutrients, and weight management knowledge domains. Scores are poor in the micronutrients, sports nutrition, and supplements domains.

Table 4
Nutrition Knowledge Scores N=28

	Mean Raw Score (SD)	**Total possible**	**Mean % (SD)**
Overall score	43.1 (8.12)	89	48.5 (9.12)
Alcohol	4.7 (1.18)	8	58.9 (14.77)
Macronutrients	17.3 (3.39)	30	57.6 (11.29)
Micronutrients	5.5 (2.53)	13	42.0 (19.47)
Sports nutrition	5.2 (1.81)	13	39.8 (13.90)
Supplements	3.4 (1.81)	12	28.0 (15.08)
Weight management	7.7 (2.07)	13	59.1 (15.95)

Estimated nutrient consumption is shown in Table 5. Average caloric intake was within the recommended range provided by the DHQIII, based upon age, height, weight, and sex, despite only 13 participants meeting the recommendation. However, because our sample is athletic and this recommendation does not consider physical activity, this is a conservative estimation. When the recommendation was individually adjusted for fat free mass (FFM) and physical activity, 21 athletes did not meet the minimum recommendation for caloric intake. The findings were similar with the carbohydrate and protein recommendation. All of the athletes met the DHQIII goal for both macronutrients; however, only 3 met the sport-specific carbohydrate recommendation, and only 18 met the sport-specific protein recommendation.

Table 5
Estimated Nutrient Intake N=28

	Mean (SD)	Recommended Intake	N Met Minimum Recommended Intake
Calories (kcal)	2059.9 (744.46)	1978-2400*	13
		2530.1§	7
Energy Availability (kcal/kg FFM/day) N=26	43.7 (16.56)	>45 †	11
Carbohydrates (g)	273.1 (101.78)	>130g**	28
Carbohydrates (%)	52.6 (5.08)	45-65%**	27
Carbohydrates (g/kg)	4.6 (1.80)	6-10 §§	3
Protein (g)	87.1 (31.86)	>46g**	24
Protein (%)	17 (3.13)	10-35%**	28
Protein (g/kg)	1.5 (.53)	1.2-2.0 §§	18
Fat (%)	32.5 (3.32)	20-35%**	25
Saturated Fat (%)	9.1 (1.96)	<10%**	22
Vitamin B12 (mcg)	4.2 (1.70)	>2.4**	27
Iron (mg)	16.6 (5.33)	18-45**	13

*Estimate from the DHQIII food frequency questionnaire
§Estimate from the BodPod
†Melin et al., 2018
**Dietary Reference Intakes (include Recommended Dietary Allowances and Adequate Intakes), Food and Nutrition Board, Institute of Medicine, National Academies of Science, Engineering, and Mathematics
§§Thomas et al. (2016)

Food group results are displayed in Table 6. Three athletes excluded some kind of animal protein foods; these results are summarized in Table 7.

Table 6
Estimated Intake from Food Groups

	Mean (SD) Consumption (N=28)	Recommended Range*	N Met Minimum Recommendation
Total Fruit (cups)	2.2 (1.20)	1.3-2.8	19
Total Vegetables (cups)	2.5 (1.92)	1.8-4.3	9
Total Grains (oz)	5.1 (1.95)	4.5-11	3
Total Protein Foods (oz)	6.7 (2.81)	4.5-7.5	22
Total Dairy (cups)	1.4 (1.02)	2.8-3.3	2

*Estimate from the DHQIII food frequency questionnaire

Table 7
Participants excluding protein foods* N=28

Excludes	Number of Girls
Red Meat	3
Fish	2
Poultry	3
Eggs	2
Dairy	0

*Only 3 participants excluded protein foods. There is crossover between these columns.

Average quality of life scores for each domain are displayed in Table 8. A higher score indicates a higher quality of life. Two questions were not included in the domain scores and were scored individually out of five.

- How would you rate your quality of life?
- How satisfied are you with your health?

The average scores for these questions were 4.6 ± 0.50 and 4 ± 0.69 respectively.

Table 8
WHOQOL-BREF Scores

WHO QOL-BREF Domain Score	Mean (SD) n=28	Average values for females aged 20-24, n=30*
Physical Health	60.4 (11.85)	83.6 (11.3)
Psychological	66.0 (9.33)	69.7 (17.9)
Social Relationships	79.9 (16.73)	75.6 (15.3)
Environment	81.4 (11.81)	72.7 (15.6)

*Hawthorne et al. (2006)

Discussion

The purpose of this study was to assess the physical health, nutrition knowledge, food consumption, and quality of life in a sample of female collegiate runners. The physical health tests revealed that blood pressure, body composition, LDL, total cholesterol, and triglycerides were predominantly within the recommended ranges. However, the fasting glucose and HDL levels in our samples were surprising. More than half of the participants demonstrated fasting glucose above 100 mg/dL with the overall average being 100.8 (9.01) mg/dl. Other research has indicated normal fasting glucose levels in the large majority of samples in athletic populations

(Borchers et. al, 2009, D'Ascenzi et al., 2018). In addition, half of participants had an HDL level below 50 mg/dL with the average being just under the recommended range. Low HDL has been demonstrated in football players, but in a large study of Olympic athletes, average HDL was much higher for all age groups than what was in our sample (Borchers et. al, 2009, D'Ascenzi et al., 2018). Although we speculated there may be a difference between the HDL levels for sprinters/jumpers and distance runners based on the quantity of endurance exercise performed, upon statistical analysis, no significant difference was found.

The results of the three questionnaires indicate that our sample could be experiencing LEA. Recent studies have found that the prevalence of LEA in elite athletics, particularly in endurance athletes, middle and long distance runners, and female track and field athletes has been high (Melin et al., 2018). Melin et al. (2018) recommend universal screening for LEA in athletes, specifically in jumpers and middle and long distance runners. Identifying LEA early can prevent or minimize long term health consequences. Although there is no standard screening tool, the PPE that all athletes undergo can detect early signs and risk factors. In our Division II sample, the PPE screening that the athletes underwent included height, weight, and blood pressure assessment. In our results, all of these measures are well within the recommended ranges for general health. Based solely on this assessment, the athletes' results would not indicate elevated risk for health consequences with participation in sport. However, upon further examination of the athletes' health, we have found that our sample displayed some concerning results consistent with risk factors and consequences of LEA.

Using a food frequency questionnaire, we discovered that when athletes' intake of calories, grams of carbohydrate and grams of protein were compared to sport-specific nutrient recommendations, only 7 (25.0%) athletes consumed adequate calories, only 3 (10.7%) consumed adequate carbohydrate, and 18 (64.3%) consumed adequate protein. These findings are consistent to those in similar populations (Hinton et al., 2004, Shriver et al., 2013). Although there is no accepted optimal energy availability in athletes, an energy availability of at least 45 calories per kilogram of fat free mass per day (kcal/kg of FFM/day) is enough to maintain physiological function in sedentary, normal weight women with normal menstruation (Melin et al., 2018). In female athletes, energy availability below 30 kcal/kg FFM/day is considered clinical LEA while energy availability of 30-45 kcal/kg FFM/day is subclinical LEA (Melin et al., 2018). In our sample, 7 (25.0%) athletes had energy availability below 30 kcal/kg FFM/day and 8 (28.6%) had energy availability between 30-45 kcal/kg FFM/day.

In addition, the results of servings consumed in specific food groups revealed that only 3 (10.7%) athletes consumed at least the recommended servings of grains and only 9 (32.1%) consumed the minimum recommendation of vegetables. These athletes are likely consuming far less energy than they are expending, resulting in LEA and potential consequences. One of these being iron deficiency. The FFQ estimated that 15 (53.6%) of the athletes did not consume the minimum recommended RDA for iron. In the 2018 IOC consensus statement on RED-S update, Mountjoy et al. (2018) explain that iron deficiency is common in female athletes and can both induce and be a result of LEA. Iron deficiency can affect bone health, thyroid function, fertility, and psychological well-being.

We found that only 3 (10.7%) of the athletes were restricting animal protein sources including red meat, fish, poultry, and eggs while 10 (35.7%) athletes did not meet sport-specific protein recommendations. Therefore we do not suspect that the lack of protein in the majority of these athletes was due to restrictions of types of protein foods.

Poor nutrition knowledge is mentioned as a factor that may cause LEA (Melin et al., 2018). Inadequate nutrition knowledge has been observed in athletic populations in numerous studies (Zawila et al., 2003, Torres-McGehee et al., 2012, Andrews et al., 2016, Trakman et al. 2018)**.** Our sample also demonstrated overall poor nutrition knowledge. When broken into specific domains, our sample scored either poor or average in all domains. The athletes likely do not understand the importance of optimal nutrition. It is possible that those who consume too few nutrients simply do not realize the appropriate quantity they should be consuming to balance the amount of training they are doing.

Despite low nutrient intake, all of the athletes were well within the normal range of body fat percentage for females of their age group. None of them exhibited an excessively low body fat percentage that would be concerning in relation to LEA. However, long-term LEA can cause metabolic and physiological adaptations that prevent further weight loss, so an athlete with LEA can still maintain weight and not have excessively low body fat (Melin et al., 2018).

The quality of life questionnaire gave a subjective rating in four domains: physical health, psychological, social relationships, and environment. The lowest average score was 60.4 (11.85) in the physical health domain. This score was over 20 points lower than the estimated norm for females aged 20-29 and 9 points lower than the average score of elite volleyball players (Hawthorne et al., 2006, Correia et al., 2017). Questions in this domain included (WHOQOL-BREF, 1996):

- To what extent do you feel that physical pain prevents you from doing what you need to do?
- How much do you need any medical treatment to function in your daily life?
- Do you have enough energy for everyday life?
- How well are you able to get around?
- How satisfied are you with your sleep?
- How satisfied are you with your ability to perform your daily living activities?
- How satisfied are you with your capacity for work?

It is possible that athletes suffering from injury would indicate lower scores because their physical pain prevents them from being able to accomplish what is required of them as athletes, they need medical treatment, or they may have trouble getting around. In relation to the low carbohydrate consumption, many of these athletes also could have received a low score because they feel they do not have enough energy for everyday life and are dissatisfied with their capacity for work. Finally, as student athletes, they may have to sacrifice time they should be sleeping to complete school work, causing them to be dissatisfied with their sleep.

The next lowest domain score was psychological. This score was closer in relation to the other populations, but was still lower at 66.0 (9.33). The questions in this domain addressed body image, self worth, negative feelings, concentration, and enjoyment of life. Mountjoy et al. (2018) explain that health consequences of LEA can be psychological, either preceding and contributing to LEA or being caused by it. Thus, the low psychological scores are concerning, warranting further assessment into psychological risk factors known for being related to LEA and eating disorders.

Melin et al. (2018) recommend using LEA screening tools to prevent RED-S and education to prevent RED-S. The PPE can be a useful tool in screening for RED-S if it is more thorough in its assessment than was for this sample. There are more specific tools for identifying risk for LEA and RED-S as well. The LEA in Females Questionnaire (LEAF-Q) was developed to be able to identify those at risk for long term LEA. This questionnaire is currently only validated in adult female elite endurance runners. The IOC also developed the RED-S Clinical Assessment Tool (RED-S CAT) to screen athletes and assist clinicians with return to play. However, this questionnaire has not been validated. In addition to specific screening for LEA and RED-S, nutrition education and counseling could be highly beneficial to athletes with poor nutrition knowledge. If their low energy consumption is a result of being unaware of optimal nutrition recommendations, nutrition counseling could increase their energy intake and mitigate the negative effects of LEA.

Conclusion

Our sample underwent minimal screening in the PPE, giving athletic trainers and coaches little information about the athletes' health and risk factors associated with participation in sport. In our assessment, we found that many of the athletes consume too few calories, specifically carbohydrates, for their energy expenditure. Their poor nutrition knowledge is one possible explanation for the low energy consumption. In the subjective quality of life ratings, the physical health and psychological domains had the lowest scores, both lower than those of similar populations. Given these findings and the high prevalence of LEA in female track and field and endurance athletes, LEA is likely prevalent in this sample and can explain the low quality of life scores. Athletes would benefit from LEA and RED-S specific screenings as well as nutrition education and counseling to minimize LEA and the negative health and performance consequences of it.

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