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Nutritional knowledge and dietary practices among Division I athletes: Do college athletes understand and fulfill sex specific nutritional and metabolic requirements?

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ABSTRACT

Objective: This study evaluated and compared male and female college athletes' dietary habits, their general nutrition knowledge, and understanding of their daily metabolic requirements during training and non-training days. The goal was to 1) determine whether a nutritional gender gap existed between male and female college athletes and 2) assess whether the level of nutritional knowledge of student athletes was generally sufficient to meet their sex-specific dietary needs.

Methods: A cross-sectional study design was used to gather dietary data from Syracuse University student athletes. Participants were asked to complete an online survey (Qualtrics Software, Qualtrics.com) approved by the Syracuse University Athletics Department and by the Syracuse University Institutional Review Board. Student athletes recruited to the study were asked to report their dietary habits and to complete a questionnaire to measure their nutritional knowledge. A subset of questions assessed individual perception of the calories and macronutrients required to support athletic performance during training and non-training days. Caloric requirements during athletic training were estimated for each individual using the Mifflin St. Jeor equation. Each formula was adjusted for activity level according to the physical demands of the sport. Macronutrient requirements were estimated by adjusting the current nutrition recommendations to the metabolic demands of each sport and between sexes. The recorded macronutrient and caloric intakes were statistically compared to estimated ideal values for each individual based on sex and sport appropriate activity factors.

Participants: Athletes were recruited from all Division I sports at Syracuse University. Responses were received from students participating in lacrosse, soccer, field hockey, tennis, cross-country, basketball ice hockey, track and field, rowing and football. Respondents included 88 females and 27 males; an additional 10 participants failed to complete the survey.

Results: The level of nutritional knowledge did not significantly differ between males and females (p= 0.4193) or between sports (X^2=9.48, df=8, p=0.0546). Individuals with high knowledge scores were more likely to have taken a nutrition course. For every 1 point increase in the knowledge score obtained, the odds of having taken a nutrition class increased by about 8.9% (p=0.0305). There were no correlations between the level of nutritional knowledge and dietary habits other than an unexpected positive correlation with fast food consumption. Male and female athletes both appeared to be aware of their increased caloric requirements for training days. No differences were found between estimated total daily energy expenditure (TDEE) and actual caloric consumption.

Conclusion: This study found that although both male and female athletes possess a good understanding of caloric needs during training days, their dietary knowledge did not necessarily translate into dietary patterns consistent with best practices. Future research should attempt to identify the reasons why athlete dietary knowledge might not translate into practices that are consistent with maximizing performance.

Nutritional knowledge and dietary practices among Division I athletes: Do college athletes understand and fulfill sex specific nutritional and metabolic requirements?

by

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A thesis proposal submitted in partial fulfillment of the requirements
of the Master of Science degree

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PART I: LITERATURE REVIEW

INTRODUCTION

Scientific studies of sex-based metabolic requirements are rare. Exercise physiology is a relatively new field and most of the early research in this area suggests that there should be little difference between male and female muscle physiology or metabolic pathways (1). This historical constraint, coupled with a primary focus on male physiology, has created a gap in our understanding of the nutritional needs of female athletes (1, 2, 3, 4, 5, 6, 7). This study was designed to explore the extent of this gender gap in terms of fundamental nutritional knowledge, patterns of macronutrient consumption, and the individual collegiate athlete's comprehension of metabolic requirements during training.

Many factors affect metabolic function, including sex, age, body composition, mental health, menstrual cycle, circadian rhythms, ambient environment, timing of nutrient ingestion, meal frequency and patterning, physical activity, and specimen collection (7, 8). Many sex-based differences in basal metabolism are regulated by predetermined expression of genes or by cell signaling mechanisms that determine gene expression; the latter is thought to be mediated through the sex hormones estrogen, progesterone and testosterone (9, 10). The complex cycles of the female endocrine system can introduce substantial variation into metabolic measurements. As a result, researchers frequently exclude female subjects from both animal and human studies in an effort to reduce metabolic variability (1, 2, 4, 7, 11). Furthermore, when female subjects are included in studies, but potentially confounding factors are not experimentally controlled, variability in results and outcomes lead to confusing nutritional recommendations that may not match sex-specific metabolic requirements.

Physical activity increases energy expenditure, but also affects hormonal control of metabolism and energy intake (8). The release of sex hormones, metabolic hormones, and stress-related hormones is interconnected and varies in response to exercise and training. As a result, exercise is a major link between hormonal modulators of energy intake and output.

Substrate utilization and hormonal responses may differ between the sexes under conditions of metabolic stress (12, 13). Metabolic stressors include fasting, hypoglycemia, hypoxia, and exercise level. Intense brief bouts of exercise may lead to increases in catecholamines, growth hormone, cortisol, thyroid hormones, estrogens and androgens, while simultaneously decreasing insulin and leptin levels. These hormonal combinations create a catabolic environment that mobilizes stored fuel (14, 15). During the initial stage of exercise, metabolic fuels such as glycogen and muscle triglycerides are predominately used by both sexes. As submaximal exercise continues, free fatty acids, glucose and amino acids increasingly contribute to metabolism. In addition, there is increased endogenous glucose production from an exercise-induced rise in hepatic glycogenolysis and gluconeogenesis. At the onset of exercise, carbohydrate oxidation rises, but as duration increases, there is a greater reliance on fat for oxidation (12). Although this represents a general pattern of macronutrient use during exercise, it is modified by differences in sex specific hormonal responses. Evidence for the differential effect of the female endocrine system on metabolism can be found in studies of metabolic stress conditions such as starvation, where females have been shown to catabolize more fat, while males make use of more protein (16). Women have a more rapid rise in blood concentrations of free fatty acids and ketone bodies, and thus more lipid catabolism. Ovarian hormones, which vary substantially in level over the life span, are likely involved in this process.

THE INTERACTION BETWEEN SEX HORMONES AND SUBSTRATE UTILIZATION

As the number of older female athletes competing in elite-level sports continues to rise, there is an increased need to understand the interactions between female physiology and the metabolic and hormonal control of substrate utilization in response to exercise (7,13). Body composition and substrate oxidation also change across different life stages. Before puberty, there is no difference between males and females in substrate oxidation during exercise (6, 12). This changes after puberty, with women relying more on fat than men for the same relative intensity of exercise (7, 12, 13, 17). The timing of this shift in fuel oxidation patterns suggest sex hormones influence substrate mobilization, transport and utilization. After menopause (when women's estrogen levels decrease), women once again experience changes in adipose distribution. The fact that these changes are diminished by estrogen replacement point to the important role of estrogen in sex specific fat storage patterns and oxidation levels (13).

ESTROGEN'S ROLE IN THE CONTROL OF BODY COMPOSITION

Estrogen is the primary female sex hormone. It diffuses across cell membranes and activates estrogen receptors, which modulate the expression of many genes (18). This hormone is present in both men and women, but levels are significantly higher in women of reproductive age. Estrogen levels in women are highest during ovulation and after menstruation. For this reason, studies that compare male and female metabolism are often done when female estrogen levels are below their peak and thus closer to the levels observed in men (2, 17).

Sex steroids regulate adipocyte metabolism and influence the deposition of body fat. In humans, the concentration of sex hormones partially determines body fat distribution (10, 19, 20, 21). Before puberty, there is little difference in body composition between boys and girls. With the onset of puberty, female body fat increases, especially in certain areas of the body (6, 20, 21, 26). Between the ages of age 10 and 16.5, subcutaneous fat thickness increases in girls by 44-93%. Data from the National Health and Nutrition Examination Survey III (NHANES III) on 15,912 subjects showed that non-Hispanic white females between 12 and 80 years have a higher percentage of fat mass than males, increasing from 6% to 11% each decade after puberty (22). The sudden change in body composition after puberty suggests that the increase in estrogen production leads to an increase in body fat deposition. Moreover, a study published by Cagnacci et al. in 2007 showed that ovariectomized women on no hormonal treatment lost body fat, whereas ovariectomized women who were administered estrogen had increased body fat (24).

From an energy balance perspective, there is no apparent reason for this sudden change in body composition, given that on average males consume more calories than females (21, 22, 25; 44.7 kcals/Kg-1 vs. 40.6 Kcal/Kg-1, adjusted for fat-free mass, NHANES III). Since men appear to consume more calories and dietary fat than women do, increases in fat and/or caloric intake are unlikely to account for the observed differences in body fat (25). The estrogen-induced fat preservation mechanism is further seen in pregnant women, who tend to deposit an additional 2-5 kg of body fat by the end of their pregnancy, even in cases of undernourishment (27). Thus it follows that the high levels of ovarian hormones present in women of reproductive age and during pregnancy are likely the major factor responsible for sex differences in body fat and body composition (18).

Changes in fat stores are also influenced by fat intake and fat oxidation. If estrogen levels are the cause of higher body fat percentages in women, it may be due to several reasons: (11) estrogen could change distribution patterns of fat storage through direct metabolic actions on lipolysis; or (2) estrogen could decrease the oxidation of lipids, leading to an increased deposition of body fat.

Hahobian et al. (27) showed that women had more appetite than men after engaging in physical activity. This study evaluated the energy-regulating hormones and appetite in 18 overweight/obese men and women (9 men and 9 women) after performing physical activity. The experiment concluded that in women, exercise altered hormone regulation in such a way that energy intake was stimulated, regardless of energy status; whereas in men, appetite was inhibited after exercise and the hormonal responses were more subtle (27).

There is also evidence that estrogen has direct effects within adipose tissue and that it is implicated in fat deposition (24, 29). Women have a tendency to preserve body fat more than men, which is most likely a physiological mechanism for reproductive purposes. A study by Pedersen et al. suggests that estrogen promotes and helps maintain the typical fat distribution observed in females, especially in the subcutaneous fat depots, with modest accumulation of intra-abdominal fat (6, 30).

Palin et al. in 2003 provided the first in vitro evidence that estrogen has a regulatory effect on key enzymes of lipogenesis and lipolysis in subcutaneous abdominal adipose tissue from women (29). This suggests that estrogen may regulate adipose tissue mass by influencing the net amount of adipose tissue present. The number and size of adipocytes in adipose tissue determines the fat mass deposited in particular areas of the body (29). A net balance between lipogenesis and lipolysis determines adipocyte size. Lipoprotein lipase (LPL) is a key lipogenetic enzyme, since its main role is the reesterification of free fatty acids (FFA). The opposite process, the hydrolysis of triglycerides into FFA and glycerol occurs by lipolysis and its key enzyme is hormone-sensitive-lipase (HSL). Sex steroids are likely to influence both of these enzymes (29).

Androgens such as testosterone and dehydroepiandrosterone (DHEA) also play an important role in energy balance and body fat deposition. Women tend to deposit and retain more adipose tissue around the hips, buttocks and thighs, resulting in a “gynoid” or “pear” body shape; whereas men store more fat around their waist and midsection, known as “android” or “apple” shape (6, 30). These differences in body shape between sexes are likely due to hormonal control of adipogenenesis. In conclusion, androgens and estrogen levels are postulated to play an important role in sex based body fat distribution, as men tend to have higher levels of visceral fat, while women store more fat subcutaneously (8,14).

HORMONE INTERACTIONS AND SUBSTRATE METABOLISM

The importance of estrogen in determining the distribution adipose in the female body and controlling lipolysis is clear. However, females have a suite of sex hormones (e.g., progesterone, testosterone, and three distinct forms of estrogen) whose complex interactions may also increase lipolysis and/or limit glucose production and utilization (12). It therefore becomes important to recognize the way in which women’s hormonal levels vary throughout the menstrual cycle and across the life span.

The menstrual cycle is divided into three phases: the follicular phase (FP), the ovulatory phase and the luteal phase (LP). As ovarian follicles grow, they secrete estrogen and after 10-15 days they break, causing the release of the immature ovum. This is when the LP phase begins and the empty follicle continues to secrete estrogen and progesterone (2, 13, 31). The increased levels of estrogen cause inhibition of gonadotropin releasing hormone (GnRH), which results in decreased levels of luteinizing hormone and ultimately causes the initiation of menstrual bleeding, along with decreased levels of estrogen and progesterone (31).

An early study by Reinke et al. investigated the effect of the menstrual cycle on carbohydrate and lipid metabolism in 10 females with an average age of 26, and concluded that only during the luteal phase (highest level of estrogen and progesterone), was there a significant increase of free fatty acids in the blood, accompanied by a rise in glycerol (32), suggesting that women's fuel oxidation varies throughout the menstrual cycle. In addition, Hackney et al. reported that females spared more muscle glycogen during the LP compared to the FP, which means that muscle glycogen was spared due to higher utilization of fats (33).

Women have a slightly higher muscle glycogen concentration during the LP of the menstrual cycle (2). In addition, protein oxidation during exercise is also higher during the LP (34). Research has shown that when controlling for menstrual cycle, training history and diet, females oxidize more lipid and less carbohydrate and protein than men during endurance exercise (2). Women tend to oxidize more fat during the LP of the menstrual cycle, which means that when compared with male metabolism, women should be tested in the FP of their cycle, when no sex differences between substrate metabolisms are present at rest.

ESTROGEN AND SUBSTRATE METABOLISM AT REST AND DURING EXERCISE

Many studies have reported that estrogen is mainly responsible for the decreased reliance upon hepatic glycogen stores, increased availability and oxidation of fatty acids, and decreased amino acid breakdown during exercise. (7, 9, 8, 12, 13, 15, 17, 19, 23, 35, 36, 37, 38). Ruby et al. showed that administration of estrogen during exercise in amenorrheic females significantly decreased the glucose rate of appearance and disappearance during exercise performed at moderate intensity (38), which resulted in muscle glycogen sparing. A different study showed that after a 15.5 km run men had 25% greater muscle glycogen utilization and 30% greater urea nitrogen excretion when compared to the women (39). This demonstrates that women not only have a greater capacity than men to spare glycogen stores, but also proteins. In addition, women had greater lipid oxidation than men as expressed by a lower respiratory ratio exchange (39).

THE IMPORTANCE OF CARBOHYDRATES IN EXERCISE PERFORMANCE

Carbohydrates play a key role in energy provision and exercise performance. They are the main fuel utilized during high intensity exercise. Glycogen is the storage form of carbohydrate with 80 to 100g stored in the liver and another 300-900g stored in skeletal muscle (40). The rate at which muscle glycogen is oxidized depends on exercise intensity. At low to moderate exercise intensity, most energy is obtained from oxidative phosphorylation of Acetyl-CoA (from both fats and CHO). As exercise intensity increases, muscle glycogen becomes the most important substrate (12, 40). Carbohydrate intake in the days prior to a competition mainly replenishes muscle glycogen stores, whereas carbohydrate intake hours before competition optimizes liver glycogen stores (40). A well-known technique used to increase muscle glycogen stores before an athletic competition is known as carbohydrate loading. The ability for women and men to carbohydrate load differs in terms of both effective methods and in capacity (1, 2, 7, 41, 42), suggesting sex specific differences exist for carbohydrate metabolism and storage.

SEX DIFFERENCES IN CARBOHYDRATE LOADING

Carbohydrate loading is a strategy used by endurance athletes who engage in events lasting longer than 90 minutes to maximize the storage of glycogen in the muscles (40). It increases time to exhaustion by about 20% and reduces the time taken to complete an endurance performance by 2 to 3% (43). Female athletes do not appear to successfully carbohydrate load in the same manner as their male counterparts. Tarnopolsky reported in 1996 that female endurance athletes did not increase muscle glycogen concentration in response to an increase in dietary carbohydrate intake from 58 to 74% of energy intake during a 4-day period, whereas men did show an increase while following the same dietary regime. Men increased muscle glycogen concentration by 41% and had a 45% increase in performance time during an 85% VO2 trial, whereas women did not increase muscle glycogen concentration (0%) and had a performance time improvement of only 5%. In addition, women oxidized more lipid and less CHO and protein when compared to men at 75% VO2 max (51). A different study by Walker et al. showed that females were able to carbohydrate load during the LP of the menstrual cycle, but to a much lesser extent than that observed in men who followed the same dietary and exercise regime (37).

Both studies showed that women did not significantly increase their muscle glycogen content after increasing their percent of dietary carbohydrate intake. A novel study by Tarnopolsky in 2001 showed that the inability of females to carbohydrate load could be due to an overall lower energy and carbohydrate intake (42). In this study 6 men and 6 women were randomly assigned to three diets (Hab for habitual; CHO, high carbohydrate (75%) and CHO + E, extra energy (additional 35%) for 4 days. This study showed that total glycogen concentration was higher for the men on the CHO and CHO + E groups. On the other hand, women increased their muscle glycogen concentration only on the CHO + E group. This sex difference in CHO loading might be explained by the fact that dietary energy intake is lower in women compared to men (21, 22, 25), even when the carbohydrate intake is expressed relative to lean mass (36). This means that women consume less carbohydrate than men when expressed relative to FFM. To exemplify this statement, the study that Tarnopolsky carried out in 1996 showed that CHO intake for men was 7.7 - 9.6 g.kg FFM -1.day-1, whereas for women it was 5.9 - 7.9 g.kg FFM-1.day-1 when both sexes increased their CHO intake from 58% to 74% of their energy intake (36). In the study that Tarnopolsky carried out in 2001, he showed that women were able to carbohydrate load with a carbohydrate ingestion of 8.0 – 10.0 k.kg FFM-1. Day-1. (42). An average female athlete who weighs 60 kilograms and consumes a diet of 2000 kcal per day, would have to increase her energy intake 93-120% in order to consume 8.0 – 10.0 g.kg FFM-1.day-1.

Tarnopolsky's research was the first to conclude that women can increase their glycogen stores not only by increasing the percent of CHOs ingested, but also their overall energy intake. The old carbohydrate loading guidelines were expressed as a percentage of dietary intake (41), which was impractical for women to achieve, unless they increased their energy intake as well. It is preferable to provide recommendations for daily CHO intake in grams relative to body mass of the athlete. CHO intake ranges of 5 to 7.kg.day-1 for general training needs and 7 to 10 g.kg.day-1 for the increased needs of endurance athletes are the current recommendations for carbohydrate intake (40,41). For endurance athletes who are involved in extreme training programs, increasing carbohydrate intake from 10 to 13 g.kg-1 when exercising on a daily basis is recommended (40) A typical male athlete achieves a daily CHO intake within the recommended range. Female athletes, especially endurance athletes, are less likely to achieve these CHO intake guidelines due to long term and daily restriction of total energy intake in order to achieve or maintain low levels of body fat (41).

THE IMPORTANCE OF FATS IN EXERCISE PERFORMANCE

Lipids become an increasingly important energy source during prolonged exercise. Large amounts of fat can be stored in the subcutaneous adipose tissue (40), but some fat can also be stored in the muscle as intramuscular triacylglycerol (IMTG). Carbohydrates are converted to fat and stored in the adipose tissue when ingestion exceeds glycogen storage ability. Only some lipids are available for use as fuel; these include fatty acids, intramuscular triacylglycerols (IMTG), and circulating plasma triacylglycerol (chylomicrons and VLDLs) (40).

Skeletal muscle can use intramuscular triacylglycerol (IMTG) for fuel. Human skeletal muscle contains approximately 12 g.kg w.w of IMTG and type I fibers contain more IMTG than type II fibers. Studies suggest that IMTG is a significant fuel source during moderate-intensity exercise in females, but not in males (44, 45). Steffensen et al. collected muscle biopsies from 21 males and 21 females before and after exercising for 90 minutes at a 60% VO2max. Post exercise, IMTG content was decreased by 25% in female subjects, whereas IMTG content in males remained unchanged. The resting IMTG contents before exercise was 40% greater in females compared to males. The gender difference in IMTG use as a metabolic fuel may be partially attributed to a higher resting IMTG content in females (45) because of their higher fat-mass content. In addition, women have a higher concentration of B-oxidation enzymes in skeletal muscles than men, which may contribute to their ability to oxidize more fat than men during endurance exercise (46).

SEX BASED DIFFERENCES IN FAT METABOLISM

It seems paradoxical that although women oxidize more lipids during exercise (7, 12, 13, 17,) and consume less energy intake per kg of lean mass than men do (11, 21, 22, 25), they also generally have a higher fat mass (22, 25). There is some evidence to support the idea that the higher fat mass in women may be due to a greater capacity for women to store fat during non-exercise and postprandial periods (22, 47). In other words, women may simply be more efficient at conserving energy and storing it as fat (22, 27, 47, 48).

Despite women burning a higher lipid to glucose ratio during exercise, women lose less fat than men do when in energy deficit (49, 50). A study by Cortright et al. showed that daily exercise reduced fat, protein and body mass in male but not in female rats, despite female rats having a greater energy deficit (49). This result is consistent with the idea that females have more efficient fat storage capacities during non-exercise periods (22, 27, 42). The higher stored fat mass might allow females to better use this fuel while exercising (45).

Consistent with this idea is a study that found that women significantly reduced their fatty acid oxidation immediately post exercise and that this effect continued for hours (51). This study reported that women experienced a greater rate of lipolysis during exercise and a decreased rate of lipolysis during recovery, whereas the rate of lipolysis in men was heightened during the recovery period. In addition, men not only oxidized more lipid immediately after exercise, but also show an elevated lipid oxidation rate 21 hours after exercise. This effect was not seen in women (51). Furthermore, a study by Jensen showed that women have a lower postprandial free fatty acid oxidation release from adipose tissue (52).

What is the mechanism that might govern the differences in these responses? Two studies have reported that estrogen could be partly responsible for the reduction of postprandial free fatty acid oxidation in women. Lwin et al. investigated the effect of oral estrogen on substrate utilization in postmenopausal women for 2 months, and concluded that estrogen treatment was associated with a decreased 24-hour and postprandial lipid oxidation and increased fat mass of 1.1 +- 1.0 Kg. (53). Similar results were observed in a study by Sullivan et al that compared oral and transdermal administration of estrogen replacement therapy, and showed that oral estrogen reduces lipid oxidation, increases fat mass and reduces lean mass (54,55). Exogenous estrogen administration directs fatty acids in the liver away from oxidative pathways and towards lipogenic pathways (55).

The metabolic effects from exogenous estrogen, however, may differ from endogenous estrogen. Exogenous estrogens appear to be more potent (22) than endogenous estrogens. The effects of endogenous estrogens are also much harder to understand. For example, a study by Uranga et al. found no difference in fatty acid metabolism between the LP and FP of the menstrual cycle (i.e., between different endogenous estrogen levels). This study, however, showed once again that meal fatty acid oxidation was greater in men than in women (56).

In conclusion, the higher fat mass observed in women compared to men, could be a consequence of a lower post-exercise and postprandial oxidation of FFA. Exogenous estrogen treatments appear to induce a reduction in lipid oxidation, possibly by suppressing hepatic processing of dietary fats. On the other hand, the effects of endogenous estrogen on lipid metabolism are still unclear (22, 56).

THE IMPORTANCE OF PROTEINS IN EXERCISE PERFORMANCE

Amino acids play a key role in the metabolism of organs and tissues. They are precursors for protein synthesis and are therefore necessary for the synthesis and homeostatic regulation of neurotransmitters, hormones, DNA, and RNA (40). Proteins also provide structure to all the cells in the body and are an integral part of muscles, skin, hair, bones and teeth. Muscle contains 40% of the total protein in the adult body and accounts for between on third and one-half of all protein turnover (57). Protein contributes to about 5% to 15% of energy expenditure at rest. The Dietary Reference Intakes (DRI) for protein intake is 0.8 g.kg-1.d-1 for individuals aged 19 years and older.

Depending on the duration and intensity of exercise, amino acids may be oxidized at a higher rate than normal. During low to moderate intensity exercise, the relative contribution of protein to energy expenditure is lower than at rest (5%) due to higher reliance on carbohydrates and fats for fuel (40). However, when carbohydrate availability is limited, protein oxidation can increase to 10% of total energy expenditure. Although most experts agree that exercise increases protein oxidation to a certain extent (58), some research suggests that daily protein requirements are not necessarily elevated in people who exercise (40, 57, 59). During resistance training, however, muscle protein turnover may increase substantially. Muscle-protein-synthesis has been shown to remain slightly higher than muscle degradation for 3 to 24 hours after intense strength training. For this reason, the recommendation for protein intake is often increased to 1.2-1.7 g.kg-1 day-1 for strength athletes (40) or slightly higher at 1.2 to 1.8 g.kg-1 day-1 for endurance athletes. Other scientists, (e.g., Butterfield et al. and Phillips et al. 1984, 1999), have shown that the body adapts to training by becoming more efficient with protein oxidation. In other words, protein requirements for athletes might be higher initially, but after training adaptation, protein needs appear to return to baseline (60, 61).

SEX BASED DIFFERENCES IN PROTEIN METABOLISM

Tarnopolsky reported that males increased 24-hour urinary nitrogen excretion (an indicator of protein utilization) following endurance exercise, whereas females did not (58). His study provided the first evidence that there may be a sex difference in oxidation of amino acids during endurance exercise (58,62). Subsequently, more studies followed showing the same sex difference in amino acid oxidation (7, 59, 62, 63, 64, 65).

McKenzie and Phillips et al. studied the effects of sex on substrate metabolism and leucine oxidation during 48 days of endurance training in 6 men and 6 women performing exercise bouts at 60% VO2max. Leucine is an essential amino acid that is mostly utilized in the liver, adipose tissue and muscle tissue. Leucine has also been shown to stimulate muscle protein synthesis. The McKenzie and Phillips study found that females had a lower leucine oxidation as compared to males during endurance exercise both before and after training sessions. In addition, both sexes exhibited an acute increase in protein oxidation and branched-chain-2-oxoacid dehydrogenase enzyme (BCOAD) activation during exercise. However, after 2 months of training, there was an attenuation in the BCOAD activation, which corresponded to a suppression of leucine oxidation during exercise for men and women (65). Thus, protein oxidation was highly attenuated by the end of the program as evidenced by the lack of increased leucine oxidation during exercise as compared to at rest (89). This response to protein adaptation is in agreement with previous studies that showed a greater protein sparing effect after an endurance-training program (60, 61). One explanation for the difference in protein oxidation between sexes may be linked the increased ability to spare glycogen observed in women (7). Estrogen has also been suggested as a causal agent for differences in protein oxidation between sexes (66, 67). The supporting research administered 17-b-Estradiol to 12 men in a randomized, double-blind study for 8 days, and found that leucine oxidation during 90 minutes of cycling decreased by 16%; fat oxidation increased to 44% and CHO oxidation was decreased by 16% (66.67). McKenzie and Phillips et al. further confirmed that females oxidized consistently more lipids and less CHO and protein during exercise compared to males.

To conclude, protein oxidation during exercise is lower among women when compared to men, and this is likely due to the role of estrogen. Protein needs are increased during the initial stages of exercise, and then an adaptation to protein oxidation occurs, which reduces protein needs back to baseline.

SHOULD PROTEIN RECOMMENDATIONS BE RECONSIDERED?

The common recommendation of 1.2-1.7 g of protein.kg-1.day-1 is a very wide range. Optimal protein intake is likely to vary based on the demands of different sports. Current recommendations do not account for the adaptive nature of training, nor do they provide specific instructions for the timing of protein ingestion for optimal muscle synthesis and repair. A novel study by Areta et al. provides evidence for the recommendation of dietary protein intake on a meal-by-meal basis (69). This study investigated the impact of timing and quantity of dietary protein delivered in a 12-hour recovery period on the stimulation of muscle protein synthesis in 24 healthy trained men. The study demonstrated that the regulation of muscle protein synthesis could be controlled by the timing and distribution of 80 grams of protein intake during a 12-hour recovery from a single bout of resistance training. A total of 80 grams of whey protein isolate was provided in a constant (8 x 10 g "pulse"); cyclical (2 x 40 g "bolus") or intermediate (4 x 20 g "intermediate") feeding pattern for a 12-hour period after a single bout of resistance training. Muscle biopsies were collected after 1-4, 4-6, 6-12 and 1-12-hour recovery periods. The results showed that all feeding patterns stimulated muscle protein synthesis, but that the intermediate pattern elevated muscle protein synthesis beyond the pulse and bolus feeding patterns. This suggests that the amino acids ingested in the bolus and pulse groups were not used as effectively for the synthesis and repair of muscle proteins as the intermediate group, and may have been oxidized or used for urea synthesis instead (69). This study advocates consuming 20 grams of protein every 3 hours after a bout of resistance training is the best way to stimulate muscle protein synthesis rate and optimize muscle repair.

The study reviewed above provides evidence to support post-exercise protein feeding patterns for optimal muscle repair and protein synthesis in men, but does not provide specific recommendations for women. Although female athletes are routinely advised to consume 15%-25% less dietary protein than male athletes, no specific recommendation for protein supplementation of female athletes has been proposed (70). In addition, the effect of protein consumption on women's exercise recovery is unknown. Rowlands et al. performed a double-blind, randomized, crossover design with 12 well-trained female cyclists to determine the protein requirements during intensive training and the effect of a high or low protein recovery diet on performance. Although the study did not observe any benefits of increased protein recovery drink on exercise performance in female athletes, the high protein group did experience a positive nitrogen balance, whereas the low protein group exhibited a negative nitrogen balance. The study concluded that female cyclists performing intense exercise training require approximately 1.6 times the recommended daily allowance of protein (0.8 g.kg-1.day-1), but only require 0.65 times the protein intake required by similar trained athletes (70). This results in an estimated protein requirement for a trained female cyclist of 1.28 g.kg-1.day-1.

SPORTS NUTRITION

Many factors contribute to successful sports performance. Although genetic endowment may be the most important requirement, other supporting factors are critical in determining success at the elite competitive levels. A paper by Ronald J. Maughan et al. suggests that good food choices will not make an average athlete into a champion, but a poor quality diet may prevent the potential champion from their optimal performance (71).

The Dietary Guidelines for Americans recommends that calories consumed must equal calories expended for any person to maintain body weight (72). Although this is true for athletes as well, physical activity dramatically increases the rate of energy expenditure. According to a study published by the Australasian Medical Journal, the first component to improve training and performance through nutrition is to ensure the athlete is consuming enough calories to compensate for energy expenditure (74). Surveys of caloric consumption have routinely found that athletes in general and female athletes in particular fail to consume sufficient energy to meet their metabolic needs (73).

Although caloric intake is important, it is not the only consideration for maximizing physical performance. It is well documented that athletes, especially student-athletes, frequently fail to follow best dietary practices. Both collegiate athletes and coaches often have limited nutritional knowledge (75). As such, studies indicate that nutrition education is needed for both athletes and those who influence them (76). Furthermore, student-athletes live and train in an environment that may increase risk for suboptimal eating and misguided nutritional practices. College athletes frequently face rigorous schedules to balance academics and athletics successfully (77). Many factors common to the sports environment can amplify body and weight related concerns, including pressure from coaches, social comparisons with teammates, team weigh-ins, performance demands, tight-fitting uniforms, and judging criteria, particularly among women (78).

College students have little time and space when it comes to meal preparation within the limitations of dorms, apartments, or shared housing. The most convenient food source for these students is usually the on campus cafeteria, which can be problematic due to the multitude of food choices, including unhealthy ones. A recent study by Wansink et al. showed that healthy snacks in cafeterias represented 22% of the entire purchases, while unhealthy snacks totaled 44% of all purchases (79). Wansink did not identify the underlying cause for the observed trend, although a study by Hendrie concluded that nutrition knowledge was a predictor of dietary intake and index of diet quality (79, 80).

Evidence suggests that nutrition knowledge varies greatly among student athletes. A study by Zawila et al. used a nutritional questionnaire to survey female collegiate cross-country runners in 6 different universities to assess nutrition knowledge and attitudes towards eating. That study found that female collegiate runners lacked nutrition knowledge critical for preventing injuries and optimizing performance. Specifically, that study found misconceptions about vitamin supplementation, natural versus vitamin-enriched foods, and vitamin content in frozen, fresh and canned vegetables. (81)

A different study examined the relationship between nutrition knowledge and attitudes towards fat consumption in male students (82). A correlation was found between high fat intake and a lower level of nutrition knowledge, but the result was not statistically significant. In addition, subjects with more negative attitudes towards dietary fat and reducing fat intake were found to have higher fat consumption levels. This study shows that amongst male students (although not student-athletes), attitudes towards healthy eating were a better predictor of adequate intake, rather than nutrition knowledge (82).

NUTRITION KNOWLEDGE AND FOOD INTAKE

Proper nutrition knowledge and behavior may be essential for the average individual, but it is particularly important for those involved in high-level athletic competition. Ironically, research has repeatedly shown that individuals who are competitively active in sports are often under-educated regarding proper nutrition (83). For example, Jacobson et al. (76) found that 21% of collegiate athletes thought protein was an immediate energy source, and 13% of respondents thought that protein increased muscle size. Another study, by Rosenbloom et al. (84), concluded that athletes could benefit from more information about the role of protein as an energy source, as well as in improving muscle mass.

Broad et al. (2008) concluded that a comprehensive understanding of the relevant scientific literature, along with the specific training and competitive demands of the sport are required to design the best diet for an athlete (85). In the past, a number of studies have failed to find a strong association between nutrition knowledge and food intake (86). The lack of associations could suggest that knowledge about diet and health is of little relevance to food choice, so simply changing knowledge is unlikely to have the desired effect on eating patterns (86). However, current research by Kunkel et al. indicates that as athletes' knowledge increases, nutritional quality of food choices improves (80). There are numerous indications that the role knowledge plays in food choice is significant and that it has been vastly underestimated, and that the notion of nutrition education has often been unwisely dismissed (87). Furthermore, much research on nutrition knowledge has relied upon ad hoc measures created specifically for a given study, many of which lack proper validation (88).

SOURCES OF NUTRITION INFORMATION

Student athletes may receive misinformation about nutrition from many influences in their lives, including friends, family, coaches, athletic trainers and strength and conditioning coaches (77, 89). Improving misguided dietary practices and nutrition knowledge depends on the athlete obtaining accurate and relevant information from credible sources (77). Of major concern is the possibility that professionals lacking sports nutrition knowledge might relay incorrect information to the student athletes who would have no reason to doubt them. It is therefore extremely important for student athletes to have a personal strong understanding of sports nutrition, allowing them to decipher from the fact and the fiction.

PART II: THESIS MANUSCRIPT

STUDY OBJECTIVES

This research project was designed to identify the sex specific metabolic and macronutrient needs of a population of college athletes, to evaluate student athlete knowledge of nutrition, and to identify gaps between personal beliefs about dietary needs and research based projected metabolic requirements. Sex based differences in dietary misconceptions and in student ability to estimate and meet the macronutrient requirements of athletic training were identified with a nutrition knowledge questionnaire.

HYPOTHESES AND STATISTICAL TESTS

This study tested a series of hypotheses concerning sex specific misconceptions about daily metabolism, how knowledge of nutrition might translate into dietary habits, how nutritional knowledge might differ between athletes who participate in different sports, and how well athletes could estimate their daily caloric needs when training. All statistical tests were at the $\alpha = 0.05$ significance level.

Hypothesis 1: Male and female athletes differ in the number and type of misconceptions concerning macronutrient needs during training.

Descriptive statistics and 2 sample t-tests were used to test this hypothesis.

Hypothesis 2: A student athlete’s knowledge of nutrition will translate into predictable dietary patterns.

Descriptive statistics, correlation analysis, and linear regression were used to analyze the relationship between dietary knowledge and diet pattern.

Hypothesis 3: The level of nutritional knowledge differs between participants of different sports.

Descriptive statistics and ANOVA were used to determine if there were differences in the level of nutritional knowledge between sports.

Hypothesis 4: Daily Energy Expenditure (TDEE) and caloric consumption differed more than (±20%) between males and females.

One-Way ANOVAS were used for analysis of this hypothesis.

METHODS

STUDY DESIGN

A cross-sectional study design was used to gather data from Syracuse University student athletes during March 2015. The research was carried out with a pool of 115 division I student athletes, both males and females. This pool represents 19.5% of the student athlete population. Potential recruits were asked to complete an online survey administered through the survey program Qualtrics. This survey assessed dietary habits, nutritional knowledge, calories consumed during training and non-training days, and the perception of macronutrients required to support optimal performance during training days. The survey is described below and can be found in the appendix section of this study (appendix A).

PARTICIPANT RECRUITMENT

The inclusion criteria for this study was that a student athlete had to be actively enrolled to participate in a Division I sport at Syracuse University. Athletes who were not enrolled in the university or student athletes who were not eligible to play were excluded from participation. Division 1 sports at SU include the lacrosse, soccer, field hockey, tennis, cross-country, basketball ice hockey, track and field, rowing and football teams. The study design was reviewed and approved by both the Syracuse University Institutional Review Board and Syracuse University Athletics Department. The athletics department listserve was used to deliver a link to the survey to all student athletes, thus permitting completion of the questionnaire online. An electronic Informed Consent document was distributed before the completion of the questionnaire. A total of 115 Syracuse University Division I student athletes began participation in the study.

THE SPORTS NUTRITION QUESTIONNAIRE

The survey instrument used in this study was slightly modified from a previously administered for a study at the California University of Pennsylvania (106). The original questionnaire had reliability coefficients of 0.66 and 0.645 for dietary habits and nutritional knowledge, respectively. A fourth section was added to the original survey instrument to assess knowledge and perception of caloric intake and macronutrient distribution; no a priori tests were completed to determine the validity and reliability of that section.

The four survey sections are as follows:

I) Demographics: Subjects completed questions to about their sex, age, year in college, sport, height and weight.

II) Dietary Habits: This section was divided into 13 questions. The objective was to assess the overall diet of the student athletes. Questions were asked about the consumption of the different food groups, consumption of beverages and supplements and consumption of fast food. In addition, food actions such as dieting and skipping meals were examined. Answers range from never (1) to always (4) for the following categories:

    i. Frequency of foods consumed from “My Plate”.

ii. Consumption of beverages,
iii. Vitamin and mineral supplements.
iv. Food intake, dieting and skipping meals.
v. Frequency of fast food consumption.

III) Nutritional Knowledge:

a. Thirty questions measured the level of nutrition knowledge of student athletes. Athletes were asked to what degree they agree with the statements, ranging from strongly disagree (1) to strongly agree (4). All correct questions were worth 4 points, except for questions 2, 6, 7, 20, and 29, which are reverse-scored on a 4-point scale. The range of possible scores was 30-120, with 120 representing the highest level of nutrition knowledge.

IV) Knowledge and perception of caloric intake and macronutrient distribution:

a. Three questions were added to the original survey to assess student athletes' knowledge of appropriate percentage of macronutrients in their daily diet. Three additional questions assessed their perception of the macronutrient percentages they thought they actually consumed. In addition, they were asked about how many calories they should consume on training days vs. non-training days. Athletes were also asked about how many calories they thought they were consuming on non-training days vs. non-training days. Due to time constraints, these questions were not pre-tested for reliability prior to survey administration.

ESTIMATING ENERGY NEEDS

Basic metabolic rate (BMR) was estimated for each respondent using the Mifflin St Jeor equation (90). This is considered the most accurate formula for determining caloric needs (90). The formula includes an activity factor that can be used to adjust the estimated BMR according to the level of daily activity (93).

The sex specific formulae used in this study were as follows:

Men: 10 x weight (kg) + 6.25 x height (cm) - 5 x age (y) + 5

Women: 10 x weight (kg) + 6.25 x height (cm) - 5 x age (y) – 161)

Each formula was further adjusted for activity level according to the physical demands of the sport played. The adjustment coefficients according to activity levels are defined in Table 1 (91):

Athletes participating in the sports of lacrosse, field hockey, soccer, tennis, basketball, ice hockey, volleyball, track and field, football and rowing were all categorized as "active". The "active" designation is appropriate for intensive aerobic exercise performed for 60 minutes or greater 5-7 days per week (91). Cross country runners can burn more than two or three times the number of calories as their untrained, weight-matched counterparts. If these calories are not replaced daily, energy for training and performance during competitions would be predicted to decline (92). Cross country athletes were therefore categorized as "very active" with a higher activity factor given that long distance, strenuous exercise requires a large number of calories.

ESTIMATING CARBOHYDRATE NEEDS

According to current recommendations, athletes should consume 5 to 7 g of CHO/kg/day for general training needs and 7 to 10 g CHO/kg/day for the increased needs of endurance athletes (41). The amount required is based on the athlete's sex, total daily expenditure and environmental conditions. Males oxidize more CHO than women during exercise (39, 41, 42), and for that reason were assigned higher CHO requirements per day.

The unique demands of each sport also shaped the predicted CHO needs for athletes. Men's basketball and football relay on both anaerobic and aerobic energy systems. These sports rely on a "stop and go" pattern of activity as opposed to prolonged aerobic exercise. As such, a predicted carbohydrate need of 6 g/kg body weight was used for athletes in the sports, slightly higher than the general recommendation of 5-10 g/kg/day recommended for most athletes. Men's lacrosse, men's soccer and men's rowing were estimated to require 7 g of CHO/kg body weight a day. These sports are more aerobic based than football and basketball thus requiring a higher CHO intake. Men's cross country participants run 80-110 miles per week while training and both daily caloric and CHO needs must be increased substantially. A CHO requirement of 9 g/kg/day was used for macronutrient predictions for these athletes.

Since women oxidize more fat and less carbohydrate than men during exercise, the suggested CHO requirement predicted for each sport were kept within the recommended range of 5-10g/kg/day, but to a lesser amount than the CHO needs predicted for male student athletes. For women's' lacrosse, soccer, field hockey, tennis, softball, track and field, and basketball, the daily predicted CHO needs were 5 g/kg body weight. For cross-country, the needs were predicted to be higher due to the endurance nature of the sport, intensity and length of training. Syracuse University cross country women run between 60-80 miles per week and their daily CHO predicted needs were estimated to be 8 g/kg body weight.

ESTIMATING PROTEIN NEEDS

The Recommended Dietary Allowance (RDA) for protein is 0.8g/kg of body weight per day for a normal adult to maintain nitrogen balance in the body. An athlete's need for protein is slightly increased as compared to the average person. Extra protein is required for post-exercise recovery and muscle building. Thus, recommended protein intakes for endurance athletes typically range from 1.2 to 1.8 g/kg/day, depending on the type of diet and level of nutrition (40,41,62). For example, if an endurance athlete's glycogen stores are already low, more amino acids will be used during a run due to faster depletion of glycogen stores. Thus, there will be an increased reliance on amino acids for fuel. For strength training athletes, daily protein requirements may increase as high as 1.6-1.7 g/kg body weight to support muscle repair and re-synthesis (40). Although no specific recommendation for protein supplementation has been proposed for female athletes, it is generally accepted that they require 15 to 25 percent less dietary protein than male athletes (70).

Based on the general recommendations outlined above, this study assigned a recommended daily protein intake of 1.3 g/kg body weight for male athletes participating in the sports of lacrosse, soccer and rowing. Cross-country runners were assigned a recommended protein intake of 1.5 g/kg/day to compensate for the increased endurance requirements of the sport. Basketball and football were also assigned a recommended protein intake of 1.5 g/kg/day to compensate for strength training and muscle building.

Women of all sports, except for cross-country, were assigned a recommended daily protein intake of 1.2 g/kg of body weight. This is 20% lower than the recommended amount for males, but still within the protein RDA for athletes. Cross-country female athletes were assigned a slightly higher (approximately 10%) recommended daily protein intake of 1.4 g/kg of body weight. This is an approximate 10% increase as compared to other female athletes and is comparable to the increase in daily protein consumption recommended for male endurance athletes to compensate for the endurance requirements of the sport.

ESTIMATING FAT NEEDS

Fat is a concentrated source of energy for the athlete. In the muscle, fats are stored as intramuscular triglycerides (IMTG), which can provide an important fuel during exercise. CHO and fat are always oxidized as a mixture and the relative contribution of these two substrates depends on exercise intensity and duration, the level of aerobic fitness, diet, CHO intake before and during exercise (40) and sex (7,9,13,17). Even though it is well documented that women oxidize more lipids than men during exercise (7, 12, 13, 17), there are no specific recommendations for fat intake for the two sexes. It is generally suggested, however, that athletes consume between 1–2 g fat/kg/day. Endurance athletes might need closer to 2 g/kg/day in order to reach their caloric needs (92). This analysis assumes female athletes have an increased need for fat based on their metabolic physiology (7, 12, 13, 17) as compared to men. Fat needs for all athletes were calculated by subtracting the estimated needed calories from carbohydrates and proteins from athletes' total estimated energy expenditure requirements.

RESULTS

DEMOGRAPHIC DATA

The study sample consisted of student-athletes who participated in a Division I sport at Syracuse University during the academic year of 2014-2015 (n=115). The sample included 88 female student athletes and 27 male student athletes (Table 2); 10 potential participants failed to complete any of the questions of the survey.

Participant ages ranged from 18 to 23 years (19.78 ± 1.43 yrs, n=115). The mean weight and height of male participants was 186.41 ± 39.4 lbs and 73.63 ± 3.46 inches respectively. The average BMI for male participants was 24.71 ± 4.27, which fell within the range of normal. The mean weight and height of female participants was 143.85 ± 23.96 pounds and 66.73 ± 3.48 inches respectively. The average BMI for female participants was 22.59 ± 2.39, also within the normal range.

Of the 115 student athletes that completed the questionnaire, 37 were freshmen, 26 sophomores, 26 juniors, 24 seniors and 2 were graduate students (Fig. 1). These athletes reported participating in the following sports: lacrosse (n=10), soccer (n=11), field hockey (n=22), tennis (n=1), cross-country (n=12), basketball (n=3), ice hockey (n=8), volleyball (n=8), track and field (n=2), football (n=2), and rowing (n=36).

SOURCES OF NUTRITION INFORMATION

Participants were asked about where they obtained nutrition information; 62% reported they received nutrition information from their coaching staff; 28% from magazines; 16% from TV; 50% from athletic trainers; 50% from parents, and 35% from other sources (Fig. 3). Only 33% (n=38) of the participants reported taking a nutrition course in college, while 67% (n=77) reported never having any formal college level course work in nutrition.

Participants were asked if they would use the services of a sports nutritionist if the Syracuse Athletics Department were to hire such a professional. Ninety-one percent (n=105) stated they would use the assistance of the nutritionist, whereas only 8.7% (n=10) reported they would not. The participants that stated they would use the assistance of a sports nutritionist also reported that they believed a sports nutritionist would help improve their performance.

DIETARY PATTERNS AND HABITS

SKIPPING MEALS

Participants were asked how many times during the week they skipped at least one meal per day. Male student athletes reported skipping an average of 2.7 meals per week (95% CI±0.8 meals/week). Female student athletes reported skipping an average of 4.06 meals per week (95% CI±0.6 meals/week). Female athletes skipped significantly more meals each week than male athletes. ($p<0.05$, Figure 4).

There was a significant negative correlation between athletes' age and the average number of meals skipped per week (β=-0.265, t(92)=-2.63, p=0.01, Fig. 5). Although the trend was significant, age did not explain a high proportion of the variance in skipped meals overall (R^2= 0.07, $F_{1, 92}$=6.93, p=0.01). Student athletes aged 19 years old skipped the greatest number of meals per week, with an average of 5.3 meals. This is could be due to changes in student housing arrangements, which are common in the sophomore year at Syracuse University. Students between the ages of 20 and 22 skipped significantly fewer meals than the 19 year olds did (Fig. 5). Both 23-year-old student athlete participants (n=2) reported never skipping meals. In addition to the significant negative correlation between skipped meals and age (r=-0.265, p=0.010, α=0.05), there were also significant positive correlations between skipped meals and alcohol use (r=0.259, p=0.012, α=0.05) and fast food consumption (r=0.204, p=0.049, α=0.05, Table 1).

FOOD TRACKING

Participants were asked how many times during the week they recorded their food intake. From the 94 responses, 71 student athletes reported never recording their food intake; 17 recorded their food intake between one and six days per week, and 6 reported recording their food intake every day of the week. Female athletes record more meals each week than male athletes. ($p<0.07$. Fig. 4). Females reported recording their food intake 2.4 ± 2.3 days on average during the week, whereas males recorded their food intake 1 ± 0 day on average during the week.

STUDENT ATHLETES AND DIETING FOR WEIGHT LOSS

Student athletes were asked if they had ever been on a diet to lose weight. Of the 94 responses, 42.6% stated that they had been on a diet to lose weight at least one time, whereas

57.4% reported that they have never been on a diet to lose weight (raw survey data, Appendix A). Interestingly, a significantly greater number of female athletes (n=88) reported dieting to lose weight than male athletes (n= 27, p=0.006). Dieting had a significant negative correlation with BMI (r=-0.215, p=0.037 Table 1).

ALCOHOL

Participants were asked how many times during the week they consumed alcohol. Male student athletes reported consuming alcoholic beverages on average 2.4±1.1 days per week (mean±SD). Female student athletes reported consuming alcoholic beverages on average 1.9±8 days per week (mean±SD). Male athletes consumed alcohol significantly more often each week than female athletes. (2-tailed independent samples t-test, assuming unequal variance, t (27.66) = 2.07, p=0.048).

Alcohol consumption had a positive relationship with the average number of meals skipped during the week (r=0.259, p=0.012, Table 1). Alcohol consumption, although a significant factor (regression: b=0.026, t(92)=2.56, p=0.012), was not the primary predictive variable for skipping a meal and did not explain a high proportion of the observed variance in skipped meals overall (R^2= 0.07, $F_{1, 92}$=6.64, p=0.012). Alcohol use also had a significant positive correlation with increased BMI (r=0.236, p=0.001, α=0.01).

ACTUAL CALORIES AND MACRONUTRIENT INTAKE VS. REQUIREMENTS

Student athletes were asked to self-report the number of servings consumed from different food groups each day. The survey allowed respondents to select serving sizes from vegetable, fruit, grain, meat, and dairy food groups. A miscellaneous group was also included to permit responses for food items such as potato chips, soda, and candy bars. The dietary intake data were analyzed using a food composition database in the My Fitness Pal diet tracker application (91) to determine the grams of carbohydrates, proteins, and fats contained in one serving of each group, and to estimate the percent each macronutrient contributed to daily caloric intake. Caloric content was assessed for each food group based on portion size. Overall, male athlete caloric intake varied greatly, with an average of 3493 (±3257) kcals/day, 390 (±358) grams of which were carbohydrates, 169 (±29) grams of protein, and 118 (±24) grams of fat. Female athletes consumed an average of 2530 (±1456) kcals/day; consisting of 253 (±21) grams of carbohydrates, 105 (±9) grams of protein, and 65 (±6) grams of fat.

When adjusted for activity factor based on sport, the Mifflin St. Jeor equation predicted an average estimated total daily energy expenditure (TDEE) of 3335(±63) kcals/day for males (n=27) and 2527 (±27) kcals/day for females (n=87). Since these projections were based on the body metrics reported by individual survey respondents, they resulted in lower standard deviations about the mean as compared to actual reported caloric intakes. Subsequent statistical analyses therefore paired observed and predicted values for each individual in paired t-tests to test for statistical differences between the projected caloric intake and that reported. Furthermore, only a subset of all participants reported dietary data that would permit a direct comparison of actual daily caloric consumption with the projected recommendations.

Male athletes who reported their dietary habits (n=22) over consumed calories for their estimated TDEE by 702 kcals/day on average with a very large standard deviation (±3281) reflecting the huge variation in caloric demand across, and even within, sports depending on position played (Fig. 6). However, when caloric intake was compared to the projected estimated TDEE on an individual basis, there was no statistical difference between actual intake and projected TDEE for all sports combined (Fig 7A, TDEE=3493 ±313 kcals/day, calories consumed =4320 ±3257 kcals/day, paired 2 sample t-test, n=22, df=21, p= 0.2466. 2-tailed t-critical = 2.07). The results indicate that 7 of the 22 individuals who reported caloric intake over consumed by a wide margin. In 6 of these cases, the individuals also had BMIs much higher than would be expected for an endurance athlete. Male cross-country athletes (n=3), however, differed notably from all other male athletes by consistently under-consuming calories (TDEE=3423 ±136 kcals/day, calories consumed =1990 ±278 kcals/day, paired 2 sample t-test, n=3, df=2, p= 0.006. 1-tailed t-critical = 2.92; Fig. 7B). Although the sample size is too small to make sweeping generalizations, it should be noted that this behavior was consistent for all three participants.

Female athletes who reported dietary habits (n=73) consumed on average enough calories to slightly exceed their activity levels by a narrower margin than males (24 ±1491 kcals/day); the large standard deviation from the mean once again, reflects the caloric demands across sports. There was no statistical difference between the TDEE and calories consumed when analyzed at the individual level (TDEE=2506 ±254 kcals/day, calories consumed =2530 ±1456 kcals/day, paired 2 sample t-test, n=73, df=72, p= 0.8900. 2-tailed t-critical = 1.66). There was no significant relationship between the difference in calories consumed and those required when plotted as a function of athlete BMI (Fig. 8A). However, similar to male athletes, female cross country athletes consistently under consumed calories (TDEE=2535 ±67 kcal/day, calories consumed =2148 ±225 kcal/day, paired 2 sample t-test, n=5, df=4, p= 0.007. 1-tailed t-critical = 4.14, Fig. 8B).

CHO INTAKE COMPARED TO DAILY REQUIREMENTS

The actual CHO intake reported by male student athletes in this study was 479 g/d

(±337), while that of female athletes was 305 g/d (±170). Based on the literature reviewed for this study and the recommendations outlined above, the predicted CHO requirements for the surveyed male and female athletes should have been 590 g/d (±75) and 339 g/d (±53), respectively. Although not statistically significant, both male and female athletes surveyed for this study reported under-consuming CHO as compared to estimated daily requirements (male CHO consumption (g), paired 2 sample t-test, n=22, df=21, p= 0.06, 1-tailed t-critical = -1.566; female CHO consumption (g), paired 2 sample t-test, n=73, df=72, p=0.058. 1-tailed t-critical = -1.59; Fig. 9).

PROTEIN INTAKE COMPARED TO DAILY REQUIREMENTS

The projected protein requirements for male and female athletes should have been 115 g/d (±27) and 80 g/d (±12), respectively. The actual protein intake reported by male student athletes in this study was 208 g/d (±139), while that of female athletes was 127 g/d (±74). Thus, both male and female athletes surveyed for this study reported a significant overconsumption of protein as compared to estimated daily requirements (male protein consumption in grams, paired 2 sample t-test, n=22, df=21, p= 0.001. 1-tailed t-critical = 3.26; female protein consumption in grams, paired 2 sample t-test, n=73, df=72, p< 0.001. 1-tailed t-critical = 5.43; Fig. 9).

FAT INTAKE COMPARED TO DAILY REQUIREMENTS

Fat needs for all athletes were calculated by subtracting the estimated needed calories from carbohydrates and proteins from athletes’ total estimated energy expenditure requirements. This resulted in an estimated need of 52 (±4) g of fat/kg/body weight for males and 95 (±1) g of fat/kg/body for women.

The reported fat intake for male athletes (n=27) was 118 (±24) g/kg/body weight and for female athletes (n=88), 65 (±6) g/kg/body weight. The male athletes surveyed for this study reported a significant over consumption of fat as compared to estimated daily requirements (male fat consumption in grams, paired 2 sample t-test, n=22, df=21, p= 0.002. 1-tailed t-critical = 3.24). Female athletes, however, reported under consuming the fat required to meet their daily metabolic requirements (female fat consumption in grams, paired 2 sample t-test, n=73, df=72, p= 0.01. 1-tailed t-critical = 1.66; Fig. 9A).

STUDENT ATHLETES' NUTRITIONAL KNOWLEDGE

Student athletes were asked to answer 30 questions to assess nutritional knowledge. Female athletes completing this portion of the survey (n=68) averaged a score of 89.52 ± 5.31 out of 120 possible correct answers. This represents an average score of 74% correct. Male student athletes (n=21) averaged a score of 90.71±1.61, representing an average score of 75% correct. Nutritional knowledge was therefore not significantly different between sexes (2 sample t-test, df=87, p= 0.4193, 2-tailed t-critical = 1.98).

Nutritional knowledge scores were also compared across sport categories (Table 2). Only sports in which more than 2 valid responses were recorded were included in this analysis. Across all sports surveyed, athletes that completed the questionnaire (n=70) scored an average of 89±0.78, or 74.16%, on the nutritional knowledge questionnaire. There was no significant difference between sports in terms of nutrition knowledge score (Kruskal-Wallis X^2=9.48, df=8, p=0.0546). Individuals with high knowledge scores were more likely to have taken a nutrition course. For every 1 point increase in the knowledge score, the odds of having taken a nutrition class increased by about 8.9% (logistic regression, X^2= 4.6809; df=1; p=0.0305).

COMPARISON OF OBSERVED AND PROJECTED CALORIC REQUIREMENTS DURING TRAINING

Based on the diet components reported in the survey caloric intake was calculated for each respondent. Male athletes (n=17) consumed an average of 3438±860 calories on a training day, whereas females (n=61) consumed an average of 2237±517 calories when training. Individual Mifflin St. Jeor predictions for these respondents resulted in the prediction that the males should have averaged 3378±355 kcals/day, while the females should have consumed an average of 2541±236 kcals/day. There was no significant statistical difference when actual caloric consumption and projected TDEE were compared using paired t- test (males: p=0.98; females: p= 0.12). Male and female athletes generally appear to meet their projected daily energetic needs.

ATHLETE PERCEPTION OF CALORIC REQUIREMENTS FOR TRAINING

Actual caloric intakes were calculated for this study based on the diet patterns reported by the participants. Participants were not informed of their estimated daily caloric intake during the survey. To assess athlete knowledge of caloric requirements during training (as opposed to measuring if they actually met their daily energetic need), respondents were asked how many calories they believed they consumed during training and non-training days. Male athletes reported that they consumed 3350±1179 Kcals, while females reported they consumed 2088±614 Kcals. These values were compared to those calculated from the diet record. There were no significant differences in the perceived caloric intake and actual caloric intake of males during training days (Chi-Square Test: P(T<=t) two-tail: 0.67). However, women's perceived intake was significantly lower than their actual caloric intake during training days. (Chi-Square Test:

P(T<=t) two-tail 0.016.)

DISCUSSION

DIETARY HABITS

In many sports (e.g., boxing, running, gymnastics, track and field) small changes in body composition and lean muscle retention have a significant impact on performance. When optimizing body composition, the most important variables are energy intake and energy expenditure (93). A study published by Duetz et al. that examined four groups of elite female athletes concluded that within day energy deficits positively correlated with body fat percentage, whereas within day energy surpluses negatively correlated with body fat percentage (94). The major conclusions from that research were that athletes should not restrict eating or skip meals if they wished to maintain an optimal body composition for competition. Skipping even one meal per day can induce a rapid increase in dietary fat, fat gain, and mid-overnight leptin increase (95). A study by Benardot et al. (96) showed that when a 250 calorie snack was given to 60 male and female college athletes for two weeks after breakfast, lunch and dinner (totaling 750 calories in snacks) a significant amount of fat (-1.03%) was lost and lean body mass (+1.2kg) gained as compared to a non-caloric snack placebo group. Furthermore, a significant increase in anaerobic power and energy output was observed in those that consumed the 250-calorie snack. No significant changes, however, were observed in those consuming the non-caloric placebo. When individuals consumed 750 kcals daily in the form of extra snacks they had a non-significant increase in total daily caloric consumption of 128 kcals; in other words, they consumed fewer calories per meal. When snacks were removed, fat lost and lean body mass gained values moved back to baseline levels after 4 weeks. These results indicate that skipping meals has a negative effect on body composition and may hinder performance. In addition, negative energy balance can lead to significant decreases in anaerobic power and energy output (96).

In the student population surveyed for this study, male athletes reported skipping an average of 2.7 meals per week, whereas female student athletes reported skipping an average of 4.1 meals per week. Although skipping meals may result in decreased daily caloric intake, athletes need to be aware that skipping meals may also lead to undesirable increases in fat mass and decreases in lean body mass. The women surveyed in this population skipped an average of 48.72% more meals per week than males. Research has shown that women experience more food-related conflict and more dissatisfaction with their body weight and shape than men do (97). The perceived pressure to be thin has been documented in early adolescence, as noted by dieting behavior starting in very young girls (97). This behavior carries over into the collegiate years. The significant number of meals skipped per week in the surveyed female athlete population may reflect an attempt to reduce caloric intake in order to maintain or achieve desired body weight and body image. The observed eating pattern is potentially counterproductive to achieving optimal lean body mass and maximizing athletic performance.

Younger student athletes had a tendency to skip more meals than their older counterparts. Student athletes aged 19 years old skipped the greatest number of meals per week, with an average of 5.3 meals skipped. Student athletes experience significant challenges with time management, financial constraints, food access, nutrition when travelling, and the pressures to achieve a desired physique (98). Heaney et. al. (98) reported that lack of time management is the biggest barrier to proper nutrition for student athletes. At Syracuse University, freshmen have the ability to eat all their meals and snacks at their dorms, whereas sophomores usually have to prepare their own meals. This lifestyle change paired with an inability to manage time efficiently could be the reason why sophomores were the largest student athlete group to report skipping meals.

An unexpected finding from this survey was that the tendency to skip meals had a positive correlation with alcohol use (r=0.259, p=0.012, a=0.05). A recent study by Rososen et.al. (99) showed that first year university students intentionally changed their eating pattern prior to drinking alcohol. For instance, men reported eating more food prior to alcohol use, whereas women reported eating less food. Women's primary motivations to restricting caloric consumption prior to alcohol use were to "avoid gaining weight" and "to get intoxicated faster", whereas men's primary motivation to increasing caloric consumption was "to prevent a hangover" (99).

Alcohol use also had a significant positive correlation with increased BMI (r=0.236, p=0.001, α=0.01) in this study. This result is consistent with a study by Carels et al. (100) that showed skipping meals or consuming alcohol was not associated with weekly weight loss. Furthermore, individuals who skipped dinner or lunch more often had lower energy expenditure and exercise duration than those who skipped dinner or lunch less often.

OBSERVED CALORIC AND MACRONUTRIENT INTAKE VS. PROJECTED REQUIREMENTS

Although self-reported caloric intake did not differ from projected recommendations within either sex, there were important differences between the sexes. Males generally reported consuming more calories than recommended (702.05 kcals/day ±3281.34), whereas women reported consuming only enough calories to slightly exceed their activity levels by a narrower margin (24 ± 1491 kcals/day). One could deduce from this pattern of consumption that restricting caloric intake was a greater concern for women than it was for men. The large variation in caloric intake observed in both sexes represents the huge variation in caloric needs across and within sports. It also represents the difficulties encountered when assessing dietary intake through a single time point survey.

When comparing caloric intake to the TDEE on an individual basis for male athletes, there was no statistical difference between actual intake and TDEE. In other words, male athletes showed consistent caloric consumption within their respective sports. Only 7 out of 22 individuals reported over consuming by a wide margin, and 6 of these individuals have a much higher BMI than would be expected for an endurance athlete. Similar patterns were observed for female athletes. Cross-country athletes of both sexes consistently under consumed the amount of calories required to support optimal performance. These results are consistent with other studies. Shriver et al (109) assessed dietary intakes and eating habits of female college athletes and compared them with the minimum sports nutrition standards. Fifty-two female NCAA Division I college athletes reported that their energy intakes were below the minimum recommended ($p<0.001$) with only 9% of the participants meeting their energy needs. Under consumption of calories amongst cross-country NCAA athletes was also reported by a recently published thesis from California State University (100). Although that work focused on the prevalence of disordered eating and the relationship between disordered eating and caloric consumption among 49 male and female NCAA cross-country runners, some of the results have relevance here. In that study, 16% (3 out of 19) of all female runners restricted their caloric intake and 17% (5 out of 30) of all male runners of male runners reported excessive exercise (100).

CARBOHYDRATE INTAKE COMPARED TO DAILY REQUIREMENTS

CHOs maintain blood glucose levels during exercise and replenish muscle glycogen. Athletes need to achieve proper CHO intake in order to fuel the working muscle and maximize performance (101). Extensive research has shown that women oxidize less CHO than males during endurance exercise, yet the recommendations for men and women do not differ. Women do not carbohydrate load in the same manner as men, although the mechanism that prevents effective carbohydrate loading in women is still unknown. The current recommendation for CHO intake for athletes (both sexes) is 5-7 g.kg.day-1 for general training needs and 7-10 g.kg.day-1 for the increased needs of endurance athletes (41). Based on the literature reviewed, it is apparent that there should be specific recommendations for carbohydrate intake based on sex-specific macronutrient requirements. The modeling results reported here were based on reducing the carbohydrate intake for female athletes to the lower end of the recommended range for all athletes. It should be noted that even at the suggested reduced CHO levels, female athletes tended to under consume carbohydrates. The same was true for male athletes. These results are in agreement with the earlier work of Grandjean et al. (102), who investigated the energy and macronutrient intake of male and female athletes and concluded that the vast majority of the group averages reported were below the recommendations for CHO intake. In a similar manner, Giroux et al. (103) studied the macronutrient consumption of 262 cross-country student athletes and reported that participants were consuming 6 g/kg/day while the recommendation for very active endurance athletes is 7-10 g/kg/d. It appears that athletes, in general, need to be better informed about the importance of carbohydrates in the training diet.

PROTEIN INTAKE COMPARED TO DAILY REQUIREMENTS

Research has shown that women require less protein during endurance training than men. The results from this survey found that both male and female athletes reported a significant overconsumption of protein as compared to estimated daily requirements. Athletes believe that consuming large quantities of dietary protein are required to generate more muscle protein (104). This could be a reason why athletes in this study tended to over consume protein. In addition, a large percentage of the surveyed athletes reported obtaining nutrition information from their coaching staff (62%), while 44% relied on magazines and television. Athletic trainers (50%) and parents (50%) were also cited as sources of nutrition information. Significantly, not a single respondent reported obtaining information from highly reliable sources, such as a sports nutritionist or reviewed research articles. Furthermore, 67% (n=77) had never had any formal college level course work in nutrition. This is problematic in a time when nutrition information is readily accessible to the public through questionable media sources. With the current rampant promotion of protein bars and powders and much public discussion about “the benefits of protein”, it makes sense that athletes with little nutrition knowledge accept the concept of protein as a magic ingredient for a faster, leaner and stronger body.

Putting media hype aside, the actual recommended protein intake for endurance and strength trained athletes ranges from 1.2-1.7 g/kg body weight per day (101). A review of current peer reviewed literature (7, 58, 59, 62, 63, 64, 65, 66, 67), however, suggests that women need less protein than men due to lower levels of protein oxidation during endurance training and to less protein needed for muscle resynthesis. According to our survey results, male athletes reported over consumption of protein by 1.05 g/kg of body weight per day, whereas females over consumed by 0.64 g/kg of body weight per day. Excessive protein intake (>2.0 g/kg/d) has no beneficial effect on performance or training adaptations (25). Protein consumption patterns reported in this survey by both sexes are excessively high and demonstrate that athletes are not aware of, or are possible misinformed about, protein recommendations.

FAT INTAKE COMPARED TO DAILY REQUIREMENTS

The estimated need for fat intake of men was 51.82 (±3.37) g of fat, and for women 94.9 grams of fat. This translates into an average recommendation of 0.611 grams of fat/kg/body weight for male athletes and 1.45 g of fat/kg/body weight for female athletes. The self-reported fat intake for male athletes was 118.3 (±23.98) grams, and 65.33 (±5.7) grams for female athletes. This equals an average of 1.40 grams of fat/kg/body weight for males and 1.00 g of fat/kg/body weight for females. By these estimates, male athletes surveyed for this study reported a significant over consumption of fat (0.79 g/kg body weight) as compared to estimated daily requirements. Female athletes, however, reported under consuming the fat required to meet their daily metabolic requirements by 0.45 g/kg body weight.

A very recent study published by Privitera et al (105) showed that NCAA division I female athletes have greater self-controlled food choices than male athletes when presented with three different food types (dessert, fried food, and fruit). This could be due to the fact that females are generally more concerned with factors related to weight gain, thus making healthier food choices in order to prevent fat gain (8). In our study, women’s low fat consumption may be explained by concerns over gaining weight, as evidenced by the increased likelihood for female athletes to diet and skip meals. This misconception could have detrimental effects on female athletes, as women have greater uptake of fats into the skeletal muscle, greater fat storage in the form of intramyocellular lipids, and greater mitochondrial fat oxidation (9). Restriction of fats could limit women’s natural fuel selection and hinder performance.

STUDENT ATHLETE'S NUTRITIONAL KNOWLEDGE

The first hypothesis for this study proposed that there should be no differences between male or female athletes in the frequency of misconceptions about metabolic and macronutrient requirements. This was supported by the survey results. Female athletes answered 74% of the questionnaire correctly, whereas males answered 75% of the questions correctly. Our findings differ from a study published by California University of Pennsylvania that showed that female athletes had significantly more nutrition knowledge their male counterparts (106). Another study that surveyed 95 student athletes from Clemson University also concluded that females had higher mean scores for nutritional knowledge than males (107).

A study published by Dunn et al. studied nutritional knowledge of 190 male and female college athletes in a Southern university. This study found that the average nutritional knowledge score of all athletes was 51.49% (±13.57%). This study also found that females had significantly more nutrition knowledge than males. However, overall this work suggested that the nutritional knowledge of athletes is marginal (108). A surprising finding was the number of student athletes who displayed alarming misconceptions about basic nutrition concepts that could be detrimental for performance. First, 42.4% of the athletes agreed and 9.6% of the athletes strongly agreed that proteins are the best and most efficient source of energy. This is a disturbing misunderstanding, as carbohydrates provide the main energy for the contracting muscle. In addition, carbohydrates are also the most important fuel for the central nervous system (40). Another alarming result of this survey was that 16.8% of the athletes disagreed and 3.2% of the athletes strongly disagreed with the statement "carbohydrates are easier to digest than fats and proteins". Considering that athletes assume that carbohydrates are the hardest macronutrient to digest, it would be interesting to assess their pre-competition meal. Our results suggest that some athletes' pre-competition meals may be comprised of protein and fats, which not only take longer to digest, but also would not provide immediate energy for working muscle. This could hinder their performance during competition.

This study did not find any significant correlations between the level of an athlete's knowledge of nutrition and their overall dietary patterns, other than a surprising positive correlation with fast food consumption. Individuals with high knowledge scores were, however, more likely to have taken a nutrition course. However, even with the high level of nutrition knowledge exhibited by the athletes studied here, there were some surprising responses to individual survey questions. These responses might provide useful insight into the average student athlete's view of nutrition. For example, 6.4% of the athletes strongly disagreed and 24% of the athletes disagreed with the statement "Cereal, bread and bagels are good sources of carbohydrates." The United States Olympic Committee Sports Dietitians suggest pasta, rice potatoes, cereals, breads and legumes are examples of what should be the main carbohydrate sources during a moderate training day. Disturbingly, 1/3 of the surveyed athletes did not consider these as excellent or good sources of carbohydrate.

Our third hypothesis was also supported: we found no significant difference in the level of nutritional knowledge between sports. Across all sports surveyed, athletes that successfully completed the questionnaire scored an average of 74.16% on the nutritional knowledge questionnaire. This is consistent with published data. For example, a study examining nutritional knowledge and attitudes among Clemson University students also found that there was no significant correlation between nutritional knowledge and sport (r=0.204, p=0.790) (108).

Finally, our results show that athletes generally self-report caloric intakes adequate to meet their daily nutritional needs. Syracuse University student athletes appear to have adequate knowledge about the caloric demands of training and generally consume enough calories to satisfy their energetic needs.

Research in the past has concluded that attitudes towards healthy eating were a better predictor of adequate intake than nutritional knowledge (82). Future studies are needed to assess what factors contribute to proper dietary behaviors amongst college athletes in order to achieve optimal performance. The athletes surveyed here did not refer to sports nutritionists for advice. Instead, they sought information from magazines, internet, coaches, athletic trainers and parents. Confusing messages published by unreliable media sources and fad diets that promise to shed weight "in just 2 weeks" have polluted the high performance sports environment. Our athletes often believe that carbohydrates are more fattening than fatty foods, and that proteins are the main source of energy. They are lost in an era where social media and marketing persistently push towards achieving the ideal body image in the most unconventional and dangerous ways. Sports nutrition education must be an important component of making athletes aware of their unique physiological requirements and nutritional needs.

STRENGTHS AND LIMITATIONS

This study was designed to assess awareness of metabolic needs, dietary behaviors and the nutritional knowledge of student athletes in a Division I school in the United States. It provides unique information and an evaluation of what student athletes understand about sex-specific nutritional requirements and how collegiate athletes' nutritional knowledge translates into dietary patterns. This study also provides a through current review of the literature on sex-specific metabolic and macronutrient requirements. The recommendation that athletes of different sexes might require different macronutrient proportions in their daily diet has been suggested by different authors, but these suggestions have never been clearly outlined or directly compared to actual daily dietary habits. This work attempted to synthesize the current knowledge of macronutrient requirements of female athletes in particular. This result of this literature review was a series of revised recommendations for carbohydrate and protein consumption for female athletes. This study then examined the dietary pattern of female athletes and compared their macronutrient consumption patterns to the revised recommendations. The results suggest there is much to be done to improve sports nutrition advice for female athletes in particular. This is the most important finding of this study. However, although this study proposes new macronutrient recommendations based on gender, it did not explicitly test them. Further research will be needed to explore how these recommendations affect performance and metabolism

Although the macronutrient recommendations are unique and potentially transformative, the study had several limitations. The small sample size in the male athlete population led to limited data for comparisons with their female counterparts. In addition, the small sample sizes for different sports can result in misleading interpretations when comparing nutritional knowledge between them. This limitation was further compounded by the use of smartphones for completion of the questionnaire. This survey was designed to be completed on a computer. The survey administered through Qualtrics allows only certain type of questions to be answered through smartphones. For this reason, the dropout rate was higher than expected, decreasing the response rate for certain questions.

Another limitation included the use of a food frequency questionnaire (FFQ) to assess dietary habits. FFQs have several limitations because the results depend upon athlete’s insights and memory. In addition, FFQs tend to overestimate intake in low-energy consumers and underestimate intake in large eaters (110). This is a serious limitation of this study. The type of

FFQ used here is not comprehensive and it not in a format commonly used to asses true food intake. Although of unusual format, this FFQ was specifically adopted for this study because it had been used for similar types of research in the past. However, it is very important to recognize that there could be a gap between the results from the food frequency questionnaire and student athlete's actual dietary habits. An additional problem was the use of a diet assessment database that is not of research quality. The MyFitnessPal database does have both USDA and manufacturer validated data entries, which were used for the purpose of this study. However, not all foods were necessarily contained in the commercial database and there is not the same level of quality assurance as there would be with a research grade database. The public database was used in this case to facilitate use by student athletes on smartphones. Difficulties were encountered in converting and importing these records into a research quality food assessment database, so the analysis was completed with the MyFitnessPal application.

CONCLUSION

To our knowledge, this is the first study to compile and synthesize recent research on sex specific macronutrient needs of Division I college athletes and compare these recommendations to actual dietary practices. Currently accepted nutrition recommendations do not account for the complex endocrine reactions to endurance exercise that shape sex-specific metabolism. This study has provided an overview of the existing literature to determine new specific macronutrient requirements based on the demands of sports and gender. In addition, this study has evaluated and compared student athletes' dietary habits, nutrition knowledge and their understanding of daily metabolic needs during training days.

This research has identified that although both men and women often misunderstand basic nutrition concepts, there is no difference in nutritional knowledge between genders. In addition, the type of sport did not predict the level of nutritional knowledge. Furthermore, women skipped an average of 48.7% more meals than males during a week, implying that women may experience more food-related conflict in an attempt to reduce caloric intake. Athletes must become aware that skipping meals not only can negatively affect performance, but, as evidenced by other research, can also lead to increases in fat mass and decreases in lean body mass.

This study did not find strong associations between nutritional knowledge and overall dietary patterns. However, other unexpected findings were discovered. For example, skipping meals was associated with alcohol and fast food consumption. In addition, alcohol use had a significant correlation with increased BMI. Student athletes' knowledge of how many calories they should consume was adequate to meet their metabolic demands. In contrast, their macronutrient consumption was often not configured in such a way to support optimal metabolic performance based on their sport and gender.

Lastly, 105 (91.3%) of Division I Student athletes have reported that they would use the assistance of a sports nutritionist and believed that a sport nutritionist would help improve athletic performance. This suggests that athletes would seek better guidance towards healthy dietary habits if it were made available, which could ultimately optimize their athletic performance.

TABLES

Table 1. Physical activity adjustment coefficients for the Mifflin-St. Jeor equation used to project metabolic requirements for different sports.

Level	PAL	Definition
Sedentary	**^{3}1.0 to <1.4]**	Includes BMR, TEF, & physical activity for independent living
Low-active	**^{3}1.4 to <1.6]**	Using 70 kg adult, walking 2 miles/d at 3-4 m/h or equivalent energy expenditure in other activities
Active	**^{3}1.6 to <1.9**	Using 70 kg adult, walking 7.3 miles/d or equivalent energy expenditure in other activities
Very Active	**^{3}1.9 to <2.5**	Using 70 kg adult, walking 16.7 miles/d or equivalent energy expenditure in other activities

Table 2. Correlations between the variables relating to college athlete dietary habits, including dietary knowledge score and the independent variables of sex, age, alcohol use, BMI, fast food consumption, dieting habits, and the tendency to skip meals.

Correlations

		Age	Alcohol	BMI	SkipMeal	Knowledge Score	Fast Food	Diet
Age	Pearson Correlation	1.00						
	Sig. (2-tailed)							
	N	115.00						
Alcohol	Pearson Correlation	0.12	1.00					
	Sig. (2-tailed)	0.24						
	N	94.00	94.00					
BMI	Pearson Correlation	-0.07	***0.326*****	1.00				
	Sig. (2-tailed)	0.45	0.00					
	N	115.00	94.00	115.00				
SkipMeal	Pearson Correlation	***-0.27***	***0.259****	0.08	1.00			
	Sig. (2-tailed)	0.01	0.01	0.44				
	N	94.00	94.00	94.00	94.00			
Knowledge Score	Pearson Correlation	-0.03	0.20	0.16	0.16	1.00		
	Sig. (2-tailed)	0.77	0.06	0.13	0.13			
	N	89.00	89.00	89.00	89.00	89.00		
FastFood	Pearson Correlation	-0.06	0.18	0.11	***0.204****	***0.322*****	1.00	
	Sig. (2-tailed)	0.56	0.08	0.30	0.05	0.00		
	N	94.00	94.00	94.00	94.00	89.00	94.00	
Diet	Pearson Correlation	-0.13	-0.11	***-0.22***	-0.16	0.17	-0.10	1.00
	Sig. (2-tailed)	0.20	0.28	0.04	0.13	0.11	0.36	
	N	94.00	94.00	94.00	94.00	89.00	94.00	94.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3. Nutritional knowledge scores for all student athletes compared across sport categories

Sport	N	Average Score out of 120 Points	Standard Deviation
Basketball	2	95	6.00
Cross country	8	91	1.26
Field Hockey	18	88	1.06
Football	2	92	4.00
Ice Hockey	6	89	3.73
Lacrosse	5	99	3.72
Rowing	10	87	1.9
Soccer	10	91.5	1.24
Track and Field	1	95	0.00
Volleyball	8	93	2.18

FIGURES

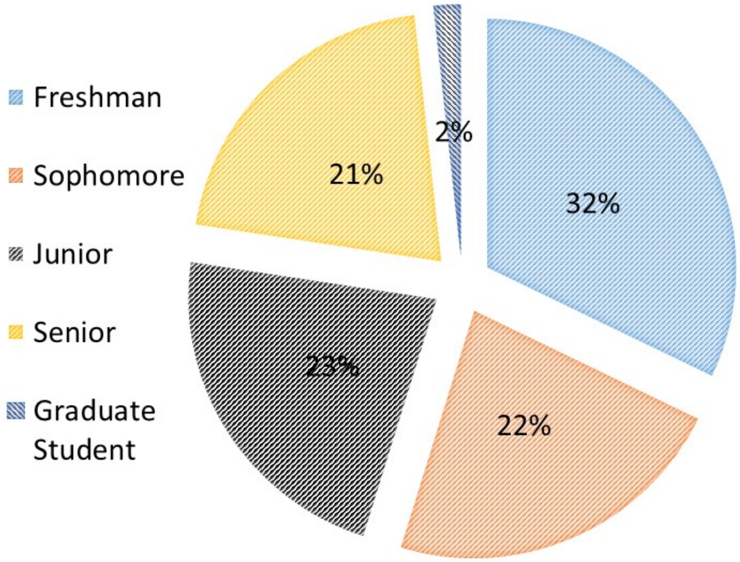


Figure 1. The distribution of participants across class rank in the survey of nutritional habits of Division I student athletes at Syracuse University

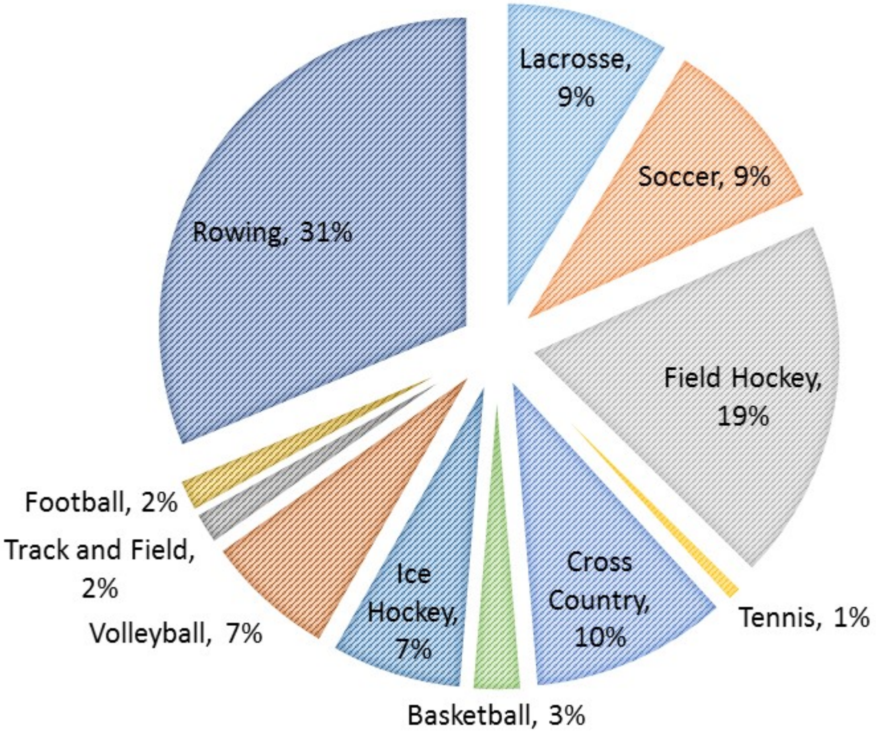


Figure 2. The distribution in sports participation for respondents in the survey of nutritional habits of Division I student athletes at Syracuse University.

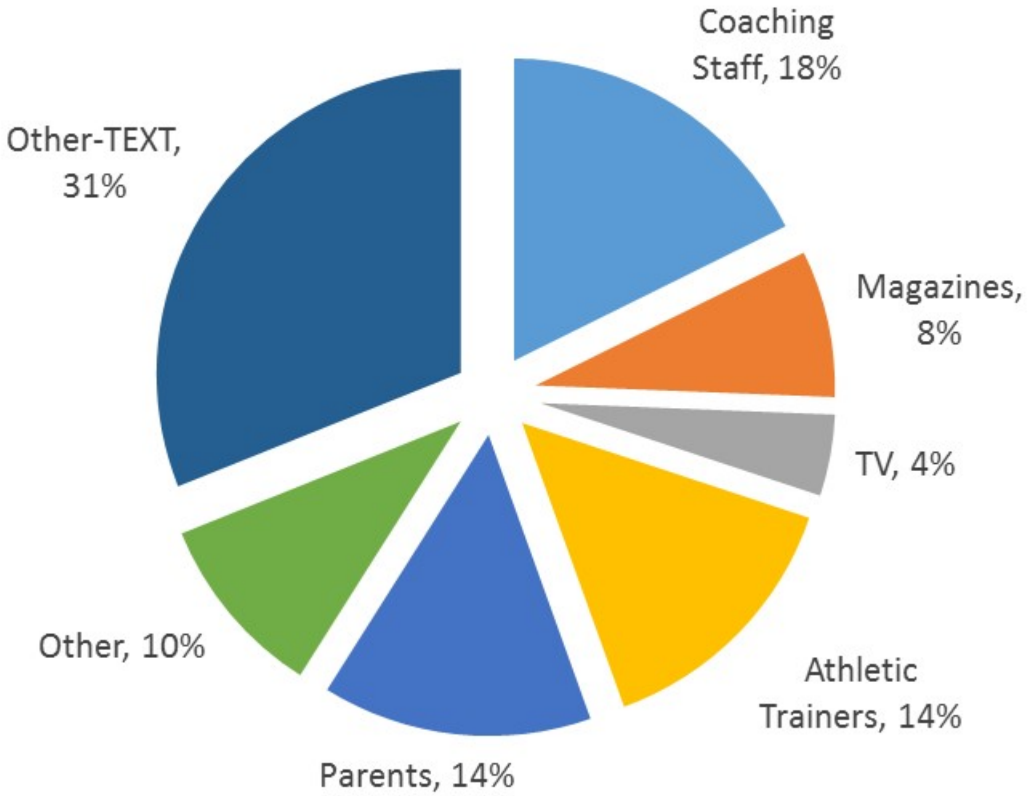


Figure 3. The distribution of sources of nutritional information reported by respondents in the survey of nutritional habits of Division I student athletes at Syracuse University.

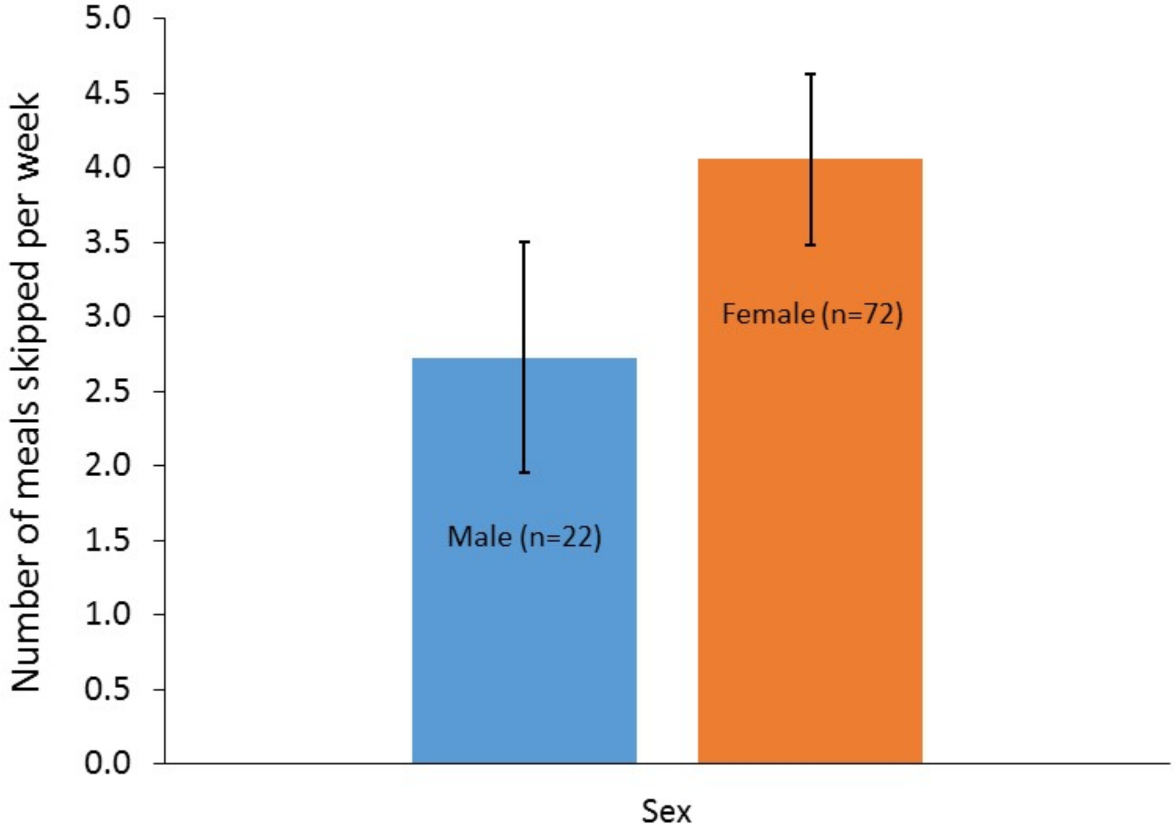


Figure 4. The number of meals skipped per week as self-reported by Division I student athletes at Syracuse University. Sample sizes are reported following each data label. Data are plotted as the mean ±95% confidence interval. Female athletes skipped significantly more meals each week than male athletes.

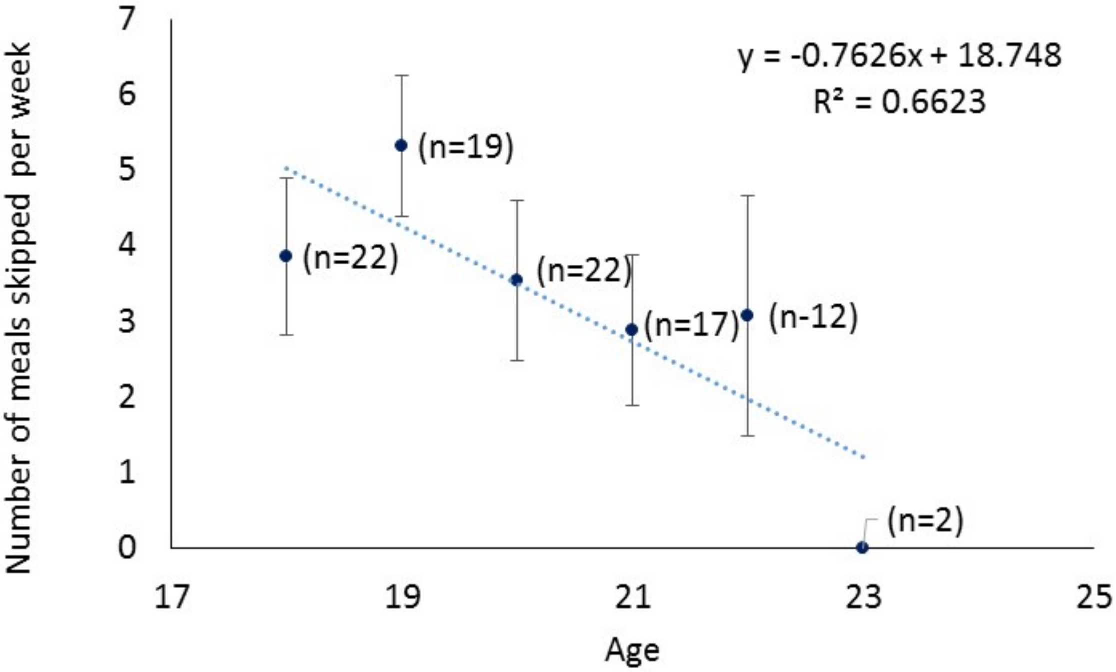


Figure 5. The number of meals skipped per week as self-reported by Division I student athletes at Syracuse University. Sample sizes are reported following each data label. Data are plotted as the mean ±95% confidence interval. There was a tendency for younger athletes to skip more meals each week than older athletes.

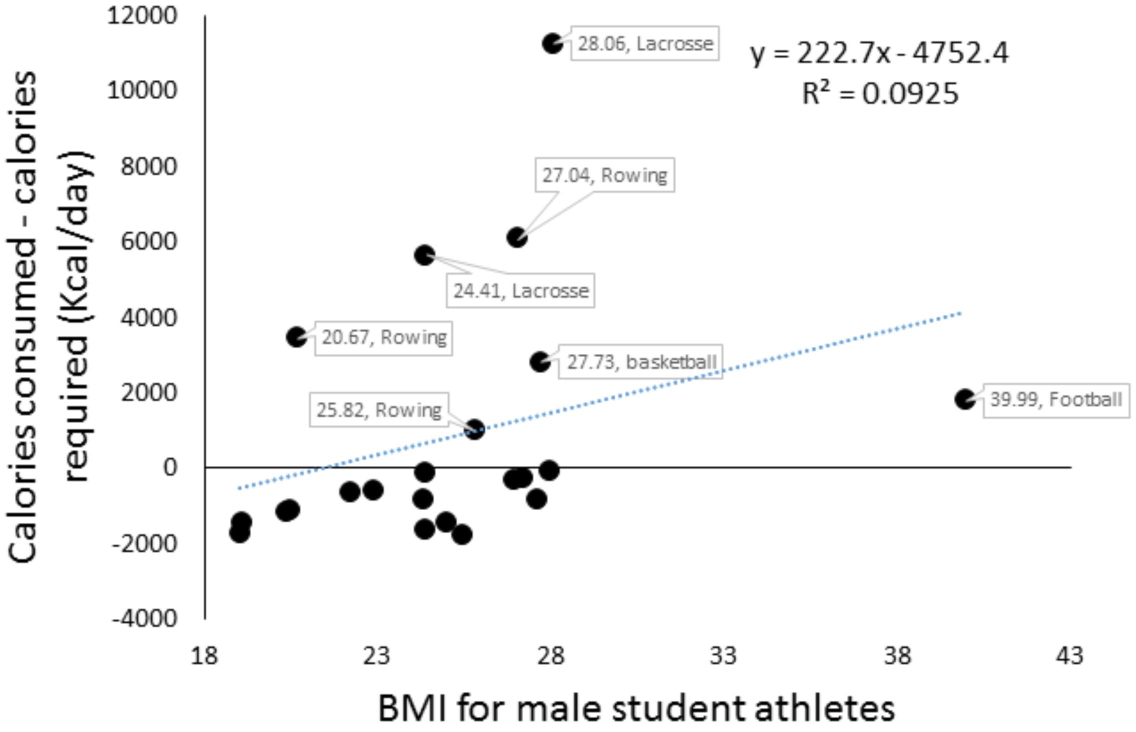
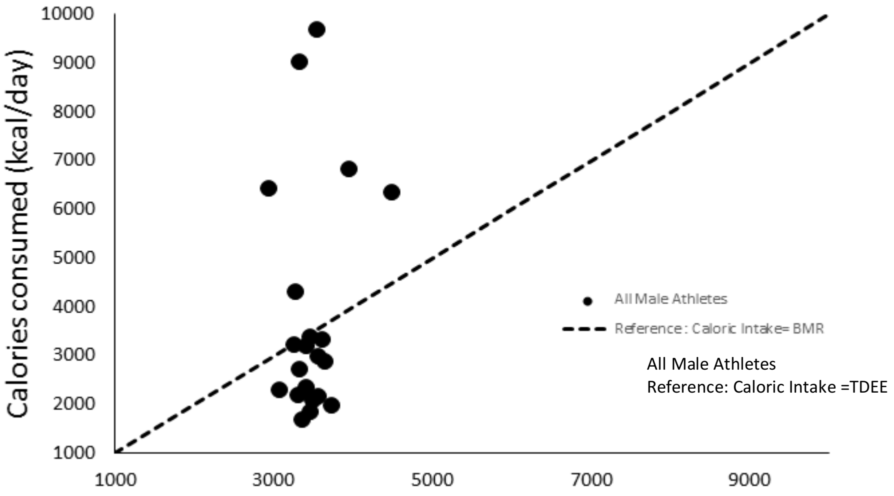


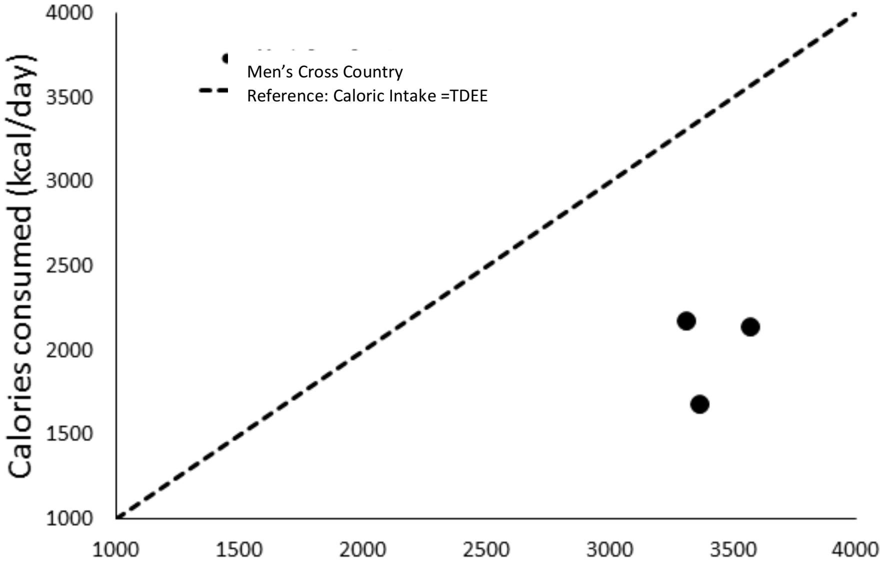
Figure 6. BMI for male athletes compared to the difference between caloric consumption and recommendations

A.



B.

Estimated TDEE for Male Athletes Combined



Estimated Energy Needs for Cross Country Athletes

Figure 7. A). Male athletes who reported their dietary habits (n=22) over consumed calories for their estimated TDEE by 702.05 kcals/day on average with a very large standard deviation (±3281.34) reflecting the huge variation in caloric demand both across and within sports. B). Male cross-country athletes (n=3), however, differed notably from all other male athletes by consistently under-consuming calories

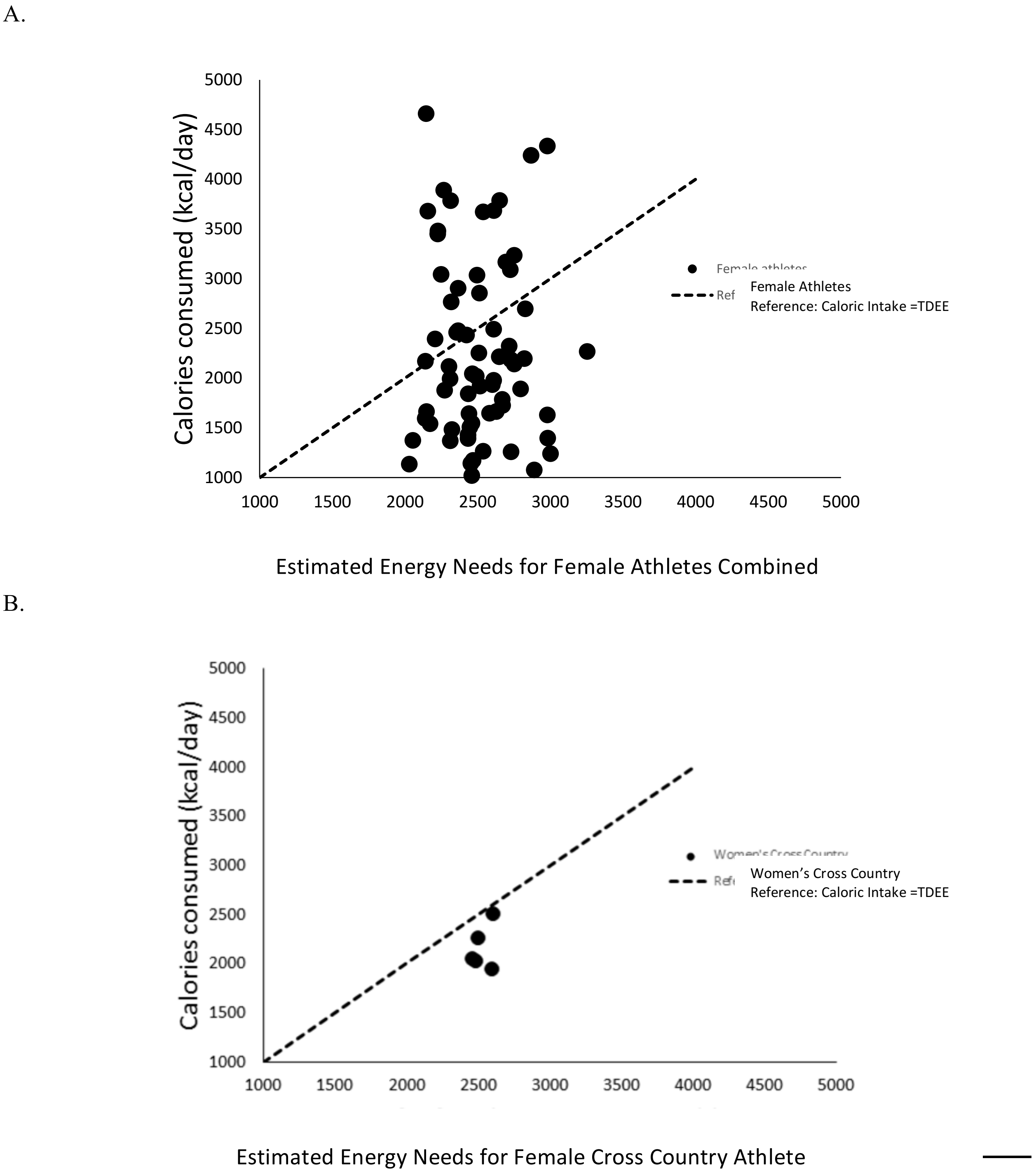


Figure 8. A. Female athletes who reported dietary habits (n=73) consumed on average enough calories to slightly exceed their activity levels by a narrower margin than males (24.21 ±1491.06 kcals/day); the large deviation from the mean once again reflects the caloric demands across sports. B. Similar to male athletes, female cross country athletes consistently under consumed calories.

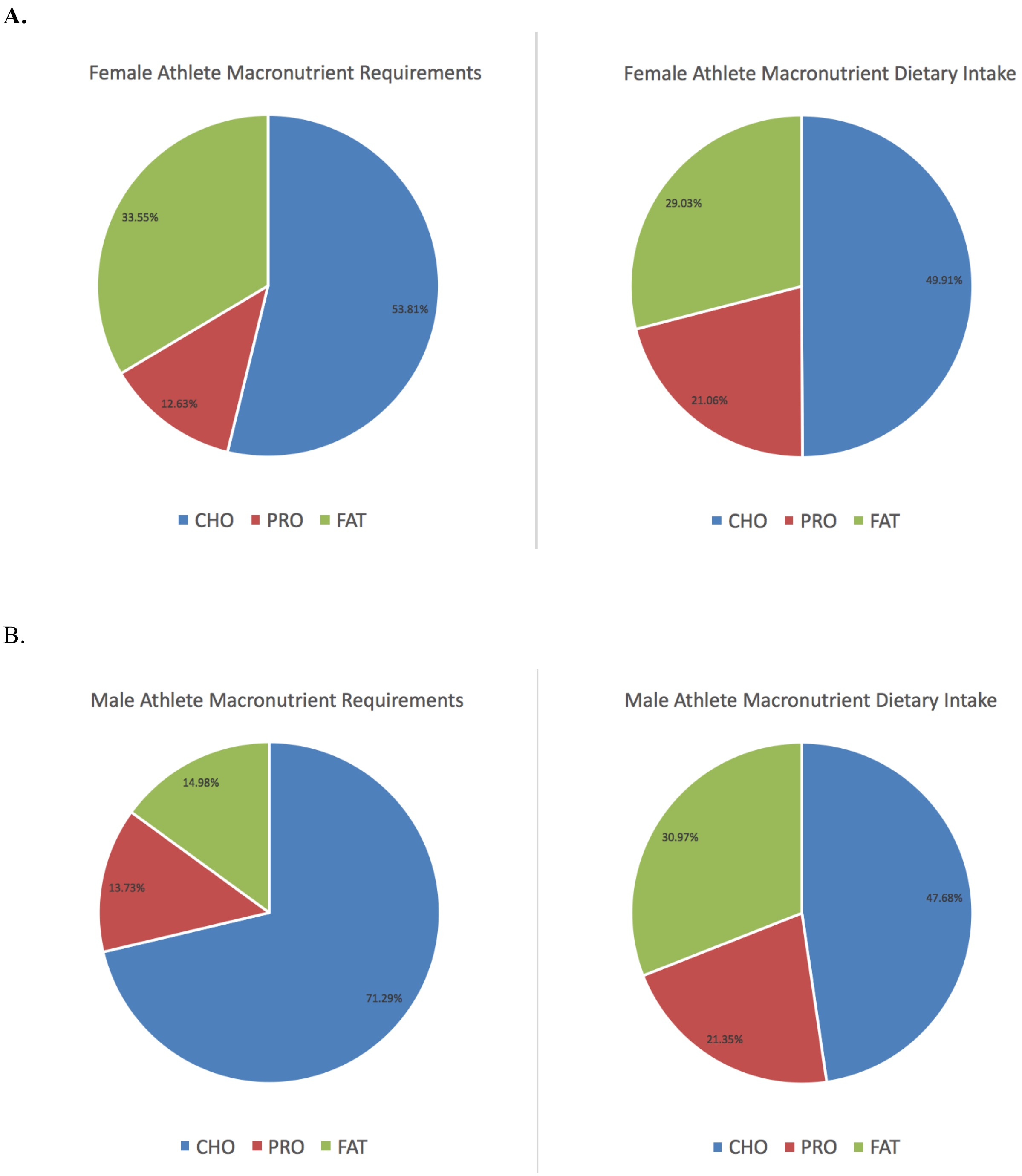


Figure 9. Dietary macronutrient composition as self-reported by Division I. A) female student athletes and B) male student athletes at Syracuse University.

APPENDICES

Appendix A. Reported scores reported for dietary habit survey

Key:	
#	Question Number
F/M	Female/Male
0-7	Number of Days
N	Sample Size = 89
F	72 Participants
M	22 Participants

#	**Question**	**F/M**	**Yes**	**No**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	How many days during a week do you eat breakfast?	F			1	2	3	2	3	16	7	38
		M			0	0	1	2	3	0	4	12
2	How many days during a week do you eat lunch?	F			0	2	1	3	13	9	8	36
		M			0	0	0	1	0	4	2	15
3	How many days a week do you often skip at least one meal per day?	F			13	8	16	9	6	3	5	12
		M			8	2	6	3	1	1	1	0
4	How many days during a week do you take a mineral supplement?	F			56	1	2	0	0	3	0	10
		M			17	0	0	1	0	0	0	4
5	How many days during a week do you take a vitamin supplement?	F			40	3	2	1	3	6	1	21
		M			13	0	1	2	1	0	1	4
6	How many days during a week do you record your food intake?	F			49	0	7	2	4	2	2	6
		M			22	0	0	0	0	0	0	0
7	Have you ever been on a diet to lose weight?	F	33	39								
		M	7	15								
8	How many days during a week do you eat fast food?	F			46	16	5	2	1	2	0	0
		M			15	2	1	3	1	0	0	0
9	How many days during a week do you seek out nutrition information?	F			22	11	14	6	9	7	1	2
		M			9	6	3	3	0	0	1	0

10	How many days during a week do you consume alcoholic beverages?	F			25	31	15	1	0	0	0	0
		M			4	10	4	3	1	0	0	0
11	Do you think you eat a variety of foods from each food group?	F	61	11								
		M	17	5								

Appendix B. Reported nutritional knowledge survey scores.

Key:	
#	Question Number
N	Sample Size = 89
SD	Strongly Disagree
D	Disagree
A	Agree
SA	Strongly Agree
🟧	Correct Response

#	Question	SD	D	A	SA	Mean
1	Skipping breakfast can negatively affect athletic performance	0	5	38	46	3.46
2	Proteins are the best and most efficient source of energy	4	20	53	12	2.82
3	Nutrition affects mental performance	0	2	46	41	3.44
4	The pre-event meal should be eaten 3-4 hours prior to competition	0	11	53	25	3.16
5	Calcium excretion from the body increases with alcohol consumption	2	28	53	6	2.71
6	According to "My Plate" one should consume 6-11 servings from the grains group every day	4	47	32	6	2.45
7	According to "My Plate" one should consume 4 servings from the dairy group every day.	2	45	36	6	2.52
8	According to "My Plate" one should consume 2-3 servings from the protein group every day.	0	11	66	12	3.01
9	According to "My Plate" one should consume 2-4 servings from the fruits group a day	0	5	70	14	3.10
10	Eating breakfast can improve concentration	0	2	37	50	3.54
11	Carbohydrates are less fattening than fatty foods	5	31	41	12	2.67
12	60% of total calories should come from carbohydrates	7	30	46	6	2.57
13	Carbohydrates are easier to digest than fats and proteins	4	21	54	10	2.79
14	Excess vitamin consumption can be toxic	5	21	44	19	2.87
15	Anemia is a deficiency in iron	2	9	41	37	3.27
16	Average percentage of body fat in females is 20-25%	1	14	58	16	3.00
17	Cereal, bread, bagels are good sources of carbohydrates	8	30	42	9	2.58

18	Tofu, nuts and beans are good sources of protein	0	4	61	24	3.22
19	Athletes tend to consume twice as much protein as recommended	0	24	46	19	2.94
20	Over consumption of proteins are beneficial for athletes	8	56	17	8	2.28
21	The best sources of iron come from animal products and fish	1	14	58	16	3.00
22	Eating cereals or breads enriched with iron should be eaten with a source of vitamin C to enhance absorption	0	23	60	6	2.81
23	Proteins act to repair and build muscle tissue and make hormones to boost the immune system	0	3	69	17	3.16
24	Fats are essential in all diets	0	4	59	26	3.25
25	If a diet is lacking in carbohydrates, proteins are then used for energy	2	16	58	13	2.92
26	Oatmeal, legumes and fruits are sources of soluble fiber	0	3	67	19	3.18
27	The recommended amount of fiber is 25 grams per day	0	19	63	7	2.87
28	Vitamin C is also known as ascorbic acid	2	26	50	11	2.79
29	If you are not thirsty, then you must not be dehydrated	39	40	6	4	1.72
30	If carbohydrates are consumed close to exertion, it can cause elevated insulin levels and a reduction in circulating sugar levels in the blood	1	33	49	6	2.67

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- Utilized Game Breaker for team & opposition evaluation for scouting reports
- Compiled and led instructional video sessions to develop players' hockey knowledge and awareness
- Managed athletes' nutritional consumption for optimal performance
- Designed the Spring fitness program to improve cardiovascular endurance and speed repeatability
- Organized the Annual Golf Outing fundraiser to help raise over $20,000 for new lockers

Syracuse University Field Hockey Syracuse, NY
Director of operations & Team Nutritionist Aug 2013-May 2015

- Coordinated team travel itineraries, reserved facilities and organized meals
- Negotiated prices for hotels, buses, flights and banquets
- Set up the alumni database; designed & distributed monthly alumni newsletters
- Led the program towards fundraising $70,000 towards new lockers and field improvements
- Delivered nutrition education lectures, cooking workshops & provided nutrition counseling to players

International Coaching USA, Argentina, Germany, Barbados, Australia
Coach 2006-present

- Coached age groups ranging from 5-18 years old in five countries
- Encouraged passion, creativity and love for the game

LEADERSHIP/DISTINCTIONS

NCAA Women Coaches Academy graduate (2016); Three-time NFHCA All-American (2008, 2009,2010); Three-time Big East Champion (2008, 2010, 2011); Four-time regular season champion (2008, 2009, 2010, 2011); Four-time appearance in NCAA; One Final Four appearance in NCAA; Syracuse University 2nd All-Time leader in career points (139); Female Athlete of the year (2010); Syracuse FH Captain (2011)

REFERENCES

Ange Bradley	Head Field Hockey Coach Syracuse University	anbradle@syr.edu
Lynn Farquhar	Head Field Hockey Coach Saint Joseph's University	lfarquha@sju.edu
Dr. Daryl Gross	Vice President & Special Assistant to the Chancellor at SU	djgross@syr.edu