ASSESSING DIETARY NUTRIENT ADEQUACY AND THE EFFECTS OF SEASON-LONG TRAINING ON BODY COMPOSITION AND METABOLIC RATES OF MEN'S DIVISION I COLLEGIATE BASKETBALL PLAYERS

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TITLE: Assessing Dietary Nutrient Adequacy and the Effects of Season-Long Training on Body Composition and Metabolic Rates of Men’s Division I Collegiate Basketball Players

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ABSTRACT

Assessing Dietary Nutrient Adequacy and the Effects of Season-Long Training on Body Composition and Metabolic Rates of Men's Division I Collegiate Basketball Players

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The success of performance in basketball may rely on both optimal body composition and nutrient intake. To our knowledge this is the first study to examine dietary intake adequacy and season-long effects on body composition and metabolism. The purpose of this study was to examine seasonal changes in body composition (BC), resting metabolic rate (RMR) and respiratory quotient (RQ), while also examining the dietary intake adequacy of NCAA DI male basketball players. BC, RMR and RQ were assessed during pre-season, in-season, and post-season (September, December, and March), while dietary assessment was collected in September and February. Results of this study indicated that players consumed inadequate amounts of energy (p<0.0001), protein (p<0.0001) and carbohydrate (p< 0.0001) relative to the recommendations for exercising individuals during the October baseline period. However, following analysis and consultations, athletes increased intake and received adequate amounts of energy and protein during follow-up, yet carbohydrate (p=0.0025) was still significantly lower. Results also revealed that there was a decrease in percent body fat (%BF) during season, an increase in Lean Body Mass from preseason to postseason, a peak in RMR during season and an increase in RQ post season. These findings indicate that significant metabolic and body composition changes occur in players over the season and suggest nutritional strategies employed concomitantly may be beneficial.

Keywords: college basketball, body composition, dietary intake, metabolism, athlete

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INTRODUCTION

Basketball is an intermittent, high intensity sport that relies on both anaerobic and aerobic systems for energy (Osterberg, 2017) . Because of this, dietary intake is an important factor for the health and performance of the players. Adequate energy and macronutrient intake must be accomplished to support optimal body composition (BC) changes, performance and help support exercise recovery (Kerksick et al., 2017). Without sufficient consumption of carbohydrates, there will be insufficient glycogen storages which can lead to decreases in power output and work rate and reduced time to fatigue during exercise (Williams & Rollo, 2015). Protein is needed in adequate amounts to provide sufficient amino acids for protein turnover, and to help preserve or gain muscle mass. Prior studies have demonstrated that athletes tend to consume insufficient amounts of calories and carbohydrate, which can negatively impact their performance (Jenner et al., 2019). This being an interesting finding with performance and player health implications warrants further studying,

Another factor that can affect performance of basketball is a player's BC. Reduction in percent body fat (% BF) and an increase in lean body mass (LBM) has been shown to be favorable for basketball players. Studies have found that lower % BF, paired with increased LBM, has been associated with increased change of direction (Spiteri et al., 2015), vertical and standing long jump (SP, 2021). However, too low of % BF can have negative health implications, therefore monitoring BC is important to frequently assess BC changes. In addition, assessing metabolic variables such as resting metabolic rate (RMR) and respiratory quotient (RQ) is important in understanding a player's nutrient needs. RMR can help determine the number of calories required in a day, therefore allowing for more accurate and specific nutrition recommendations to be made to meet the individual's needs (Dunford et al., 2021). Determining an athlete's RQ, allows for better understanding of the fuel sources being used, their metabolic flexibility, and to examine whether athletes are consuming enough calories overall (Dunford et al., 2021). Repeatedly assessing player RMR and RQ values, along with BC, provides insight into understanding if changes in the nutrition recommendations are needed or if the current recommendations are in line with athletes' needs and goals. A limited number of studies have been published that have assessed the changes in BC over the season on collegiate male basketball players (Fields et al., 2018; Hoffman JR, 1991; Siders et al., 1991). There does not appear to be previous studies that have performed repeated measures of RMR and RQ values of athletes over the season. Therefore, the purpose of this study was to assess gaps in the literature regarding changes of BC, nutrient needs, and intake via metabolism throughout a season, while also understanding nutrient intake adequacy in male college basketball players.

1.1 Research Questions

The work presented herein aimed to address the following questions:

1) Are there any significant changes that occur to BC (weight, LBM, %BF) and metabolism (RMR and RQ) in NCAA DI collegiate male basketball players over the course of a typical season?
2) Do NCAA DI collegiate male basketball players consume adequate amounts of nutrients to meet their personalized recommendations?
   a) How does knowing their recommendations and nutrition counseling affect their dietary intake?

Chapter 2

BACKGROUND

Dietary intake and BC are two important factors that affect the performance of an athlete. Most collegiate athletes are unaware of their needs, which can lead to the under or overconsumption of nutrients causing detrimental effects on BC and performance (Jagim et al., 2021). The frequent assessment of these outcomes is a necessity to ensure that optimal changes occur to best support athletic performance, health, and wellbeing. Assessment of nutrient intake adequacy and needs should be conducted by way of assessing metabolism variables, thus being more accurate and personalized. Frequent assessment of dietary intake, BC and metabolism facilitates the understanding the extent to which the player is consuming enough food and subsequently modify recommendations, as needed, to achieve personal goals and optimize performance. The purpose of this literature review is to assess and underscore the importance of dietary intake and BC on performance in NCAA DI male basketball players.

2.1 Dietary Intake

Consuming adequate amounts of nutrients is a key component needed to enhance performance, recovery, training and fulfil body composition goals in athletes (Thomas et al., 2016). Although studies have underlined the importance of optimal nutrient intake on performance, access to nutrition sources is limited for most collegiate athletes. Without proper sources, collegiate athletes tend to lack general knowledge about nutrition and their nutrient needs. Collegiate athletes reported receiving most of their nutrition recommendations from social media, coaches, and athletic trainers (Klein et al., 2021), most of who do not have any or have minimal education in nutrition. One study reported that collegiate athletes only answered 48% correctly on sport nutrition questions, which is deemed as “poor” sports nutrition knowledge (Jagim et al., 2021). Interestingly, the measured lack of nutrition knowledge scores correlated with less-than-optimal BC (Jagim et al., 2021). Current literature indicates that college athletes consume fewer calories and less carbohydrate than recommended while consume total fat, saturated fat, cholesterol, and sodium at levels higher that those recommended by the Dietary Guidelines (Hinton et al., 2004). These observations align with what is seen regarding dietary intakes for professional athletes, where caloric intake and carbohydrate consumption are lower than recommended whereas consumption of total fat, saturated fat, and cholesterol are all above dietary reference intake (DRI) recommended levels (Jenner et al., 2019). Suboptimal consumption of nutrients can impact negatively performance and BC; thus it is important to increase nutrition information and education provided to athletes thereby allowing them to better understand how to best meet their nutritional needs.

2.1.1 Recommended Intake for Athletes

The heightened energy expenditure expressed in athletes leads to an increase in energy and macronutrient needs compared to their nonathletic counterparts. Athletes needs can range between 38-45 calories per kilogram per day (kcal/kg/day) which is approximately a 30-45% increase compared to sedentary counterparts, who only need approximately 30-31 kcal/kg/day (Dunford et al., 2021).

The current recommendations of macronutrients for athletes are typically made under two assumptions. The first assumption is that adequate caloric intake is being achieved. Inadequate or excess caloric intake can alter metabolic processes, resulting in different optimal recommendations than the recommendations derived based on the dietary guidelines. The second assumption is that the athlete is receiving a mixed diet of both plant and animal-based products (Dunford et al., 2021).

The recommended dietary allowance (RDA) of protein is 0.8 grams per kilogram of bodyweight per day (g/kg/day) (Institue of Medicine, 2005), which pertains to the general population. Research has shown that merely meeting the RDA does not secure an adequate amount of protein to optimize turnover and recovery of muscles in athletes (Vliet et al., 2018). Therefore, modified recommendations have been stated for athletes, with the general recommendation being in the range of 1.2-2.0 g/kg/day (Dunford et al., 2021), depending on the duration and intensity of exercise and subsequently the type of sport. The International Society of Sports Nutrition (ISSN) has recommended a range of 1.4-2.0 g/kg/day to build or maintain lean mass in most athletes, regardless of the type of exercise (R. Jäger et al., 2017). An increase of protein intake to 2.3-3.1 g/kg/day has been recommended for those who are in a hypocaloric state, to prevent the degradation of LBM (R. Jäger et al., 2017). Those that do not consume adequate amounts of high quality protein, or a mixed diet with appropriate protein levels and quality, need to follow recommendations suggesting increased protein intake to meet needs (National Research Council Subcommittee on the Tenth Edition of the Recommended Dietary Allowances, 1989).

Similar to protein, athletes require higher amounts of carbohydrates intake to adequately replenish muscle glycogen storages, which is used as fuel to provide energy throughout exercise. Current intake guidelines propose 3-12 g//kg/day of carbohydrate (Thomas et al., 2016). The amount recommended varies based on several factors including intensity, duration, and type of exercise. Athletes who perform at higher intensities and for longer durations, typically require 6-10 g/kg/day, while athletes that engage in low intensity, short duration exercises normally meet their needs when consuming 3-5 g/kg/day (Thomas et al., 2016).

Unlike the other macronutrient recommendations, the recommendations for fat are based on the number of total calories, protein, and carbohydrate needed to be consumed. The amount recommended for an athlete will also depend on the type of exercise/sport, with the standard guidelines being approximately 1 g/kg/day (Dunford et al., 2021) and up to 2 g/kg/day for endurance athletes (Pendergast et al., 2000). These values allow for the fat intake to range between 20-35% of total daily caloric intake, which is consistent with the acceptable macronutrient distribution range (AMDR) (Institue of Medicine, 2005) . For athletes in weight loss programs, recommendations suggest 0.5 g/kg/day, with no less than 20% of total caloric intake acquired from fat (Thomas et al., 2016).

2.1.1.1 Nutrient Recommendations for Basketball Players

Basketball is an intermittent high intensity sport, which has both anaerobic and aerobic components (Osterberg, 2017). During bouts of high intensity, sprints, change of directions and jumps, the body will rely on the creatine phosphate system and anaerobic glycolysis to stimulate energy from stored muscle glycogen, therefore higher amounts of carbohydrate intake will be recommended for depleted glycogen storage restoration (Osterberg, 2017). With the increased use of glycogen, recommended amounts of carbohydrate should be between 5-7 g/kg/day. Protein intake should be between 1.3-1.8 g/kg/day for muscle maintenance (Phillips & Van Loon, 2011) or up to 3.1 g/kg/day when in a hypocaloric deficit for weight loss purposes (R. Jäger et al., 2017), while fat should comprise 20-35% of total daily caloric intake. Importantly, the recommendation of caloric and macronutrient intake should be personalized for each athlete to accommodate BC changes, performance goals and dietary preferences.

2.1.1.2 Nutrient Timing

Another important consideration that contributes to obtaining the maximal benefit of nutrient consumption on performance and BC changes, is the timing of nutrient consumption. The three main consideration for nutrient timing include before the workout, during the workout and after the workout. Pre workout recommendations include consuming a snack or mixed meal consisting of 1-

4g/kg of carbohydrate, at least 1-4 hours prior to exercise, with moderate amounts of protein and a small amount of fat (Dunford et al., 2021). The American College of Sport Medicine (ACSM) recommends hydrating to euhydration before exercise, by consuming approximately 5-10 mL of fluids per kg of body weight, 2-4 hours prior to exercise with an additional 3-5 mL/kg if hypohydrated (Dunford et al., 2021). During exercise, consuming 30-60 g/kg/hour of carbohydrate is also recommended to help optimize performance and prevent/delay fatigue. Consuming adequate amounts of fluids and electrolytes throughout exercise periods to prevent more than 2% body weight loss is also recommended (Sawka et al., 2007). Following the end of the workout, intake should occur as soon as possible, optimally no later than 30 minutes after the workout ends. Recommendations consist of consuming between 0.25-0.3 g/kg for protein and 1.5 g/kg for carbohydrate (Dunford et al., 2021). Fluid intake should restore the amount of body weight loss with 1.25-1.5 L being consumed for every kg lost (Sawka et al., 2007; Thomas et al., 2016). The rest of the macronutrient needs should be distributed evenly throughout the day. Athletes should aim to consume meals every 3-4 hours, aiming for 0.31 g/kg of protein per meal, for the following 24 hours to help maximize muscle protein synthesis (MPS) (Pendergast et al., 2011).

2.1.2 Nutrition and Sports Performance

Ensuring energy and macronutrient recommendations are met is crucial to achieve optimal performance. If not met, insufficient glycogen stores, decreased

MPS and other imbalances which can negatively impact performance can be observed.

2.1.2.1 Energy

Adequate caloric intake is necessary to provide enough energy to sustain exercise and facilitate adequate recovery and replenishment of fuel sources as needed. Inadequate energy intake typically promotes shift to using suboptimal substrates as fuel. Severe caloric restriction compared to energy expenditure promotes increase in protein breakdown to provide amino acids as substrates for gluconeogenesis. Even when consuming adequate amounts of protein, acute energy deficits can still lead to the suppression of muscle fractional synthetic rate and synthetic signaling protein, thus leading to decreased ability to synthesize new muscle (Pasiakos et al., 2010). Meanwhile, dietary carbohydrate will be used as fuel and less of it will be able to replenish glycogen stores in the liver and muscle (Burke et al., 2004). The implications of increased protein breakdown and decreased glycogen storage on performance is discussed below.

2.1.2.2 Protein

Protein consumption influences various factors that have a positive impact on physical performance such as strength, muscle protein turnover, remodeling, and glycogen synthesis (Phillips & Van Loon, 2011). Hoffman et al (2007) reported that there was a significant increase in strength for 1-RM squat when athletes consumed 2.0g/kg/day of protein for 12 weeks compared to those that only consumed 1.24 g/kg/day (Hoffman et al., 2007). These results align with another study demonstrating that adequate protein intake can be favorable for hypertrophy and strength, when a person has been training for at least a few weeks (Pasiakos et al., 2015). Adequate protein consumption can also have a positive impact on lean body mass (LBM), which is discussed below in the *Effects of Nutrition and Body Composition* section of the background.

2.1.2.3 Carbohydrate

Carbohydrate is the primary fuel source during moderate and high intensity exercises (Burke et al., 2011). During these bouts of exercises, the body will rely on stored glycogen in the muscle and liver to provide energy. Consuming carbohydrate during exercise has been shown to increase time to fatigue, decrease perceived exertion thus increasing performance by allowing for the prevention of hypoglycemia through the use of exogenous carbohydrate, when endogenous carbohydrate stores are depleted (Jentjens et al., 2004). On the other hand, chronic inadequate carbohydrate intake will cause low glycogen availability during exercise leading to decreased strength and power performance (Costill et al., 1971; Leveritt & Abernethy, 1999). *Figure 1* shows effects of chronic low carbohydrate intake on glycogen stores over 3 days of training (Costill et al., 1971).

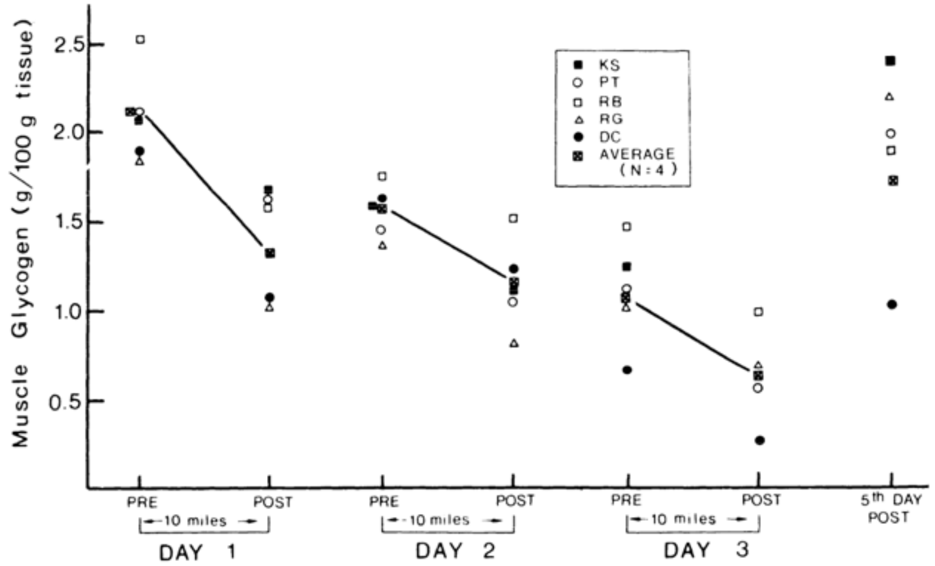


Figure 1. Effect of Chronic Carbohydrate Intake on Muscle Glycogen Stores from Costill et al. (1971)

When glycogen storages are depleted, the body will increase fat oxidation to support energy needs. The increased reliance on fat oxidation causes a decrease in exercise intensity since more oxygen is needed to metabolize fat, resulting in symptoms of fatigue (Murray & Rosenbloom, 2018). Decreased carbohydrate intake can also have an unfavorable impact on protein balance (Howarth et al., 2010). A decrease in protein balance occurs due to the increase in protein degradation to produce substrates for gluconeogenesis. This indicated that inadequate carbohydrate intake causes typical metabolic processes to shift, subsequently resulting in a negative effect on BC and performance.

2.1.2.4 Fat

Unlike with carbohydrates, during times of rest and low intensity exercise the body will rely primarily on fat as the source of energy. Inadequate fat intake can lead to negative effects in training, performance, and health of an athlete.

Consuming less than 20% of total energy from fat is associated with limiting the amount of intramuscular triglyceride stores (Dunford et al., 2021) and inadequate intake of essential fatty acids and fat soluble vitamins (Lupton et al., 2002). As a person becomes more physically fit, increased use of fat as fuel occurs due to training adaptations, which allow for the preservation (sparing) of endogenous carbohydrate stores (Melanson et al., 2009). Without adequate intake of fat, there will not be sufficient replenishment of intramuscular fat storages. Therefore the body will have an increase reliance on carbohydrate stores leading to a decrease in time of optimal performance (Pendergast et al., 2000). Fat soluble vitamins, such as vitamins D and K, are crucial in the regulation of bone mineralization. Thus, inadequate intake of fat can lead to a decreased absorption and bioavailability of these vitamins. Inadequate amounts of these vitamins can lead to decreased bone mineralization and an increase for the risk of fractures, highly unfavorable for athletes (Holick, 2006). On the other hand, overconsumption of fat can lead to increased amounts of nonessential fat stores, hence an increase in overall %BF. The increase %BF has been shown to extend negative effects on performance, especially in basketball players which is discussed in the *Body Composition* section of the background.

2.1.2.5 Nutrient Timing

The appropriate timing of nutrient intake is beneficial to enhance recovery and tissue repair, increase MPS and replenish glycogen storages (Kerksick et al., 2017). Consuming carbohydrate before exercise will allow for replenishment or maintenance of glycogen storages that can then be used during exercise

(Kerksick et al., 2017). Carbohydrate ingested during exercise will allow for the increased use of exogenous carbohydrate as fuel eventuating in increased time to fatigue, decreased perceptive rate of exertion and finally optimal performance for an extended period of time (Jentjens et al., 2004). Haff et al (2000) found that consuming 0.5 g/kg of carbohydrate during resistance exercise reduced glycogen losses by 49% compared to not consuming any carbohydrate, thus allowing for the preservation of glycogen, which explains the increase time to fatigue. Fluids during exercise allow for better regulation of core body temperature, and may help with the prevention of cramping and thus contribute to performance optimization (Dunford et al., 2021). In basketball specifically, fluid losses greater than 2% of bodyweight during exercise results in slower movements, less accuracy in shooting and decline in attention/focus (Baker et al., 2007).

After exercise, consuming both high glycemic carbohydrates and high-quality protein foods will blunt catabolic processes occurring during exercise and stimulate anabolic processes, allowing for the decrease in MPB and the increase in MPS and muscle glycogen resynthesis/restoration. Carbohydrate will allow for the maximal replenishment of muscle glycogen used during exercise, which will help the body be adequately prepared for future exercise, thus improving conditioning (Costill et al., 1971; Williams & Rollo, 2015) . Finally, the consumption of protein will help maximize protein turnover (Kerksick et al., 2017).

2.1.3 Measurements of Dietary Intake

Various methods have been established to assess the dietary intake of a person. Some of the most common ways used in studies are diet records and food frequency questionnaires (FFQ), both of which have limitations to their use (Thompson & Subar, 2001). Food records can be conducted over various time point with the most common being 3 days, 5 days, or 7 days, giving a better understanding of usual intake rather than one timepoint specific intake. Disadvantages include alteration of diet for the food record, misreporting portion sizes, and more logistical burden on the athlete. On the other hand, FFQ are forms that ask about the frequency of consuming a certain food over a period of time (Thompson & Subar, 2001). Although FFQ are less time consuming than diet records, athletes must remember what they consumed in the past which can lead to greater error when answering the questions. FFQ generally may present substantial degree of error, while diet records and recalls have been proven to more accurately assess short term intakes (Thompson & Subar, 2001). Each method has its own purpose in research, but based on the goals of observing actual caloric intake, diet records are most beneficial for the case of this study (Thompson & Subar, 2001).

2.1.4 Current Literature of Dietary Intake of Male Basketball Players

The research into the dietary intake adequacy of male basketball players alone is limited. Studies involving male basketball players found that most players consumed inadequate amounts of calories and carbohydrate, and adequate amounts of protein compared to recommendations for athletes. (Schroder, 2004; Short & Short, 1983). A study done with elite Spanish players showed intake of carbohydrate to be 4.6 ± 1.7 g/kg/day (Schroder, 2004), which is similar to that found with the dietary intake of various athletes. Similar to that of other athletes, studies have found that dietary intake of fat ranged from 196 to 254 g/day for male basketball players, which is higher than the recommended amount of 1 g/kg/day (Schroder, 2004; Short & Short, 1983).

2.2 Body Composition

Dietary intake plays an important role in determining the profile an individual's BC, which in turn, as well as diet, impacts an athlete's health and performance. Most practitioners use body mass index (BMI) to determine health status. Although widely used, BMI is not an ideal predictor of health in athletes due to BMI only considering weight and height rather than the composition of the body. Rather, looking at various BC variables is a more meaningful indicator of health and performance especially in athletes (Ackland et al., 2012). The status of different BC variables is able to help evaluate the quality and effectiveness of athletes' training and nutrition regimens (Shepherd et al., 2017). Although BC is a combination of variables, lean body mass (LBM) and percent body fat (%BF) are the two major variables that will be considered in this review.

2.2.1 Lean Body Mass

LBM is an important contributor to the health of the general population. The amount of LBM will depend on various factors, one of which is genetics (Garthe et al., 2013). Decreased lean mass (LM) can contribute to reduced quality of life, decreased performance of physical activity, increased risk of osteoporosis and metabolic health risk (Hunter et al., 2019). Physical activity, alongside proper nutrition, has been shown to help stimulate MPS which can allow for the increase or preservation of LBM (Turocy et al., 2011). For athletes, increases in LBM has been associated with increased strength and power development, while allowing for an athlete to generate more force during a specific period of time (*NSCA's Guide to Tests and Assessments* 2012).

With the physical nature of basketball, body size is seen as an advantage, yet proper combinations of LBM and fat mass (FM) is needed for optimal performance. A study found that basketball players tend to have greater amounts of LBM compared to other sports (Fleck, 1983). Specifically, Sanfilippo et al (2019) found that the average LBM for basketball players was 74.836 ± 8.325 kg, which was higher than the LBM value compared to most other sports including: soccer, golf, and hockey.

LBM is sometimes used interchangeably in studies with fat free mass (FFM) and lean tissue (LT), however there is differences in what these terms measure. FFM is the total mass of the body without FM included, meaning that the measurement also includes bone mass. On the other hand, LBM is described as the bone mineral content (BMC) subtracted from the FFM or the mass of all the soft tissue in the body (Imboden et al., 2017).

2.2.2 Body Fat & Percent Body Fat

Body fat (BF), or FM, is a combination of essential and nonessential fat in the body. The total body FM can be used to calculate a person's percent body fat (%BF). %BF is calculated by dividing total FM by the person's total mass and multiplying by 100 (Dunford et al., 2021).

There are two types of fat in the body: essential and nonessential fat. Essential fat is the amount of fat needed to maintain normal physiological functions and can be found in bone marrow, lungs, liver, kidneys, heart, muscles and tissues within the central nervous systems (Norgan, 1997). Those physiological functions include sex hormone production, cell membrane structure, absorption of fat-soluble vitamin and more. Males and females differ in average %BF due to difference of essential fat needs for hormonal difference and biological adaptations (Sansone et al., 2022). In males, 3% BF is considered to be essential, while in females 12% BF is considered to be essential (Norgan, 1997). Anything above the essential amount of body fat is said to be nonessential, or storage fat. Nonessential fat is the fat that provides substrates for metabolism (Turocy et al., 2011)

The presence of excessive BF can have detrimental effects on a person's health and lead to increased risk of mortality. Positive associations have been made with increased BF and chronic inflammation markers (Maffetone et al., 2017). This increased chronic inflammation can result in increased risk of chronic diseases such as cancer, diabetes, and cardiovascular disease (Maffetone et al., 2017). Within sports, excessive amounts of storage fat is thought to negatively impact the performance of athletes. Studies have found that increased BF has been associated with increased risk of injuries in basketball players (Sprague et al., 2018). However, very low %BF also has negative effects on the athlete. Low %BF has been associated with decreased in physical performance and recovery, negative impacts on heart function, and reduction in immune function (Rossow et al., 2013).

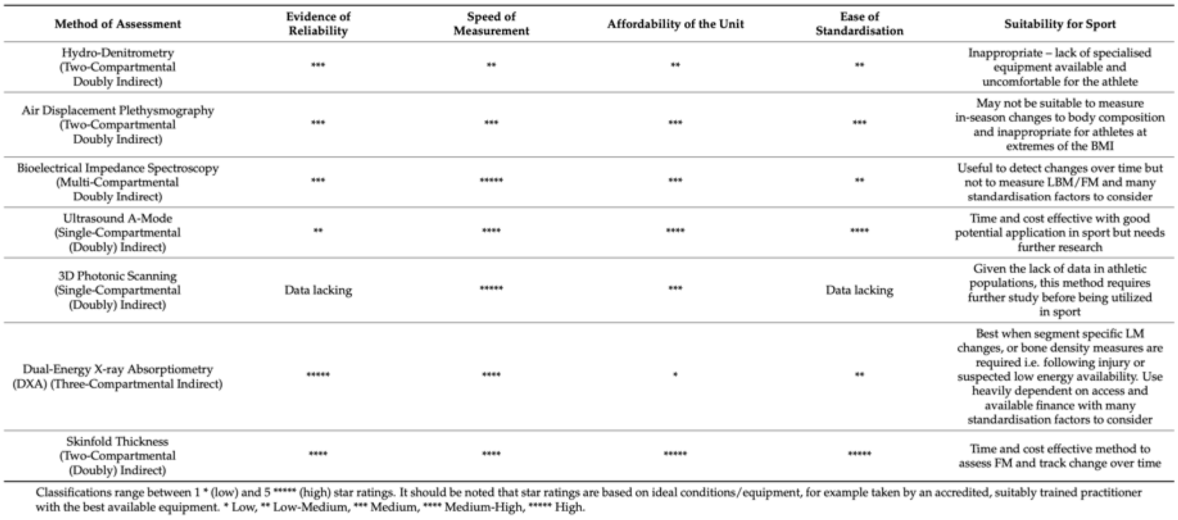
Ideal %BF for optimal performance varies between sports and different positions within sports. Athletes that participate in endurance sports (i.e. marathon running) and weight class sports (i.e. wresting) tend to have lower %BF compared to those that use their body weight for support (i.e. swimming, basketball) (Fleck, 1983). Sansone et al (2022) investigated the %BF in basketball players. Results demonstrated that the mean %BF for males was 13.1%, while females had increased body fat at 20.7%. Another study found that the average %BF for NCAA DI male basketball players was 12.2 ± 2 %. (Sanfilippo et al., 2019).

Comparable differences in measurement of %BF have been noted between techniques. %BF measurements from dual-energy X-ray absorptiometry (DXA), has been observed to produce higher values when compared to bioelectrical impedance (BIA) and skinfolds (Sansone et al., 2022). Therefore, it is important to note the measurement used when comparing %BF between studies.

2.2.3 Methods of Assessing Body Composition

There are various methods to assess BC in athletes. Both laboratory and field methods such as DXA, BIA, skin folds, hydrostatic weighing, and air displacement plethysmograph (i.e., BOD POD) are commonly used among athletes. Table 1 provides detailed information on various techniques used for body composition assessment.

Table 1. Overview of Different Methodologies for Assessing Body Composition in Sports, Rated Based on Current Evidence from Kasper et al. (2021)



Method of Assessment	Evidence of Reliability	Speed of Measurement	Affordability of the Unit	Ease of Standardisation	Suitability for Sport
Hydro-Denitrometry (Two-Compartmental Doubly Indirect)	***	**	**	**	Inappropriate – lack of specialised equipment available and uncomfortable for the athlete
Air Displacement Plethysmography (Two-Compartmental Doubly Indirect)	***	***	***	***	May not be suitable to measure in-season changes to body composition and inappropriate for athletes at extremes of the BMI
Bioelectrical Impedance Spectroscopy (Multi-Compartmental Doubly Indirect)	***	*****	***	**	Useful to detect changes over time but not to measure LBM/FM and many standardisation factors to consider
Ultrasound A-Mode (Single-Compartmental (Doubly) Indirect)	**	****	****	****	Time and cost effective with good potential application in sport but needs further research
3D Photonic Scanning (Single-Compartmental (Doubly) Indirect)	Data lacking	*****	***	Data lacking	Given the lack of data in athletic populations, this method requires further study before being utilized in sport
Dual-Energy X-ray Absorptiometry (DXA) (Three-Compartmental Indirect)	*****	****	*	**	Best when segment specific LM changes, or bone density measures are required i.e. following injury or suspected low energy availability. Use heavily dependent on access and available finance with many standardisation factors to consider
Skinfold Thickness (Two-Compartmental (Doubly) Indirect)	****	****	*****	*****	Time and cost effective method to assess FM and track change over time

Classifications range between 1 * (low) and 5 ***** (high) star ratings. It should be noted that star ratings are based on ideal conditions/equipment, for example taken by an accredited, suitably trained practitioner with the best available equipment. * Low, ** Low-Medium, *** Medium, **** Medium-High, ***** High.

The use of DXA as a measurement of BC has increased in popularity over the recent years. DXA has been seen as one of the most accepted methods of BC and is considered the gold standard due to all of its advantages when compared to other methods (Kasper et al., 2021). The three-compartment model of DXA allows for information on LBM and FM, as well as BMC (Nana et al., 2014). Unlike the other techniques, the software in DXA can measures total BC as well as regional measurements. Out of all the BC techniques, DXA has the smallest standard error of estimate (SEE) percentage at ±1.8 %, while the two-compartment model show less accuracy with SEE ranging from ±2.2-5%, depending on the instrument used (Turocy et al., 2011). This indicates that DXA is more accuracy and reliable to detect changes during repeated measures. Other advantage to DXA include: results are minimally influenced by water fluctuation, speed of measurement and comfort to the patient (Ceniccola et al., 2019).

Although DXA is considered the gold standard for BC, it does not come without limitation. A major limitation that needs to be considered with basketball players is the scanning field of DXA. The scanning field for the DXA machine varies between models but is approximately 60-66 cm wide by 190-198 cm long (Silva et al., 2006), which does not allow for players of various size to fit on the machine. Although this is a major disadvantage, researchers have found methods to be able to maneuver around this problem (Santos et al., 2013). Other disadvantages include: the cost of the equipment, the size of the equipment and proper technician training and certification is required in the State of California (Ceniccola et al., 2019). Because of these disadvantages, other methods such as BIA and skinfolds are still widely used.

2.2.4 Nutrition’s Effect on Body Composition

As stated previously, nutrition is a major factor that impacts BC. Positive energy balance, when combined with resistance exercise, will increase anabolic activities and help stimulate the synthesis of LBM (Garthe et al., 2013). However, too much energy intake can lead to an increase in BF, which is undesirable for athletes, therefore nutrition protocols need to be carefully planned (Garthe et al., 2013) Out of all the macronutrients, protein has been shown to be the most influential macronutrients on LBM. Various studies have found that high-protein intake leads to increase MPS and protein turnover and decreases the loss of muscle mass when in a caloric deficit. One study found that consuming high quality protein had significant increase in the cross-sectional area of Type I and II muscles fibers, compared to consuming the same caloric amount of carbohydrate (Ralf Jäger et al., 2017). MPS is heightened 100-150% above basal rates, post exercise (Churchward-Venne et al., 2012), therefore consuming adequate amounts of high quality protein immediate post exercise will maximize MPS and help with favorable changes to LBM. In terms of weight loss, athletes that consumed 1.6 and 2.7 g/kg/day, lost significant amount of weight with over 64% of the weight being from FM compared to when eating the RDA of protein (Ralf Jäger et al., 2017), allowing for the preservation of LBM. Unlike protein, the research in the role of carbohydrate on LBM is more unclear. Consuming carbohydrate along with protein increases muscle hypertrophy compared to carbohydrate alone or different protein quality sources post exercise. Ample carbohydrate intake for an athlete will allow for adequate resynthesis of muscle glycogen and help maintain muscle mass while also support growth of muscle (Dunford et al., 2021).

2.2.5 Body Composition and Performance in Basketball

Optimal BC variables differ based on sex, sports (type), and even within-sport positions (Fields et al., 2018). Basketball is an intermittent high intensity sport, with considerable physical load (Stojanović et al., 2018). The demands of the sport require players to possess increased power and strength to optimize vertical and standing jumps. It also requires players to demonstrate increased agility, change of direction and endurance due to the anaerobic and aerobic components of the game (*NSCA's Guide to Tests and Assessments* 2012).

Ribeiro et al. (2015) found a negative correlation between power and %BF and a positive correlation between power and %FFM. Other studies have also reported similar results, with a negative relationship between BF and performance, specifically change of direction, vertical and standing jumps (Norgan, 1997; Spiteri et al., 2015). The effect of BC variables on different performance outcomes can be seen in *Table 2.*

Table 2. The Effect of Different Body Composition Variables on Performance Outcomes

	Increase LBM	**High %BF**
Standing Jumps	↑	↓
Vertical Jumps	↑	↓
Power	↑	↓
Change of Speed	↑	↓

Periodization is a widely knowledge tool that uses cycles to help drive physical and metabolic improvements to optimize performance. This allows for the athlete to be able to capitalize on the preceding phases to increase intensity, load, and higher work capacity (Phillips et al., 2016). For basketball specifically, preseason is used to increase aerobic capacity as well as target resistance training to transfer the strength and power gained during off season into motion used during the game. Players will undertake both resistance training and higher volume basketball activities to help with sport-specific development during this period, aiming to gain and preserve muscle gained during off season (Higgins & Thom, 2019). With the use of periodization to help improve performance, consistent measurements throughout the seasons are helpful to determine if effective changes are being implemented.

Limited studies have investigated the seasonal body composition changes in collegiate basketball players. The results from studies previously conducted have been inconsistent. Fields et al (2018) conducted a study to assess the seasonal and longitudinal changes in NCAA DI basketball players. Results showed no significant changes to BC variables occurred over the season, which is similar to the results of a previous study (Hoffman JR, 1991). Contrary to those results, one study involving collegiate male basketball players reported a 1.6 kg increase in FFM and a 2.3 kg decrease in FM from pre-season to post-season (Siders et al., 1991). Comparable to the findings of Sider et al (1991), Stanforth et al (2014) and Carbuhn et al (2010) saw significant changes of BF between pre- and post- season in college female basketball players. The inconsistency of results, combined with the limited number of studies with collegiate male basketball players, underline a need for further research aiming to delineate how optimal BC changes may be achieved.

2.3 Metabolism

An important aspect of optimizing performance and obtaining BC goals is to assess if nutrient recommendations are meeting needs, and if they are not, to adjust accordingly. Resting metabolic rate (RMR) and respiratory quotient (RQ) are two measurements that can be used to make recommendations for athletes and help reassess if athletes are consuming enough energy and if their recommendations need modification.

2.3.1 Resting Metabolic Rate

Total energy expenditure (TEE) is the number of calories that a person utilizes in a day adjusted to the amount of activity performed (Dunford et al., 2021). TEE is comprised of RMR, physical activity and the thermic effect of food (TEF), where RMR accounts 60-80% of TEE (Shook et al., 2016). RMR, also known as resting energy expenditure (REE), is the amount of energy required by the body to maintain a nonactive yet alert state (Dunford et al., 2021).

2.3.1.1 Influences on Resting Metabolic Rate

There are a variety of factors that can influence a person's RMR including: sex, age, genetics, body size, body composition and environmental factors (Dunford et al., 2021). Sex, age, and genetics are three involuntary factors that affect RMR. Regarding sex, one study found that the RMR in males was 23% higher compared to that of females, and was still significantly higher when BC variables were controlled for (Arciero et al., 1993). However, recent research has found that sex might have less of an effect on RMR when evaluating athletes (Jagim et al., 2019). Unlike sex, aging results in a 1-2% decline in RMR in everyone (Dunford et al., 2021). Some have thought that this is in relation to the 1-2% decrease in FFM mass per decade, however, studies have found that increasing in age has been significantly associated with lower RMR, when FM and FFM are controlled for (St-Onge & Gallagher, 2010).

Unlike sex, age and genetics, BC is a factor under some voluntary control that impacts RMR. BC and amount of FFM has been proven to be one of the biggest influences on RMR (Dunford et al., 2021; Johnstone et al., 2005; Sparti et al., 1997). FFM is more metabolically active compared to FM (Gallagher et al., 1996), therefore increased proportion of FFM to BM will lead to an increase RMR compared to increased proportion of FM. Johnstone et al (2013) found that 63% of variance in RMR was explained by FFM, while 6% of variance was explained by FM. Meanwhile, results reported by Sparti et al (1997) indicated that FM and FFM were shown to account for 83% of the variability for RMR.

Temporary effect to RMR include different environmental factors such as temperature and altitude. Many studies have noted substantial differences in the RMR of people living in various environments, with those in colder places having increased RMR (Leonard, 2012). Not only does temperature effect RMR but changes in RMR have been associated with altitude. Athletes that trained in altitude for 4 weeks saw an increase in RMR compared to baseline, indicating higher altitude will increase energy need of athletes (Woods et al., 2017).

2.3.2 Respiratory Quotient

RQ is a useful measurement that will determine the type of substrate that is being used as a fuel source. Understanding the fuel source being used at rest can determine if a person is consuming enough calories to meet their energy needs. RQ is the amount of CO_2 produced divided by the amount of O_2 consumed, as shown *Figure 2.*

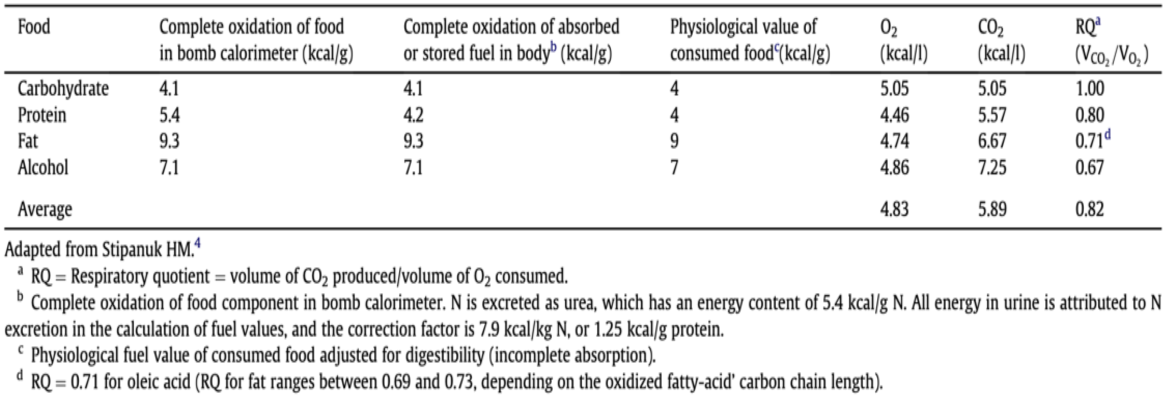
$$RQ = \frac{Volume\ of\ \mathrm{CO}_2\ produced}{Volume\ of\ O_2\ consumed}$$

Figure 2. Respiratory Quotient Equation

2.3.2.1 Substrate Utilization

The RQ value of carbohydrate and fat will differ due to the amount of O_2 consumed and CO_2 that is produced, allowing us to indicate what fuel source is primarily being used. When carbohydrate is metabolized for energy, it will undergo a series of processes that require O_2. For every molecule of glucose, 6 atoms of O_2 will be required. Glucose will undergo glycolysis a series of reactions to form pyruvate and will release 1 CO_2 molecule. Pyruvate will then enter the Krebs cycle and electron transport chain to generate two more CO_2 molecules, therefore a total of 3 CO_2 molecules will be released for every molecule of pyruvate. The result of the series of reactions for one glucose molecule will result in 6 molecules of CO_2, 6 molecules of water and energy (Melzer, 2011). The RQ for pure carbohydrate metabolism is 1. Unlike carbohydrate, fats will undergo beta-oxidation before being metabolized for energy. Part of the beta oxidation will lead to the formation of acetyl-coA therefore reducing the amount of CO_2 molecules that will be used. For example, palmitate will require 23 O_2 atoms and will only produce 16 CO_2 molecules, therefore causing the RQ to be 0.7 (Melzer, 2011). *Table 3*. indicates the amount of O_2 and CO_2 associated for each substrate of food and their resulting RQ value.

Table 3. Substrate Utilization at Rest from Melzer (2011)



Food	Complete oxidation of food in bomb calorimeter (kcal/g)	Complete oxidation of absorbed or stored fuel in body[b] (kcal/g)	Physiological value of consumed food[c](kcal/g)	O_2 (kcal/l)	CO_2 (kcal/l)	RQ[a] (V_{CO_2}/V_{O_2})
Carbohydrate	4.1	4.1	4	5.05	5.05	1.00
Protein	5.4	4.2	4	4.46	5.57	0.80
Fat	9.3	9.3	9	4.74	6.67	0.71[d]
Alcohol	7.1	7.1	7	4.86	7.25	0.67
Average				4.83	5.89	0.82

Adapted from Stipanuk HM.[4]

[a] RQ = Respiratory quotient = volume of CO_2 produced/volume of O_2 consumed.

[b] Complete oxidation of food component in bomb calorimeter. N is excreted as urea, which has an energy content of 5.4 kcal/g N. All energy in urine is attributed to N excretion in the calculation of fuel values, and the correction factor is 7.9 kcal/kg N, or 1.25 kcal/g protein.

[c] Physiological fuel value of consumed food adjusted for digestibility (incomplete absorption).

[d] RQ = 0.71 for oleic acid (RQ for fat ranges between 0.69 and 0.73, depending on the oxidized fatty-acid' carbon chain length).

2.3.2.2 Unusual RQ

Unusual RQ values outside of the 0.7 to 1.0 range can indicate if a person is under or over receiving calories compared to their needs. At rest, the primary fuel source should typically be stored fat, which can allow for the protection against BF accumulation (Shook et al., 2016). If the RQ values are below 0.7 or closer to 1.0, it provides insight into if a person is over or under the optimal caloric intake.

An RQ above 1.0 has been shown to indicate the overconsumption of foods for a person, while an RQ below 0.7 indicates undereating below nutrient needs. The overconsumption of energy will stimulate lipogenesis in the body. Increase RQ values have been associated with increase FM and gains in BM (Shook et al., 2016). On the other hand, receiving inadequate calories will cause the body to start breaking down proteins in the body to be used as a fuel source, resulting in the production of ketones. The breakdown of ketones as an energy source will utilize more O_2 thus resulting in an RQ value of below 0.7 (Chen & Stralovich-Romani, 2007).

2.3.3 Methodologies to Assess RMR and RQ

Assessment of RMR can be measured in various ways with the two most popular being via predictive equations and through indirect calorimetry. Predictive equations are more commonly and widely used to determine RMR. Various predictive equations occur such as: Mifflin St. Jeour, Harris and Benedict, FAO/WHO/UNU, and more (Frings-Meuthen et al., 2021), are used frequently yet they are all based on minimally active people. The different BC of athletes and increased activity render these equations inadequate for estimating RMR in athletes (Frings-Meuthen et al., 2021). Research has shown that these predictive equations produce RMR values that are significantly different compared to actual RMR in master athletes with almost all predictive equations significantly underestimating needs (Frings-Meuthen et al., 2021).

Unlike predictive equations, indirect calorimetry is considered the gold standard for measuring RMR (De Lorenzo et al., 1999). Indirect calorimetry can determine the amount of energy expended through gas exchange, since there is a relationship between the amount of oxygen (O_2) consumed and carbon dioxide (CO_2) produced to the amount of energy consumed and heat produced (Dunford et al., 2021). There are various metabolic systems that can predict RMR, yet some have been shown to be less reliable in accurate measurements compared to other (Brehm et al., 2004). Metabolic carts can measure O_2 uptake by a breathing tube connected to a mouthpiece, face mask or ventilated hood. Portable metabolic systems have been created but limitations exist, such as not measuring O_2 consumed or CO_2 expired, and studies have shown the portable devices to be less accurate when compared to the metabolic cart (Brehm et al., 2004). Another advantage to the metabolic cart is that it can measure simultaneously RMR and provide the RQ of an athlete, allowing for the insight of the needs of an athlete and show if those needs are being met.

2.3.4 Usefulness of RMR and RQ for athletes

With the importance of RMR and RQ in helping in assessment, no previous research has been found investing RMR and RQ values in basketball players throughout the season. Obtaining an athlete's RMR allows for a more accurate understanding of their energy needs and helps tailor nutrition recommendations to provide adequate energy to help meet their goals. Assessments of RMR throughout the seasons are helpful in tweaking recommendations to best support the athlete as changes occur to player's BC and physical activity levels. Meanwhile, measuring RQ provides insight on if the players receive adequate energy. As previously stated in the dietary intake portion of the background, inadequate energy needs can have detrimental effects to performance, therefore this assessment can help athlete's understand changes that need to be made to their diet to optimize performance.

Chapter 3

METHODS

3.1 Participants

All members of the men's basketball team (n=17) voluntarily chose to participate, however, four were excluded due to season-long injuries resulting in 13 players completing the study. Baseline characteristics of participants are found in Table 1. Inclusion criteria consisted of completing three DXA scans and metabolism measurements done throughout the season (Sept., Dec., and March), 3-day food records and 24-hour recall. Players were also required to sign a Consent Form for Sports Nutrition Projects and Release Form for DXA scans. All participants were informed of the procedures, benefits, and risk of participating in the study and provided written informed consent prior to enrollment. All participants were made aware that they could cease their participation at any time. The study was reviewed and approved by the Institutional Review Board for Human Subjects Research of California Polytechnic State University San Luis Obispo.

Table 4. Baseline Characteristics of the Players

Number of players	13
Age	20.45 ± 1.20
Height (cm)	189.86 ± 7.55
Weight (kg)	91.33 ± 11.62

n=13; values are presented in mean ± SD

3.2 Study Design

During the basketball preseason (September/October), baseline measurements were taken. Baseline measurements consisted of anthropometrics (height, weight), BC (LBM and %BF), metabolic measurements (RMR and RQ), and dietary analyses. Nutrition consultations were done with each player in October. Reassessment of BC and metabolic measurements were performed in December and follow up analyses of dietary intake were performed in February. Final assessments of BC and metabolism were performed post season in March. Figure 3 displays the study design.

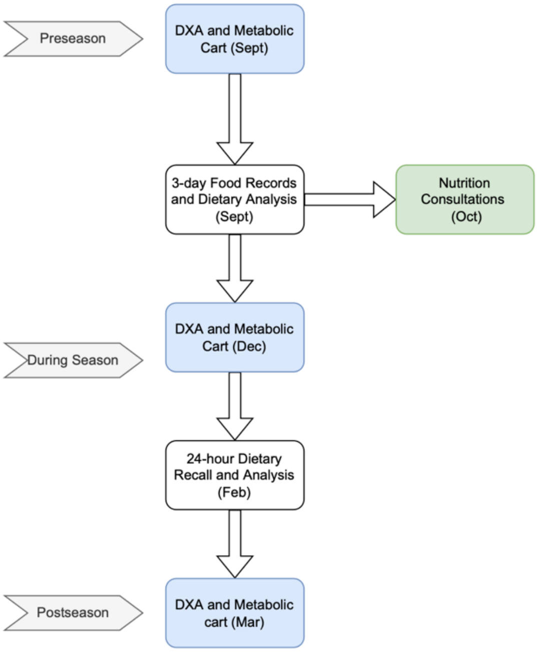


Figure 3: Study Design

3.3 Project Components

3.3.1 Dietary Intake

Dietary intake was assessed two times throughout the study. In September, participants were asked to fill out a 3-day food record (2 weekdays and 1 weekend day) to obtain baseline dietary intake details. Dietary intakes were recorded within two weeks of when the first body composition and metabolic measurements were obtained. A meeting was held with the participants to describe the proper way to fill out the food record to improve accuracy of the diet records. The information from the food records were analyzed by Food Processor III Nutrition Software version 8.6 (ESHA Nutrition Research, Salem, OR, USA). Personalized recommendations for each player were derived and were based on Dietary Reference Intakes (DRIs) created by the National Academies of Science, Engineering and Medicine, previously known as the Institute of Medicine and National Academy of Sciences. Each participant height, weight, age, sex, and activity level were considered when calculating the recommendation. Nutrition consultations with participants were given to discuss their dietary intake and how it compared to nutrition recommendations for optimal health and performance and body composition goals. During this session, three personalized ideal diets were given to participants based on their food preferences and recommendations. In February, participants were asked to fill out a 24-hour recall to assess if their dietary intake had changed since September. Another nutrition consultation was done with participants in February to discuss the findings from their 24-hour recall compared to recommendations and baseline intake.

3.3.2 Body Composition

Participants reported to the Nutrition and Health Assessment Lab in the Food Science and Nutrition Department of California Polytechnic State University San Luis Obispo for BC measurements in the morning. BC measurements were taken using Dual Energy X-ray absorptiometry (DXA) on a Lunar iDXA (GE

Healthcare, Madison, WI, USA). Each measurement was performed by the same technician. All procedures were done according to GE Lunar specifications and were analyzed with enCORE software (version 11.0; GE Healthcare). The morning of each testing day, the iDXA was calibrated to verify proper function. Participants were instructed to fast for 10-12 hours before each scan was taken and were asked to wear light clothing. Height and body weight were taken without shoes on using a wall stadiometer and physician scale prior to each scan.

3.3.3 Metabolism

The metabolism measurements of each participant were completed at the Nutrition and Health Assessment Lab in the Food Science and Nutrition Department of California Polytechnic State University San Luis Obispo. Indirect calorimetry was used to determine each participant’s RMR and RQ. Each morning of testing, the metabolic cart (True One 2400- Metabolic Measurement System, ParvoMedics Inc., Sandy, UT, USA) was calibrated according to the manufacture specifications. The testing was done on the same morning as the DXA scans for each participant, after a 10-12 hour fast. A canopy system (clear hard plastic breathing hood with drape) was placed over the participant’s head and upper body for measurements. Participants underwent testing on the metabolic cart for 25 minutes. The mean oxygen uptake and carbon dioxide output for each breath was measured and the average was taken for every 15 second interval. Data from the last fifteen minutes of each session were used to calculate the RMR and RQ values.

3.4 Statistical Analysis

JMP® Version 16.1 (SAS Institute Inc., Cary, NC, 1989-2021) was used for statistical analysis. To test for significance between 3-day dietary intake, 24-hour dietary intake and recommended intake of energy and macronutrients, paired t-tests were used. To assess seasonal changes in body composition and metabolism measurements, a repeated measures analysis of variance (ANOVA) was used with time being the repeated measure. If significance was found for time, Tukey's HSD post hoc analysis was done. Results were considered significant at $p \leq 0.05$.

Chapter 4

RESULTS

4.1 Dietary Intake

The age-, sex- and activity-specific DRI recommendations for calories were an average of 4141.48 ± 337.4 kcal for this group. Three athletes were recommended 500 kcal less than DRI recommendations due to goals of losing weight, therefore our average recommendations while including weight loss goals were 4098.53 ± 214.78 calories. Averages of dietary intake and recommendations for macronutrients can be Figure 4-7 and 8-11.For the figures, * denotes statistical significance between dietary intake and recommended intake. † denotes statistical significance between baseline intake and follow-up intake.

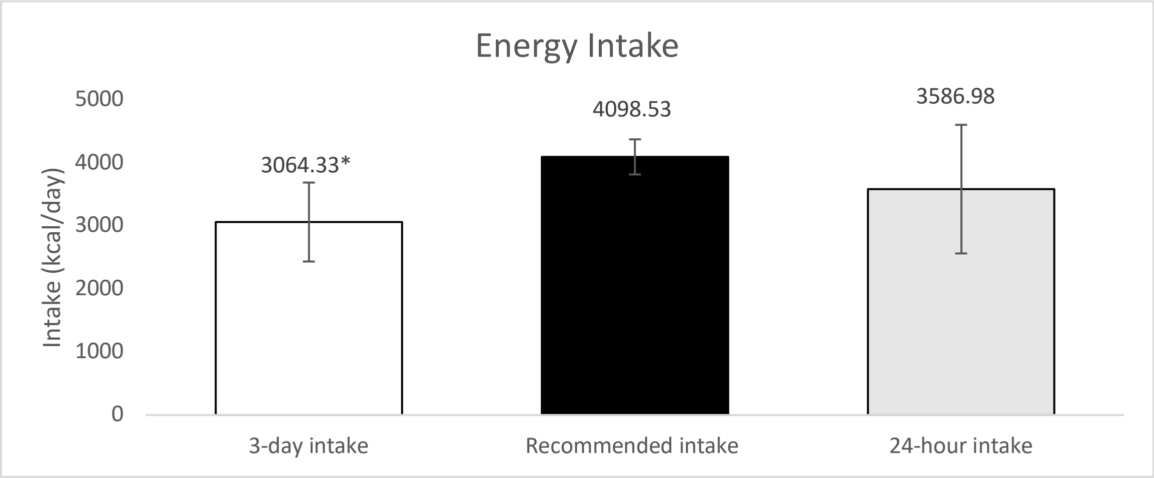


Figure 4: Baseline, Follow-up, and Recommended Intake of Energy in kcal/day

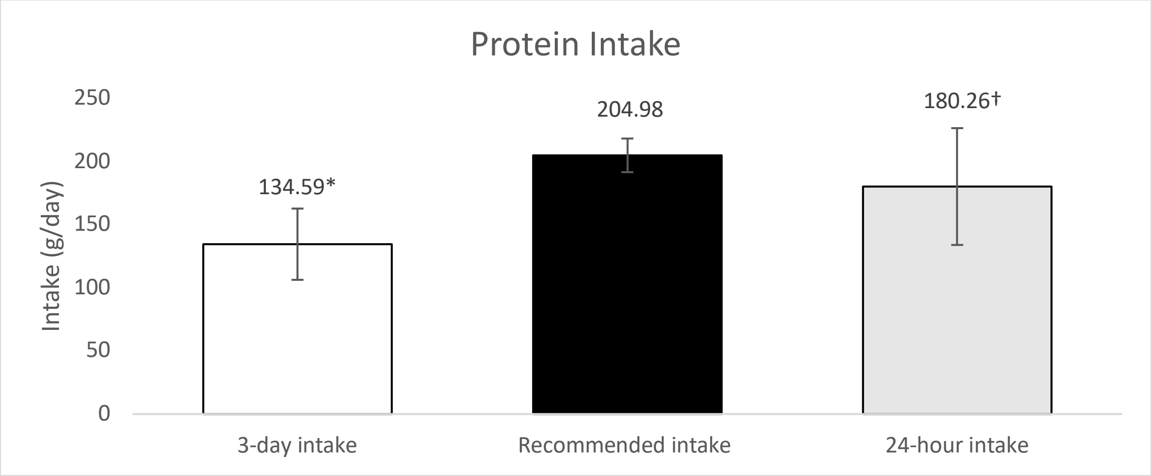


Figure 5: Baseline, Follow-up, and Recommended Intake of Protein in g/day

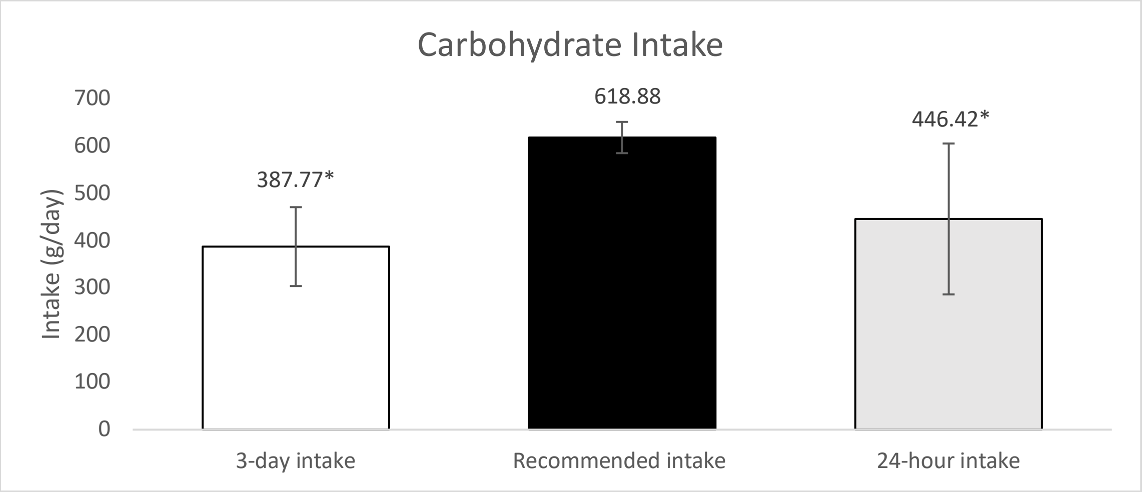


Figure 6: Baseline, Follow-up, and Recommended Intake of Carbohydrate in g/day

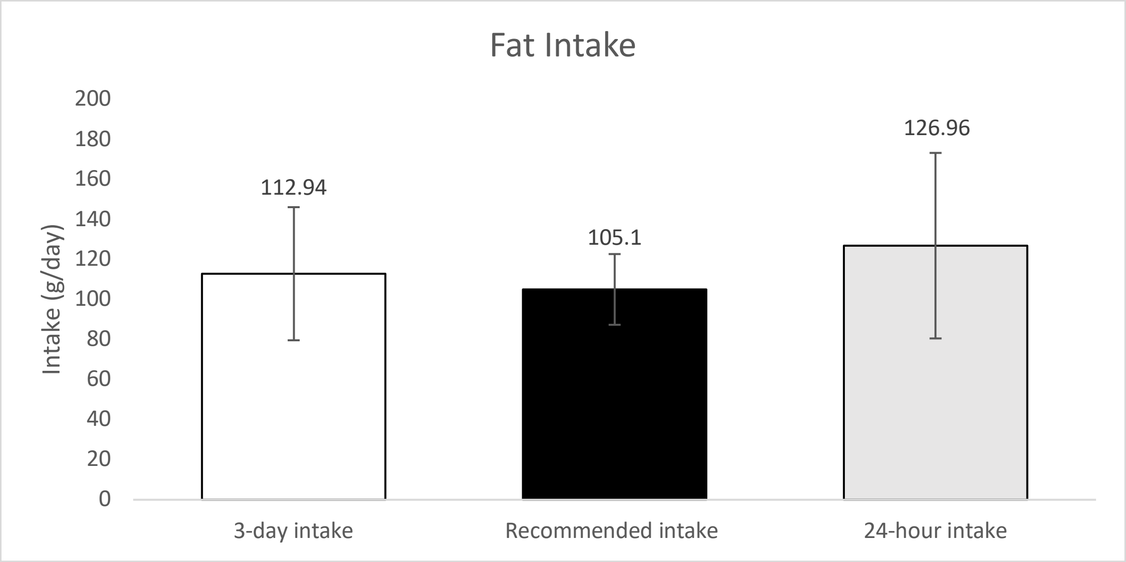


Figure 7: Baseline, Follow-up, and Recommended Intake of Fat in g/day

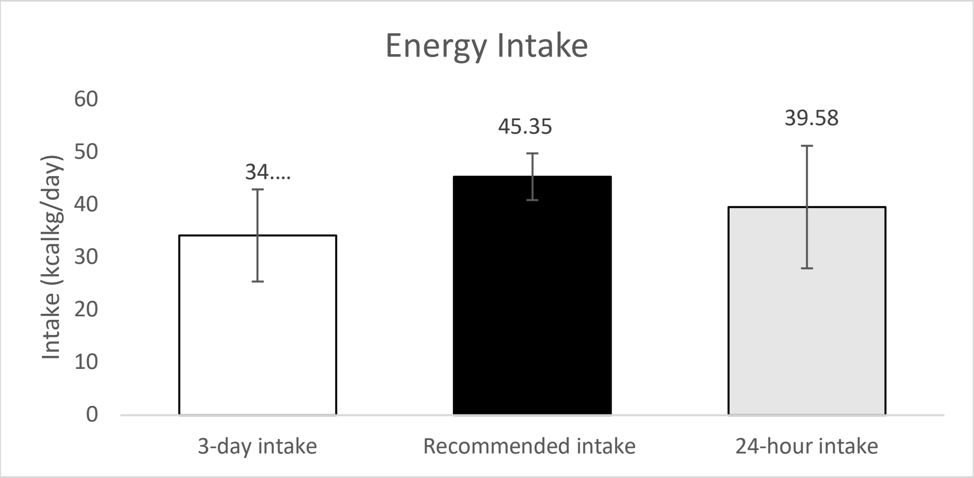


Figure 8: Baseline, Follow-up, and Recommended Intake of Energy in kcal/kg/day

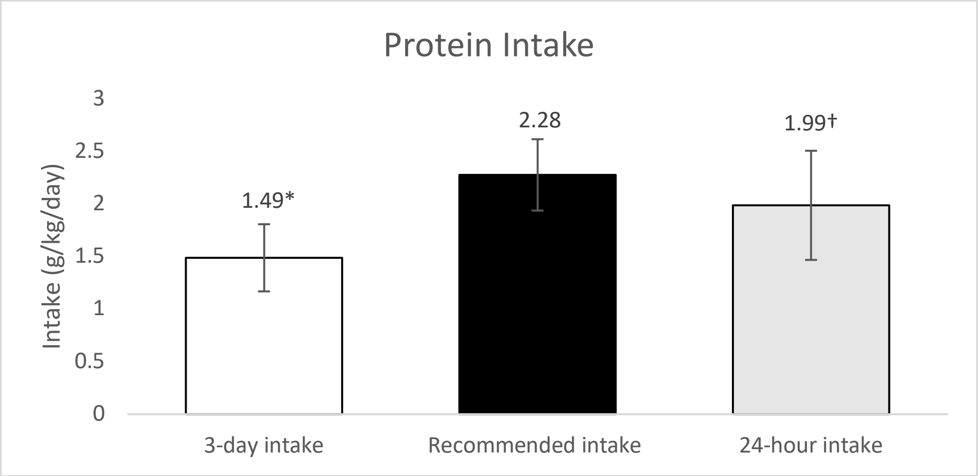


Figure 9: Baseline, Follow-up, and Recommended Intake of Protein in g/kg/day

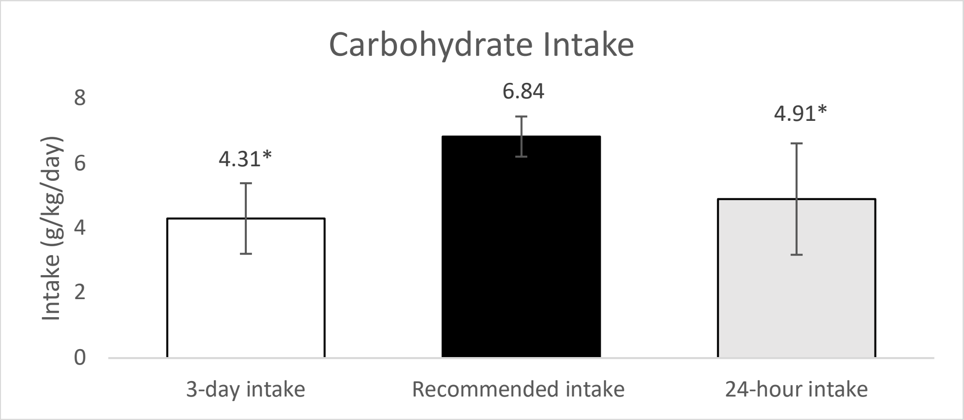


Figure 10: Baseline, Follow-up, and Recommended Intake of Carbohydrate in g/kg/day

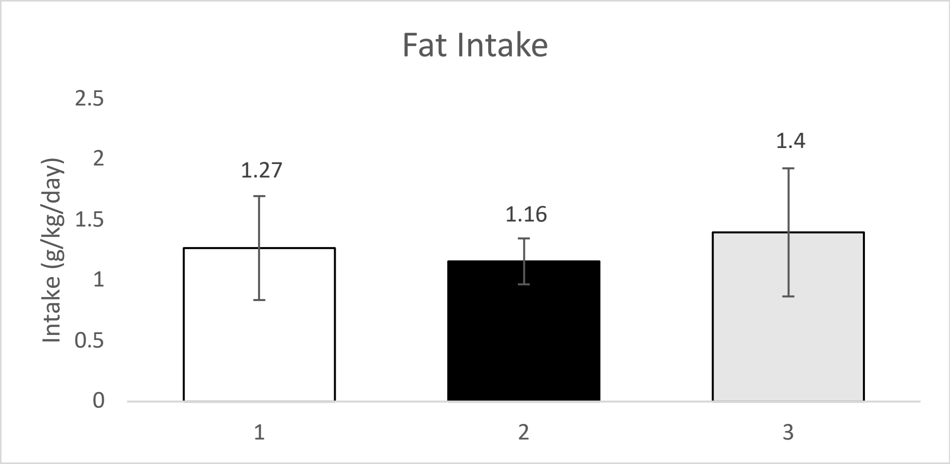


Figure 11: Baseline, Follow-up, and Recommended Intake of Fat in g/kg/day

Mean dietary intake at baseline [3064.33 ± 621.20 kcal] was significantly lower than the mean recommended intake [4098.53 ± 214.78 kcal; $p<0.0001$]. Follow up intake showed an increase in calories consumed [3586.98 ± 1043.77 kcal], which was insignificantly different compared to the recommended intake ($p=0.0999$). Players consumed more calories during the time following the initial assessment as indicated by the follow up analysis near the end of the season ($p=0.1364$).

Baseline dietary protein intake [134.58 ± 28.23 g] was significantly lower than the intake recommended [204.98 ± 13.33 g; $p<0.0001$] for athletes. An increase in protein consumption occurred during the follow up intake [180.26 ± 46.27 g]. Post initial analysis and consultation to a level that was not significantly different than recommended ($p=0.0947$). The difference in protein consumption between baseline and follow-up was significant ($p=0.0021$).

Dietary carbohydrate intake during baseline [387.77 ± 83.60 g] was significantly lower than recommended intake [618.88 ± 33.12 g; $p< .0001$] for athletes. Although there was an increase in intake of carbohydrate during the follow up period [446.42 ± 159.79 g], intake was still significantly lower than recommended (p=0.0025). The consumption of carbohydrate in the follow up did exhibit a significant increase when compared to baseline carbohydrate intake (p= 0.1990).

Dietary fat intake at baseline [112.94 ± 33.26 g] was slightly higher but not statistically different than recommended intake [105.1 ± 17.67 g; p=0.4556]. An increase of dietary fat occurred during the follow up [126.96 ± 46.35 g], which was insignificantly higher than recommended intake (p=0.0834). The difference between baseline and follow up fat intake were not statistically different (p=0.4090).

The frequency of meal consumption per day at baseline [3.86 ± 1.01 times per day] were significantly under the recommended amount [6 times per day; p<0.001] for athletes. The follow up showed a significant increase in the number of meals that the players ate [5.15 ± 1.14 times eaten per day; p=0.0008].

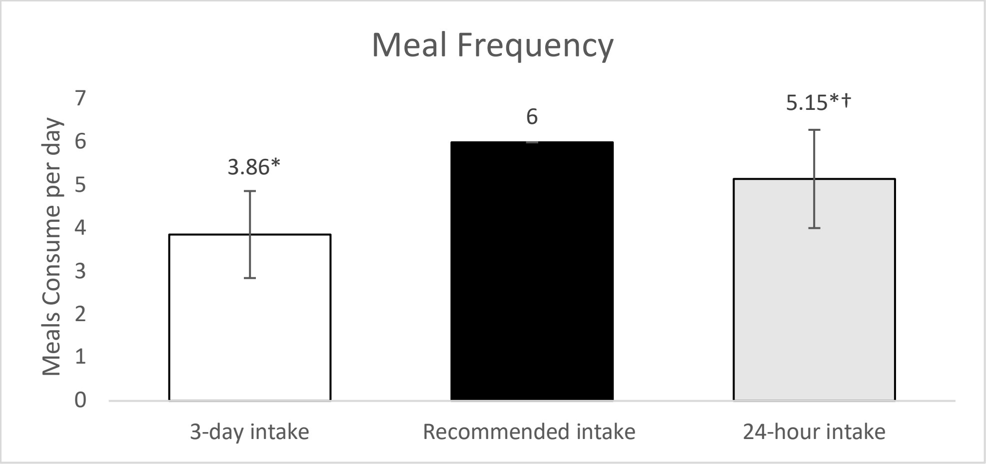


Figure 12. Baseline, Follow-up and Recommended Meal Frequency in Meals Eaten per Day

4.2 Body Composition

DXA scans were performed at three time points. Table 4 presents the body composition data before, during and post season.

Table 5. Body Composition Changes Throughout the Season

Measure	Pre-season	In-season	Post-season
Weight (kg)	91.33 ± 11.62^{a}	91.18 ± 10.53^{a}	91.46 ± 10.77^{a}
Lean Body Mass (kg)	74.63 ± 8.87^{a}	75.53 ± 8.59^{a,b}	75.75 ± 9.26^{b}
% BF	13.48 ± 3.60^{a}	12.39 ± 3.60^{b}	12.46 ± 3.54^{b}

Values are presented in mean ± standard deviation; different letters superscript denote statistical significance. Significance valued at $p \leq 0.05$

No significant changes were seen between season phases in player's weight (p=0.899). %BF and LBM changes were significant throughout the season (p=0.0018; p=0.0436). Following pre-season, a decrease in %BF was observed and remained constant through post-season [mean difference; 95% CI: 1.092; 0.24, 1.84]. LBM increased significantly at post-season compared to pre-season [mean difference, 95%CI: -1.127; -2.24, -0.01]. There was not a significant difference found in LBM between in-season and the other two time points.

4.3 Metabolism

Each athlete's metabolism was assessed at three time points that were the same as the DXA scans. Table 5 presents the metabolism data, RMR and RQ.

Table 6. Metabolism Changes Throughout the Season

Measure	Pre-season	In-season	Post-season
RMR (kcal/day)	2329.93± 232.85^{a}	2491.01± 215.15^{b}	2368.95 ± 264.13^{a}
RQ	0.696 ± 0.04^{a}	0.676 ± 0.03^{a}	0.763 ± 0.06^{b}

Values are presented in mean ± standard deviation; different letters superscript denote statistical significance. Significance valued at $p \leq 0.05$

There were significant differences in the RMR between the seasons (p=0.0069). The RMR was significantly higher in-season compared to pre-season [mean, difference, 95% CI: 161.08; 41.63,280.52] and post-season [mean difference, 95% CI: 122.06; 2.62,241.5]. The post-season RQ was significantly different as compared to the other timepoints. [p<0.001; mean difference, 95% CI: 0.067, 0.027, 0.11].

Chapter 5

DISCUSSION

To the best of our knowledge, no previous research has investigated both seasonal changes in body composition and metabolism variables, as well as the dietary intake, in NCAA Division I male basketball players within the same study. Therefore, the purpose of this study was examining these factors to provide helpful insight for athletes, coaches, and trainers of this popular collegiate sport. Three major findings were reported: (1) male basketball players' energy, protein, and carbohydrate intake were significantly lower compared to recommended values prior to dietary analyses and consultations. During the follow up intake, players consumed adequate energy and protein, yet carbohydrate intake was still significantly lower and fat intake became significantly higher than recommended. (2) Body composition changes included a %BF significant decrease by the in-season timepoint, and LBM being highest at the post-season timepoint. (3) RMR was significantly elevated at the in-season timepoint and the RQ was highest at the post-season timepoint.

5.1 Dietary Intake

The average intake at baseline was assessed to be 34.18 ± 8.76 kcal/kg of body weight, which was significantly lower than the recommended intake of 45.35 ± 4.44 kcal/kg of body weight. The follow up dietary intake assessment during the season indicated that players consumed 39.58 ± 11.65 kcal/ kg of body weight, which was more than at baseline, which aligned with the result of previous studies (Nepocatych et al., 2017; Zanders et al., 2021). One study assessed the dietary intake of collegiate female basketball players (n=10) throughout the season found that the players were not consuming as much energy during pre-season (1925 ± 466 kcal/day) but their intake increased significantly at the end of season (2326 ± 782 kcal/day) (Nepocatych et al., 2017).

In this current study, players consumed 1.49 ± 0.32 g/ kg of body weight of protein during baseline was significantly lower than the recommended amounts of 2.28 ± 0.34 g/ kg of body weight. The recommended intake of this study is above the recommended intake of 1.5-2.0 g/kg for strength athletes (Tarnopolsky et al., 1992) due to the increase in protein recommendations for those who were in a caloric deficit of 500 calories a day than their needs to help preserve lean body mass (Mettler et al., 2010). Multiple studies involving basketball players have shown that players tend to consume adequate amounts of protein within the recommended ranges of 1.2-2.0g/kg when assessed by dietary records (Schroder, 2004; Short & Short, 1983). As seen in our study, the increase intake of protein and calories during the follow-up assessment may support the increase in LBM changes due to sufficient number of amino acids being consumed to help stimulate MPS (Margolis et al., 2016; Pasiakos et al., 2010).

This study also found that carbohydrate intake at baseline was significantly lower than the recommendation and was still significantly lower at the dietary intake follow up assessment. During baseline, players in this study consumed 4.31 ± 1.09 g/kg of body weight. A study looking at the dietary habit of elite Spanish basketball players (n=55) showed that carbohydrate consumption was 4.6 ± 1.7 g/kg body weight (Schroder, 2004), similar to the findings of our study. Other studies have also found carbohydrate intake to be similar and therefore in agreement with our findings (Nowak et al., 1988; Zanders et al., 2021). Chronic low carbohydrate intake below the recommendations of 6-10 g/kg of body weight for endurance athletes may result in the basketball players having inadequate glycogen stores before performance, which in turn may decrease performance and time to fatigue (Kerksick et al., 2017).

Unlike the previously discussed macronutrients, fat intake was not significantly different at baseline compared to recommendations and increased, but not significantly, during the follow up. The follow up intake was more than the recommended intake, although insignificantly different. Follow up intake was 1.40 ± 0.53 g/kg of body weight, which is 120% the recommended intake of 1.16 ± 0.19 g/kg of body weight. Findings from other studies have also shown that fat intake tends to be significantly higher than recommended (Schroder, 2004; Short & Short, 1983) . For example, Short and Short (1983) found that average fat intake of collegiate male basketball players (n=8-17) ranged from 196 to 254 g over the course of 4 years (Short & Short, 1983). The demands of balancing training and school schedules can cause college athletes to gravitate towards readily available foods higher in fat (Long et al., 2011) and this may at least partially explain our data.

In the present study, the average meal frequency at baseline was 3.86 ± 1.01 times per day, and this seems to be consistent with a few previous studies.

One study involving female college athletes found similar results to our study where the mean dietary intake as they reported 3.8 ± 0.9 meals per day at baseline (Zanders et al., 2021). Another study involving elite basketball players, showed that 66% of the players did not consume at least 3 meals a day (Eugene & Agwubuike, 2012). Findings from our study indicated that during the follow up assessment of meal frequencies demonstrated that frequency had significantly increased to 5.15 ± 1.14 times eaten per day, yet this was still significantly less than recommended. Inconsistent intake of nutrients throughout the day can decrease the players' ability to adhere to nutrient timing, which can have consequences on a player's performance and recovery. (Kerksick et al., 2017)

5.2 Body Composition

The findings from our study indicated that %BF and LBM were significantly altered through the season. %BF was higher during pre-season and decreased significantly during in-season and remained decreased for post- season. Significant seasonal %BF changes among basketball players are inconsistent among previous studies. One study examined BC changes in collegiate male basketball player (n=19) found that the BF significantly decreased by 2.3 kg from pre-season to post-season. Other studies had similar findings to our study, where there was a decrease in FM and %BF when comparing pre-season to post-season measurements (Carbuhn et al., 2010; Johnson et al., 1982; Siders et al., 1991; Sinnging, 2013; Stanforth et al., 2014). On the contrary, there were two studies in male basketball players whose findings showed no significant changes to %BF throughout the season (Fields et al., 2018; Hoffman JR, 1991). Lower

%BF during the season is favored as it has been shown to improve performance, allowing for an increase in vertical and standing long jump, when paired with increases in LBM (SP, 2021).

Our study also found that LBM was increased significantly from pre-season to post-season, which is similar to the findings of some other studies (Johnson et al., 1982; Siders et al., 1991; Sinnging, 2013). Aligning with the findings from our study, the same study that found a decrease in FM in collegiate male basketball players also found that there was a significant increase of 1.6 kg in FFM from pre-season to post-season (Siders et al., 1991). Unlike the findings from our study, Fields et al (2018) reportedly found no changes to the LBM of collegiate male basketball players throughout the season (n=16) (Fields et al., 2018). The studies that did not align with our findings used other forms of measurement for BC (i.e., Skinfolds and air displacement plethysmography), which may explain the inconsistency in the results. Therefore, it is important to consider the method that was used to gather BC data when comparing values.

5.3 Metabolism

To the best of our knowledge, other studies have not examined RMR and RQ at pre-season and post-season in in collegiate male basketball players. In this current study, RMR was significantly increased at the in-season time point compared to pre- and post-season timepoints. A study involving male elite rugby player (n=22) found that RMR has been seen to be increased for three days after a game compared to the day before the game yet RMR did not change after training days (Hudson et al., 2020). The result of that study may potentially serve as an explanation as why there was an increase in RMR during in-season compared to pre- and post-season in our study.

Regarding the RQ data, there was a significant increase from in-season to post-season. While in pre-season and in-season, players had an RQ value of less than 0.7, which is an indication that players were undereating (McClave et al., 2003). The increase in RQ post season was an indication that the players were consuming adequate amounts of calories to meet their needs, which could serve as an explanation as to why there was an increase in LBM over the season.

5.4 Strengths and Limitations and Future Directions

This study may be the first of its kind to investigate seasonal BC and metabolism changes in NCAA DI male basketball players, while also assessing their dietary intake adequacy. This study used DXA and the metabolic cart, which many consider to be the gold standard for their respective measurements (Scafoglieri & Clarys, 2018). Perhaps a limitation of this study was the small sample size of only 15 players. Because of the size limitation, it is difficult to derive general conclusions. Another limitation of this study may be the inconsistency in methods of dietary intake assessments, the 24-hour food log during the follow up period only gives a glimpse of one day of intake where the 3-day food record that was used for baseline collection is an average of various days throughout the week. The variances in the 24-hour food logs are greater when compared to the 3-day food records tend. (Crawford et al., 1994). In the future, using a 3-day food records at several time points may provide more comprehensive information regarding food intake.

Chapter 6

CONCLUSIONS

In conclusion, we found that NCAA DI male basketball players appeared to consume significantly less than optimal amounts of food compared to recommended amounts early in the season, which may lead to negative consequences both to their performance and BC. The changes to dietary intake should be monitored in the athletes to make sure adequate amounts of energy and macronutrients are being consumed to optimize BC and performance. Regular BC and metabolism measurements should be done, as well as the assessment of dietary intake, to ensure proper dietary recommendations are being given to the athletes to meet their needs and goals. Because this study is the first address the dietary, body composition and metabolism changes in NCAA DI male basketball players future research needs to be done to fully understand the demands and effects of the season and how dietary strategies may promote positive effects.

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Appendix A

Food Record Instructions

In order for your diet analysis to be accurate, you must do the best job possible of accurately writing down what you eat.

- **<u>We also encourage you to take pictures of meals and labels</u>** because this can help our accuracy. Just email us the photos with info regarding when it was eaten.
- **<u>Questions - Ask Dr. Reaves by text 805-215-9273 or sreaves@calpoly.edu</u>**

Instructions for the Food Record:

1. You will be recording everything you eat for three days. You will record **two weekdays** and **one weekend day**.

Tips for recording accurately:

1. Record each individual food item plus any supplements you take. For example, if you ate oatmeal, fruit and coffee for breakfast, the meal would be represented as shown below:

Time of Day	Portion Size (amount)	Food Description including location/brand	Preparation Method
7:00 am Breakfast (B)	½ cup dry	Quaker Oats, old fashioned, dry	As instructed
B	2 teaspoons	Smart Balance light buttery spread with flax	
B	1 large	egg	scrambled
B	1 cup	Lactaid milk, 1%	
B	1 tablespoon	Brown sugar	
B	½ cup	Blueberries, fresh	
B	1 cup	Brewed drip coffee	As instructed
B	1 tablespoon	Land O'Lakes Nonfat half and half	
B	1 tablet	Men's One-A-Day vitamin and mineral supplement	

Please notice all details about the oatmeal including added foods (buttery spread, milk, brown sugar), brand names if applicable (Quaker, Smart Balance, Land-o-Lakes), descriptions of the food products ("light," "1%") and specific amounts ("2 teaspoons," "1/2 cup") are provided. Please be as specific as possible ("fresh," "frozen," "blanched," "fried," "steamed") so proper assessment of the *quality* of your diet can be evaluated.

2. If you don't know the exact portion, revert to the Food Portions Guide as a tool to estimate your portion size. Some examples are provided in the table below:

Time of Day	Portion Size (amount)	Food Description including location/brand	Preparation Method
8:00 pm Dinner (D)	**1 deck of cards** = 3 oz	Safeway Select Chicken breast, boneless skinless	Sautéed w/ canola oil and salt then finished in the oven
D	**1 ½ quarters** = ½ tablespoon	Canola oil	

D	¼ teaspoon	Salt	
D	**1 fist full** = 1 cup cooked	Brown rice, long-grain	As instructed

Remember to record the amount of **salt** you add when you cook. It is not necessary to add other spices and seasonings; we are more concerned with added salt, which contains the mineral sodium. Notice that preparation method details have also been included when appropriate.

Food Record Day #1

Name: _______________________ Date: ______________ Day: __________________

Time of Day	Portion Size (amount)	Food Description including location/brand	Preparation Method

Food Record Day #2

Name: ________________________________ Date: ______________ Day: __________________

Time of Day	Portion Size (amount)	Food Description including location/brand	Preparation Method

Food Record Day #3

Name: ____ Date: _______________ Day: ____________________

Time of Day	Portion Size (amount)	Food Description including location/brand	Preparation Method