Predicting Energy Availability in Recreational Athletes

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Abstract

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Predicting Energy Availability in Recreational Athletes

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The purpose of this investigation was to develop a prediction equation for energy availability in recreational athletes. Fifteen apparently healthy individuals (8 females, 7 males) participated in the 7-day data collection of dietary intake and energy expenditure. The first session included a maximal oxygen consumption (VO₂ max) test, completion of the Eating Disorder Examination Questionnaire (EDE-Q), and a body composition (BOD POD) measurement; the researcher also outlined the details of the research process. Results indicated that energy availability had a number of predictors that varied based on gender. Potential predictors for the entire group included: carbohydrate (g/kg) ($R^2 = 0.45$), fat mass ($R^2 = 0.73$), percent contribution of fat to the diet ($R^2 = 0.85$), exercise frequency ($R^2 = 0.97$), and skipping of lunch ($R^2 = 0.99$). Potential predictors for females included: body fat percentile ($R^2 = 0.90$), percentage contribution of alcohol in the diet ($R^2 = 0.987$), weight concern ($R^2 = 0.997$), and percentage contribution of carbohydrate to the diet ($R^2 = 0.999$). The potential predictor for males was carbohydrate (g/kg) ($R^2 = 0.44$).
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Chapter 1: Introduction

There are many physiological functions within the human body that require energy. Achievement of adequate energy availability is important for athletes in order to maximize performance while minimizing the potential destructive health effects associated with training. Two ways in which energy is typically calculated are energy balance and energy availability. Energy availability is typically used in athletes, as an output, to calculate the energy remaining to support physiological function following exercise. Energy availability is calculated as dietary intake minus exercise energy expenditure in units of kcal/kgFFM/day. Energy availability below a threshold of 30 kcal/kgFFM/day is associated with a myriad of health issues that may impair performance. Low energy availability is common in endurance athletes such as marathon runners, and other aerobically driven sports such as swimming (Loucks, 2007). Athletes may reduce energy availability either intentionally or unintentionally due to an attempt to improve body composition and performance, disordered eating, or a lack of a strong biological drive to match dietary intake with expenditure (Loucks, Kiens, & Wright, 2011).

The presence of low energy availability has been well documented in sport. Current research is now attempting to determine the cause and treatment of low energy availability in athletes. Some of the causes may include disordered eating, body dissatisfaction, inability to match intake with expenditure, and high carbohydrate diets (Nattiv, Loucks, Manore, Sungot-Borgen, & Warren, 2007; Loucks et al., 2011; Mountjoy et al., 2014).
Statement of Problem and Purpose of the Investigation

While previous research has established the prevalence of low energy availability, no research has sought to predict the development of low energy availability in recreational athletes. Thus, the purpose of this investigation is to develop a prediction equation for energy availability in recreational athletes. This would benefit both athletes and coaches since the procedure would be minimally invasive, include minimal personnel and equipment, be cost effective, and be easy to administer.

Hypothesis

The hypothesis for this investigation was:

Energy availability can be significantly predicted by the following factors: (a) exercise frequency; (b) meal skipping; (c) fat mass; (d) body fat percentile; (e) grams per kilogram of body weight of each macronutrient; (f) percentage of each macronutrient contribution of total diet; (g) percentage contribution of alcohol to total diet; (h) weight concern; (i) shape concern; (j) eating concern; (k) training status (VO2max); (l) body composition; (m) fat-free mass; (n) duration of training per week; and, (o) dietary restraint.

Assumptions

This investigation was limited by the following assumptions:

1. Test results depended upon the participants’ ability to follow all instructions given to them prior to inclusion into this study.

2. Test results were dependent on the participants’ ability to maintain typical dietary intake and exercise expenditure throughout the duration of this study.
3. A 7-day dietary record provided a valid analysis of actual intake.

4. Subjects recorded dietary information accurately and as instructed.

5. A 7-day exercise energy expenditure record provided a valid analysis of actual expenditure.

6. Subjects wore the exercise devices (accelerometer and heart rate monitor) correctly and as instructed.

7. Continuous heart rate monitoring was representative of energy expenditure.

8. Participants answered all questions and recorded all data to the best of their ability as confidentiality was ensured by the primary investigator.

**Delimitations**

The parameters of this investigation were delimited by the following factors:

1. Participants were apparently healthy volunteers between the ages of 18-44 years.

2. Participants were from rural Appalachian Ohio.

3. Participants completed an exercise questionnaire. Only those who participated in at least 150 min of aerobic activity per week for the past 6 months were included in this study.

4. Participants completed a health history questionnaire to determine their relative level of risk, according to the American College of Sports Medicine (Pescatello, 2014). Only those individuals who were considered to be at low risk for a cardiovascular event were included in this study.

5. Participants read and signed a consent form prior to participation.
Operational Definitions

**Accelerometer**: An instrument for measuring acceleration of a body in space, including vertical, horizontal, and diagonal movements.

**Air displacement plethysmography**: A method that utilizes pressure changes precipitated between the test chamber and reference chamber by a moving diaphragm mounted on the common wall between the chambers in order to assess body volume and body composition; BOD POD (brand name) operates via this method.

**Basal metabolic rate**: The amount of energy that a body requires to maintain function at rest.

**Body composition**: Body composition is referred to as the breakdown of the body’s components and for this investigation was limited to fat mass and lean muscle mass.

**Body mass index**: A weight-to-height ratio, often used as an indicator of obesity that is calculated by dividing an individual’s weight in kilograms by the square of his/her height in meters.

**Dietary restraint**: Restriction of dietary intake or avoidance of eating associated with an attempt to lose or maintain an ideal weight.

**Disordered eating**: A wide spectrum of potentially harmful and frequently ineffective weight management strategies including but not limited to: dietary restriction and binge eating.

**Drive for thinness**: Motivation to improve body composition based on individual belief that losing weight will help in achieving success.
**Eating concern**: Preoccupation with food or consuming calories, often associated with guilt and a fear of losing control over eating.

**Energy availability**: Dietary energy intake minus exercise energy expenditure in units of kcal/kgFFM/day.

**Energy balance**: Dietary energy intake minus total energy expenditure.

**Energy expenditure**: The amount of kilocalories expended during a given time period.

**Energy intake**: Total number of kilocalories ingested daily.

**Exercise energy expenditure**: The amount of kilocalories expended during planned activity.

**Fat free mass (FFM)**: The number of kilograms in a body that is not fat.

**Female athlete triad**: The interrelationship between low energy availability, menstrual dysfunction, and low bone mineral density in female athletes.

**Graded exercise test (GXT)**: A continuous incremental test that is designed to produce metabolic stress, resulting in oxygen consumption.

**Heart rate monitor**: A personal monitoring device that allows an individual to measure his/her heart rate in time.

**Kilocalorie (Kcal)**: The amount of energy needed to raise the temperature of 1 liter of water by 1 degree Celsius.

**Low energy availability**: An energy availability below 30 kcal/kg fat free mass/day.
Maximal oxygen consumption: Maximal oxygen consumption (VO$_2$max) is the maximum rate of oxygen consumed during a maximal graded exercise test.

Percent body fat: The percentage of body mass that is not composed of lean muscle, water, bones, or vital organs.

Recreational athlete: An individual who participates in exercise or sport in their spare time for enjoyment.

Relative energy deficiency in sport (RED-S): An expansion of the female athlete triad to include men and many aspects of physiological function that include but are not limited to metabolic rate, menstrual function, bone health, immunity, protein synthesis, cardiovascular and psychological health.

Resting metabolic rate (RMR): The energy needed for maintenance processes in the body.

Thermic effect of food (TEF): The amount of energy expenditure due to the cost of processing food.

Total energy expenditure (TEE): A combination of resting metabolic rate, energy expenditure, and the thermic effect of food.
Chapter 2: Review of Literature

Relationship of Energy to Exercise

The capacity at which individuals extract and utilize energy from food products is a determinant of their ability to perform physical activity (McArdle, Katch, & Katch, 2009). Energy is never created or destroyed and for that reason the total energy in an isolated system remains constant (McArdle et al., 2009). Energy is typically measured in terms of heat in units of kilojoules (kJ) but in the field of exercise physiology is measured in kilocalories (kcals) which is representative of kJ. Mechanical work is produced through muscle contraction and subsequent movements. The muscle fibers convert chemical energy, from food products, into mechanical energy to perform work and in the process some energy is “lost” as heat (McArdle et al., 2009). The upper limits of exercise depend on the rate at which the muscle fibers can extract, conserve, and transfer chemical energy in food products to the contractile components of skeletal muscle (McArdle et al., 2009). Ultimately, maximal exercise is dependent on the body’s capacity to convert chemical energy into mechanical work.

Energy Availability vs. Energy Balance

There are two ways in which energy is typically measured in humans: energy availability (EA) and energy balance (EB). EA and EB differ slightly both by definition and by the settings in which they are typically used, with EA being used most often in relation to exercise and EB most often in dietetics (Loucks et al., 2011).

EA is defined as the amount of energy remaining following exercise to be used for all other metabolic processes (Reed, De Souza, & Williams, 2013). Some of these
metabolic processes include but are not limited to thermoregulation, reproduction, growth, and immunity (Loucks et al., 2011). These metabolic processes remain relatively constant; therefore, when considering athletes, EA is better defined as dietary energy intake (DI) minus the energy expended in exercise (EEE) (Loucks et al., 2011). EA is calculated as follows: EA = DI – EEE (Loucks et al., 2011). An example of how EA is calculated is shown in Table 1. EA is relative to the individual by incorporating total kg of fat-free mass (FFM), and is calculated in units of kcal/kgFFM/day. The drawback of utilizing EEE is that other forms of physical activity may be omitted. These other forms of activity are termed non-exercise activity thermogenesis (NEAT) and include physical activity that is not planned, such as chewing gum, shaking your leg, or tapping your fingers (Burke & Deakin, 2000). The omission of these activities can lead to an underestimation of the overall energy expended. To summarize, EA is thought of as the amount of energy remaining following exercise training for all other processes and, therefore, is considered an input to the overall system (Loucks, 2007).

Table 1

Sample Calculation of Energy Availability

Subject Characteristics: 75kg male, 20% body fat, DI = 3000kcal, EEE = 640kcal

FFM = 75kg x (1-.20) = 60kgFFM

3000kcal – 640kcal = 2360kcal

2360kcal/60kgFFM = 39.3kcal/kgFFM/day
EB differs from EA in that total energy expenditure (TEE) is used in place of EEE. TEE incorporates basal energy expenditure, the thermic effect of food (TEF), and energy expended due to physical activity (Burke & Deakin, 2000). Basal metabolic rate (BMR) is the energy required to maintain normal physiological function and temperature at rest. TEF is the energy expenditure required for digestion, absorption, as well as metabolism and storage of macronutrients within the body (Burke & Deakin, 2000). Both TEF and BMR are relatively constant, while EEE is much more variable. EB is defined as the amount of EI added or lost from the body’s overall energy system stores following the total amount of work accomplished (or energy expended) for the day (Loucks et al., 2011). Therefore, is considered to be an input to the overall system. EB is calculated as follows: \( EB = EI - TEE \).

Another important difference between EA and EB is cost and ease of measurement. EA incorporates the use of relatively inexpensive and readily accessible equipment such as heart rate monitors and diet analysis software. EB is more difficult to calculate and requires equipment and personnel not readily available (Loucks, 2007). Historically, both methods of measurement have been incorporated to determine energy status across populations. Most importantly, each has a threshold that is considered to be healthy and any drop below this threshold can be detrimental to an individual’s overall health. The threshold for EB is 0 kcal/day; the threshold for EA is 30 kcal/kgFFM/day (Loucks et al., 2011). The threshold of 30 kcal/kgFFM/day is associated with resting metabolic rate and, therefore, is the minimum amount of energy required to sustain normal physiological function (Loucks, 2007). An EA of 45 kcal/kgFFM/day is
suggested, but an EA of 30-45 kcal/kgFFM/day can be maintained in the short term in order to achieve healthy weight loss (Loucks et al., 2011).

**Low Energy Availability in Relation to the Female Athlete Triad**

The concept of low EA was first introduced in relation to the female athlete triad in which low EA negatively impacts both menstrual function and bone health. Menstrual dysfunction is associated with an estrogen deficiency and, therefore, may also affect cardiovascular function, given the role that estrogen plays in the ability of the vessels to vasodilate. The severity of menstrual dysfunction and bone degradation varies based on the severity of low EA. Menstrual dysfunction ranges from eumenorrhea which is considered normal menstruation where menstrual cycles regularly occur (between 21 and 35 days) to amenorrhea which is the absence of menses. There are also consequences that occur when EA is low for a short time period (1-3 days) that include electrolyte imbalances, cardiac arrhythmias, increased risk of injury, and decreased performance (Hinton & Beck, 2005).

The International Olympic Committee (IOC) has recently expanded the scope of issues surrounding the female athlete triad to include men and other issues such as psychological function. The IOC introduced a more comprehensive term for the syndrome, RED-S. RED-S is an acronym for Relative Energy Deficiency in Sport that represents the female athlete triad in a much broader sense to incorporate all aspects that can be affected in relation to an energy deficiency (Mountjoy et al., 2014). RED-S is defined as a syndrome that results in a relative energy deficiency that affects many aspects of physiological function including metabolic rate, menstrual function, bone
health, immunity, protein synthesis, as well as cardiovascular and psychological health (Mountjoy et al., 2014).

Low EA has been identified as one of the driving factors for low bone mineral density (BMD) (Hind, Truscott, Evans, 2006). Ducher et al. (2011) determined that the combination of low EA and estrogen deficiency exacerbates the effects of bone demineralization on BMD. Further, bone metabolism is less affected when EA is above threshold even when estrogen is deficient, conversely normal estrogen levels do not counteract the effect of low EA on bone (Lambrinoudaki & Papadimitriou, 2010). Bone resorption can be increased in female athletes who drop below threshold in as little as 5 days once an EA above threshold is obtained (Ducher et al., 2011). BMD declines as the number of missed menstrual cycles increases (Ducher et al., 2011).

Recent evidence shows that low EA causes additional cardiovascular stress by negatively affecting endothelial function (Lanser, Zach, & Hoch, 2011). Recent research has suggested that endothelial dysfunction may be a fourth factor contributing to the female athlete triad. The mechanism is thought to be related to estrogen deficiency. Estrogen plays a role in the release of nitric oxide from the endothelial lining, which is a potent vasodilator (Lanser et al., 2011). Endothelial dysfunction can be a limitation from an exercise standpoint and lead to accelerated development of atherosclerosis.

**Causes of Low Energy Availability**

The American College of Sports Medicine (ACSM) has identified three leading causes of low EA: eating disorders, efforts to improve body composition, and failure to increase EI in order to compensate for increases in EEE (Nattiv et al., 2007). The ACSM
emphasizes that athletes who expend a large number of calories can become energy
deficient without the presence of an eating disorder, disordered eating, or dietary restraint
(Nattiv et al., 2007). Athletes can also fail to match EI with EEE due to suppression of
appetite which is commonly associated with increases in EEE.

Low EA can be the product of reduced EI, high EEE, and/or a combination of
both (Loucks, 2007). Athletes at the greatest risk are those who incorporate both, or those
in whom body composition plays a pivotal role. For example, endurance athletes are at
high risk due to the overall high daily EEE and for those who are aiming to improve body
composition in an effort to improve performance (Loucks et al., 2011). The
overwhelming issue associated with endurance athletes is the inability to match intake
with expenditure, because exercise itself does not stimulate appetite (Loucks, 2007).
Athletes involved in sports in which body composition is of key importance, such as
wrestling or dancing, are also susceptible to low EA. Extreme reduction in EI is
undertaken in sports such as wrestling, since body weight is a requirement for admission
to competition. However, it is important to realize that any individual who is striving for
athletic success or even weight loss is at risk of an energy deficiency if EA is not
regularly monitored.

Low EA can also occur inadvertently since there is no strong biological drive to
increase EI to match increases in EEE (Truswell, 2001). In other words, increases in
expenditure do not drive hunger. Stubbs et al. (2004b) conducted a study in which the
same caloric deficit due to food deprivation and increases in expenditure were compared.
They found that food deprivation increased appetite while the same deficit produced by
increasing expenditure did not. This effect is sometimes exacerbated in endurance athletes who consume high carbohydrate/low fat diets (Stubbs et al., 2004a). In the study conducted by Stubbs et al. (2004b) two different diets were analyzed, a 62% carbohydrate diet and 37% carbohydrate diet, which resulted in a cumulative caloric deficit of 1,948 kcals and 908 kcals over 7 days respectively. The exact mechanism has not been identified but it is suspected to be the greater bulk and fiber content of the carbohydrate-rich foods which promote satiety (Mann et al., 2007). Ultimately, appetite is not a reliable indicator of energy needs (Truswell, 2001). Suppressive effects of exercise on appetite combined with a high carbohydrate diet appear to be additive, and therefore can negatively impact an athlete who loads carbohydrates (Loucks et al., 2011).

Disordered eating is often described as a continuum that starts with appropriate eating (matching EI with EEE) to clinical eating disorders (Mountjoy et al., 2014). The ACSM has defined disordered eating as a wide spectrum of potentially harmful and frequently ineffective weight management strategies (Yeager, Agostini, Nattiv, & Drinkwater, 1993). These strategies include a wide range of behaviors including binge eating, caloric restriction, laxatives, and fasting (Hinton & Beck, 2005). An example of these behaviors are very low calorie diets which is defined as the consumption of less than 1,200 kcals. Very low calorie diets have been established as the minimum intake necessary to meet basic nutritional requirements. Females are also predisposed to disordered eating for reasons outside of sport as a result of social and media influences. Twice as many women as men perceive themselves as overweight and these numbers
increase as BMI declines, resulting in nine times as many lean women attempting to lose weight as lean men (Wardle, Haase, & Steptoe, 2006).

Gibbs and colleagues (2010) demonstrated that high drive for thinness is associated with energy deficiency in exercising women. Further, high drive for thinness produced 26% greater severity of menstrual disturbances than those with a normal drive who were not actively trying to improve body composition (Gibbs, Williams, Scheid, Toombs, De Souza, 2010). Gibbs et al. (2013) conducted further research to determine the role of dietary restraint on energy availability and found that EA was significantly lower in those individuals with high dietary restraint. This effect was caused by a significantly lower EI in those with high dietary restraint and although EEE was higher in the high dietary restraint group the result was not significant. These effects resulted in a 7 kcal/kgFFM/day difference between groups.

Athletes may also attempt to use a short-term energy deficiency to their advantage in terms of weight management, similar to how periodization is used with physical training. More specifically, an athlete may go through short bouts of low EA at the peak of physical conditioning and training in an attempt to improve body composition and overall fitness (Drenowatz, Eisenmann, Pivarnik, Pfeiffer, & Carlson, 2011). Therefore, when the athlete is expected to taper (decreases overall volume of training) they can simultaneously achieve a healthy EA in an attempt minimize the effects of the previous energy deficiency (Drenowatz et al., 2012). It follows that some athletes may adjust DI and EEE in an attempt induce an energy deficiency to improve athletic performance.
Prevalence of Low Energy Availability in Sport

Reed, De Souza, and Williams (2013) conducted a study on 19 female collegiate soccer players to determine if the training season or meal occasions played a role in low EA. It was found that the largest prevalence of low EA occurred at midseason, and was correlated with a large decrease in EI. Both body dissatisfaction and drive for thinness were found to be negatively correlated with low EA. Results showed that lunch was the meal restricted most often, which was attributed to the fact that this was the only meal throughout the day that the athletes ate independently. Low EA was also observed at dinner during midseason and was suspected to be due to the suppression of appetite associated with moderate intensity exercise of practice, given that the team typically ate dinner immediately following practice.

Hassapidou and Manstrantoni (2001) assessed DI and EA of elite female athletes from a variety of different sports including volleyball, middle distance running, ballet dancing, and swimming. The difference between the training season and competitive season was also analyzed. Overall, the training season had a 10.5% lower EA than the competitive season. However, on average the athletes had low EAs across both the training and competitive seasons. When volleyball is excluded from the average, the competitive season had a 20.9% lower EA than the training season. Overall, ballet dancers had the lowest average EA, and volleyball had the highest average EA. However, it was noted that across both seasons on average the athletes had low EA. These values were thought to be exaggerated due to the nature of measurements taken: EEE being measured based on prediction equations and EI based on past recall.
Hinton and Beck (2005) investigated the prevalence of EA in endurance trained males and females with a variety of different eating behaviors. Participants were separated into two major groups: asymptomatic (no diagnosed eating disorder or symptoms) and symptomatic (no diagnosis but with symptoms of an eating disorder). The symptomatic group was then further broken down into two subcategories: a binge eating group and a caloric restriction group. Interestingly, on average the women across all eating behaviors were above the necessary threshold of 30 kcal/kgFFM/day. However, the men in both the binge eating and caloric restriction groups had EAs below threshold, at 27.4 kcal/kgFFM/day and 24.9 kcal/kgFFM/day, respectively. Based on questionnaires, the disordered eating behaviors observed in these men did not appear to be driven by a motivation to improve body composition. Conversely, those women who had low EA reported disordered eating patterns in attempt to improve body composition. The men who exhibited low EA reported lower overall DI, but no significant differences in EEE. Additionally, DI incorporated lower carbohydrate intake and increased fat intake.

Stubbs et al. (2002) conducted a study on moderately trained males to determine if increases in graded exercise affected DI and thus EA. The two exercise groups included a moderate exercise group (5.1 kcal/kg/day) and a high exercise group (10.2 kcal/kg/day), with the difference between the groups being the addition of one 40-min exercise session. Both the moderate and high exercise groups produced an energy deficit of 239 kcals and 1,242 kcals, respectively. However, DI was only 23.9 kcals greater in the high exercise group. This demonstrated a failure to compensate for the increase in expenditure and resulted in an energy deficiency. This finding was paralleled by
subjective eating behavior questionnaires indicating no difference in hunger, appetite, or mood between the exercise groups. This finding suggests that energy deficiency may be tolerable in the short term.

To date, only one study has been conducted in an attempt to assess the risk of athletes developing low EA. The Norwegian Olympic Training Center, with the assistance of the IOC Consensus Group, developed a new model to assess risk of sport participation based on the risks of low EA. Those athletes at high risk are to be given the “red light” and, therefore, are not cleared to participate in sport because engagement in sport presents a serious health risk. These athletes are advised take time off from sport to focus on treatment and recovery. Athletes at moderate risk, were placed in the “yellow light” risk category, and were cleared for supervised participation to be accompanied with a medical treatment plan. Regular re-evaluation (1-3 months) is suggested to assess the health status of the athlete. In the final category, the “green light” category, the athlete is cleared to play without intervention. The major disadvantage of the model is that it requires invasive questions relating to eating disorders and menses, laboratory personnel, qualifications, and equipment. This model requires diagnosis of an eating disorder, biochemical analysis of hormonal profiles, analysis of body composition including bone scans, and more. Therefore, this model limits the feasibility of coaches to identify athletes at risk.

Measuring Dietary Intake

There are two major ways in which DI is recorded: current DI and past DI (Burke & Deakin, 2000). Current DI is a food record that is conducted at the time of
consumption and most often involves the weighing of foods as well as diet analysis software. Past DI is based on recall of diet throughout a given time period, but is typically done for 24-hour periods (Burke & Deakin, 2000). The current diet record is considered the most ‘accurate’ and for that reason is most commonly used in research (Bingham & Cummings, 1985; Marr, 1971). The weighted diet record, which incorporates weighing all food and beverages at the time of consumption, is considered the gold standard (Bingham & Cummings, 1985; Marr, 1971). The number of days dietary intake is recorded can affect the accuracy of the measurement. For example, 7-day recording is suggested to increase accuracy of predicting a true DI, but research has also shown that recording longer than 4 days decreases compliance (Bingham & Cummings, 1985; Guthrie, 1984). A minimum of 4 days is required to estimate typical protein, fat, and carbohydrate intake. Seven days of continuous recording is suggested as the most accurate and considered to be the most representative of normal eating habits (Bingham, 1987; Guthrie, 1984).

The largest error associated with DI data collection is the inaccuracy in recalling and/or reporting true DI (Block, 1989). The ability to record accurate information depends highly upon motivation of the individual, as well as memory and awareness of both type and quantity of consumption (Burke & Deakin, 2000). Report bias is common in those individuals who fear revealing inappropriate dietary behavior or want to impress the investigator (Burke & Deakin, 2000). The act of self-recording itself can distort the true intake by discouraging certain eating behaviors (Worsley, Baghurst, & Leitch, 1984). For example, a greater prevalence of fruits/vegetables may be over-reported whereas
foods high in sugars and fats may be under-reported. In a study conducted by Macdiarmid and Blundell (1997), half of the subjects who completed food records admitted altering DI due to inconvenience, self-consciousness, or being ashamed. Common ways to improve accuracy include education, demonstrating how to measure, availability of everyday household items to improve ease of measure (such as measuring cups), knowledge of how to use everyday household items to estimate serving sizes (e.g., cooked meat the size of a deck of cards is roughly 3 oz.), and the use of cell phones to scan bar codes and photograph meals.

**Measuring Energy Expenditure**

There are two different ways in which energy expenditure is typically measured in humans: indirect calorimetry and doubly labeled water (Burke & Deakin, 2000). There are also a variety of prediction equations that can be used outside of the laboratory to predict TEE. Both indirect calorimetry and doubly labeled water require laboratory equipment and personnel. Indirect calorimetry uses the rate of oxygen consumption (VO$_2$) and carbon dioxide production (VCO$_2$) to predict oxidation of carbohydrates and fats (Burke & Deakin, 2000). VCO$_2$/VO$_2$ is termed the respiratory exchange ratio (RER) and is an indirect measurement of the respiratory quotient. Respiratory quotient represents the ratio of oxidation between carbohydrates and fats (Burke & Deakin, 2000). Therefore, the RER values depend on the substrate (carbohydrates or fats) being utilized and typically range form 0.7-1.0. A RER of 0.7 represents oxidation of fat and 1.0 represents the oxidation of carbohydrate. A typical RER at rest ranges from 0.82-0.87 and increases as the intensity of exercise increases (Burke & Deakin, 2000). Indirect
calorimetry requires a metabolic cart, as well as a mask, hood, or mouthpiece for gases to be collected and analyzed.

Doubly labeled water (DLW) is another form of indirect calorimetry based on the elimination of two different isotopes: deuterium ($^2$H$_2$) and oxygen ($^{18}$O) (Burke & Deakin, 2000). $^2$H$_2$ is eliminated as water while $^{18}$O is eliminated as both water and CO$_2$, and the difference between the elimination rates of the two is a measure of CO$_2$ production (Goldberg et al., 1991). The advantage to DLW is that, following ingestion, EEE can be measured in free-living humans and only requires periodic urine collection (Burke & Deakin, 2000). Another advantage is that DLW allows the subject to engage in everyday activities without the inconvenience of heart rate monitors or accelerometers (Burke & Deakin, 2000). Two major disadvantages are the high expense and that DLW only provides an estimation of CO$_2$ production and not O$_2$ consumption, leaving the method vulnerable to large error (Burke & Deakin, 2000). Jequier, Acheson, & Schutz (1987) found a five times greater potential for error using this method.

Prediction equations can be used when personnel and/or a laboratory are not available. Prediction equations are used to estimate RMR and then an activity factor is used to estimate energy expenditure. There are a number of different prediction equations that have been developed for different populations that vary in age, gender, activity level, as well as body composition. The Cunningham equation has been found to be the most accurate in active males and females, but requires measurement of lean body mass (Fink, Burgoon, & Milesky, 2006). Mifflin-St. Jeor is the preferred equation when the measurement of lean body mass is not possible (Fink et al. 2006). Both equations provide
an estimation of RMR, and thus require multiplication of an activity factor to determine energy expenditure. Activity factors range from 10-20% of RMR in bed-ridden individuals to >100% RMR in very active individuals.

HR monitoring is another validated method used to estimate EEE. HR monitoring is used to determine expenditure during exercise due to its linear relationship with VO\(_2\) (Ceesay et al., 1989). During exercise, continuous HR monitoring provides an estimation of VO\(_2\) and establishes a relationship with EEE through the use of indirect calorimetric equations. Low activity levels pose a challenge to accurate measurement because the relationship between VO\(_2\) and HR is poor. A calibration process can be used to minimize this effect and is defined by the mean of the highest HR during rest and lowest HR during the lightest physical activity (Stubbs et al., 2002). HR monitors can also be calibrated individually through exercise and use of a metabolic system. For example, Stubbs et al. (2002) used a cycling protocol of increasing intensity that elicited variable HRs while collecting expired gases to ensure accuracy.

Accelerometry is a method that uses the acceleration of a body in space in order to calculate steps and kilocalories, among other variables. Accelerometry has been increasing in popularity as smart devices have begun counting steps and estimating caloric expenditure. Accelerometers have the ability to detect movement vertically, horizontally, and even diagonally. Accelerometers have been utilized in research as a means to calculate energy expenditure in aerobically trained athletes, older adults, and children (Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). Accelerometers estimate energy expenditure indirectly based on the linear relationship between acceleration and
energy expenditure. The development of these equations are based on locomotion patterns (e.g., running) or lifestyle patterns (e.g. housework), which either underestimate or overestimate energy expenditure, respectively (Ward et al., 2005). The epoch length is an important component of the accelerometer that must be considered based on population group. The epoch length is the amount of time the accelerometer collects data, as the data collection is not constant. Typical epoch lengths vary from 5 s to 1 min. Shorter epoch lengths are advantageous in children and adolescents who are typically more active, where longer epoch lengths are often reserved for older adults who are more sedentary (Ayabe, Kumahara, Morimura, & Tanaka, 2013). Longer epoch lengths can lead to the overestimation of energy expenditure, as the device assumes the individual is maintaining the activity for the duration of the epoch. Shorter epoch lengths is suggested in free-living individuals given that 60% of all walking bouts are for a duration of less than 30 s (Ayabe et al., 2013).

**Summary**

The majority of the literature has focused on the prevalence of low EA in sport, rather than prevention. Low EA has been documented in a variety of sports, although endurance sports have received the most attention. The strong aerobic component in endurance sports (such as long distance running or swimming) introduces vulnerability in the development of low EA. To date, the International Olympic Committee has produced the only model targeted at the prevention of low EA in sport, and to recognize the symptoms. The issue with this model is the overall invasiveness of the questions and laboratory procedures, thus requiring certified personnel and equipment. For this reason,
the present research is focused on developing a predictive model to be utilized by recreational athletes and coaches in aerobically trained individuals without the involvement of qualified personnel and laboratories.
Chapter 3: Methods

Overview of Research Design

The purpose of this investigation was to determine if EA could be predicted based on a variety of factors. All participants completed the informed consent process, a health history questionnaire, and an exercise questionnaire prior to admission into the study. Following admission into the study, participants were required to report to the laboratory to complete an eating behavior questionnaire, body composition measurement, and perform a maximal graded exercise test. All participants were required to record dietary intake and energy expenditure for a 7-day period, and were instructed to continue normal eating and exercise behaviors throughout the duration of the study. All participants were required to return to the laboratory midway through data collection (day 3-4) wherein the primary investigator provided feedback on both the dietary and exercise records. The timeline for participants was a minimum of 9 days with the preliminary screening, 7-day data collection, and a final meeting when equipment was returned and logs were reviewed. The timeline was extended if an individual had to repeat a day of data collection, where the maximum timeline was 2 weeks. An overview of the research design is outlined in Figure 1 below.

The requirement for entry into the study depended on individual past exercise history. Recreational athletes participating in a minimum of 150 min of aerobic activity per week for the previous 6 months were recruited. This study was approved by the Ohio University Institutional Research Board.
Preliminary Screening

All participants underwent a preliminary screening process prior to admission into the study. This process included: a health history questionnaire, exercise questionnaire, eating disorder questionnaire, and determination of body composition and aerobic fitness.

Eating Disorder Examination Questionnaire (EDE-Q 6.0). The EDE-Q 6.0 is comprised of four sub-scales including: dietary restraint, eating concern, weight concern, and shape concern. There is a total of 28 items that are based over a 28-day period. The items vary based on a 6-point scale with the first 12 questions varying from no days to everyday and the last eight questions from not at all to markedly. Each item corresponds with a subscale and the mean of those items were used to assess each behavior. The higher the score, the more the behavior is associated with a potential eating disorder.

Fairburn, Cooper, & O’Connor (2008) conducted a study on 243 females of varying ages
and training status and developed the following norms: global score (all four subscales) = 1.55, dietary restraint = 1.25, eating concern = 0.62, shape concern = 2.15, and weight concern = 1.59. Lavender, DeYoung, and Anderson (2010) conducted a similar study on 404 undergraduate men to determine the following norms: global score = 1.09, dietary restraint = 1.04, eating concern = 0.43, shape concern = 1.59, and weight concern = 1.29. The questionnaire was not used for diagnostic purposes.

**Body composition.** Body composition was determined via the BOD POD which uses air displacement plethysmography to measure body volume. Once a reliable body volume is determined, body density and body fat percentage can be estimated. This method has been validated as a reliable instrument for measuring body fat percentage in various populations including adults, children, and athletes (Ballard, Fafara, & Vukovich, 2004; Davis et al., 2007; McCrory, Gomez, Bernauer, Mole, 1995; Vescovi et al., 2001).

The participants were required to come into the laboratory for assessment, and to wear form-fitting clothes (provided by participant) and a Lycra swim cap (provided by investigator). All participants were asked to use the restroom (if necessary), remove all jewelry, eyeglasses, and other accessories that could affect body volume. It was verified that the participants had not eaten or exercised for 3-4 hours prior to testing. Participants were weighed on a calibrated scale prior to entry into the BOD POD chamber. Once fully enclosed, two measurements of body volume were made and if they differed by greater than 150 milliliters, a third measurement was taken. From the data collected (body mass and body volume) the BOD POD computer software estimated body density and body fat percentage using the Siri equation (McCrory et al., 1995). The body fat percentage of
each individual was converted to a percentile ranking based on age and sex. The Siri
equation used was:

\[
\% \text{ Body Fat} = \left(\frac{495}{\text{body density}}\right) - 450
\]

**Maximal oxygen consumption.** Maximal oxygen consumption (VO\(_{2}\text{max}\)) was
determined via a maximal graded exercise test (GXT) on a motor driven treadmill (TMX-
425, Full Vision Inc., Newton, KS). Gas exchange and ventilatory parameters were
measured with a metabolic system (Truemax 2400 Metabolic Measurement System,
ParvoMedics, Sandy, UT), which was calibrated according to manufacturer’s
recommendations prior to each use. Calibration required a tank with known
concentrations of oxygen and carbon dioxide (Scott Medical Products, Plumsteadville,
PA) and a 3-liter calibration syringe (no. 5530, Hans Rudolph, Inc., Kansas City, MO).
Expired gases were collected through a Hans Rudolph one-way valve (Kansas City, MO)
mouthpiece and analyzed for fractions of oxygen and carbon dioxide (TrueOne 2400,
ParvoMedics Systems, Sandy, UT). The GXT was terminated upon volitional fatigue of
the participant. In order to be considered a valid VO\(_{2}\text{max}\) test, three out of the four
following criteria were met: an RER of 1.1 or greater, attainment of age-predicted max
heart rate (within 10 beats per min), a Rating of Perceived Exertion (RPE) greater than or
equal to 18, or a plateau in VO\(_{2}\) (increase in VO\(_{2}\) less than or equal to 0.15 liters per min
with an increase in workload).

**Measurement of EA**

**Dietary record.** Each participant completed a 7-day dietary record, and was
utilized in this study because this duration has been suggested to increase accuracy of DI
prediction. Participants were provided scales (Classic Glass Digital Food Scale) and other measuring utensils. The weighted method required individuals to weigh all foods and beverages consumed using the food scale or standard household measures. Participants were instructed on how to properly measure and report food through use of a food model demonstration. Participants also recorded the time of day and meal type. Participants were required to meet with the primary investigator midway through data collection for review and clarification of the food records. Diets were analyzed (Nutritionist Pro, San Bruno, CA) for total daily kilocalories, grams of macronutrients, percentage of total kilocalories of each macronutrient, and grams per kilogram of body weight (g/kg) for each macronutrient. To minimize error the same investigator met with participants and analyzed diets. The mean energy intake for this 7-day period was used to estimate habitual energy intake, in units of kcal/kg FFM/day.

**Energy expenditure.** Each participant completed a 7-day energy expenditure record. Continuous heart rate monitoring was used due to its direct relationship with VO$_2$, and was ultimately used to estimate exercise expenditure (Ceesay et al., 1989). Participants were provided HR monitors (Garmin Forerunner 310xt) and were required to wear the HR monitors for the duration of each exercise session. The HR monitor utilized GPS (speed and grade), continuous HR monitoring, height, weight, and type of activity to estimate energy expenditure. The HR monitor provided an output which includes expenditure in terms of kcals, kcals/min, and second-by-second HRs. An Actigraph GT3X accelerometer was used in addition to the Garmin Forerunner 310xt in order to analyze activity outside of exercise. The accelerometer was worn during all waking
hours, with the exception of when the individual was exercising. The accelerometer provided an output which included activity counts, intensity of the activity, total time at each intensity (low, moderate, vigorous), estimate of caloric expenditure, and more. The accelerometer was utilized for the duration of data collection without requiring the participant to upload data or charge the device. The epoch length was 20 s to prevent overestimation of activity. If the individual did not have a “typical” day based on the moderate, vigorous, or very vigorous intensity workloads (minutes) (± 2 SD) they were asked to repeat that particular day. The mean energy expenditure for this 7-day period combined with the dietary record was used to estimate habitual energy status, in units of kcal/kgFFM/day.

**Statistical analysis.** An alpha level of 0.05 was utilized for all statistical analyses. PASW 18.0 (Window’s version, PASW Inc., Chicago, IL) was utilized for data analysis. In order to discover the best predictors of low energy availability, a stepwise linear regression analysis was conducted. One variable was entered into the model at a time, starting with the variable that contributes the most to the $R^2$ value (has the highest predictive value). Subsequent variables were added to the model, and the process ceased when the change in $R^2$ is no longer significant (the variable no longer contributes to the prediction of the dependent variable, EA). Independent sample t-tests were also conducted in order to compare the differences between males and females. Based on the results of the t-tests, two separate stepwise linear regression analyses were conducted on males and females.
Chapter 4: Results

Participants

A total of 23 individuals volunteered for the study, 13 males and 10 females. A total of 15 individuals were included in the analyses, 8 females and 7 males. Reasons for exclusion were failure to complete the 7-day data collection \((n = 1)\), repeat days in which the accelerometer day exceeded \(\pm 2\) SD from the moderate, vigorous, or very vigorous workloads \((n = 1)\), meet the requirement of 150 min/week of aerobic activity \((n = 6)\). Table 2 depicts participant characteristics of those who completed the study.

Table 2

<table>
<thead>
<tr>
<th>Participant Characteristics</th>
<th>Age (y)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
<th>FFM (kg)</th>
<th>BF (%)</th>
<th>VO(_2) max (ml/kg/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females ((n = 8))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>26.4 ± 6.1</td>
<td>1.6 ± 0.1</td>
<td>63.8 ± 10.3</td>
<td>48.4 ± 10.7</td>
<td>26.3 ± 5.2</td>
<td>43.5 ± 11.8</td>
</tr>
<tr>
<td>Range</td>
<td>21.0-39.0</td>
<td>1.4-1.8</td>
<td>50.6-83.4</td>
<td>39.9-73.3</td>
<td>18.3-34.5</td>
<td>25.1-55.9</td>
</tr>
<tr>
<td>Males ((n = 7))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>27.0 ± 7.2</td>
<td>2.6 ± 2.2</td>
<td>79.4 ± 9.1</td>
<td>68.3 ± 10.1</td>
<td>14.2 ± 3.8</td>
<td>55.0 ± 11.7</td>
</tr>
<tr>
<td>Range</td>
<td>21.0-41.0</td>
<td>1.7-1.9</td>
<td>68.1-95.5</td>
<td>54.2-87.1</td>
<td>8.8-20.5</td>
<td>35.0-66.9</td>
</tr>
</tbody>
</table>
Dietary intake. Participants completed a 7-day dietary record. Dietary characteristics were analyzed for total kcals, total g, g/kg, and percentage of each macronutrient (carbohydrates, proteins, and fats). On average, participants consumed $1989.2 \pm 738.8$ kcals, with males consuming $788.6 \pm 542.0$ kcals more than females. An independent samples t-test was conducted and dietary intake between males and females was significantly different ($p < .001$). A contributor to the low reported DI was the presence of active dieting among participants, with 53% currently dieting. On average, participants consumed an average of $96.1 \pm 56.0$ g of protein, $221.8 \pm 131.7$ g of carbohydrate, and $78.9 \pm 39.9$ g of fat. An independent samples t-test was conducted and the difference between males and females for grams of carbohydrate and protein was significant ($p < .001$, $p < .001$, respectively). On average, males consumed $96.0 \pm 54.4$ g more carbohydrate and $34.8 \pm 18.2$ g more protein than females. Average g/kg of carbohydrate, protein, and fat were $3.1 \pm 1.4$, $1.3 \pm 0.5$, and $1.1 \pm 0.3$, respectively. Averages for the whole group, females and males, are presented below (see Figures 2-4). An independent samples t-test was conducted and there were no significant differences between males and females for g/kg of carbohydrate, protein, or fat ($p = .17$, $p = .15$, $p = .70$ respectively). The percentage contribution of each macronutrient (carbohydrate, protein, fat) was 40.9%, 18.4%, and 37.3% respectively, an alcohol percentage was also calculated to be 3.5%. There were no significant differences between males and females for percent contribution to the total diet of carbohydrate, protein, fat or alcohol ($p = 0.36$, $p = 0.54$, $p = 0.22$, $p = 0.98$, respectively).
**Figure 2.** Relationship of each macronutrient (g/kg) and EA for the group. Average g/kg consumed of all macronutrients (fat, CHO, and protein) is presented. Each macronutrient is represented with different symbols, fat in squares, CHO in triangles, and protein in circles.

**Figure 3.** Relationship of each macronutrient (g/kg) and EA for females. Average g/kg consumed of all macronutrients (fat, CHO, and protein) is presented. Each macronutrient is represented with different symbols, fat in squares, CHO in triangles, and protein in circles.
Figure 4. Relationship of each macronutrient (g/kg) and EA for males. Average g/kg consumed of all macronutrients (fat, CHO, and protein) is presented. Each macronutrient is represented with different symbols, fat in squares, CHO in triangles, and protein in circles.

Accelerometry. Accelerometry was used to control energy expenditure outside of planned exercise. Participants were required to wear the accelerometers during all waking hours with the exception of planned exercise. The accelerometers reported in terms of kcals and minutes (moderate, vigorous, and very vigorous) which were analyzed to ensure outside activity did not interfere with planned exercise. In the event that an individual exceeded $\pm 2\ SD$ in the moderate, vigorous, or very vigorous intensity workloads that participant was asked to repeat the day and were excluded from the study in failure to do so. Participants expended $356.9 \pm 242.0$ kcals on average, with $24.3 \pm 15.9$ min of moderate intensity activity, $0.4 \pm 0.8$ min of vigorous activity, and 0 min of very vigorous activity. An independent samples t-test was conducted to determine that there was a significant difference ($p < 0.001$) between males and females, with males...
expending 220.8 ± 161.3 more kcals and spending 12.9 more min in moderate intensity activity \((p = 0.007)\), and 3.0 min more in vigorous intensity activity \((p = 0.04)\).

**Exercise energy expenditure.** Participants were instructed to wear the HR monitor during any planned exercise activity for a total of 7 days. Participants were not required to exercise for all 7 days. On average participants exercised 5.2 ± 1.1 days for a total of 436.7 ± 213.2 min, or 62.4 ± 30.5 min per session. On exercise days, the participants expended an average of 469.4 ± 298.8 kcals. An independent samples t-test determined that there were no significant difference between males and females for kcals, frequency, or total min \((p = 0.23, p = 0.86, p = 0.93)\).

**Energy availability.** The averages for EI, EEE, and individual FFM were used to calculate EA. EA averaged 26.7 ± 8.2 kcal/kgFFM/day and ranged from 14.8-41.1 kcal/kgFFM/day. Sixty percent of all participants were below threshold, and 80% were below 35 kcal/kgFFM/day. An independent samples t-test determined that were no significant differences between males and females \((p = 0.797)\). Further, 50% of females and 71% of males had low EA. Table 3 depicts average DI, EEE, and EA for all participants, and by gender.
Table 3

Energy Availability Summary

<table>
<thead>
<tr>
<th></th>
<th>Dietary intake</th>
<th>Energy expenditure</th>
<th>Energy availability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td>All (n = 15)</td>
<td>1989.2</td>
<td>469.4</td>
<td>26.7</td>
</tr>
<tr>
<td></td>
<td>± 738.8</td>
<td>± 298.9</td>
<td>± 8.2</td>
</tr>
<tr>
<td>Range</td>
<td>1226.1-3972.4</td>
<td>166.1-1379.9</td>
<td>14.8-41.1</td>
</tr>
<tr>
<td>Females (n = 8)</td>
<td>Mean</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>1621.2</td>
<td>377.5</td>
<td>26.6</td>
</tr>
<tr>
<td></td>
<td>± 329.6</td>
<td>± 196.1</td>
<td>± 7.8</td>
</tr>
<tr>
<td>Range</td>
<td>1226.1-2103.8</td>
<td>166.1-814.9</td>
<td>14.8-37.5</td>
</tr>
<tr>
<td>Males (n = 7)</td>
<td>Mean</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>2409.8</td>
<td>574.4</td>
<td>27.1</td>
</tr>
<tr>
<td></td>
<td>± 871.7</td>
<td>± 373.5</td>
<td>± 9.3</td>
</tr>
<tr>
<td>Range</td>
<td>1447.7-3972.4</td>
<td>219.2-1379.9</td>
<td>15.3-41.1</td>
</tr>
</tbody>
</table>

Note. All consists of both males and females. Dietary intake in units of kcals. Energy expenditure in units of kcals, for the days in which participants exercised. Energy availability in units of kcal/kgFFM/day.

EA Predictors

Group. A stepwise linear regression was conducted on all variables for the group, both males and females. The prediction equations below were developed to predict EA rather than low EA, due to the low number of individuals who were above threshold. The
significant predictors were: CHO (g/kg), FM, fat (%), exercise frequency, and lunch (total skipped). Fat (%) is the percent contribution of fat to DI, represented as an average. Lunch is represented as a total number of lunches skipped throughout the 7-day data collection. Figures 5-9 below illustrate the relationships between EA and the predictors. CHO g/kg, FM and fat (%) had a positive relationship with EA. Exercise frequency and skipping lunch had a negative relationship with EA. The prediction equation for the group was:

\[ EA \text{(kcal/kgFFM/day)} = 7.318 \times \text{CHO (g/kg)} + 0.647 \times \text{FM} + 0.619 \times \text{Fat} - 3.25 \times \text{Exercise Frequency} - 3.91 \times \text{Lunch} - 8.96 \]

Table 4

<table>
<thead>
<tr>
<th>Prediction equation</th>
<th>( R^2 )</th>
<th>% Increase in ( R^2 )</th>
<th>F</th>
<th>% Increase in F</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHOg/kg</td>
<td>0.45</td>
<td>-</td>
<td>9.7</td>
<td>-</td>
</tr>
<tr>
<td>CHOg/kg + FM</td>
<td>0.73</td>
<td>62.9</td>
<td>14.7</td>
<td>52.1</td>
</tr>
<tr>
<td>CHOg/kg + FM + Fat</td>
<td>0.85</td>
<td>16.2</td>
<td>18.3</td>
<td>24.0</td>
</tr>
<tr>
<td>CHOg/kg + FM + Fat + ExeFreq</td>
<td>0.97</td>
<td>14.8</td>
<td>75.0</td>
<td>310.6</td>
</tr>
<tr>
<td>CHOg/kg + FM + Fat + ExeFreq + Lunch</td>
<td>0.99</td>
<td>2.0</td>
<td>151.7</td>
<td>102.4</td>
</tr>
</tbody>
</table>
Figure 5. Relationship between EA and CHO g/kg for the group.

Figure 6. Relationship between EA and FM for the group.
Figure 7. Relationship between EA and dietary fat (%) for the group.

Figure 8. Relationship between EA and exercise frequency for the group.
Males vs. females. An independent samples t-test was conducted for all variables to determine if there was a difference between males and females. Aside from the variables above there was a significant difference for the following variables: shape concern, weight concern, dietary restraint, body fat percentage, lean body mass, weight and height. For this reason, and in combination with the differences determined above for EI and accelerometry, males and females were separated into two separate groups to be analyzed.
Table 5

**EDE-Q Eating Behavior Summary for Males and Females**

<table>
<thead>
<tr>
<th></th>
<th>Eating concern</th>
<th>Shape concern</th>
<th>Weight concern</th>
<th>Dietary restraint</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Females</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVG</td>
<td>0.85</td>
<td>3.25</td>
<td>2.73</td>
</tr>
<tr>
<td></td>
<td>Norm</td>
<td>0.62</td>
<td>2.15</td>
<td>1.59</td>
</tr>
<tr>
<td></td>
<td>% Difference</td>
<td>37.10</td>
<td>33.80</td>
<td>41.80</td>
</tr>
<tr>
<td><strong>Males</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AVG</td>
<td>0.31</td>
<td>0.84</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Norm</td>
<td>0.43</td>
<td>1.59</td>
<td>1.29</td>
</tr>
<tr>
<td></td>
<td>% Difference</td>
<td>27.90</td>
<td>47.20</td>
<td>62.00</td>
</tr>
</tbody>
</table>

**Note.** Shape concern, weight concern, dietary restraint were significantly higher in females than males ($p = .03$, $p = .02$, $p = .03$, respectively). Females were above norm for all behaviors (eating concern, shape concern, weight concern, and dietary restraint). Males were above norm for dietary restraint.

**Female predictors.** A stepwise linear regression was conducted on all variables for the females ($n = 8$). The following variables were determined to be significant predictors of EA: body fat percentile, alcohol (%), fat g/kg, weight concern, and CHO (%). Body fat percentile was based on norms outlined by the ACSM. Alcohol is representative of the percent contribution of alcohol to DI. Weight concern is represented as an average outlined by the EDE-Q. The relationship between EA and the variables are portrayed in Figures 10-14 respectively. The prediction equation for females was:

$$\text{EA (kcal/kgFFM/day)} = -0.20 \times \text{(Body fat percentile)} + 0.65 \times \text{(Alcohol)} + 2.85 \times \text{(Fat g/kg)} + 0.24 \times \text{(Weight concern)} + 0.18 \times \text{(CHO)} + 28.86$$
Table 6

*Statistical Summary for Prediction Equations for Females*

<table>
<thead>
<tr>
<th>Prediction equation</th>
<th>$R^2$</th>
<th>% Increase in $R^2$</th>
<th>F</th>
<th>% Increase in F</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF percentile</td>
<td>0.897</td>
<td>52.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF percentile + Alc</td>
<td>0.987</td>
<td>10.0</td>
<td>189.3</td>
<td>260.6</td>
</tr>
<tr>
<td>BF percentile + Alc + Fatg/kg</td>
<td>0.997</td>
<td>1.0</td>
<td>391.4</td>
<td>106.8</td>
</tr>
<tr>
<td>BF percentile + Alc + Fatg/kg + WtConc</td>
<td>1.000</td>
<td>0.3</td>
<td>111548.9</td>
<td>28397.5</td>
</tr>
<tr>
<td>BF percentile + Alc + Fatg/kg + WtConc + CHO</td>
<td>1.000</td>
<td>0.0</td>
<td>167390.8</td>
<td>50.1</td>
</tr>
</tbody>
</table>

![Figure 10](image.png)

*Figure 10.* Relationship between EA and body fat percentile in females.
Figure 11. Relationship between EA and alcohol (%) in females.

Figure 12. Relationship between EA and fat (g/kg) in females.
Male predictors. A stepwise linear regression was conducted on all the variables for males \( (n = 7) \). The only variable with statistical significance was CHO g/kg. The
relationship between EA and CHO g/kg is depicted in Figure 15. The prediction equation for males was:

\[ EA \text{ (kcal/kgFFM/day)} = 4.50 \text{ (CHO g/kg)} + 11.18 \]

*Figure 15. Relationship between EA and carbohydrate (g/kg) in males.*
Table 7

**Pearson Product Moment Correlation Summary for Total Group**

<table>
<thead>
<tr>
<th></th>
<th>Group</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Males</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CHO (%)</td>
<td>CHOG (g/kg)</td>
<td>PRO (%)</td>
<td>PRO g (g/kg)</td>
<td>Fat (%)</td>
<td>Fat g</td>
<td>Fat g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson</td>
<td>0.29</td>
<td>0.57</td>
<td>0.60</td>
<td>-0.51</td>
<td>0.34</td>
<td>0.56</td>
<td>-0.06</td>
<td>0.38</td>
<td>0.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.30</td>
<td>0.03*</td>
<td>0.02*</td>
<td>0.06</td>
<td>0.21</td>
<td>0.03*</td>
<td>0.84</td>
<td>0.17</td>
<td>0.03*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alc (%)</td>
<td>EDE-Q Shape conc</td>
<td>Wt. conc.</td>
<td>Eat conc</td>
<td>DR</td>
<td>Bfast</td>
<td>Lunch</td>
<td>Meal skip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson</td>
<td>-0.12</td>
<td>0.03</td>
<td>0.54</td>
<td>0.48</td>
<td>-0.18</td>
<td>0.14</td>
<td>0.21</td>
<td>0.20</td>
<td>0.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.66</td>
<td>0.93</td>
<td>0.04*</td>
<td>0.07</td>
<td>0.51</td>
<td>0.61</td>
<td>0.46</td>
<td>0.48</td>
<td>0.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exe freq</td>
<td>Exe min</td>
<td>VO2 max</td>
<td>BF %tile</td>
<td>% BF</td>
<td>FFM</td>
<td>FM</td>
<td>BMI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson</td>
<td>-0.20</td>
<td>-0.40</td>
<td>0.02</td>
<td>-0.40</td>
<td>0.39</td>
<td>-0.21</td>
<td>0.43</td>
<td>-0.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.48</td>
<td>0.14</td>
<td>0.94</td>
<td>0.15</td>
<td>0.16</td>
<td>0.45</td>
<td>0.11</td>
<td>0.81</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: * indicates significance at the 0.05 level.*
Table 7: continued

<table>
<thead>
<tr>
<th>Sig. (2-tailed)</th>
<th>0.009</th>
<th>0.56</th>
<th>0.11</th>
<th>0.58</th>
<th>0.59</th>
<th>0.71</th>
<th>0.85</th>
<th>-</th>
<th>0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exe freq</td>
<td>Exe min</td>
<td>VO2 max</td>
<td>BF %tile</td>
<td>% BF</td>
<td>FFM</td>
<td>FM</td>
<td>BMI</td>
<td></td>
</tr>
<tr>
<td>Pearson</td>
<td>0.43</td>
<td>0.18</td>
<td>0.08</td>
<td>0.24</td>
<td>-0.23</td>
<td>-0.19</td>
<td>-0.49</td>
<td>-0.40</td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.34</td>
<td>0.71</td>
<td>0.89</td>
<td>0.60</td>
<td>0.62</td>
<td>0.69</td>
<td>0.27</td>
<td>0.38</td>
<td></td>
</tr>
</tbody>
</table>

### Females

<table>
<thead>
<tr>
<th>CHO (%)</th>
<th>CHO g</th>
<th>CHO g/kg</th>
<th>PRO (%)</th>
<th>PRO g</th>
<th>PRO g/kg</th>
<th>Fat (%)</th>
<th>Fat g</th>
<th>Fat g/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson</td>
<td>0.06</td>
<td>0.36</td>
<td>0.26</td>
<td>-0.84</td>
<td>-0.37</td>
<td>0.69</td>
<td>0.09</td>
<td>0.006</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.89</td>
<td>0.38</td>
<td>0.54</td>
<td>0.01*</td>
<td>0.36</td>
<td>0.06</td>
<td>0.20</td>
<td>0.99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alc (%)</th>
<th>EDE-Q conc</th>
<th>Shape conc</th>
<th>Wt conc</th>
<th>Eat conc</th>
<th>DR</th>
<th>Bfast</th>
<th>Lunch</th>
<th>Meals skip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson</td>
<td>0.51</td>
<td>-0.12</td>
<td>0.74</td>
<td>0.76</td>
<td>-0.34</td>
<td>0.46</td>
<td>0.59</td>
<td>0.28</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.20</td>
<td>0.78</td>
<td>0.04*</td>
<td>0.03*</td>
<td>0.41</td>
<td>0.26</td>
<td>0.13</td>
<td>0.51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exe freq</th>
<th>Exe min</th>
<th>VO2 max</th>
<th>BF %tile</th>
<th>% BF</th>
<th>FFM</th>
<th>FM</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson</td>
<td>-0.73</td>
<td>-0.69</td>
<td>-0.67</td>
<td>-0.86</td>
<td>0.86</td>
<td>-0.37</td>
<td>0.91</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.04*</td>
<td>0.06</td>
<td>0.88</td>
<td>0.01*</td>
<td>0.36</td>
<td>0.36</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). DR = dietary restraint, Bfast = breakfast, BF %tile = body fat percentile, Exe min = exercise minutes. Exe freq and Exe min are based on the total for the week. Bfast and lunch are based on the number of that particular meal skipped for the week. Meal skip is the total number of meals skipped (Bfast or lunch) for the week. Dinner was not skipped by any participant; therefore, it is not represented. No males skipped lunch.
Chapter 5: Discussion

The main finding was that low EA was discovered in recreational athletes ($n = 9$), with a higher prevalence in males ($n = 5$) as compared to females ($n = 4$). It was determined that a number of variables contributed to EA, and that the predictors varied according to gender.

Exercise Frequency and Meal Skipping

EA was negatively correlated with exercise frequency and skipping lunch. Decreasing EI while increasing EEE is common in individuals who develop low EA. Excessive exercise and meal skipping are common weight control measures, and 53% of all participants were dieting at the time of data collection. Another common method is very low calorie diets ($< 1,200 \text{ kcal/day}$), which occurred on 13% of the days of data collection. Excessive exercise, skipping meals, and very low calorie diets are common factors in those individuals who are considered to be at risk of an eating disorder. Wright, Ford, and Botha (2014) identified exercise outside of sport and meal skipping as the primary methods used to lose weight, both being negatively correlated with EI and EA. The results were similar to the current study, as exercise frequency and the skipping of lunch were negatively correlated with EA.

Fat Mass and Body Fat Percentile

FM had a positive correlation with EA for the group, and body fat percentile had a positive correlation for females. Men on average had a body fat percentile of 68, and women had a body fat percentile of 42. The females with the lowest body fat percentile (10, 15, and 25) were above threshold and had the highest EAs. Wright et al. (2014)
outlined that higher body weights were negatively associated with desired weight loss. Kant and Graubard (2005) reported that individuals with the highest BMI also reported the highest intakes, despite weight loss desires. Further, those individuals with higher FM have been associated with increased fat intake which may have contributed to higher EAs (Weltens, Zhao, & Van Oudenhove, 2014). Wright et al. (2014) identified that training hours/week were positively associated with BMI. The result was similar to the present study, where Wright and colleagues (2014) established a connection between body weight and eating disorder behaviors. The three females with the lowest body fat percentile also presented two of the highest EDE-Q scores among the group as whole. Conversely, those individuals with higher body fat percentiles (the leanest) were associated with the lowest EAs. For example the two individuals with the highest body fat percentiles (99, 70) also had the lowest EAs (14.8, 17.4 kcal/kgFFM/day) both of which were below threshold.

**Carbohydrate**

CHO g/kg had a positive correlation with EA for the group and males. Viner, Harris, Berning, & Meyers (2015) conducted a study on 10 adults (6 males, 5 females) in which low EI and CHO intake was the main contributor to low EA. Conversely, Viner and colleagues (2015) had a high prevalence of low EA (80%) but the two individuals who were above threshold also had the highest CHO intakes. Similarly, in the present study the average CHO g/kg was below the recommendation of a minimum of 6.0 g/kg for regular exercisers, however the two individuals with the highest CHO intakes were above threshold. Thus, CHO g/kg may be predictive based on consuming above or below
the recommendation. In other words, the greater amount of CHO g/kg consumed the greater the EA.

CHO (%) had a positive correlation with EA for the women. The average contribution for the group was 43.3%, the men’s average was 46.1% and the women’s average was 40.9%. All averages were below the ACSM’s recommendation for athletes of 50-60%. This finding is not uncommon among women, as females reported consuming less CHO g/kg than males in the study conducted by Viner and colleagues (2015), with a value of 3.7 g/kg CHO. Shriver, Betts, & Wollenberg (2013) conducted a study on 52 female athletes who consumed an average of 4.0 g/kg CHO, with the majority failing to compensate for the energy needs of training. It was reported that 33% of these females had a desire to lose weight, and many reported skipping meals.

Carbohydrate consumption may also have been affected by the heavy presence of dieters (53%) among both groups. Viner and colleagues (2015) suggested that their participants were influenced by fad diets. These fad diets incorporated the restriction of CHO in which gluten-free alternatives were preferred. Similar to the present study, CHO foods were scarcely reported in the dietary records and gluten-free alternatives were often reported. Wright et al. (2014) discovered similar results in that 20% of individuals reported the use of low carbohydrate, high protein diets in an effort to improve body composition. These behaviors are suggestive of disordered eating.

Fat

Percent contribution of fat to DI had a positive correlation with EA. In the present study participants consumed an average of 35% fat, which is above the ACSM’s
recommendation for athletes. Fat consumption affects overall DI due to its high energy density (Kant & Graubard, 2005). The role of fat in regulation of DI is primarily driven from the fact that individuals are unable to determine high energy dense food from low energy dense food, thus leading to over-feeding (Rolls & Bell, 1999). Further it has been suggested that satiety is greater in diets of a lower energy density, comprising mostly of fruits and vegetables as compared to fats (Kant & Graubard, 2005). Volume and/or weight of food can also lead to overconsumption, as volume may have a stronger influence over termination of eating than the physiological need for energy (Rolls & Bell, 1999). Therefore, it is possible that individuals who consume high energy dense food may fail to terminate eating when energy needs were met, due to the low volume of food consumed. Kant and Graubard, (2005) determined that high energy dense foods increased DI, fat intake, and lowered the intake of fruits and vegetables.

The issue of high energy dense food is compounded when considering the fact that fat, and foods high in sugar, are considered to be “comfort foods” (Appelhans, 2009). “Comfort foods” are energy dense foods, that are consumed during times of stress in an attempt activate the reward system. Consumption is not driven primarily by energy need, but also by hedonic factors such as taste, pleasure, and reward (Appelhans, 2009). Further, an individual may continue to consume despite feelings of satiety. Born et al. (2010) conducted a study that determined that when individuals’ were under stress, EI was increased, and the food choices were energy dense. Kant and Graubard (2005) determined that high energy dense foods increased overall DI, fat intake, and lowered the intake of fruits and vegetables.
**Alcohol**

Alcohol (%) was positively correlated with EA in females. Half of all females consumed alcohol (50%) and averaged 3.6 drinks for the 7-day dietary collection. The USDA outlined that a 14 g alcoholic beverage averages 99.5 kcals. Given this estimate the individuals consumed an additional 355 kcals. Aside from the increased caloric intake from the alcohol, women who consume alcohol have also shown to increase DI (Kim, Breslow, Ahn, & Salem, 2007). Females consumed an average of 230 additional kcals per day when compared to their non-drinking counterparts.

Quality of diet is also affected by alcohol consumption, in that alcohol consumption is linked with increased intake of fat and meat (Valencia-Martin, Galan, & Rodriguez-Artalejo, 2011). More specifically, alcohol consumption is associated with increased intake of unhealthy fats and decreased intake of essential fats (Kim et al., 2007). Alcohol consumption at mealtimes also affects food preferences and choices, in which there is poor adherence to known food guidelines (Valencia-Martin et al., 2011). Therefore, alcohol consumption independently increased DI, but also may have affected the increase of other macronutrients (fat) to further increase DI and ultimately EA.

**Weight Concern**

Weight concern was positively correlated with EA in females. Females had above average body fat, and a high desire to lose weight (88%). Mismanaged efforts to improve body composition is common in the development of low EA. There was evidence of disordered eating among both groups, with a greater prevalence among females. Males were above average for dietary restraint, while females were above average for all four
categories (eating concern, shape concern, weight concern, and dietary restraint). The averages for females were 0.85, 3.25, 2.73, and 3.33 respectively, with dietary restraint differing the most from the norm further suggesting the potential of an eating disorder. There was evidence of disordered eating among the groups such as meal skipping, very low calorie diets, exercise frequency, and CHO restriction which likely contributed to the high prevalence of low EA.

**Prediction Equation Practicality**

The focus of the present study was the ease of use and practicality of developing a prediction equation that coaches and athletes could utilize without the need of outside resources. In other words, the goal is to eliminate the barriers that are associated with calculating EA such as the analysis of dietary intake, exercise expenditure, and body fat. A common factor in the prediction equations were variables that incorporated dietary analysis such as carbohydrate (%, g/kg) and fat (%, g/kg). Therefore, the prediction equations may need to be tailored to the feasibility of an athlete to conduct. There are a number of variables that are easily assessed such as exercise frequency, the skipping of lunch, and weight concern. Future research should focus on variables that ease the ability of coaches and athletes to evaluate the risk of the development of low EA.

**Limitations**

The present study had several limitations. The participants were living independently meaning the investigation was dependent on individual compliance to the instructions outlined by the investigator. The study was conducted in rural Appalachian Ohio which limits the ability to generalize among the population. The study also relied on
indirect measures of DI and EEE. The study was also limited to aerobically trained individuals, without focus on a particular specialty, which may limit the ability to generalize among populations. The study was likely also limited by sample size, in that the sample presented a small range of EAs which prevented the ability to predict low EA. The study was also limited to the number of eating behaviors chosen, these behaviors were chosen merely as descriptors and were not intended to imply any suggestion about the mechanism underlying each behavior.

Future research should focus on attaining a larger sample size of both men and women, because the predictors may differ between groups. This study should serve as a model for future research, as this is the first investigation to develop a prediction equation for EA. More research is needed in the prevention of low EA, and should focus on variables that can be utilized with and without the use of experienced personnel and sophisticated equipment. Further, more variables associated with disordered eating, as well as the possible causes of these behaviors, should be incorporated.

**Conclusion**

In conclusion, low EA was demonstrated in both groups of recreational athletes, males and females. The group of recreational athletes included aerobic exercisers that utilized a variety of different modes including: running, biking, walking, the elliptical trainer, yoga, soccer, basketball, ultimate Frisbee, and more. This finding demonstrates that low EA is an issues across different aerobic activities and gender. The present study is one of the first of its kind and the prediction equations provided a foundation upon which future research can expand. Future research should focus on the prevention of low
EA, the factors that contribute to its development, as well as the practicality of a coach/athlete to conduct the calculation.
References


Viner, R. T., Harris, M., Berning, J. R., & Meyers, N. L. (2015). Energy availability and dietary patterns of adult male and female competitive cyclists with lower than

Appendix A: Instruments

EATING QUESTIONNAIRE

Instructions: The following questions are concerned over the past four weeks (28days) only. Please read each question carefully. Please answer all the questions. Thank you.

Questions 1 to 12: Please circle the appropriate number on the right. Remember that the questions only refer to the past four weeks (28days) only.

<table>
<thead>
<tr>
<th>On how many of these past 28 days</th>
<th>No days</th>
<th>1-5 days</th>
<th>6-12 days</th>
<th>13-15 days</th>
<th>16-22 days</th>
<th>23-27 days</th>
<th>Every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Have you been deliberately trying to limit the amount of food you eat to influence your shape or weight (whether or not you have succeeded)?</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>2 Have you gone for long periods of time (8 waking hours or more) without eating anything at all in order to influence your shape or weight (whether or not you have succeeded)?</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>3 Have you tried to exclude from your diet any foods that you like in order to influence your shape or weight (whether or not you have succeeded)?</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>4 Have you tried to follow definite rules regarding your eating (for example, a calorie limit) in order to influence your shape or weight (whether or not you have succeeded)?</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>5 Have you had a definite desire to have an empty stomach with the aim of influencing your shape or weight?</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>6 Have you had a definite desire to have a totally flat stomach?</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Question</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
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<td>7 Has thinking about food, eating, or calories made it very difficult to concentrate on things you are invested in (for example, working, following a conversation, or reading)?</td>
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<tr>
<td>8 Has thinking about shape or weight made it very difficult to concentrate on things you are invested in (for example, working, following a conversation, or reading)?</td>
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<td>9 Have you had a definite fear of losing control over eating?</td>
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<tr>
<td>10 Have you had a definite fear that you might gain weight?</td>
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<tr>
<td>11 Have you felt fat?</td>
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<tr>
<td>12 Have you had a strong desire to lose weight?</td>
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Questions 13-18: Please fill in the appropriate numbers in the boxes to the right. Remember that the questions only refer to the past four weeks (28 days).

Over the past four weeks (28 days) ……

<table>
<thead>
<tr>
<th>Question</th>
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<tbody>
<tr>
<td>13 Over the past 28 days how many times have you eaten what other people would regard as an unusually large amount of food (given the circumstances)?</td>
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<tr>
<td>14 …… On how many of these times did you have a sense of having lost control over your eating (at the time that you were eating)</td>
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<tr>
<td>15 Over the past 28 days on how many DAYS have such episodes of overeating occurred (i.e., you have eaten an unusually large amount of food and have had a sense of loss of control at the time)?</td>
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<tr>
<td>16 Over the past 28 days, how many times have you made yourself sick (vomit) as a means of controlling your shape or weight?</td>
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<tr>
<td>17 Over the past 28 days how many times have you taken laxatives as a means of controlling your shape or weight?</td>
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</tbody>
</table>
18 Over the past 28 days how many times have you exercised in a "driven" or "compulsive" way as a means of controlling your weight, shape or amount of fat, or to burn off calories?

Questions 19 to 21: Please circle the appropriate number. Please note for these questions that term “binge eating” means: eating what others would regard as an unusually large amount of food for the circumstances, accompanied by a sense of having lost control over eating.

<table>
<thead>
<tr>
<th>Question</th>
<th>Range</th>
<th>Days</th>
<th>1-5 days</th>
<th>6-12 days</th>
<th>13-15 days</th>
<th>16-22 days</th>
<th>23-27 days</th>
<th>Every day</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>days</td>
<td>Days</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Over the past 28 days, on how many days have you eaten in secret (i.e., furtively)?</td>
<td>None of the times</td>
<td>A few of the times</td>
<td>Less than half of the times</td>
<td>Half of the times</td>
<td>More than half of the times</td>
<td>Most of the time</td>
<td>Every time</td>
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</tr>
<tr>
<td>20</td>
<td>times</td>
<td>Times</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Over what proportion of the times that you have eaten have you felt guilty (felt that you've done wrong) because of its effect on your shape or weight?</td>
<td>Not at all Markedly</td>
<td>Slightly</td>
<td>Moderately</td>
<td></td>
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<tr>
<td>21</td>
<td>days</td>
<td>Days</td>
<td>0</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Over the past 28 days, how concerned have you been about other people seeing you eat?</td>
<td>Not at all Markedly</td>
<td>Slightly</td>
<td>Moderately</td>
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Questions 22 to 28: Please circle the appropriate number on the right. Remember that the questions only refer to the past four weeks (28 days).

<table>
<thead>
<tr>
<th>Over the past 28 days</th>
<th>Not at all Markedly</th>
<th>Slightly</th>
<th>Moderately</th>
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<tbody>
<tr>
<td>22 Has your weight influenced how you think about (judge) yourself as a person?</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>23 Has your shape influenced how you think about (judge) yourself as a person?</td>
<td>0</td>
<td>1</td>
<td>2</td>
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<tr>
<td>24 How much would it</td>
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</table>
have upset you if you had been asked yourself once a week (no more, or less, often) for the next four weeks?

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<tr>
<td>25 How dissatisfied have you been with your weight?</td>
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<tr>
<td>26 How dissatisfied have you been with your shape?</td>
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<tr>
<td>27 How uncomfortable have you felt seeing your body (for example, seeing your shape in the mirror, in a shop window reflection, while undressing or taking a bath or shower)?</td>
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<th>6</th>
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</thead>
<tbody>
<tr>
<td>28 How uncomfortable have you felt about others seeing your shape or figure (for example, in communal changing rooms, when swimming, or wearing tight clothes)?</td>
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What is your weight at present? (Please give your best estimate) ________________

What is your height? (Please give your best estimate) ________________

If female: Over the past three-to-four months have you missed any menstrual periods?

   If so, how many? ________________

   Have you been taking the “pill”? ________________

THANK YOU

Restraint sub-scale: mean of items 1, 2, 3, 4, 5

Eating concern sub-scale: mean of items 7, 9, 19, 20, 21
Weight concern sub-scale: mean of items 8, 12, 22, 24, 25

Shape concern sub-scale: mean of items 6, 8, 10, 11, 23, 26, 27, 28