Intakes of Carbohydrates and Resistant Starch Food Sources Among Regular Exercisers in Blacksburg, VA and San Jose, Costa Rica

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ABSTRACT

Carbohydrates and fats are the main fuel sources for energy production during exercise. Consumption of low glycemic index foods slows digestion and absorption in the small intestine. The slow digestibility of resistant starch containing foods contributes to the slow and sustained release of glucose into the bloodstream, minimizing occurrence of hyperinsulinemia-induced suppression of lipolysis. The objectives of this study were to determine the consumption of resistant starch (RS) by regular exercisers (Blacksburg and San Jose (SJ)); and to analyze the eating and exercise habits of the subjects. Subjects were recruited at gyms in SJ (n=27) and Blacksburg (n=26). Participants kept 3-day food records and completed a questionnaire on eating habits and physical activity. Mean body mass index for the subjects was similar (SJ: 23.06 Kg/m^2 ± 2.55; Blacksburg: 23.53 Kg/m^2 ± 3.09). Average exercise time was 12 hours/week, and > 50% engaged in weight training in addition to aerobic type exercise. Percentage contribution of carbohydrates to the total energy intake was significantly higher for SJ males (53.53% ± 8.06%) compared to Blacksburg males (48.39% ± 6.33%; α=0.10). Prominent RS food sources in both groups were pasta, potatoes, bananas, and corn. Rice and various legumes were more frequent in the SJ group. It appears that consumption of RS is higher among SJ subjects. Consumption of RS prior to prolonged exercise could cause stable glycemic and insulinemic responses that may help delay the onset of fatigue during exercise.

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ALD.

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I. INTRODUCTION

During exercise, carbohydrates and fats are the main fuel sources for energy production. Several factors impact the proportions in which fats and carbohydrates are oxidized. For example, increasing the exercise intensity increases dependence on glucose oxidation, and augmenting the duration of exercise at low or moderate intensity increases the reliance on free fatty acid oxidation (Spriet & Watt, 2003). Furthermore, the composition of the diet has a significant impact on the extent to which fats and carbohydrates are utilized for fuel source. For most individuals, including athletes, carbohydrates are the main macronutrient consumed in their daily diet. Additionally, starch is considered to be a staple in the diet of a large amount of the world's population (Slattery et al., 2000).

Starch is composed of amylose, a linear chain of glucose units, and a branched component called amylopectin (Whistler & BeMiller, 1999). The physicochemical and digestibility properties of starch are mostly determined by its amylose to amylopectin ratio, and its molecular weight. Starch is classified as readily digestible starch, slowly digestible starch and resistant starch. Resistant starch has been defined as the sum of starch and starch products of degradation not absorbed in the small intestine of healthy individuals (Asp 1992; Topping et al., 2003). The limited accessibility of the enzymes to the resistant starch only allows minimal digestion of this carbohydrate type to occur. Furthermore, the slow digestibility of resistant starch containing foods allows glucose to be released slowly but constantly into the bloodstream (Haralampu, 2000), which can be used in applications involving controlled glucose release. Metabolism of resistant starch takes place 5 to 7 hours after consumption (Muir et al., 1995; Haralampu, 2000). Therefore, it can be expected that because of the many hours needed to metabolize resistant starch, this nutrient reduces postprandial glycemic and insulinemic responses, compared to high glycemic foods, and also increases the lasting feeling of satiety (Reader et al., 1997; Haralampu 2000).

Adequate ingestion of carbohydrates before and during exercise helps delay fatigue by maintaining blood glucose levels, thus allowing the exercise intensity to be maintained for a longer time. Consumption of carbohydrates before exercise affects metabolic responses with the onset of exercise. Ingestion of meals or snacks containing high glycemic index carbohydrates results in increased blood glucose concentrations followed by an increased insulinemic response, whereas low glycemic index foods cause moderate or low glycemic responses. Insulin is responsible for the uptake of glucose into skeletal muscle and adipose tissue (Bessesen, 2001). Furthermore, high insulin levels suppress lipolysis. Consequently, a decrease in the levels of nonesterified fatty acids released from adipose tissue occurs (Bessesen, 2001).

Late in intense exercise, the liver and muscle glycogen stores are low (Coyle & Coggan, 1984; Coggan & Coyle, 1987; Goodpaster et al., 1996). Thus, in prolonged exercise, as muscle glycogen decreases, the role of blood glucose becomes more important. In addition, ingestion of carbohydrates following exercise is necessary to replenish glycogen stores.

II. JUSTIFICATION

Nutrition plays a determining role in the athletic performance of individuals. Carbohydrates and fats are the main energy sources during exercise. For many years the term carbohydrate has been incorrectly used as a synonym for starch or it has been referred to simply as glucose. There are various types of carbohydrates which take part in different physiological functions, however, not all carbohydrates will cause similar blood glucose and insulin responses (Costacou & Mayer-Davis, 2003). Resistant starch is considered a dietary fiber, which is not digested nor absorbed in the small intestine of healthy individuals, and it can be fermented in the colon without causing any gastrointestinal discomfort (Brouns et al., 2002). Thus, foods containing significant quantities of resistant starch have a low glycemic index.

There are contradicting opinions regarding what types of carbohydrates should be eaten and in what amounts, and also on what the feeding schedule should be to maximize physical performance (i.e., maintain exercise intensity for longer periods of time; delay the onset of fatigue; maintain the power output). Regarding pre-exercise carbohydrate ingestion, Febbraio and collaborators (2000) stated that various studies have shown an increased, decreased, or unaltered effect on muscle glycogen use. Moreover, those studies have demonstrated an increased, decreased or similar exercise performance associated with consumption of carbohydrates before exercise. The discrepancies in the results obtained by these studies most likely are associated with the types of carbohydrates used, the quantity of carbohydrate consumed, differences in the times of pre-exercise ingestion, and types of exercise protocols utilized.

Frequently, it is believed that high glycemic index carbohydrates are more beneficial than low glycemic index foods in enhancing performance. Nonetheless, consumption of low glycemic index foods, such as those containing resistant starch which slow the digestion and absorption processes in the small intestine may help maintain adequate blood glucose levels during exercise through a slow and sustained release of glucose into the bloodstream (Haralampu, 2000), and reduce the inhibition of lipolysis. These metabolic effects can be especially useful for athletes who do not ingest sports drinks or carbohydrate foods during the sporting event, and / or late in intense exercise when the liver and muscle glycogen stores are low.

Maintaining adequate blood glucose levels during exercise aids to delay physical and mental fatigue, thus, avoiding a decrease in performance (Davis, 2004). In addition to the many physiological benefits produced by resistant starch after its ingestion, it may increase the production of short chain fatty acids significantly, which stimulate fluid and electrolyte uptake in the proximal colon (Topping & Clifton, 2001). Therefore, the main goal of this project was to determine the consumption of resistant starch by “regular exercisers” (subjects who exercise at least four times a week for one hour or more each time) in Blacksburg, VA and San Jose, Costa Rica. The rationale for recruiting participants both in Blacksburg and San Jose was to be able to compare the eating habits of recreational exercisers with different cultural backgrounds.

III. OBJECTIVES

The primary purpose of this study was to determine the consumption of resistant starch, a non-digestible and fermentable type of starch, by regular exercisers in Blacksburg, VA and San Jose, Costa Rica.

Specific objectives:

1. To analyze the eating habits and intakes of carbohydrates among regular exercisers in two communities, Blacksburg and San Jose.

2. To assess perceptions and awareness of exercisers regarding the relationship between food selection, carbohydrate classes, glycemic index and athletic performance.

3. To compare the exercise habits of regular exercisers in Blacksburg and San Jose.

IV. LITERATURE REVIEW

A. Overview of Starch

Starch

There is an ongoing debate amongst health professionals about the best macronutrient distribution of diets in order for individuals to obtain the most physiological benefits from their food intake. Even though dietary regimens tend to shift because of trends, the fact is that carbohydrates, especially starches, are still the primary energy source for most individuals around the world (Slattery et al., 2000).

Starch is a polysaccharide found in plants composed of granules containing linear and branched polymers of glucose, referred to as amylose and amylopectin respectively. Amylose is a linear chain of α-1,4-D-glucopyranosyl residues, which has a right handed helix formation with hydrophobic and lipophilic interiors capable of forming complexes. Amylopectin is a branched polymer with a backbone of α-1,4-D-glucopyranosyl units, and every 40 to 50 residues a branch of glucose units is linked by an α-1,6-D bond (Whistler & BeMiller, 1999). In addition, starches contain small amounts of an intermediate fraction with a higher degree of branching than amylose but lower than that of amylopectin (Whistler & BeMiller, 1999). This component can make up 5-10% of some cereal starches (Lineback, 1984).

Types of Starch

Starch is classified into readily digestible starch, slowly digestible starch and resistant starch. Readily digestible starch is hydrolyzed and absorbed in the small intestine at a fast rate. On the other hand, slowly digestible starch is a source of slowly available glucose, which can be eventually absorbed by the small intestine or may pass through to the large intestine as resistant starch. Resistant starch has been defined as the sum of starch and starch products of degradation not absorbed in the small intestine of healthy individuals (Asp 1992; Topping et al., 2003). Generally, cooked starch is digested almost immediately as compared to the metabolism of resistant starch that takes up to 5-7 hours after ingestion (Muir et al., 1995; Haralampu, 2000).

Starch is also referred to according to its amylose content. Starch containing 0-2% amylose is termed waxy starch, 5-12% is considered as having a very low amylose fraction, 12-20% is low amylose, 20-25% is thought of as an intermediate amylose content, and 25-33% amylose is high (Juliano, 1992; Singh et al., 2003).

Starch Digestibility

Starch is the only natural polysaccharide that can be digested by the enzymes present in the gastrointestinal tract (Topping et al., 2003). The presence of sufficient amounts of α-amylase and amyloglucosidase in the gastrointestinal tract ensures starch hydrolysis. The digestibility of starch, as well as its physicochemical properties, are determined by the extent of polymerization and branching (Slattery et al., 2003).The ratio of amylose to amylopectin varies depending on the food source, the processing and modification it undergoes. Most of the starch sources have approximately 20-40% amylose (Murphy, 2001).

The structural arrangement of amylose and amylopectin causes amylopectin to be more vulnerable to enzymatic attacks. The ratio of amylose to amylopectin also affects starch digestibility, given the fact that amylose undergoes retrogradation at a faster rate than does amylopectin (Whistler & BeMiller, 1999)

Retrogradation occurs when foods are subjected to heat and then cooled down, and also during storage. Retrogradation is understood as the gradual increase of crystalline aggregates in starch gels that result from breaking of hydrogen bonds between amylose polymers, followed by a slow rearrangement into a more orderly configuration and establishment of new hydrogen bonds (McWilliams, 2001). The molecular re-association of starch produces tightly packed structures which decrease the accessibility of the digestive enzymes (Haralampu, 2000). In addition, starch hydrolysis is affected by factors such as the amount of pancreatic amylase available, transit time through the small intestine (Englyst & Hudson, 1996), food processing techniques involving heat, moisture or chemicals (Niba, 2002). Furthermore, food processing such as milling damages the starch granules and makes them more susceptible to hydrolysis. The particle size of the ingested food also affects the quantity of starch products that reach the colon because large particles travel more rapidly through the gastrointestinal tract and are therefore subjected to less digestion in comparison with smaller particles (Topping et al., 2003).

Starch that resists digestion in the small intestine is slowly fermented in the large intestine (Haralampu, 2000). The primary products of starch fermentation in the human colon are short chain fatty acids, carbon dioxide, methane, hydrogen and heat (Topping &Clifton, 2001). Short chain fatty acids have a positive effect on the metabolism, structure and functioning of epithelial cells (Wang et al., 1998).

Resistant Starch

The American Association of Cereal Chemists defines dietary fiber as “the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Dietary fiber includes polysaccharides, oligosaccharides, lignin and associated plant substances. Dietary fibers promote beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or blood glucose attenuation” (Anonymous, 2000; Marlett et al., 2002; McCleary, 2003). This definition clearly states that resistant starch should be considered as a component of dietary fiber.

As it was previously mentioned, resistant starch is commonly defined as the sum of starch and starch products of degradation not absorbed in the small intestine of healthy individuals (Asp 1992; Topping et al., 2003). Resistant starch is classified as RS1 (physically inaccessible), RS2 (ungelatinized starch), RS3 (retrograded starch) and RS4 (chemically modified starch). Resistant starch as a complex carbohydrate occurs naturally in tubers, cereals, legumes and vegetables; it is mainly ingested as a result of food processing and storing techniques (Muir et al., 1995; Brighenti et al., 1998).

The pancreatic enzymes in the small intestine are not capable of significantly hydrolyzing resistant starch because of the limited accessibility of the starch. RS1 is physically entrapped starch within whole or partially milled seeds (Topping & Clifton, 2001); RS2 is found as a compact structure (tightly packed) within the granule which limits enzymatic accessibility (Haralampu, 2000); RS3 is retrograded starch that becomes tightly packed by the re-association of hydrogen bonds (Haralampu, 2000); RS4 is starch that has been chemically modified, and becomes resistant to enzymatic hydrolysis. Therefore, only minimal digestion of this complex carbohydrate occurs, and most of it continues to the large intestine (McCleary, 2003). Once in the large intestine, resistant starch is fermented partially or completely by colonic bacteria generating short chain fatty acids, which contribute to the normal functioning of the colon and help prevent diseases (Björck et al., 2000; Topping & Clifton, 2001). In comparison to other fermentable carbohydrates, resistant starch generates higher levels of butyrate (Englyst & MacFarlane 1986; Scheppach et al., 1988; Brighenti et al., 1998). More recently, Brouns and collaborators (2002) also indicated that colonic butyrate is generated in higher amounts by resistant starch fermentation. Also, fermentation of resistant starch causes low levels of gas formation (Brouns et al., 2002).

Butyrate is the primary energy substrate of colonocytes since its oxidation is responsible for 70% or more of the oxygen consumption by the human colonic tissue (Roediger, 1980; Brouns et al., 2002). Butyrate is not only involved in promoting colonic health through the development of normal intestinal cells, but it also decreases the proliferation of abnormal cells, promotes apoptosis of tumorous cells, and provides anti-inflammatory capabilities (Velazquez et al., 1996; Brouns et al., 2002).

In addition to enhancing the colonic microflora through the production of short chain fatty acids, resistant starch is considered a prebiotic. In 1995, Gibson and Roberfroid defined the term prebiotic as a nondigestible food which helps lactic acid bacteria (probiotics) reach the large intestine where they improve host health by stimulating the growth and activity of this beneficial bacteria (Topping et al., 2003).

Resistant starch also has positive effects on glucose and lipid metabolism (Björck et al., 2000). Resistant starch behaves as soluble dietary fiber, and its viscosity affects digestion and absorption processes in the small intestine (Englyst et al., 2003). Since the presence of resistant starch causes slower digestion, the incorporation of resistant starch containing foods to the diet may be used as a way to slow down the release of glucose (Haralampu, 2000).

Short Chain Fatty Acids / Cation Uptake

Fermentation of resistant starch and starch products of degradation in the colon produces short chain fatty acids, especially butyrate, propionate and acetate. These fatty acids can be absorbed and utilized as metabolic substrates (Topping et al., 2003).

Topping and collaborators (2001, 2003) elucidated that another physiological benefit produced by consumption of resistant starch related to the increased production of short chain fatty acids is that these fatty acids stimulate the uptake of water, sodium, potassium and calcium, especially in the proximal colon. In addition, increased magnesium intake is also associated with resistant starch consumption (Brouns et al., 2002).

Glucose Absorption

Sugars are mainly absorbed in the small intestine (Englyst & Hudson, 1996). The transporters that are associated with glucose absorption are the sodium dependent glucose co-transporter (SGLT-1), glucose transporter 5 (GLUT-5) and glucose transporter 2 (GLUT-2) (Johnson, 2001). Both glucose and galactose are competitively absorbed by secondary active transport through SGLT-1 (Johnson, 2001). Sodium and glucose both have an affinity for the SGLT-1 carrier, which binds two sodium ions for each glucose molecule. The sodium-potassium ATPase is responsible for maintaining a sodium gradient in favor of glucose entry into the cells (Johnson, 2001). At the basolateral membrane, the GLUT-2 transporter aids the passage of glucose from the cell into the bloodstream.

Once in the bloodstream glucose is carried by the portal vein to the liver, and then most of it is released into the bloodstream again for distribution to the tissues. Glucose uptake by muscle cells includes several steps. First is the delivery of glucose from the blood to the interstitial space, followed by transmembrane transport to the inside of the cell, increasing glucose availability to carry out the intracellular metabolism of this sugar (Richter et al., 2001).

With the onset of exercise, the increased blood flow to the muscles increases glucose delivery and the capacity of muscle membrane glucose transport also increases (Richter et al., 2001).

Glycemic Index and Glycemic Load

The glycemic index is understood as the blood glucose response after consumption of a single food, beverage or a meal. This index is dependent on factors such as the nature and processing of the starch, size of the food particle, presence of soluble fiber, and the interactions of other nutrients with the starch (Jenkins et al., 2000; Slavin, 2003).

Given the branched structure of amylopectin, it is more rapidly broken down into glucose units as compared to amylose. Consequently, starches with a high amount of amylopectin will be associated with a higher glycemic index, and those higher in amylose content will most probably have a lower glycemic index (Goodard et al., 1984; Brand Miller et al., 1992; Jozsi et al., 1996).

Since resistant starch is not absorbed in the small intestine, and its interaction with other nutrients in the gastrointestinal tract affects its digestion and absorption, foods containing significant amounts of resistant starch are considered low glycemic index foods, which attenuate postprandial glycemia.

When the glycemic index of foods is used in predicting the blood glucose and insulin responses of individuals, it is necessary to also take into account the glycemic load. The glycemic load is the glycemic index of a given food multiplied by the ingested amount.

B. Overview of Exercise and Carbohydrates

Carbohydrates, Exercise and Glycemic / Insulinemic Responses

Glucose, glycogen and fatty acids are the main sources of fuel for exercise. The glucose supply to individuals is derived from dietary carbohydrates, muscle and liver glycogen stores. These sources of fuel are limited (Burke et al., 2004), and the availability of glucose to the muscles and to the brain is extremely important to delay fatigue (Davis, 2004) and prevent negative effects on athletic performance. On the other hand, fat sources such as free fatty acids obtained from adipose tissue breakdown, and intramuscular triglycerides are abundant (Burke et al., 2004).

The benefits in sports performance related to good nutrition practices have long been documented and discussed. Researchers agree that carbohydrate consumption before and during exercise helps delay fatigue, and therefore allows individuals to maintain the exercise intensity for a longer time (Coyle, 2004). However, there are contradicting opinions on what the carbohydrate feeding schedule should be like before exercising and what types of carbohydrates should be eaten. Possible reasons for this confusion are that the energy demands related to exercise intensity and duration, and also the extent to which energy systems are utilized to supply the fuel, vary from one sport to another. Also, the nutritional recommendations in the available literature are often vague.

Individuals participating in endurance events (prolonged continuous aerobic exercise) lasting more than 90 minutes may benefit from increasing their carbohydrate intake the days before competition because this practice raises muscle glycogen levels (Hargreaves et al., 2004). Carbohydrate loading seemingly does not provide added benefits to performance during intense exercise sessions lasting 60-90 minutes or less (Sherman et al., 1981; Madsen et al., 1990; Hawley et al., 1997; Hargreaves et al., 2004).

It is generally thought that consuming carbohydrates 3-4 hours before exercise enhances physical performance (i.e., delays the onset of fatigue) because it also increases muscle and liver glycogen concentrations (Coyle et al., 1985; Hargreaves et al., 2004; Sherman et al., 1989; Wright et al., 1991; Schabort et al., 1999). However, there are some studies that have not observed beneficial effects in performance, such as lower timed trials or delaying the time to exhaustion, after consumption of a high carbohydrate meal 4 hours prior (Okano et al., 1996; Whitley et al., 1998; Hargreaves et al., 2004).

Some investigators believe that glucose ingested one hour or less before the start of exercise is a source of energy during exercise (Goodpaster et al., 1996), while others feel that glucose consumption before exercising has a negative effect on physical performance because of a hyperinsulinemic response followed by hypoglycemia with the start of exercise (Foster et al., 1979; Costill & Miller 1980; McMurray et al., 1983; Goodpaster et al., 1996).

Ingestion of high glycemic index carbohydrates within an hour of the exercise session causes a large increase in blood glucose and hyperinsulinemia (Hargreaves et al., 2004). Consequently with the start of exercise, there is a significant decrease in blood glucose concentrations. In addition, hyperinsulinemia as a result of pre-exercise carbohydrate ingestion inhibits lipolysis, therefore, not allowing the usual increase in free fatty acids concentrations in blood with the onset of exercise (Horowitz et al., 1997; Hargreaves et al., 2004). Furthermore, researchers have stated that inhibition of lipid oxidation in the muscle also occurs (Coyle et al., 1997; Hargreaves et al., 2004), which implies that even intramuscular triglycerides may not be used as a fuel source. It should be noted that the inhibition of lipolysis and lipid oxidation occurs even with small increases in insulin concentrations (Hargreaves et al., 2004). Several researchers have said that in comparison with high glycemic index foods, consumption of a low glycemic index food before submaximal exercise reduces post prandial blood glucose levels and insulinemia, which is associated with higher concentrations of non-esterified fatty acids during exercise (Thomas et al., 1994; Febbraio & Stewart 1996; Sparks et al., 1998; Wee et al., 1999; Febbraio et al., 2000; Wu et al., 2003).

Wu and collaborators (2003) performed a cross-over study where they fed carbohydrate meals with differing glycemic indices (glycemic index = 77.4 vs. 36.9) to male participants (recreational runners, n = 9) 3 hours before a 60 minute run at 65% maximal oxygen uptake. In addition, the subjects completed the run in a fasting state. As could be expected, the high glycemic index meal had a greater postprandial glycemic and insulinemic response than the low glycemic index meal. Consequently, fat oxidation during exercise was much higher with the low glycemic index meal, given that the lower insulinemic postprandial response probably caused a reduced suppression of lipolysis (Wu et al., 2003).

Goodpaster and colleagues (1996) performed a cross-over study with college age competitive male cyclists (n = 10) to determine whether the glycemic responses would be different following feedings of waxy starch (high amylopectin content), resistant starch and glucose ingested prior to strenuous exercise. Thirty minutes after the feedings, the participants cycled for 120 minutes in total, the first 90 minutes at 66% of maximal oxygen consumption, and then 30 minutes of “all out” cycling. Results indicated that there were no significant differences either in total work output or in the rates of perceived exertion among the glucose, waxy starch and resistant starch trials.

In addition, Febbraio and associates (2000) carried out another study to assess the influence of pre-exercise consumption of carbohydrates with different glycemic indices on glycogen use and glucose kinetics. Trained male cyclists (n = 8) consumed either a high glycemic index, low glycemic index or placebo meal thirty minutes before cycling at 70% maximal oxygen uptake for 120 minutes, followed by a performance cycle lasting 30 minutes. The results obtained in this study confirm that pre-exercise consumption of carbohydrates with varying glycemic indices causes different metabolic responses during exercise. They observed that after consumption of a low glycemic index meal the participants had a more stable glycemic and insulinemic response. On the other hand, the high glycemic index meal brought upon hyperinsulinemia accompanied by an increased glucose uptake and decreased free fatty acid concentrations. Nonetheless, the authors concluded that consumption of carbohydrates before exercise, regardless the glycemic index of the foods, had no effect on cycling performance after 120 minutes. These results support preceding findings from this research group, but are in disagreement with the results obtained in other studies that have observed enhanced physical performance after consumption of a moderate or low glycemic index meal (Febbraio et al., 2000).

Febbraio and colleagues (2000) also measured the rate of appearance of glucose into plasma and disappearance (uptake by muscles). Their findings show that even when the glucose and insulin levels of participants exercising after consumption of the high glycemic index meal returned to levels comparable to the other trials, the rate of glucose disappearance remained increased and the availability of free fatty acids stayed depressed. This makes a case for the persistent effect of hyperinsulinemia even when insulin levels return to normal during exercise (Febbraio, 2000).

Carbohydrate Consumption during Exercise

In general, people who exercise at moderate intensities (i.e., < 70% maximal oxygen uptake) for less than one hour without experiencing fatigue do not seem to benefit from consuming carbohydrates while they exercise (Coyle, 2004). Moreover, it can be inferred that carbohydrate intake during events lasting 30-45 minutes or less will not aid performance (Febbraio et al., 1996; Coyle, 2004).

In a non-extreme temperature environment, as muscle glycogen decreases during prolonged intense exercise, being able to maintain glucose availability is a key factor for performance (Coyle, 2004; Davis, 2004). Therefore, carbohydrate consumption is recommended during exercise sessions, continuous or intermittent, lasting more than 1 hour and where fatigue is present in a non-hyperthermic dependent manner (Febbraio et al., 1996; Coyle, 2004). There are guidelines regarding the amount of carbohydrates that an athlete should ingest during exercise to maximize the associated benefits. However, each athlete must be careful to consume carbohydrates in an amount that does not cause them gastrointestinal discomfort.

Glycogen Restoration

Foods with a high glycemic index cause greater increases in glycemia and insulinemia, thus allowing for faster glycogen replacement in the muscles if consumed in adequate amounts (Burke et al., 1993).

Jozsi and colleagues (1996) designed an experimental protocol to study the effect of starch structure on glycogen restoration and subsequent physical performance. The subjects (8 male cyclists) underwent an exercise protocol to decrease glycogen concentration in the *vastus lateralis,* and during the next 12 hours each participant consumed approximately 3000 Kcal with a macronutrient distribution of 65% carbohydrate, 20% fat and 15% protein. In addition, most of the carbohydrate contribution to the diet was derived from one of four solutions: glucose, maltodextrin, waxy starch (100% amylopectin) and resistant starch (100% amylose). Since there is an enhanced glucose uptake by the muscle during the first 5 hours of recovery (Freidman et al., 1991; Ivy, 1991; Jozsi et al., 1996) more carbohydrate was given to each participant during this time. The findings were that glycogen stores increased similarly in the glucose, maltodextrin and waxy starch trials; however, glycogen replenishment was significantly lower in the resistant starch trial. Nevertheless, during exercise bouts following the recovery stage there were no significant statistical differences in the work output among the 4 trials (Jozsi et al., 1996).

The optimal rates of muscle glycogen recovery come about during the first hour after exercise (Ivy et al., 1988; Burke et al., 2004). There are several physiological factors which explain this heightened storage of glycogen, such as increased insulin sensitivity brought upon by exercise (Richter et al., 1989; Burke et al., 2004), activation of glycogen synthase as a consequence of glycogen depletion (Wojtaszewski et al., 2001; Burke et al., 2004), and the permeability of the muscle cell membrane to glucose (Burke et al., 2004). It has also been stated that the intake of carbohydrate during the first 2 hours of recovery from exercise permits a faster rate than normal of glycogen restoration (Burke et al., 2004). Regarding the total resynthesis of glycogen over a period of 24 hours, it makes no significant difference if the carbohydrates are consumed as snacks throughout the day or as large meals (Burke et al., 2004).

C. Micronutrients (Na^{+}, K^{+}, Ca^{+2}, Mg^{+}) and Exercise

Adequate concentrations of electrolytes are needed for appropriate functioning and performance of the human body. Recently, Topping and associates (2001, 2003) stated that short chain fatty acids stimulate the uptake of water and some electrolytes (sodium, potassium and calcium) in the colon. Given that fermentation of resistant starch produces considerable amounts of short chain fatty acids, it is possible that this is another method through which the ingestion of resistant starch could contribute to athletic performance.

Heat dissipation during exercise is extremely important to allow proper functioning of cellular structures and metabolic pathways (Powers & Howley, 2004). The principal mechanism of heat dissipation is the evaporation of sweat. Along with water in sweat, electrolytes such as sodium, potassium, chloride and magnesium are lost (Powers & Howley, 2004). Sodium, potassium, calcium and magnesium are macrominerals, and all of these are usually found in foods and in the body as cations. A brief overview of these minerals follows.

- Sodium

This cation assists in the transmission of nerve impulses, and is also involved in controlling muscle contraction (Whitmore, 2000). Also, it is responsible for maintaining adequate extracellular fluid volume (Powers & Howley, 2004). Sodium ions, as well as chloride anions, are absorbed in all the regions of the colon (Johnson, 2001). In the large intestine the entry of sodium into the epithelium cells is mainly regulated by restricted diffusion through channels mediated by mineralcorticoids (Johnson, 2001). In addition, sodium is involved in a counter transport with hydrogen ions, which is associated with the chloride ions and bicarbonate counter transport (Johnson, 2001).

Hyponatremia is a major health concern defined as low blood sodium concentrations (<135 mmol/L) (Hsieh, 2004). Hydration techniques lasting for long periods of time and involving large amounts of liquids containing little sodium will most likely cause hyponatremia. Sodium lost in sweat differs among individuals; concentrations may range from 20 to 80 mmol/L (Maughan, 1991; Schedl et al., 1994; Coyle, 2004). Athletes who lose excessive amounts of this electrolyte while exercising can experience muscle cramps or weakness (Coyle, 2004).

The inclusion of sodium in sport drinks has several benefits. Addition of this cation improves taste and stimulates thirst. Moreover, the presence of sodium increases the intestinal absorption rate of fluids, and glucose absorption is also associated with sodium dependent carriers (Schedl et al., 1994; Coyle 2004). Nonetheless, the endogenous movement of sodium into the gastrointestinal tract assures that enough sodium will be present to aid absorption at all times (Coyle, 2004).

- Potassium

Potassium is also responsible (sodium) for maintaining an adequate water balance, osmotic equilibrium, and acid-base balance (Whitmore, 2000). This macromineral is also needed for regulation of neuromuscular activity and promotion of cellular growth.

Also, potassium is regarded as the major ion of intracellular fluid (Powers & Howley, 2004). In the colonic epithelium there is a high intracellular concentration of potassium as a consequence of the sodium / potassium ATPase, and consequently leakage of potassium occurs due to the permeability of the apical and basolateral membranes to this cations (Johnson, 2001).

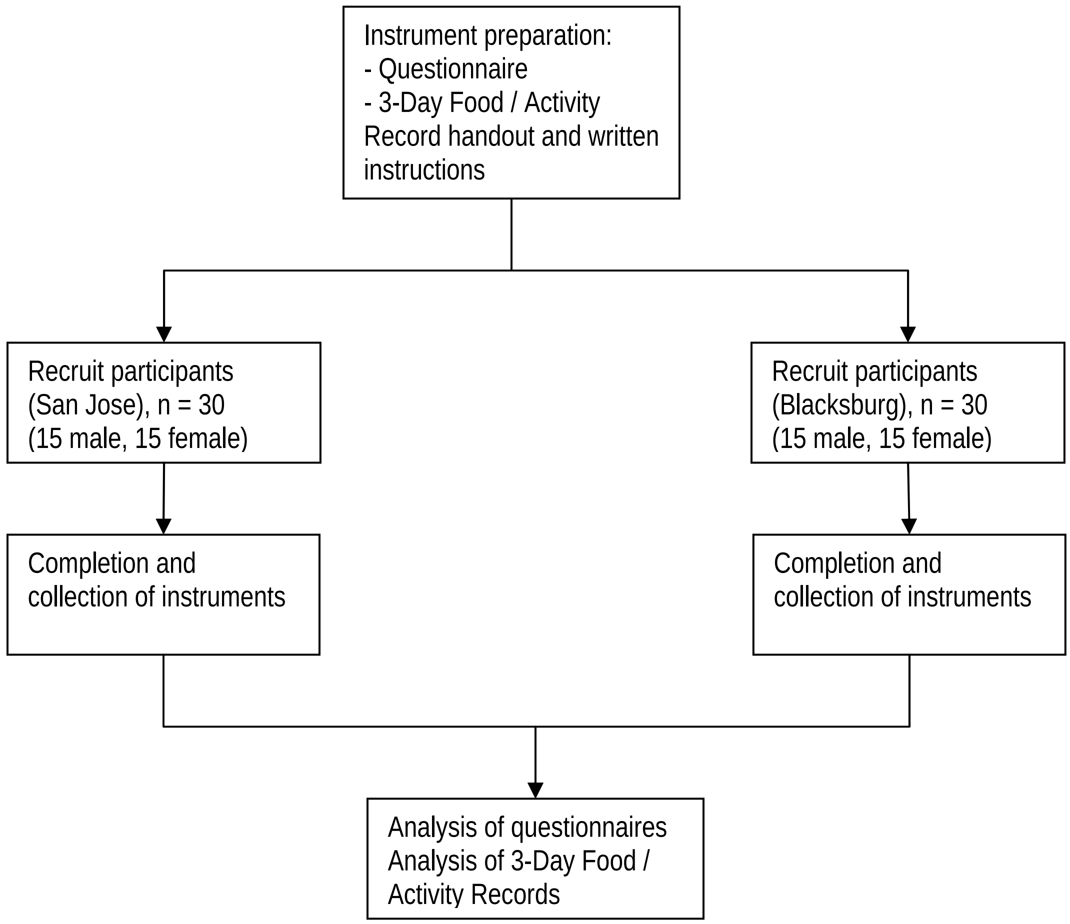
- Calcium

Calcium is widely known for its importance in bone and tooth health; however it is also involved in many other important functions. It is associated with blood clotting, it assists nerve impulse conduction, and it is essential for contraction of muscles (Powers & Howley, 2004).

- Magnesium

This cation, as well as calcium, also provides bone strength. In addition, it is implicated in assisting enzyme, nerve, and heart functions (Powers & Howley, 2004).

V. PROJECT OUTLINE



VI. MATERIALS AND METHODS

The protocols used in this study were approved by the Institutional Review Board (IRB # 04-355) at Virginia Polytechnic Institute and State University.

Recruitment of Participants

The subjects were recruited in gyms (University and local gyms) and athletic clubs in Blacksburg, Virginia and San Jose, Costa Rica. Thirty subjects were recruited in each location, 15 females and 15 males. Inclusion criteria was that subjects had to be between 18 and 50 years of age, and exercise at least 4 times per week for more than 1 hour each time, mostly aerobic type exercise (i.e. jogging, walking, swimming, basketball and cycling).

The goal was to obtain a sample size of 30 participants (n=30) per population with a non-probability sampling scheme (Cochran, 1977), meaning that the subjects who were recruited in the selected gyms and sports clubs, and that agreed to participate in the study would most likely share similar characteristics (e.g. age range, college students, education level). It was assumed that both populations have a normal distribution, and a sample size of 30 guarantees that non-extreme departures from normality would be adequately approximated (Central Limit Theorem) (Vining, 1998). The Central Limit Theorem states that the distribution of the sample mean can be approximated to the normal distribution if the sample size is sufficiently large. Achieving a response rate from recruited participants of 100% was not possible, however the sample size from each population (San Jose: n = 27; Blacksburg: n = 26) was still sufficiently large.

At the gyms, individuals who were practicing cardiovascular type exercise were approached. Individuals were asked for a few minutes of their time in order to tell them briefly about the study before proceeding with the recruiting process. Participants were recruited by selective sampling. To determine if individuals could be eligible to participate in the study, prospective subjects were asked their age, how many times a week they exercise and for how long, and what types of exercise they practice each week. The subject's availability and interest to participate was assessed. At the time of recruitment the subjects were informed that participation would be voluntary (no additional compensation), that the collected information would be kept confidential and codes would be utilized instead of personal names to analyze the data, and that they had freedom to withdraw at any given time. It should be noted that some of the individuals who were approached declined to participate in the study or did not meet the inclusion criteria. Therefore, all subjects who volunteered to be part of the study met the inclusion criteria and were genuinely interested in participating.

Instrument Preparation

The "Eating Habits and Physical Activity Questionnaire" (see appendix A) and the "3 Day - Food / Activity Record" (see appendix B) were prepared with the help of graduate students and faculty from the Department of Human Nutrition, Foods and Exercise at Virginia Tech. Furthermore, the questionnaire was revised by the Virginia Tech Statistical Consulting Center to assure that this data collection instrument was organized in a logical manner and its design would allow the researchers to obtain useful information. Written instructions on how to complete the 3 Day – Food / Activity Record were also prepared (see appendix C).

The reliability of the questionnaire was tested by having 6 subjects complete the instrument twice within a two week period. Then the questionnaires were analyzed to determine if the information provided on both occasions was comparable. It should be noted that the information collected the first time the questionnaire was completed was very similar to the information that was recorded several days later.

Weight and Height Measurements

The weight and height of the participants was recorded with calibrated instruments. In San Jose a portable electronic balance and a wall standiometer was utilized, whereas in Blacksburg the electronic balances available in the gyms were used.

Analysis of the Eating Habits and Physical Activity Questionnaire

Analysis of data obtained with this instrument provided valuable information regarding the eating habits, physical activity habits, current knowledge about the relationship between nutrition and athletic performance of the two sample populations.

Analysis of the 3 Day – Food / Activity Records

Food records were analyzed to determine the total energy content of the diets regularly consumed by the subjects', average daily macronutrient distribution, dietary fiber and alcohol intake. Nutritionist Pro^{TM} software (version 2.2.16; First DataBank Inc., San Bruno, CA) was utilized to conduct nutrient analysis of the 3-Day Food Records.

Statistical Analysis

Results are presented as mean values with standard deviations, except for frequencies. Two sample t-tests (α=0.10) were conducted to test differences between the means of variables when appropriate using Minitab® Release 12 software (Minitab Inc., State College, PA) (see Appendix D).

VII. RESULTS

General Characteristics of Subjects

Tables 1 and 2 show the characteristics of the subjects from San Jose, Costa Rica (CR) and Blacksburg, VA, respectively. The sample population from San Jose was recruited at gyms near the University of Costa Rica, and it was composed of 27 subjects (14 female and 13 male). In Blacksburg, VA the participants were recruited from the two on-campus gyms available to Virginia Tech students, and it was composed of 26 subjects (12 female and 14 male). The participants were considered to be healthy based on the information provided, and were physically active people. In both groups only 5 subjects had undergone previous nutritional counseling. Less than 19% of the subjects from CR were on a diet at the time the data was collected, and in VA less than 12% were dieting.

The average time spent practicing physical activity per week was very similar in both populations (approximately 12 hours/week). Nonetheless, there were differences among each gender regarding the amount of physical activity performed per week. These differences were not statistically significant. In addition, the range of exercise hours was considerable, 4 hours to 26 hours in VA and 5.5 hours to 21 hours in CR.

Table 1. Subjects' characteristics, San Jose (n = 27, 14 female, 13 male).

Characteristic	All subjects	Female subjects	Male subjects
Age (years)	24.93 ± 6.72	25.57 ± 6.95	24.23 ± 6.69
BMI (Kg/m^2)	23.06 ± 2.55	22.54 ± 2.54	23.62 ± 2.53
Diagnosis of chronic diseases	None	-----	-----
Previous nutrition education/counseling	5 (18.52%)	3 (21.43%)	2 (15.38%)
Currently on a diet	5 (18.52%)	4 (28.57%)	1 (7.69%)
Nutritional supplements	6 (22.22%)	4 (28.57%)	2 (15.38%)
Physical activity per week (hours)	12.27 ± 4.65	12.27 ± 5.16	12.27 ± 4.30

Table 2. Subjects' characteristics, Blacksburg (n = 26, 12 female, 14 male).

Characteristic	All subjects	Female subjects	Male subjects
Age (years)	19.77 ± 1.70	19.33 ± 1.30	20.14 ± 1.96
BMI (Kg/m^2)	23.53 ± 3.09	22.02 ± 1.81	24.84 ± 3.40
Diagnosis of chronic diseases	None	-----	-----
Previous nutrition education/counseling	5 (19.23%)	3 (25.00%)	2 (14.29%)
Currently on a diet	3 (11.54%)	1 (8.33%)	2 (14.29%)
Nutritional supplements	8 (30.77%)	4 (33.33%)	4 (28.57%)
Physical activity per week (hours)	12.13 ± 6.55	9.81 ± 5.71	14.11 ± 6.76

Tables 1 and 2, and also figure 1 provide information regarding the subjects' Body Mass Index (BMI). The average BMI for female subjects from CR was 22.5 Kg/m^2, and the men had an average BMI of 23.6 Kg/m^2. One of the subjects from CR had a BMI less than 18.5 Kg/m^2, 18 had a BMI between the normal range, and 8 had a BMI greater than 25 Kg/m^2 but less than 30 Kg/m^2. The average BMI for the subjects from VA also fell in the normal range category, 22.0 Kg/m^2 for females and 24.8 Kg/m^2 for males. None of the participants from VA had a BMI smaller than 18.5 Kg/m^2, 19 had a BMI between the normal range, 6 subjects had a BMI greater than 25 Kg/m^2, and 1 subject had a BMI greater than 30 Kg/m^2.

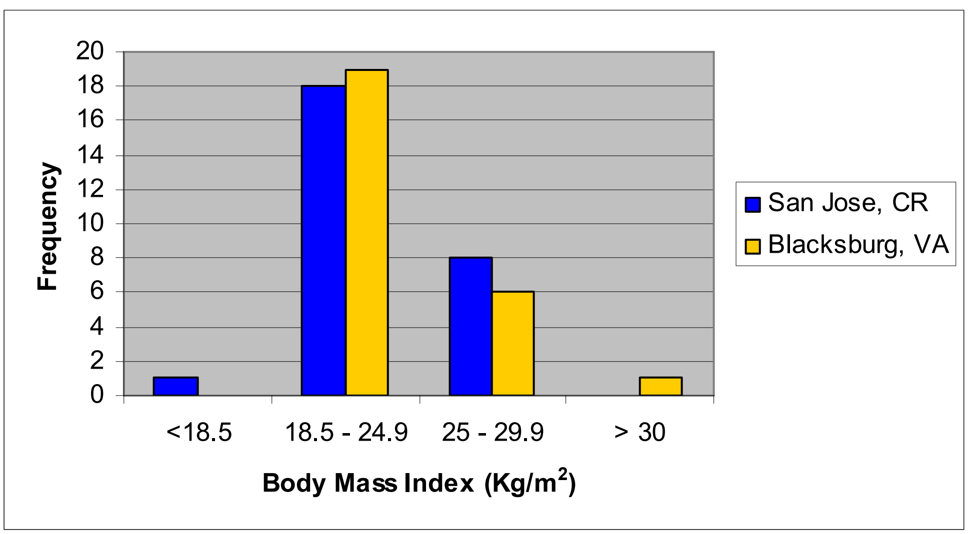


Figure 1. Distribution of subjects according to BMI categories.

Eating Habits

Regarding the subjects' meal patterns, the participants from CR regularly consume an average of 4.41 (± 0.93) meals per day. Having 5 meals per day was a common practice (13 subjects, 48.15%), whereas 6 (22.22%) subjects had 3 meals per day, another 6 participants regularly consume 4 meals per day, and only 2 (7.41%) subjects have 6 meals daily. All of them reported eating breakfast and lunch, 16 (59.26%) participants consume a morning snack, 17 (62.96%) have an afternoon snack, 26 (96.30%) consume dinner and 6 (22.22%) subjects regularly eat a night time snack. Only 3 subjects reported food allergies, 2 of which are allergic to sea food.

The sample population from Blacksburg, VA generally consumes an average of 4.12 (± 0.77) meals per day. Twenty five (96.15%) subjects reported to regularly eat lunch and dinner. Eighteen (69.23%) participants make a habit out of eating breakfast, 9 (34.62%) consume a morning snack, 14 (53.85%) and 16 (61.54%) of the subjects regularly have an afternoon and night time snack, respectively. Most of the participants from VA consume 4 (11 subjects, 42.31%) and 5 (9 subjects, 34.62%) meals on a daily basis, while 6 subjects from the sample usually have 3 meals per day. Regarding food allergies, three subjects reported an allergy to milk or lactose intolerance, and one an allergy to nuts.

Figures 2, 3 and 4 show foods that have a low (Fig. 2), moderate (Fig. 3) or high glycemic index (Fig. 4) and compares the frequency of consumption of these foods by the regular exercisers from San Jose and Blacksburg.

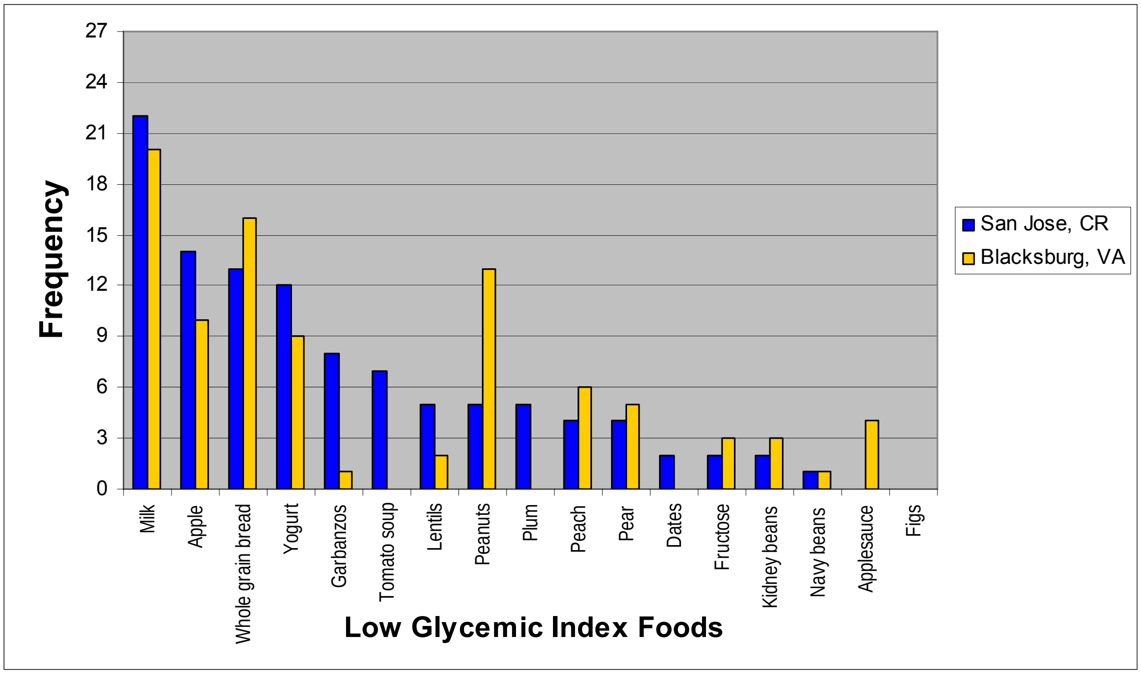


Figure 2. Frequency of consumption of certain low glycemic index foods by the sample populations from CR and VA.

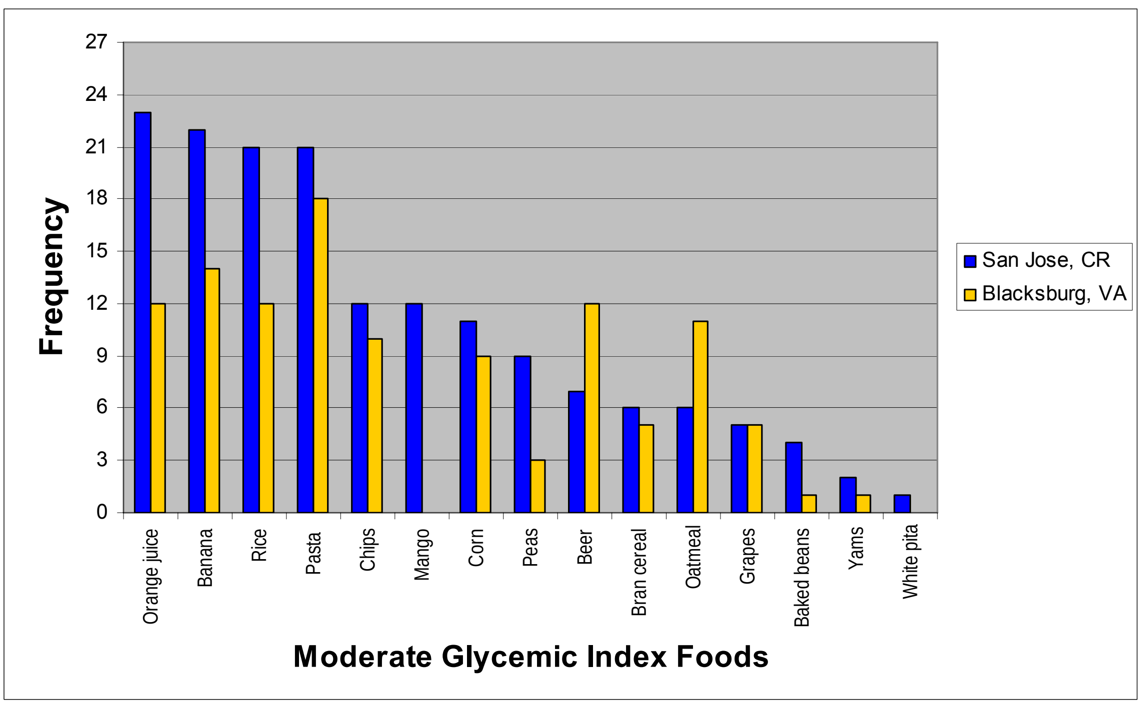


Figure 3. Frequency of consumption of certain moderate glycemic index foods by the sample populations from CR and VA.

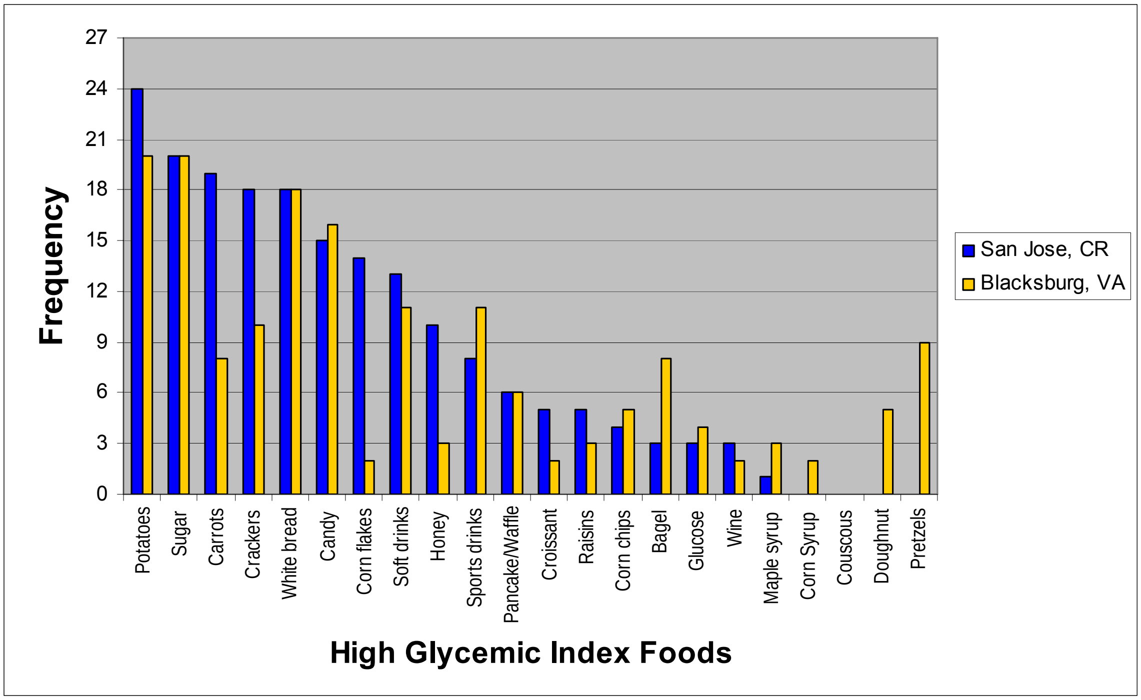


Figure 4. Frequency of consumption of certain high glycemic index foods by the sample populations from CR and VA.

Table 3 shows a list of foods, by food groups, which puts together all of the foods that are consumed by the subjects on a regular basis (at least once a week). The starches most commonly consumed by both sample populations are potatoes, pasta, bread and rice. Consumption frequency of dairy products, chicken and beef is very similar, whereas regular consumption of legumes is more common among Costa Ricans. The types of fruits and vegetables consumed by both sample populations are variable; however banana is the most commonly eaten fruit by each group.

Table 3. Foods regularly consumed by both sample populations.

Food group	Foods / Beverages	Frequency CR	Frequency VA	Food group	Foods / Beverages	Frequency CR	Frequency VA	Food group	Foods / Beverages	Frequency CR	Frequency VA
Cereals/ Starches	Potato	21	15	Legu-mes	Black beans	19	6	Fruits	Banana	15	12
	Rice	19	6		Lentils	9	0		Apple	14	8
	Pasta	18	14		Garbanzos	8	1		Papaya	11	0
	Bread	6	8		Peas	4	1		Orange	10	4
	Breakfast cereal	5	10		Green beans	4	6		Mango	10	0
	Yucca	5	0		Lima beans	0	2		Pineapple	9	3
	Plantain	4	0		String beans	0	1		Watermelon	8	1
	Corn	3	2		Navy beans	0	1		Plum	6	0
	Yam	3	0						Strawberries	5	3
	Tortillas	2	2	Vegeta-bles	Tomato	19	2		Cantaloupe	5	3
	Whole grain bread	2	0		Lettuce	13	7		Peach	4	5
	Oatmeal	1	3		Carrot	10	7		Pear	3	3
	Crackers	0	2		Cucumber	9	2		Jocotes	3	0
	Pretzels	0	1		Chayote	9	0		Grapes	2	4
					Broccoli	8	10		Kiwi	1	0
Sugars	Soft drinks	9	10		Cabbage	8	0		Orange juice	0	6
	Granulated sugar	8	2		Squash	6	1		Raisins	0	1
	Candy	6	11		Mushrooms	6	2		Apricot	0	1
	Sweets	3	9		Cauliflower	3	1				
	Gum	1	0		Beet	3	0	Dairy	Milk	21	20
	Honey	1	0		Celery	0	1		Cheese	21	16
	Jelly	1	0		Radish	0	1		Yogurt	11	5
	Molasses	1	0		Peppers	0	1				
	Syrup	0	3		Spinach	0	1				

Table 3. Foods regularly consumed by both sample populations (continued).

Food group	Foods / Beverages	Frequency		Food group	Foods / Beverages	Frequency		Food group	Foods / Beverages	Frequency	
		CR	VA			CR	VA			CR	VA
Meats / Fish	Chicken	19	20	Fats	Butter	7	2	Fast foods	Burgers	11	7
	Beef	16	15		Vegetable oil	7	0		Fried chicken	8	6
	Fish	16	2		Chocolate	7	5		Fries	6	9
	Tuna	8	6		Avocado	6	0		Tacos	4	1
	Shrimp	3	1		Cream cheese	3	0		Pizza	3	2
	Pork	2	6		Olive oil	3	0		Hot dog	1	2
	Ham	1	3		Sour cream	3	0		Subs	1	1
	Turkey	1	7		Mayonnaise	1	1		Cheese steak	0	1
	Salami	0	1		Nuts	1	1		Hash browns	0	1
	Bologna	0	1		Peanut butter	1	0				
					Ice cream	0	6				
					Flax seed oil	0	1				
					Salad dressing	0	1				

Food Record Analysis

Tables 4 and 5 show data obtained from the evaluation of 3 day food records. The average daily energy intake among the sample population from CR was approximately 1970 Kcal. Females consumed about 1900 Kcal; however the sample had a considerable range of energy consumption, 916 Kcal to 3501 Kcal. The average caloric intake for men was 2050 Kcal, with an energy intake range of 1447 Kcal to 2721 Kcal.

Female subjects from VA consumed approximately 1800 Kcal (range: 1488 Kcal to 2065 Kcal), while the men had an average daily intake of about 2430 Kcal (range: 1669 Kcal to 3597 Kcal). The average energy intake for all the subjects from Blacksburg was about 2140 Kcal. Significance testing for difference between means for energy intake revealed that statistically the only difference was seen among male subjects from each sample population.

The average dietary fiber intake was similar for both populations, but it was below recommended levels. The subjects from CR consumed an average of 17.6 grams of dietary fiber (range: 6.3 g to 38.0 g), and the participants from VA consumed 15.6 grams (range: 5.6 g to 30.6 g). It should be noted that among female subjects there was a statistically significant difference between the means for fiber intake.

In addition to the data provided in Tables 4 and 5, figure 5 shows the contribution of macronutrients and alcohol to the total daily energy intake. Intake of proteins and carbohydrates was slightly higher by the CR group, which means that percent fat intake by the Blacksburg sample group was greater. The difference between means for fat intake among sample populations was statistically significant. The difference between means for percent carbohydrate contribution to the total energy intake was statistically significant among male subjects. The percent ranges for the macronutrients are as follows. Intake of carbohydrates: 1) CR-female 38.5% to 63.2%; 2) CR-male 40.2% to 71.1%; 3) VA-female 42.5% to 68.4%; 4) VA-male 34.7% to 59.3%. Intake of protein: 1) CR-female 11.6% to 32.2%; 2) CR-male 11.3% to 30.0%; 3) VA-female 8.4% to 21.1%; 4) VA-male 11.8% to 23.1%. Intake of fats: 1) CR-female16% to 38.4%; 2) CR-male 17.6% to 40.9%; 3) VA-female 23.2% to 42.0%; 4) VA-male 18.9% to 41.6%.

Table 4. Food record analysis: Energy intake, macronutrient distribution, and dietary fiber ingestion (San Jose, Costa Rica).

Calories/Nutrient	**All subjects**	**Female**	**Male**
Energy intake (Kcal)	1966.37 ± 595.95	1889.42 ± 743.71	2049.23 ± 394.94
Protein (%)	17.65 ± 5.54	18.09 ± 6.25	17.18 ± 4.88
Carbohydrates (%)	52.74 ± 8.14	52.01 ± 8.44	53.53 ± 8.06
Fat (%)	28.23 ± 6.49	27.97 ± 6.26	28.52 ± 6.96
Alcohol (%)	1.41	1.99	0.79
Dietary fiber (grams)	17.62 ± 8.87	18.96 ± 9.24	16.18 ± 8.59

Table 5. Food record analysis: Energy intake, macronutrient distribution, and dietary fiber ingestion (Blacksburg, VA).

Calories/Nutrient	**All subjects**	**Female**	**Male**
Energy intake (Kcal)	2138.62 ± 544.67	1795.42 ± 187.31	2432.79 ± 581.98
Protein (%)	16.38 ± 3.74	14.91 ± 3.52	17.64 ± 3.56
Carbohydrates (%)	50.30 ± 6.82	52.53 ± 6.96	48.39 ± 6.33
Fat (%)	31.40 ± 5.66	31.23 ± 5.61	31.54 ± 5.91
Alcohol (%)	1.93	1.34	2.43
Dietary fiber (grams)	15.62 ± 6.15	13.78 ± 4.90	17.20 ± 6.83

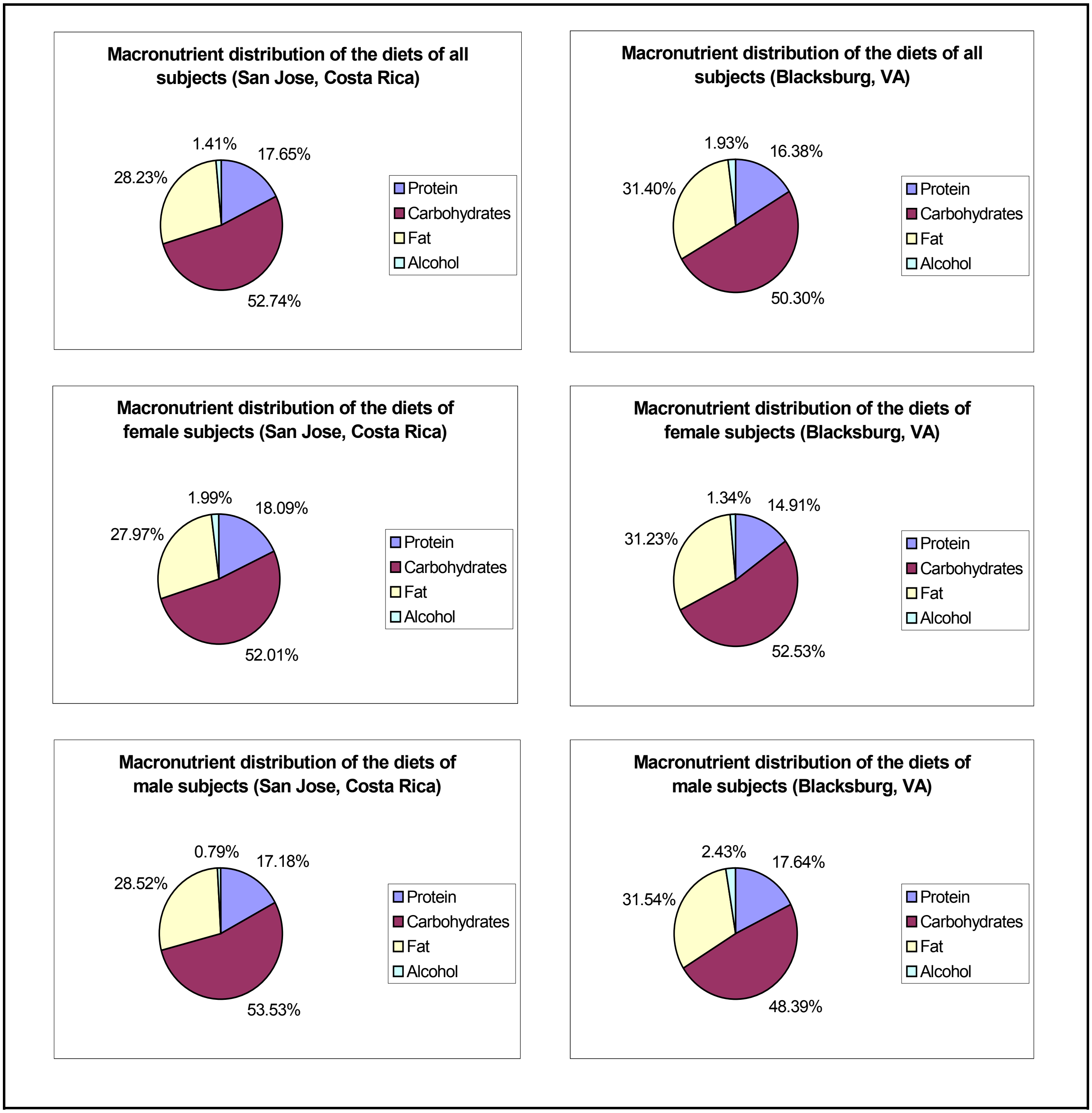


Figure 5. Percent contribution of macronutrients and alcohol to the total energy intake of the subjects from San Jose, CR and Blacksburg, VA.

Physical Activity

Tables 6 and 7 show the types of physical activity performed by the subjects from the two sample populations and the average time spent in each activity per week. Jogging, weight training, walking and aerobics were among the most popular activities practiced by subjects from both groups. The average duration of the exercise sessions for these activities were also similar among the groups.

Table 6. Types of physical activity practiced by the subjects from San Jose, Costa Rica.

Activity	Frequency	Times /week	Minutes / session
Weight training	16	3.66 ± 1.19	79.38 ± 33.56
Aerobics (Aerobics, dance, Taebo)	11	3.82 ± 1.68	73.64 ± 36.41
Walk	11	3.77 ± 2.09	36.64 ± 20.01
Karate / Boxing / Kickboxing	9	4.00 ± 2.00	91.67 ± 21.80
Jog	8	3.75 ± 2.49	38.5 ± 13.55
Swim	7	3.00 ± 0.96	84.29 ± 46.14
Cycling (Road, stationary)	6	2.83 ± 1.72	85.00 ± 50.79
Basketball or Volleyball	1	6.00	120.00
Soccer	1	1.00	90.00
Tennis	1	1.00	150.00
Yoga	1	5.00	30.00
House work	1	1.00	120.00

*Note: Only 26 out of the 27 participants completed this section of the questionnaire.

Table 7. Types of physical activity performed by the subjects from Blacksburg, VA.

Activity	Frequency	Times /week	Minutes / session
Jog	16	3.88 ± 2.16	45.16 ± 27.70
Weight training	14	3.43 ± 1.41	67.86 ± 29.98
Basketball	13	3.69 ± 1.70	101.54 ± 37.83
Walk	13	6.00 ± 1.83	34.81 ± 22.92
Aerobics	5	4.00 ± 2.32	69.00 ± 39.12
Cardio machines	4	3.50 ± 2.38	24.38 ± 7.18
Swim	3	1.67 ± 1.15	69.00 ± 39.12
Cycling (Road, stationary)	3	2.33 ± 0.58	26.67 ± 5.77
Soccer	3	1.33 ± 0.58	60.00 ± 0.00
Volleyball	3	3.33 ± 2.08	120.00 ± 0.00
Golf	3	1.00 ± 0.00	240.00 ± 60.00
Abs, push ups, jumping jacks	2	5.25 ± 1.06	30.00 ± 0.00
Baseball	1	4.00	180.00
Pilates	1	1.00 – 2.00	40.00

Table 8 shows that approximately 46% of the subjects from both groups practice three different types of sports or exercise activities per week. Ten subjects from CR and 12 subjects from VA only engage in cardiovascular/aerobic type exercise. In average, weight training represents about 41% and 36% of the total physical activity practiced by subjects who strength train from CR and VA, respectively. It should also be noted that 22 of the participants from each group had maintained their physical activity level for more than 4 months at the time of data collection. Furthermore, approximately 35% of the subjects from CR and

62% of the subjects from VA have maintained their current physical activity level for more than three years.

Table 8. Physical activity levels of subjects.

Characteristic		Frequency	
		CR*	VA
Number of subjects who practice different sports / types of exercise per week	1 activity	3	1
	2 activities	4	5
	3 activities	12	12
	4 activities	6	3
	> 4 activities	1	5
Amount of time the subjects have maintained their current physical activity levels for	< 1 months	3	0
	1-3 months	1	4
	4-6 months	4	1
	< 1 year	4	3
	1-3 years	5	2
	> 3 years	9	16
Number of subjects who practice only cardiovascular/aerobic type exercise		10 (38.46 %)	12 (46.15%)
Weight training: average percentage of total physical activity.		40.99% ± 16.78%	35.59% ± 27.36%

*Note: Only 26 out of the 27 participants completed this section of the questionnaire.

Table 9 highlights the personal rating of the amount of hours spent exercising weekly by the subjects. None of the subjects from VA classified their current physical activity levels as low, and most of them rated their level as high. Most of the participants from CR rated their amount of exercise time per week as moderate or high. Interestingly, the subjects from VA who rated their physical activity as moderate exercised in average for less time than those subjects from CR who rated their level as low. Also, the participants from VA in the high rating category exercised for about the same time as those from CR who classified their physical activity level as moderate.

Table 9. Personal rating of current physical activity levels among subjects.

Rating	**Frequency**		**Hours / week**	
	CR*	**VA**	**CR**	**VA**
Low	3	0	7.83 ± 2.25	N/A
Moderate	10	6	11.00 ± 4.06	7.29 ± 1.87
High	10	14	13.30 ± 4.88	11.64 ± 6.13
Very high	3	6	17.50 ± 0.87	18.08 ± 6.46

*Note: Only 26 out of the 27 participants completed this section of the questionnaire

The subjects were also questioned about the relationship between nutrition and athletic performance. The first question was to list foods that they believe should be eaten by physically active people to enhance athletic performance. A wide range of foods were mentioned but the most common ones for both groups were pasta, sources of carbohydrates, meat, fruits and vegetables and protein sources. The subjects from CR also mentioned legumes and rice, but not as frequently. In addition, a few of the subjects from the two groups mentioned dairy products.

Subjects were also questioned on which foods should be avoided by athletes/physically active people, and the consensus was that high fat foods in general should not be consumed. Other foods agreed upon were alcohol, soft drinks and fast foods. The participants from VA also agreed that foods containing high amounts of sugar should be avoided.

Regarding the consumption of carbohydrates subjects were asked directly “what amount of carbohydrates should the daily diet of a physically active person provide?” The majority of the subjects from San Jose answered that carbohydrate consumption should be moderate (40.0%) or high (40.0%). These were also the most popular responses among the sample population from Blacksburg, where 38.46% answered moderate and 53.85% said high. The remaining subjects (7.69%) from Blacksburg said that carbohydrate consumption should be very high. A higher percentage of subjects from CR, 15.38%, indicated that consumption needs to be very high.

When asked specifically what types of carbohydrates should be consumed regularly by active people, both groups agreed on the following foods, in descending order, pasta, fruits, vegetables, grains and rice. Bread was listed quite frequently by the subjects from VA but not by those from CR. Also, several participants from CR mentioned legumes. Table sugar and sweets were popular responses to the question of which carbohydrates should be avoided.

Subjects were also asked to rate, on a scale from 0 to 10, “How likely is it that eating more carbohydrates may improve athletic performance?” The average response from Blacksburg’s sample population was 6.92 ± 1.90, and the response from San Jose’s group was 7.50 ± 1.71.

VIII. DISCUSSION

Description of Subjects' Characteristics

The primary objective of this study was to determine the consumption of resistant starch containing foods by regular exercisers in two distinct communities. Participants were recruited from San Jose, Costa Rica and Blacksburg, Virginia. A physical activity and eating habits questionnaire and 3-day food records were utilized to obtain data regarding the subjects' dietary habits, level of physical activity, and to assess general knowledge about the impact of nutrition practices on athletic performance.

The mean age for the sample population from San Jose (SJ) was considerably higher than that of the sample population from Blacksburg (Tables 1 and 2). The age range for SJ was 18 years to 46 years, whereas in Blacksburg it was 18 to 24 years of age. This difference in ages among the subjects could be due to several factors; the gyms where participants were recruited in Blacksburg are mainly for the use of college students, and undergraduates were more willing to participate in the study than graduate students. Whereas in SJ, most of the gyms where the subjects were recruited are highly visited by college students but are also open to non-students.

The mean body mass index (BMI) for all of the subjects was very similar (Tables 1 and 2). Comparing among genders, the mean BMI for female subjects from SJ was slightly higher than that of female subjects from Blacksburg. In contrast, the mean BMI for males in Blacksburg was higher than the mean for their counterparts from SJ. Nonetheless, all of the BMI means were between the normal BMI range of 18.5 Kg/m^2 to 24.9 Kg/m^2.

Five subjects from SJ had a BMI between 25 Kg/m^2 and 25.6 Kg/m^2, which is very close to the normal range. Three other subjects had BMIs smaller or equal to 28.0 Kg/m^2, which would classify them as overweight. Overweight and obesity usually accompany each other, however this is not a set rule. For example, regular exercisers may have a BMI above the normal range but not have excessive body fat so they would not be considered obese individuals. BMI is increased both by high amounts of muscle mass and fat mass, so it is possible for an individual with high muscle mass to have a high BMI even though their body fat content is not excessive (Witt & Bush, 2005). Therefore, when conducting research with exercisers or athletes related to nutritional status the subjects' body fat content should be calculated whenever possible in order to obtain more reliable information regarding body composition. One male subject from SJ had a BMI lower than 18.5 Kg/m^2, which classifies this individual as underweight. None of the subjects from Blacksburg had a BMI that would classify them as underweight.

In Blacksburg, only one female subject had BMI above 25.0 Kg/m^2 but it was very close to the normal range. Five male subjects had a BMI in the range for overweight classification; however, the BMI for three of them was below 27.0 Kg/m^2. Only one subject had a BMI above 30.0 Kg/m^2, which classifies him as an obese individual.

Description of Subjects' Eating Habits

Very few of the subjects from both sample populations had undergone previous nutritional counseling or had attended educational sessions. They indicated the sessions were given mostly by health professionals, including nutritionists, dietitians and medical doctors. Also, a small number of the subjects from each population were following a dietary plan. Mainly, low fat diets, high protein diets or calorie restriction diets. About one third of the sample from Blacksburg and one fifth of the subjects from SJ take nutritional supplements on a regular basis. Mostly, these subjects were taking multi-vitamin and mineral supplements. The fact that some of the subjects had received nutritional education sessions, others were on a dietary plan, and several were taking nutritional supplements allows one to assume that a significant portion of both sample populations is composed of nutrition/diet conscious individuals.

To better understand the subjects' eating habits they were asked about their meal pattern. The average number of meals consumed per day for both sample populations was approximately 4. The majority of subjects always have lunch and dinner. Less than 70% of the sample population from Blacksburg is accustomed to having breakfast, whereas 100% of the subjects from SJ normally eat breakfast. Morning snacks are more popular among participants from SJ, while night time snacks are more common with the sample from Blacksburg. This difference in snack time preference can probably be explained by the fact that the Blacksburg sample is composed of only college students, whereas the SJ sample population is more diverse regarding occupation.

It has been documented that living arrangements of college students often affect their eating and physical activity habits (Brevard & Ricketts, 1996; Driskell, 2005). In a study conducted by Driskell and collaborators (2005) which compared the eating and physical activity habits of lower and upper level college students, about 57% of the subjects reported normally having breakfast, ~ 20% a morning snack, ~87% lunch, ~54% an afternoon snack, ~95% dinner and ~73% a night time snack. These observations about which meals college students normally have are similar to our findings.

Eating Habits: Glycemic Index and Exercise Performance

The glycemic index is a measure of the blood glucose response after ingestion of foods. Consumption of a low glycemic index carbohydrate meal before exercise can contribute exogenous carbohydrate for substrate utilization without suppressing lipolysis to the degree that a high glycemic index meal would (Wu et al., 2003). The occurrence of fatty acid oxidation during exercise may delay the onset of glycogen depletion (Horowitz & Klein, 2000).

Given that resistant starch (RS) is not digested in the small intestine, its presence lowers the glycemic index of foods (Hoebler et al., 1999; Shamai et al., 2003). Good food sources of RS are legumes (116.8 g/Kg dry weight), kidney beans (5.3% RS content), lentils (3-4% RS or 114.4 g/Kg dry weight), black beans (1.7-11.6%), faba beans (1-7%), lima beans (2.1-4.4%), peas (11.0-12.4%), bananas, potatoes (3.2-3.8%), pasta (2.2-3.7%), high amylose corn, rice (50.9 g/Kg dry weight), corn flakes (2.8%) bread (2.0-2.2%), crackers (18.4 g/Kg dry weight), breakfast cereal (1.8-2.3%), and stale foods (Lintas & Capelloni, 1992; Rabe & Sievert, 1992; Tovar & Melito, 1996; Brighenti et al., 1998; Skrabanja et al., 1999; Brown, 2004; McCleary & Rossiter, 2004).

Human studies looking at the effect of resistant starch intake on postprandial glycemic and insulinemic responses have described variable results. Nonetheless, it is generally believed that consumption of RS decreases postprandial glycemia moderately but lowers insulin concentrations significantly (Higgins et al., 2004).

Higgins and associates (2004) studied the effect of the RS content of a meal on post absorptive fat oxidation. Subjects received tests meals that were isocaloric and had the same nutrient composition except for their content of RS, either 0%, 2.7%, 5.4% or 10.7%. This group observed that a 5.4% addition of RS to the meal increased postprandial fat oxidation. Fat oxidation was increased at 6 hours post ingestion of the meal and at 24 hours it remained elevated, which showed that inclusion of RS to a meal results in a prolonged effect on substrate utilization. Furthermore, the increased oxidation of fat resulted in a reduction in carbohydrate oxidation, which during exercise could contribute to spare glycogen stores.

The low glycemic index foods (Fig.2) more commonly consumed by both sample populations are milk, whole grain bread, apples and yogurt. Peanuts are consumed by half of the sample population in Blacksburg but not regularly consumed by most of the subjects from SJ. Consumption of garbanzos was reported by approximately 30% of the participants from SJ, and only 1 subject from Blacksburg regularly eats this type of legume. Lentils are not consumed too frequently by the SJ subjects, but their consumption is still more common among this sample population than the Blacksburg group. Reported consumption of kidney beans and navy beans was low for both sample populations. In retrospect, black beans should have been included in the list of low glycemic index foods from which the subjects were asked to mark the regularly consumed foods. The reason being that black beans are often times consumed on a daily basis by most Costa Ricans. Legumes usually have greater RS contents than cereals given their higher amylose content (Niba, 2002). It has been shown that the higher the content of amylose the greater the susceptibility of the starch to undergo retrogradation (Topping et al., 2003), and become more resistant to digestion.

Frequent consumption of baked beans was low for both populations, however, its consumption was higher among the SJ sample (Fig. 2). The moderate glycemic index foods / beverages which were reported to be more frequently eaten by both groups are pasta, bananas, rice, orange juice, potato chips, and corn (Fig. 3). From these foods / beverages, orange juice, bananas and rice were notably consumed by more subjects from the SJ sample as compared to the Blacksburg sample. This fact was not really surprising given that rice, along with black beans, is a staple in the diet of Costa Ricans, and bananas are widely available and one of the less expensive fruits in Costa Rica. The lower consumption of orange juice by the subjects from Blacksburg, in comparison to the SJ sample, could be associated to the fact that breakfast is not regularly consumed by about 30% of this sample population.

Peas are also good sources of resistant starch, and the consumption of this food is much more frequent among subjects from SJ. In contrast, consumption of oatmeal is more common among the subjects from Blacksburg. Oats are a good source of beta glucans, a viscous form of fiber which is also associated with improving glycemic and insulinemic responses (Hallfrisch & Behall, 2000).

The most frequently consumed high glycemic index foods by both groups are potatoes, granulated sugar, white bread, candy, soft drinks and sports drinks. Consumption of high glycemic index foods is recommended for glycogen recovery after exercise, especially during the first couple of hours post exercise when the glycogen synthesis rate is faster (Burke et al., 2004). Potatoes are high glycemic index foods but at the same time if the starch fragments undergo retrogradation then their resistant starch content would increase, and subsequently the glycemic index of potatoes may decrease. Carrots, crackers, corn flakes and honey are more commonly consumed by the subjects from SJ, whereas consumption of bagels and pretzels is much greater among the subjects from Blacksburg. Potatoes, bread and corn flakes usually contain retrograded starch (Brouns et al., 2002). It can be assumed that most of the RS consumed by individuals is retrograded starch, given that even though RS occurs naturally in foods most of the RS in the diet of individuals is available as a result of food processing techniques (Muir et al., 1995; Brighenti et al., 1998).

Currently there are no specific dietary recommendations regarding the amount of resistant starch that should be consumed daily; however, some studies suggest that at least 20 grams per day should be ingested to obtain physiological benefits (Baghurst et al., 1996; Brouns et al., 2002). Brighenti and colleagues (1998) estimated the content of RS in the typical Italian diet to be 8.5 grams / day. It has been estimated that in other European countries the average RS consumption was approximately 4 grams per day (Voragen, 1998). Moreover, a Western diet usually provides about 4.5 grams of RS per day (Van Munster et al., 1994; Grubben et al., 2001). The estimated resistant starch intake for the SJ group was higher than that of the Blacksburg group, 9.6 grams /day and 5.2 grams / day respectively. It should be noted that this is a rough estimate which was calculated based on the reported consumption frequency of various foods, estimated portion sizes, and the percent RS content of foods.

The intake of RS is associated with several physiological benefits, including high fermentability; low levels of gas formation during fermentation; reduction of colonic pH; and prebiotic actions (Brouns et al., 2002). Therefore, most individuals would benefit from increasing their consumption of foods which are sources of RS. Another way to increase the intake of RS intake is by adding chemically modified RS to foods, and this can be done without modifying the physical characteristics of foods (Murphy, 2001).

In addition to the effects of RS ingestion before exercise on glycemic and insulinemic responses, which may help exercisers maintain the exercise intensity for a longer period of time, RS intake may also benefit exercisers by influencing the absorption of water and electrolytes in the colon. Fermentation of RS occurs mainly in the proximal colon, and it yields short chain fatty acids. Short chain fatty acids stimulate water absorption and uptake of sodium, potassium, calcium and magnesium, thus the increased production of these acids by fermentation of RS in the proximal colon results in increased fluid and electrolyte absorption (Brouns et al., 2002; Topping et al., 2003).

Table 3 lists foods that are regularly consumed by subjects from both communities. Most of the information from this table follows a similar pattern of consumption as that shown in the figures which list foods by glycemic index. However, there are some discrepancies in the reported frequency of consumption of some foods by the subjects. A possible explanation for this occurrence is that subjects were prompted for the information in two different ways in the questionnaire. In one section they were asked to list the foods / beverages that they consume on a regular basis in blank spaces next to the name of the food groups, and in the other part the subjects were asked to select foods from a specific list of foods.

Nonetheless, potatoes, pasta, bread and rice are also reported as the more regularly consumed starches by both groups. Rice and legumes also appear to be more regularly consumed by subjects from SJ. Consumption of fats is reported to be low by the subjects, however, a considerable number of subjects from both groups eat fast food regularly.

Regarding fruit and vegetable consumption, the 2005 Dietary Guidelines for Americans recommend that a reference 2000 calorie diet should include two cups of fruit and 2.5 cups of vegetables per day. In addition, it is not only important to try to consume a certain number of fruits and vegetables per day but the variety of these in the daily diet are also very important. It appears that subjects from SJ consume a greater variety of vegetables and fruits in comparison to the sample population from Blacksburg.

Macronutrient, Dietary Fiber and Alcohol Intake

T-tests were utilized to test for differences between the means for energy, macronutrients and fiber intake among the sample populations. In addition, comparisons according to gender were also made. A significance level of α=0.10 was utilized for all the tests. The justification for using this significance level is that once the samples were divided by gender the sample size became too small (i.e. 12 female subjects from Blacksburg and 14 from SJ) to identify differences at a higher significance level.

The mean energy intake of the subjects from Blacksburg was slightly higher than that of the SJ sample. Energy intake of female subjects was relatively similar, and the energy intake of male subjects from Blacksburg was significantly higher than that of male subjects from SJ.

The fat intake of Blacksburg's sample was significantly higher than that of the participants from SJ. However, the mean fat intake was still appropriate according to the 2005 Dietary Guidelines for Americans. These guidelines suggest that total fat intake should be between 20 to 35% of the total daily energy intake. Although it should be noted that the range for percent fat intake was 18.9% to 42.0%, which shows that some of the subjects have a fat intake above the recommended levels. The same occurs with the sample from SJ where the mean intake for fat is below 30%; however the intake of this macronutrient ranges from 16.0% to 40.9%.

The female sample from SJ consumed in average a higher amount of their total energy intake as protein; nonetheless this was not a statistically significant difference. The mean protein intake for all subjects was between the recommended range of 15% to 20% of total energy intake.

Approximately half of the daily energy consumed by Blacksburg's subjects was eaten in the form of carbohydrates. The mean intake of carbohydrates by the subjects from SJ was slightly higher. The only significant difference regarding carbohydrate consumption was observed among male subjects, where male subjects from SJ consumed in average 5% more carbohydrates.

Both groups had dietary fiber intakes considerably below the recommended levels. Subjects from SJ consumed approximately two more grams of fiber than Blacksburg's subjects. Female participants from SJ had a significantly higher fiber intake than female participants from Blacksburg. Since RS acts physiologically as soluble fiber (Haralampu, 2000), increasing consumption of resistant starch products could help subjects obtain physiological benefits similar to those provided by fiber.

Alcohol intake did contribute on average a small percentage of energy to the daily diet of both sample populations. Nonetheless, only 6 subjects from each group reported alcohol consumption during the time the food records were kept.

Levels of Physical Activity among Subjects

The 2005 Dietary Guidelines for Americans indicate that one of the keys to maintain body weight in adulthood is to engage in about 60 minutes of moderate to vigorous intensity activities on most of the week days.

To be eligible to participate in this study subjects had to exercise at least four times a week for one hour or more, so all of the subjects did meet the recommendation regarding quantity of exercise per week set forth by the Dietary Guidelines to maintain body weight. The mean for hours per week spent doing physical activity by all subjects was approximately 12 hours. There was no gender variation in the average time subjects from SJ were physically active. However, this was not the case among participants from Blacksburg. Male subjects exercised, in average, about 4 more hours per week than female subjects. In addition, female subjects from SJ exercised approximately 2.5 hours more per week than female participants from Blacksburg, whereas the men from Blacksburg exercised for more time than the men from SJ. However, none of these differences in exercise hours per week were significantly different.

The most popular activities among both groups were jogging, weight training, walking and aerobics. Contact sports such as karate and kickboxing, as well as swimming and cycling were popular among San Jose's subjects, while basketball was frequently practiced by subjects from Blacksburg. These results were probably influenced by the infrastructure of the place of recruitment.

The Dietary Guidelines for Americans also emphasize working to achieve/maintain physical fitness by practicing several types of exercise, such as those intended for cardiovascular conditioning, stretching and resistance exercises. From the questionnaire we learned that more than 60% and 53% of the subjects from SJ and Blacksburg, respectively, practice cardiovascular / aerobic type physical activity combined with weight training. It should also be mentioned that a minority of subjects from both sample populations engage in only 1 type of physical activity during the week.

Knowledge about Nutrition and Athletic Performance

To gain a better understanding of the knowledge of regular exercisers about the relationship between nutrition and athletic performance the subjects were asked several questions on this topic. The first question asked the subjects to list foods which they consider that athletes / physically active people should consume to enhance athletic performance, and explain why. Then the following question asked them to list foods that should be avoided by athletes. The foods which were frequently listed as good for exercisers by both groups were pasta, sources of carbohydrates, meats, fruits and vegetables, and sources of protein. Subjects from SJ also listed legumes and rice. Most of the subjects understood that carbohydrates are sources of energy; some of them even knew that carbohydrates are the main source of energy for athletes. For this reason pasta was listed frequently as a food that physically active people should eat. Also, protein intake was considered important for rebuilding / repairing muscle and increasing muscle mass. Fruits and vegetables were highlighted as being good sources of vitamins and fiber.

Rosenbloom and colleagues (2002) assessed the nutrition knowledge of athletes involved in different sports at a Division I NCAA University, and reported that approximately 59%of the subjects understood that carbohydrates and fat are the primary energy sources for physical activity. Still, about 45% of the athletes also responded positively when asked if protein is the main energy source for the muscle. Previous studies on the nutrition knowledge of athletes have also shown that many believe that protein is the main energy source for muscles (Wiita et al., 1995; Wiita & Stombaugh, 1996; Rosenbloom et al., 2002). These findings provide further evidence that there is still confusion among some athletes about which macronutrients provide the energy for exercise.

High fat foods, alcohol and soft drinks were regularly listed as the foods that should be avoided by athletes. The main reasons why high fat foods were considered as harmful were because they are sources of cholesterol, may deteriorate blood circulation, and may cause weight gain. Soft drinks were listed because of their caffeine and high sugar content.

These two questions were asked again, but instead of asking which foods in general should be consumed or avoided by exercisers the subjects were questioned specifically on carbohydrates. Granulated sugar and sweets were listed as the carbohydrate food sources that may harm performance. As could be expected pasta was the most frequently mentioned carbohydrate which is perceived as beneficial to athletes, followed by fruits, vegetables, grains and rice. In addition, subjects from Blacksburg repeatedly listed bread as an answer for this question. A few of the subjects indicated that consumption of grains is associated with a slower but constant release of energy, and that sugar should be avoided because of the high glycemic response it causes.

Subjects were also questioned on the amount of carbohydrates that the diet of a physically active person should contain. The vast majority of subjects answered that consumption of carbohydrates should be either moderate or high. A few subjects answered that consumption of this macronutrient should be very high.

Subjects were asked to choose a number on a scale from 0 to 10 to answer how likely it is that by eating more carbohydrates athletic performance may be improved. The mean rating given by the participants from San Jose was slightly higher, 7.50 vs. 6.92, than the responses given by Blacksburg's group. Nonetheless, both answers confirm the fact that subjects believe adequate carbohydrate consumption does play an important role in athletic performance.

IX. CONCLUSIONS

The more frequently consumed food sources of resistant starch by both groups were pasta, potatoes, bananas and corn. Rice and legumes, such as black beans, garbanzo beans, lentils and peas were consumed more regularly by the subjects from San Jose. Based on the greater variety of resistant starch foods regularly consumed by the sample population from San Jose, it can be speculated that resistant starch consumption of these subjects is higher than those from Blacksburg. Furthermore, an estimation of the resistant starch intake also showed that consumption was higher by the San Jose group, 9.6 grams / day compared to 5.2 grams / day. In addition, the average dietary fiber intake was slightly higher among the subjects from San Jose. Consumption of low glycemic index foods, such as those containing resistant starch and fiber, before exercise can result in a slower release of glucose into the bloodstream, and produce a stable insulinemic response which may benefit exercisers by not inhibiting lipolysis.

Individuals who practice aerobic type exercise and usually do not consume carbohydrates or ingest sports drinks during exercise sessions may benefit the most from consuming RS before exercise.

The majority of the subjects had a good understanding of the relationship between nutrition and exercise performance, and how the composition of the daily diet can affects one's level of energy throughout the workout.

Carbohydrates were perceived as the main energy source which should be consumed in moderate to high amounts.

Limitations of this Study

Possible factors that could have affected the results of this study are the following: fatigue of the participants while answering the questionnaire; alteration of food selection while keeping the record either to simplify the process or to come across as an individual with healthy eating habits; under or over reporting of foods on the records; and fatigue while keeping the food records.

Studies based on self reported data by subjects always have the limitation of having to rely on the reporting accuracy of the individual. To minimize the occurrence of these possible limitations, a 3-day food record was utilized, instead of one with a longer duration, to decrease the possible onset of fatigue or loss of interest by the individual. Also, at the time of recruitment it was emphasized to the subjects that they should record every single food or beverage regardless of its nutritional value.

Another possible limitation of this study was that the two samples were not completely comparable since most but not all of them were college students and the age range differed. In addition, the findings regarding the eating and physical activity habits of the regular exercisers from these two communities can not be generalized to all young adults or competitive athletes.

Potential Future Research

Future studies in this research area should perform dietary interventions, resistant starch feedings before physical activity, with regular exercisers or athletes. These studies could be dose response studies, or comparison studies on the effect of different types of RS on glycemic and insulinemic responses and on substrate utilization. In addition, the effect of consuming RS before exercising at different intensities or durations could be evaluated.

Also, the RS content of foods should continue to be quantified. Eventually this information could be included in a nutrition analysis program, which could allow health professionals to obtain an estimation of the daily intake of RS of individuals.

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Appendices

APPENDIX A: Eating Habits and Physical Activity Questionnaire

Eating Habits and Physical Activity Questionnaire

Dear Participant,

Thank you for agreeing to participate in this survey. The information will be kept confidential, and will be used solely for my Master's thesis research. Kindly complete the questionnaire and return it once completed. If you have any questions please feel free to contact me at aldengo@vt.edu, phone number (540) 232-3190, or my thesis advisor, Dr. Lorraine Niba at lniba@vt.edu, phone number (540) 231-8763. Thank you for your time!

Ana Laura Dengo
Dept .of Human Nutrition, Foods and Exercise
Virginia Tech

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1. Personal information

Date ____________________
Assigned # ____________________
Name ____________________
Age ____________________
Gender ____________________
Occupation ____________________

2. Anthropometric data

Height __________
Present wt __________
Usual wt __________
Ideal wt __________
BMI __________

3. Do you currently suffer from any gastrointestinal complications (for example, constipation, diarrhea, vomiting, nausea, etc)? If yes, please list.

Yes____ No____ Not sure_____

____
____

4. Do you have any chronic diseases (for example, diabetes, hypertension, dyslipidemia, etc)? If yes, please list.

Yes____ No____ Not sure_____

____
____

5. Are you currently taking any medicines, vitamin / mineral / nutritional supplements? If yes, please list.

Yes____ No____

____
____

EATING HABITS

1. Have you had previous nutrition counseling / diet education sessions? If yes, please explain and indicate who educated you (dietitian, medical doctor, etc.).

Yes____ No____

____

____

2. Are you allergic / intolerant to any foods? If yes, please list.

Yes____ No____ Not sure_____

____

____

3. Do you follow a special dietary regimen (e.g. Atkins, low fat, low carbohydrate)? If yes, please explain.

Yes____ No____

____

____

4. Please mark which of the following meals you have each day (at least 5 times a week):

Meal time	Yes	Example	Meal time	Yes	Example
Breakfast			Dinner		
Morning snack			Night time snack		
Lunch			Other		
Afternoon snack			-----		

5. Please list the foods / beverages which you consume on a regular basis.

Food groups	Foods / beverages consumed	Frequency	Preferences
Dairy (milk, yogurt, cheese)			
Fruits			
Vegetables			
Cereals (pasta, rice, etc.) and starches (potatoes, etc.)			
Legumes (beans, lentils, etc.)			
Meats and Fish			
Fats			
Sugars (table sugar, candy, soda, syrup)			
Fast foods			

6. From the following list, please mark the foods which you consume regularly (at least once a week):

Fructosa		All-bran cereal		Glucose	
Apple		Banana		Sugar	
Applesauce		Grapes		Maple syrup	
Milk		Oatmeal		Corn syrup	
Kidney beans		Orange juice		Honey	
Navy beans		Pasta		Bagel	
Garbanzo beans		Rice		Candy	
Lentils		Mango		Corn flakes	
Dates		Yams		Carrots	
Figs		Corn		Crackers	
Peaches		Baked beans		Potatoes	
Plums		Potato chips		Raisins	
Pears		Macaroni		Wheat / white bread	
Whole grain bread		Peas		Soda pop	
Yogurt		White pita bread		Sports drinks	
Tomato soup		Beer		Doughnut	
Peanuts				Couscous	
				Corn chips	
				Croissant	
				Pancakes / waffles	
				Pretzels	
				Wine	

7. Are you considering or planning to modify your diet? If so, how?

Yes____ No____ Not sure_____

____

____

PHYSICAL ACTIVITY

1. Approximately how much time per week do you spend doing some type of physical activity? Physical activity should be understood as any activity you engage in during your leisure time instead of sitting around (including gardening, housework, jogging, running, sprinting, etc.).

______ hours per week

2. Please indicate the type of physical activity which you do on a regular basis, and the average time, in minutes or hours, that you spend each week practicing them.

Activity	Frequency (per week)	Average time
Walk ________	________	________
Jog ________	________	________
Swim ________	________	________
Aerobics ________	________	________
Weight lift ________	________	________
Basketball ________	________	________
Soccer ________	________	________
Tennis ________	________	________
Other: (list) ________	________	________
________	________	________
________	________	________
________	________	________
________	________	________

3. How would you rate your current level of physical activity?

______ Very high
______ High
______ Moderate
______ Low
______ Very low

4. For how long have you been this active?

< 1 mo ______	< 1 yr ______
1-3 mo ______	1- 3 yrs ______
4-6 mo ______	> 3 yrs ______

5. Are you considering or planning to increase your level of physical activity / exercise? If yes, how so?

____
____
____

GENERAL QUESTIONS

1. List any specific foods that you believe should be eaten by athletes / physically active people to enhance athletic performance in specific sports. Please indicate how you believe these foods help athletes.

____
____
____
____

2. List any specific foods that you believe an athlete should avoid? Please indicate how you believe these foods affect athletes.

____
____
____
____

3. What amount of carbohydrates (starch, sugar, grains, whole grains, pastas, fruits and vegetables, etc.) should the daily diet of a physically active person provide?

______ Very low
______ Low
______ Moderate
______ High
______ Very high

4. List any specific types of carbohydrates that you consider physically active people should eat regularly? Please indicate how you believe these carbohydrates help athletes.

____
____
____
____

5. List any carbohydrates that they should avoid? Please indicate how you believe these foods affect athletes.

____
____
____
____

6. On a scale from 0 to 10 (0=not at all, 10=very likely), how likely is it that eating more carbohydrates may improve athletic performance?________________________________

THANK YOU VERY MUCH FOR YOUR PARTICIPATION!!!

Appendix B: Food / Activity Record

Food / Activity Record

Name initials________________ Code #__________
Day of the week______________ Date____________

Please DO NOT alter your normal diet while keeping this record. Keep the record for 2 week days and 1 weekend day. Use additional pages if necessary. For foods eaten out, indicate the place of purchase. For mixed foods, include the complete recipe on page 3. Please include nutritional supplements (type, brand name and dose).

Be sure to fill out the physical activity section.

Physical activity record:

Type of activity	Amount (minutes and frequency)	Observations

Food record:

Time (am/pm)	Food eaten / How prepared (fried, baked, toasted, steamed, dried, grilled, broiled, mashed, etc.)	Amount eaten	Observations

Time (am/pm)	Food eaten / How prepared (fried, baked, toasted, steamed, dried, grilled, broiled, mashed, etc.)	Amount eaten	Observations

Appendix C: Instructions for completing the 3 day food / activity record.

Instructions for completing the 3 day food record:

1. Please fill out the 3 day food record during 2 days of the week and 1 weekend day (for example, Sunday, Monday and Tuesday).

2. Please keep this record as complete and specific as possible.

3. Do not alter your normal diet or physical activity habits while keeping this record.

4. Please write down everything you eat (including hard candy, gum, etc.) and/or drink.

5. Remember to write down at what time each food was eaten.

6. For foods eaten out, describe the foods and indicate where they were purchased.

7. For mixed foods, please include the recipes on a separate page (be sure to include yield and serving size).

8. Please fill out each column for each food item.

--Time: include a.m./p.m.

--Food eaten / how prepared: detailed description of the ingredients utilized and the cooking method used to prepare the food.

--Amount eaten: In order to be able to analyze the food records correctly, please try to be as exact and detailed as possible when writing down the food amounts. Your collaboration is greatly appreciated! Some tips of how to record the food amounts are the following:

- Try to use amounts such as cups, tablespoons, ounces, etc.
- 1 cup is about the size of a baseball, or of an average size fist, and usually 1 scoop of a main dish in a cafeteria.
- ½ cup is usually 1 scoop of a side dish in a cafeteria, or about the size of a tennis ball.
- ¼ cup is approximately the size of a golf ball.
- 1 teaspoon is approximately the size of the end of your thumb, and 3 teaspoons makes up a tablespoon.
- 3 ounces of meat is about the size of a deck of cards, or the size of an average hand palm.

- If the foods and drinks are purchased at a fast food restaurant, mention where you ate, say exactly what the item was (regular or diet, sweet or unsweetened) and its size (small/medium/large,6-inch/12-inch,single/double, 8 oz/ 12 oz/ 20 oz/ 24 oz, etc.) Also, be sure to mention anything that you added such as ketchup, sugar, etc.
- If you prepare the food yourself, tell us how many pieces/slices of each thing on sandwiches, how much of each condiment or topping, etc.
- If the item is packaged, please enter the size of the package as labeled.
- When possible, please tell us the brand name and the product name of the food you ate.

--Observations: for any additional comments you wish to make.

If you have any questions about how to enter a food or drink please contact me at aldengo@vt.edu

11. Please don't forget to write down your physical activity on the back of the record. Try to be as specific as possible about what you did, how strenuous it was, for how long you exercised, and the starting time (a.m./p.m). If any snacks or sports drinks were consumed during the exercise session, be sure to include them in the food record as soon as possible.

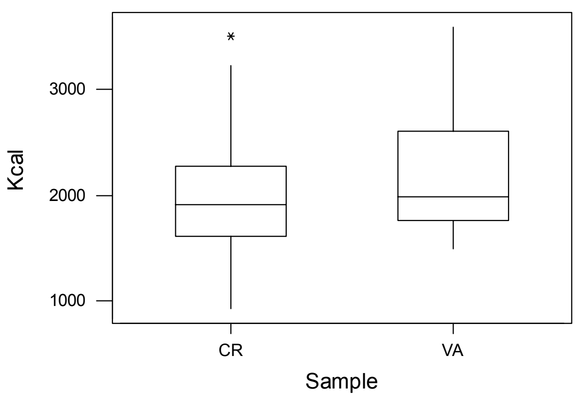
Thank you for your time and participation!

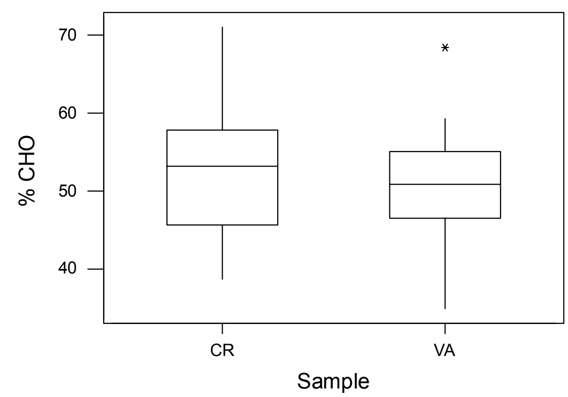
Appendix D: Comparison Statistics

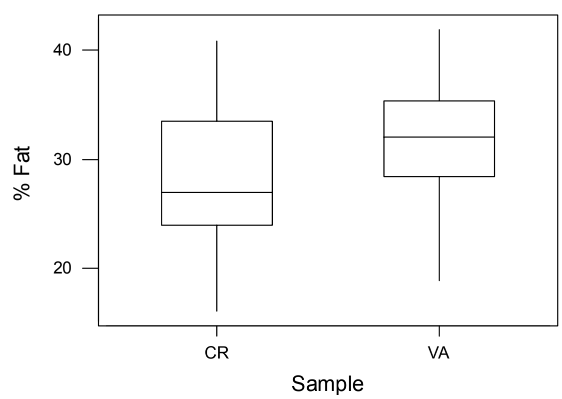
A) Energy intake, macronutrient distribution, and fiber intake analysis

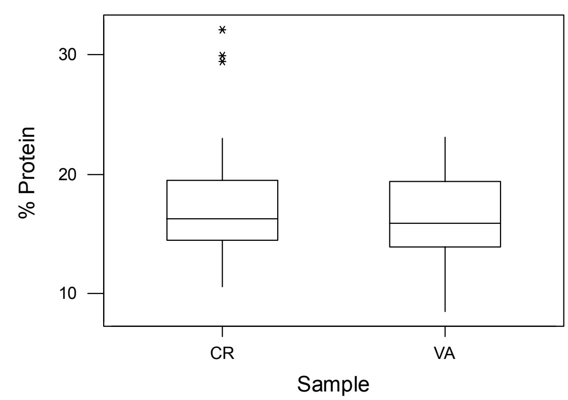
<u>SJ vs. Blacksburg (All subjects)</u>

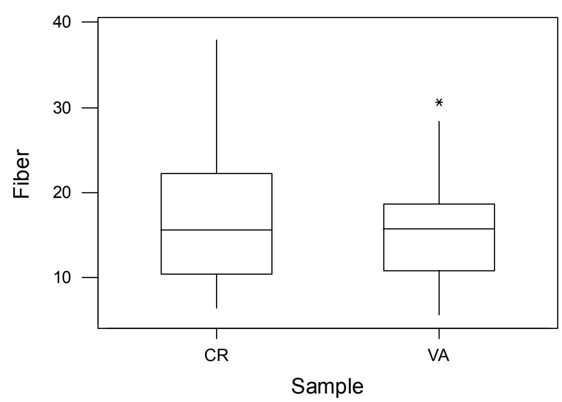
Parallel box plots, for each of the variables, were utilized to determine if it is reasonable to assume equal variances between the samples. The results are the following:











These graphs provide information about the variances of each variable and allow comparisons between the two sample populations to be made. From these results, one can assume an equal variability among samples for all the variables, which will increase the power of the tests.

Two Sample T-Test for Energy Intake (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	27	1966	596	115
VA	26	2139	545	107

T-Test mu (CR) = mu (VA) (vs not =): T = -1.10 P = 0.28 DF = 51
Both use Pooled StDev = 571

Fail to reject the null hypothesis. There is no significant difference between the means for energy intake (P > 0.10).

Two Sample T-Test for % Protein (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	27	17.65	5.54	1.1
VA	26	16.38	3.74	0.73

T-Test mu (CR) = mu (VA) (vs not =): T = 0.97 P = 0.33 DF = 51
Both use Pooled StDev = 4.75

Fail to reject the null hypothesis. There is no significant difference between the means for percent energy contribution from protein to the total energy intake (P > 0.10).

Two Sample T-Test for % Carbohydrates (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	27	52.74	8.14	1.6
VA	26	50.30	6.82	1.3

T-Test mu (CR) = mu (VA) (vs not =): T = 1.18 P = 0.24 DF = 51
Both use Pooled StDev = 7.52

Fail to reject the null hypothesis. There is no significant difference between the means for percent energy contribution from carbohydrates to the total energy intake (P > 0.10).

Two Sample T-Test for % Fat (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	27	28.23	6.49	1.2
VA	26	31.40	5.66	1.1

T-Test mu (CR) = mu (VA) (vs not =): T = -1.89 P = 0.065 DF = 51
Both use Pooled StDev = 6.09

Reject the null hypothesis. There is a significant difference between the means for percent energy contribution from fat to the total energy intake ($P < 0.10$). Rejection of the null hypothesis at the 95% confidence level was almost achieved, a greater sample size would probably have confirmed the rejection.

Two Sample T-Test for Fiber Intake (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	27	17.62	8.87	1.7
VA	26	15.62	6.15	1.2

T-Test mu (CR) = mu (VA) (vs not =): T = 0.95 P = 0.35 DF = 51
Both use Pooled StDev = 7.66

Fail to reject the null hypothesis. There is no significant difference between the means for fiber intake ($P > 0.10$).

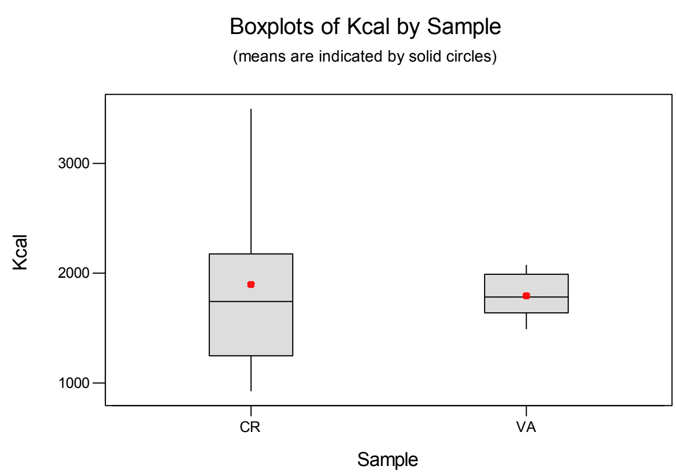
SJ vs. Blacksburg (Female subjects)

For the following tests (gender comparisons) an equal variance assumption will be made whenever the box plots show that this is a reasonable decision. The Minitab® output will indicate if a pooled standard deviation was used in the test.

Two Sample T-Test for Energy Intake (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	14	1889	744	199
VA	12	1795	187	54

T-Test mu (CR) = mu (VA) (vs not =):
T = 0.46 P = 0.66 DF = 14

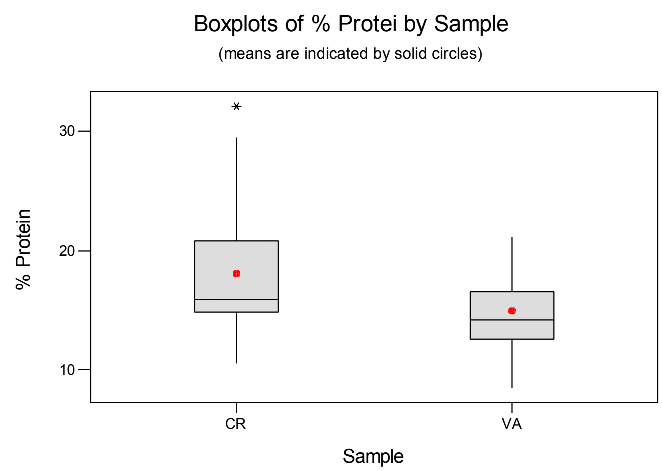


Fail to reject the null hypothesis. There is no significant difference between the means for energy intake (P > 0.10).

Two Sample T-Test for % Protein (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	14	18.09	6.25	1.7
VA	12	14.91	3.52	1.0

T-Test mu (CR) = mu (VA) (vs not =):
T = 1.63 P = 0.12 DF = 21

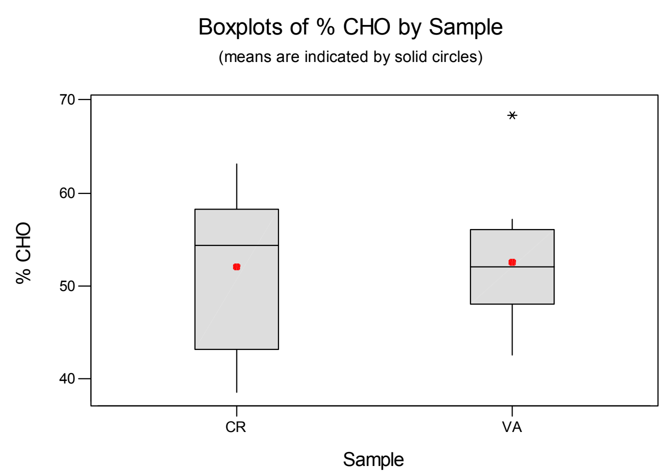


Fail to reject the null hypothesis. There is no significant difference between the means for percent contribution of energy from proteins to the total energy intake (P > 0.10).

Two Sample T-Test for % Carbohydrate (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	14	52.01	8.44	2.3
VA	12	52.53	6.96	2.0

T-Test mu (CR) = mu (VA) (vs not =):
T = -0.17 P = 0.87 DF = 23

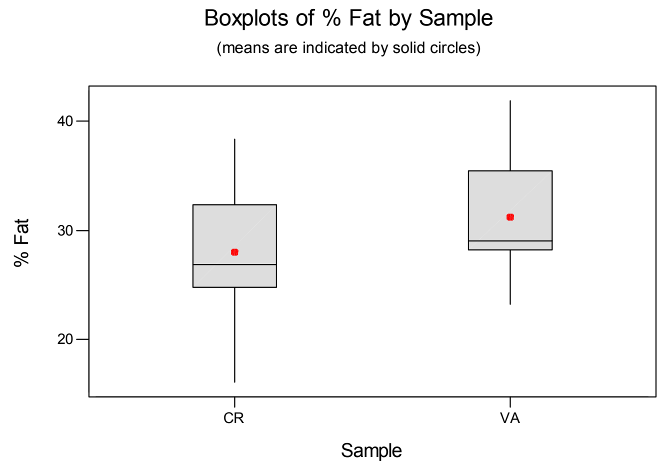


Fail to reject the null hypothesis. There is no significant difference between the means for percent energy contribution from carbohydrates to the total energy intake (P > 0.10).

Two Sample T-Test for % Fat
(α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	14	27.97	6.26	1.7
VA	12	31.23	5.61	1.6

T-Test mu (CR) = mu (VA) (vs not =):
T = -1.39 P = 0.18 DF = 24
Both use Pooled StDev = 5.97

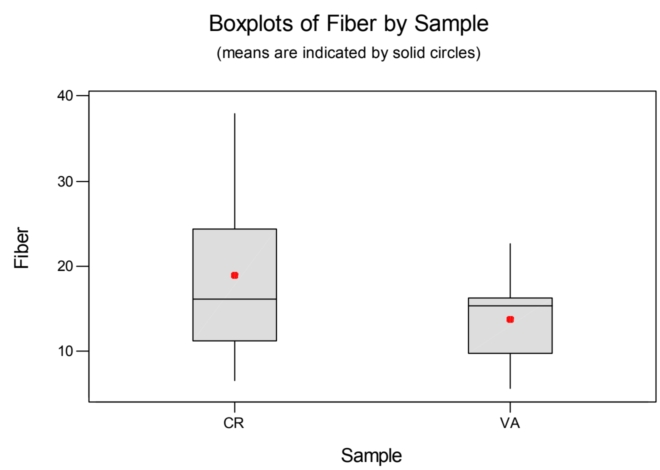


Fail to reject the null hypothesis. There is no significant difference between the means for percent energy contribution from fat to the total energy intake (P > 0.10).

Two Sample T-Test for Fiber Intake
(α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	14	18.96	9.24	2.5
VA	12	13.78	4.90	1.4

T-Test mu (CR) = mu (VA) (vs not =):
T = 1.82 P = 0.084 DF = 20



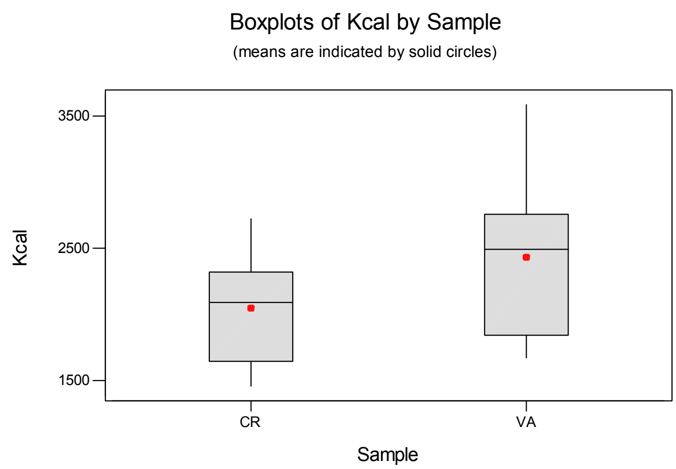
Reject the null hypothesis. There is a significant difference between the means for fiber intake (P < 0.10). The null hypothesis could not have been rejected at the 95% confidence level.

SJ vs. Blacksburg (Male Subjects)

Two Sample T-Test for Energy Intake ($\alpha = 0.10$)

Sample	N	Mean	StDev	SE Mean
CR	13	2049	395	110
VA	14	2433	582	156

T-Test mu (CR) = mu (VA) (vs not =):
T = -2.02 P = 0.056 DF = 22

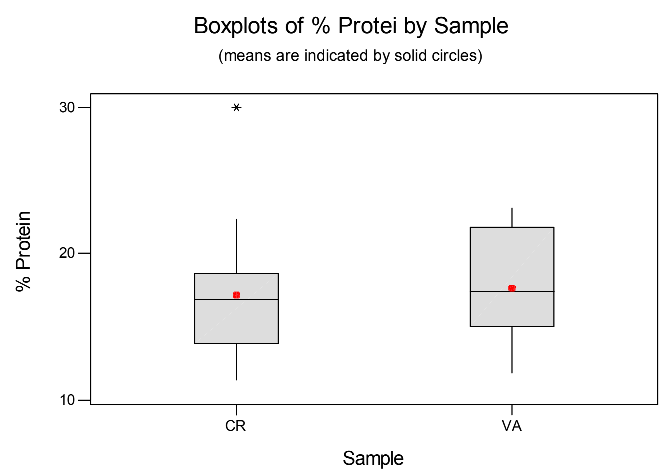


Reject the null hypothesis. There is a significant difference between the means for energy intake ($P < 0.10$).

Two Sample T-Test for % Protein ($\alpha = 0.10$)

Sample	N	Mean	StDev	SE Mean
CR	13	17.18	4.88	1.4
VA	14	17.64	3.56	0.95

T-Test mu (CR) = mu (VA) (vs not =):
T = -0.28 P = 0.78 DF = 21

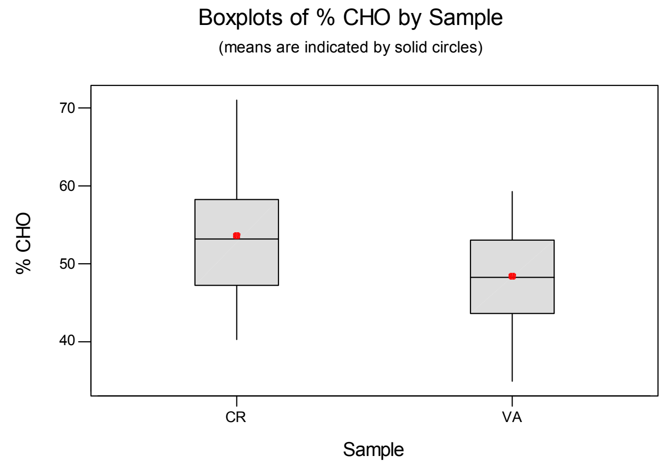


Fail to reject the null hypothesis. There is no significant difference between the means for percent contribution of energy from proteins to the total energy intake ($P > 0.10$).

Two Sample T-Test for % Carbohydrate (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	13	53.53	8.06	2.2
VA	14	48.39	6.33	1.7

T-Test mu (CR) = mu (VA) (vs not =):
T = 1.85 P = 0.076 DF = 25
Both use Pooled StDev = 7.21

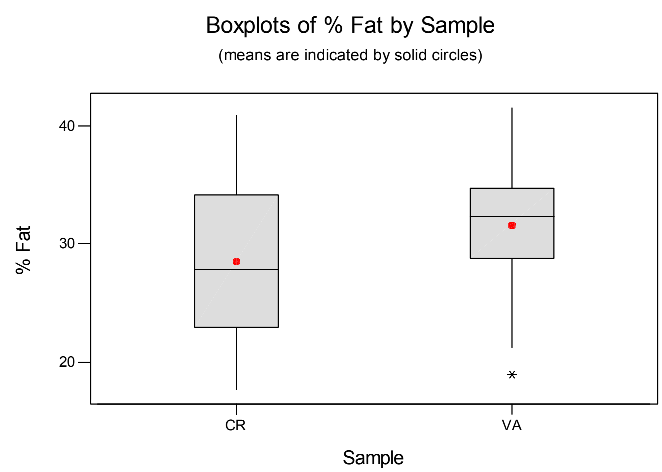


Reject the null hypothesis. There is a significant difference between the means for percent energy contribution from carbohydrates to the total energy intake ($P < 0.10$). The null hypothesis could not have been rejected at the 95% confidence level.

Two Sample T-Test for % Fat (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	13	28.52	6.96	1.9
VA	14	31.54	5.91	1.6

T-Test mu (CR) = mu (VA) (vs not =):
T = -1.21 P = 0.24 DF = 23

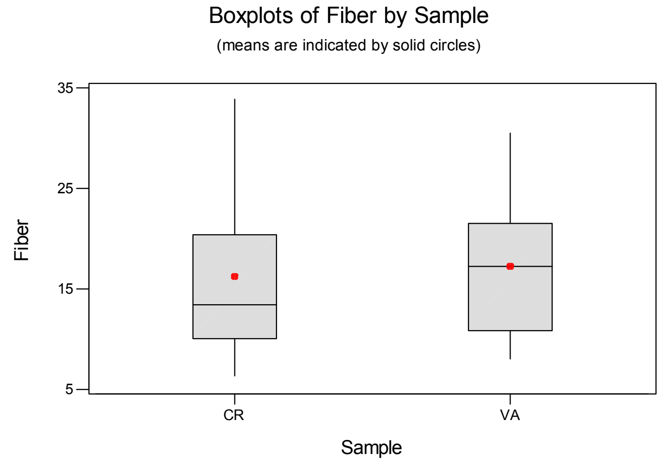


Fail to reject the null hypothesis. There is no significant difference between the means for percent energy contribution from fat to the total energy intake ($P > 0.10$).

Two Sample T-Test for Fiber Intake ($\alpha = 0.10$)

Sample	N	Mean	StDev	SE Mean
CR	13	16.18	8.59	2.4
VA	14	17.20	6.83	1.8

T-Test mu (CR) = mu (VA) (vs not =):
T = -0.34 P = 0.74 DF = 25
Both use Pooled StDev = 7.72



Fail to reject the null hypothesis. There is no significant difference between the means for fiber intake
(P > 0.10).

B) Physical activity analysis

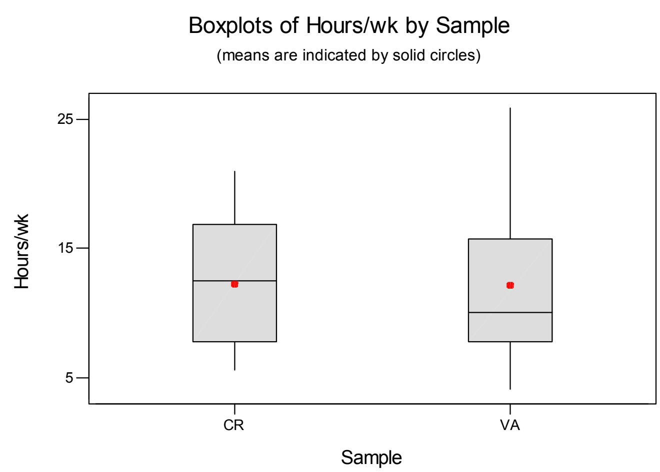
For the following tests an equal variance assumption will be made whenever the box plots show that this is a reasonable decision. The Minitab® output will indicate if a pooled standard deviation was used in the test.

<u>SJ vs. Blacksburg (All subjects)</u>

Two Sample T-Test for Hours/wk ($\alpha = 0.10$)

Sample	N	Mean	StDev	SE Mean
CR	26	12.27	4.65	0.91
VA	26	12.13	6.55	1.3

T-Test mu (CR) = mu (VA) (vs not =):
T = 0.09 P = 0.93 DF = 50
Both use Pooled StDev = 5.68



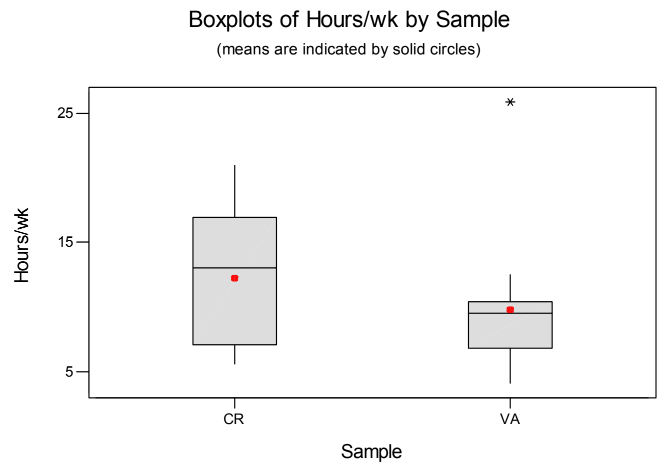
Strongly fail to reject the null hypothesis (means are practically the same). There is no significant difference between the means for hours of physical activity performed per week (P > 0.10).

SJ vs. Blacksburg (Female subjects)

Two Sample T-Test for Hours/wk (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	13	12.27	5.16	1.4
VA	12	9.81	5.71	1.6

T-Test mu (CR) = mu (VA) (vs not =):
T = 1.13 P = 0.27 DF = 22



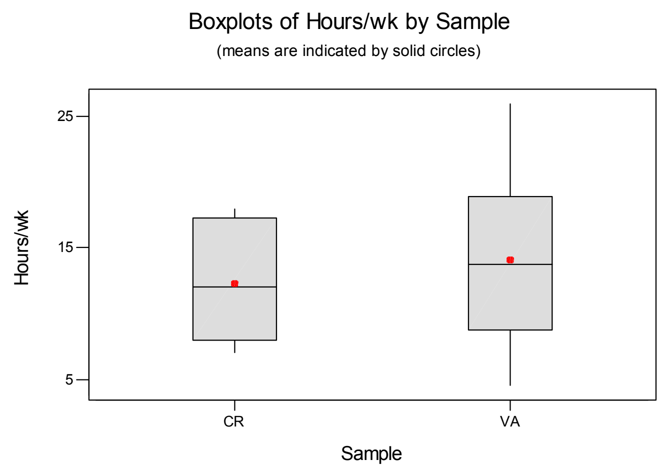
Fail to reject the null hypothesis. There is no significant difference between the means for hours of physical activity performed per week (P > 0.10).

SJ vs. Blacksburg (Male subjects)

Two Sample T-Test for Hours/wk (α = 0.10)

Sample	N	Mean	StDev	SE Mean
CR	13	12.27	4.30	1.2
VA	14	14.11	6.76	1.8

T-Test mu (CR) = mu (VA) (vs not =):
T = -0.84 P = 0.41 DF = 25
Both use Pooled StDev = 5.71



Fail to reject the null hypothesis. There is no significant difference between the means for hours of physical activity performed per week (P > 0.10).

Appendix E: Institutional Review Board Approval

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Institutional Review Board

Dr. David M. Moore
IRB (Human Subjects)Chair
Assistant Vice President for Research Compliance
CVM Phase II- Duckpond Dr., Blacksburg, VA 24061-0442
Office: 540/231-4991; FAX: 540/231-6033
email: moored@vt.edu

DATE: July 15, 2004

MEMORANDUM

TO: Lorraine L. Niba Human Nutrition, Foods, & Exercise 0430
/Ana Dengo

FROM: David Moore

SUBJECT: **IRB Exempt Approval:** "Carbohydrate and Whole Grain Intakes and Perceptions of Glycemic Index Among Regular Exercisers in Blacksburg, VA and San Jose, Costa Rica" IRB # 04-355

I have reviewed your request to the IRB for exemption for the above referenced project. I concur that the research falls within the exempt status. Approval is granted effective as of July 14, 2004.

cc: File
Department Reviewer Kathy Hosig 0430

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