The Corinthian

Volume 15 | Article 8

2014

Sports Nutrition: Critical Components for Optimal Performance

Allyson Barys
Georgia College & State University

Sports Nutrition:
Critical Components for Optimal Performance

Allyson Barys

Dr. Scott Butler
Faculty Mentor

Introduction

The purpose of this paper is to examine the critical nutritional components of an athlete's diet for ideal energy and strength while exercising. This paper analyzes the importance behind hydrating the body and suggests timing for macronutrient and fluid ingestion as well as recommended consumption amounts to sustain that energy. Information regarding refueling and rehydrating techniques through sports drinks, gels, and jellybeans, as well as details concerning the positive and negative effects of ergogenic aids are also included. According to the United States Anti-Doping Agency (USADA), as an athlete's level of competition and training are intensified, the body's demand for energy increases as well (USADA, 2010). For those that undergo extensive physical exercise, attention must be given to the nutritional aspects that should accompany every workout in order to obtain optimal sports performance. It is essential for athletes to consume an adequate diet that meets their body's needs. Therefore, maintaining a proper level of hydration, coupled with a balanced diet of carbohydrates, fats, and proteins allows the body to efficiently prepare itself for activity and repair itself afterwards. The timing of macronutrient consumption as well as the amount ingested by the athlete can also affect their performance. Performance levels can range from a long period of time at a low intensity to short bouts of high-intensity exercise. High-intensity exercise is described as elevating one's heart rate anywhere from 80-90% of its maximal capacity for short periods of time (McCall, 2009). This can range from 30 seconds to about a minute (McCall, 2009). The remainder of the workout should consist of active recovery intervals in between the bursts of high intensity. The active recovery should lower the maximum heart rate to about 65-70% for a period of 2 to 3 minutes (McCall, 2009). Sports drinks and gels, as well as ergogenic aids, can enhance this process by increasing hydration levels, giving energy to an individual or help by improving strength. However, carbohydrate supplements can add unnecessary amounts of sugar to an inactive individual's diet, and ergogenic aids have several related health risks. According to the USADA, by making informed decisions about how to balance nutrition and level of physical activity, athletes will have an advantage over their competition that choose to ignore the importance of the right food to fuel activity (USADA, 2010).

Importance of Hydration

One of the most important factors in maintaining a high level of energy output during physical activity and exercise is the conservation of the body's fluid balance, especially water (Benardot, 2006). Of the six nutrients needed for a healthy lifestyle, water is critical to an active individual. Water has several colligative properties that are used to aid the body in athletic performance (Wolinsky, 1998). Two such advantages stem from the concept that water has a relatively high capacity for heat, which allows it to absorb excess warmth generated by the body and it acts as a primary coolant when heat needs to be released (Thompson & Manore, 2012). According to *Nutrition in Exercise and Sport* (1998), the specific heat of water is determined by the heat required to raise one kilogram of water one degree Celsius (Wolinsky, 1998). Thus, water acts as a buffer towards heat in the human body (Wolinsky, 1998). As a result, water maintains a property of high heat vaporization (Wolinsky, 1998). In other words, when the body's blood flow increases in the core due to physical activity, blood vessels transport the heat closer to the integument (Thompson & Manore, 2012). As this happens, sweat is secreted from subdiferous glands, and as it evaporates, heat is released from the body (Thompson & Manore, 2012). For every gram of sweat evaporated from the skin, the body loses approximately 0.58

kilogram calories of heat (Wolinsky, 1998). In addition, water is essential for the control of osmotic pressure and the balance of electrolytes in cells (Williams, 1995). Athletes must guard against dangerous elevations in body temperature and reductions in blood volume as a result of increased osmolarity, which can be prevented by fluid ingestion (Thompson & Manore, 2012). Serving as the body's most important solvent, water is responsible for dissolving and transporting various electrolytes in order to preserve a certain ionic, internal environment that supports many body functions (Wolinsky, 1998).

As the main component in blood, water becomes the primary mechanism for transporting oxygen, nutrients, hormones, and other compounds to cells and removing their waste products (Williams, 1995). Fluids, such as water, account for the body's blood volume as well, which is defined as "the amount of fluid in blood" (Thompson & Manore, 2012, p. 230). One of the most fundamental parts of living matter is their cell protoplasm, which is built from water (Williams, 1995). Water's inability to be compressed allows it to protect parts of the body such as the brain and spinal cord from damage, friction, and pressure during the constant movement of physical activity (Williams, 1995).

The electrically charged particles found in fluids that help the body carry out its functioning are known as electrolytes. Electrolytes are mineral salts that, when dissolved in water, become ions (Kenefick & Cheuvront, 2012). Electrolytes help regulate fluid balance, enable our nerves to respond to stimuli, and signal our muscles to contract – all of which are important functions for playing sports (Thompson & Manore, 2012). The major electrolytes found in the blood and tissues of the body include: sodium, potassium, chloride, phosphorous, calcium, and magnesium (Benardot, 2006). Theses minerals are required in greater than 200 milligrams per day (Campbell et al., 2012). Additionally, each electrolyte serves as specific function in the human body.

Athletes that consume enough water and are well hydrated are referred to as being "euhydrated" or "normohydrated" (Benardot, 2006, p.76). On the other hand, those who exhibit dehydration or have below normal water levels are considered "hypohydrated" (Benardot, 2006, p.76). Homeostasis refers to the body's ability to conserve a condition of normalcy internally (Thompson & Manore, 2012). Water level in the body is maintained by the kidneys (Williams, 1995). The kidneys are stimulated by hormones and enzymes that work together to adjust the volume of water that is expelled or retained (Benardot, 2006). The body stores water within its cells. Sixty-five percent of the body's water is intracellular and the remaining 35% is extracellular (Benardot, 2006). In the body of an athlete, well-hydrated muscles consist of about 75% water, bones are about 32% water, and blood is approximately 93% water (Benardot, 2006). Therefore, it is important that an athlete constantly rehydrates to sustain their water weight, which totals about 70% of their total body weight (Benardot, 2006). When it comes to fluid hydration, athletes need to consider the amount of fluid they are losing during their physical activity and the best way to replace that water (Kenefick & Cheuvront, 2012). To maintain homeostasis within the body, the amount of water that is expelled must equal the amount of water that is consumed (Thompson & Manore, 2012). Although the amount of water consumed is based on age, body size, health status, the intensity of a workout, and the surrounding environment, it is important to adjust the amount of fluids one ingests to achieve a balance between how much is lost and how much is gained (Thompson & Manore, 2012).

For training sessions lasting approximately an hour or less, water is enough to satisfy the body's thirst (Skolnik & Chernus, 2010). However, activity spanning longer periods of time or training sessions of high intensity require the consumption of carbohydrates (Skolnik & Chernus, 2010). Sports drinks offer these extra carbohydrates and help increase sodium absorption in order to achieve a higher rate of water absorption (Skolnik & Chernus, 2010). Within a 30 minute time period, it is estimated that an athlete undergoing moderate exercise can lose 900 milliliters of sweat (Benardot, 2006). However, a workout completed in a hot environment where heat generated from the sun is added to the heat produced by the body during physical activity of high intensity can prompt the loss of approximately 1.8 liters of water through sweat in as little as an hour (Benardot, 2006). Some may even lose more than 3 liters of fluid per hour if the athlete is well trained and can push themselves in such adverse environments (Benardot, 2006). Sweat, the body's primary coolant, is the main source of water loss in athletes (Wolinsky, 1998). Composed of about 99% water and the remaining 1% electrolytes, the concentration of sweat is hypotonic (Williams, 1995). As mentioned earlier, sodium and chloride are major electrolytes found in sweat because they reside in the extracellular fluids within the body (Wolinsky, 1998). Often athletes can note the formation of salt crystals on their skin or clothing after prolonged periods of exercise (Williams, 1995). If the loss of water through sweat, urine, and insensible water loss such as through the skin and lungs are not compensated for through beverages and food, dehydration becomes a threat (Thompson & Manore, 2012). The only way to avoid dehydration is to "assume there is a constant output of fluids that must be dealt with by having an equally constant input of fluids" (Benardot, 2006, p. 87). Athletes must consume more fluid during the day than the average individual because of the amount of water lost through sweating. The most obvious sign of dehydration is the sensation of thirst (Skolnik & Chernus, 2010). However, athletes can learn to observe the color of their urine to assess dehydration levels as well (Benardot, 2006). When not enough water is present in the body, extra fluid is not available to dilute the products that are excreted from the body through urine (Skolnik & Chernus, 2010). Therefore, dark urine color or low urine output serve as signs that the body is lacking in water (Benardot, 2006). In some cases, these symptoms may precede the activation of the thirst mechanism in the body (Benardot, 2006).

Risk of dehydration is the consequence of more than just inadequate fluid intake. Diarrhea, vomiting, induced high sweat rates, laxatives, diuretics, dieting, and illness can all lead to a large loss of water from the body (Benardot, 2006). However, regardless of the cause, dehydration can take a serious toll on the body and has the potential to affect athletes negatively. Involuntary dehydration is most severe when it comes to aerobic endurance performance (Williams, 1995). This type of dehydration puts a strain on the heart – for every 1% loss of water, the heart beats 5-8 beats faster per minute resulting in the increase of the body's temperature anywhere from .4 to .5 degrees Fahrenheit (Skolnik & Chernus, 2010). Other symptoms include disturbed electrolyte balances and fatigue (Williams, 1995). Fatigue arises from the decreased transport of fuel to cells because of the reduced blood flow (Skolnik & Chernus, 2010). Muscles without fuel from the blood consume glycogen faster, depleting the storage of sugar in the muscles (Skolnik & Chernus, 2010). On the other hand, voluntary dehydration often exhibited by wrestlers in order to meet weight class requirements, is induced by heavy sweating, diuretics, or decreased intake of fluids (Williams, 1995). According to several studies on voluntary dehydration, hypohydration will most likely not affect physical performance if the event involves a short period of muscular effort (Williams, 1995). However, other studies claim that anaerobic muscular endurance may be impaired in athletes with low water levels, especially if the loss is 4% or higher (Williams, 1995).

Lack of water can also lead to heat cramps, heat exhaustion, and sunstroke (heatstroke). Heat cramps – defined as "painful muscle spasms in the legs and abdomen" – develop from fluid and electrolyte imbalances as a consequence of dehydration (Thompson & Manore, 2012, p. 252). Heat cramps can be prevented by the ingestion of a sports drink that has been supplemented with a teaspoon of salt (Benardot, 2006). A more severe case of dehydration can result in heat exhaustion. Weakness, a feeling of faintness, nausea, cold skin, and fatigue are all symptoms due to a lack of blood flow to the brain (Benardot, 2006). To solve this problem, rapid cooling techniques are required such as ice baths or applying cold cloths to the body (Benardot, 2006). Lastly, if heat exhaustion is left untreated, heatstroke may occur. This adds symptoms of rapid pulse, dry skin, high body temperature, and in some cases, heatstroke may be fatal (Thompson & Manore, 2012). Like heat exhaustion, immediate cooling is needed to reduce the severe consequences (CDC, 2013).

Overall, hydration is important for maintaining proper bodily functions, especially in athletes (Kenefick & Cheuvront, 2012). Hydration before, during, and after exercise will help promote optimal performance. The National Athletic Trainer Association and the International Association of Athletics recommend 17 to 20 ounces of fluid 3 hours before training and 7 to 10 ounces 20 minutes immediately before training (Skolnik & Chernus, 2010). Fluids consumed during exercise should include sodium (Skolnik & Chernus, 2010). Also, drinking 11-19 grams of carbohydrates per 8 ounces of water is suggested to maintain blood sugar and glycogen levels in the muscles (Skolnik & Chernus, 2010). Finally, after a workout, for every pound lost, 16-24 ounces of fluid should be ingested (Skolnik & Chernus, 2010). However, despite these recommendations, athletes should hydrate even when they are not thirsty (Williams, 1995). Athletes must guard against temperature increases and deficiencies of necessary nutrients by consuming enough fluid to prevent the negative impacts of dehydration (Wolinsky, 1998). Hydration does not improve one's performance; however, it keeps dehydration from robbing the body of its potential and promotes productivity, safety, and morale (Skolnik & Chernus, 2010).

Carbohydrates

Carbohydrates are organic molecules supplied through food that provide energy to cells, especially those in the brain (Dietary Reference Intakes, 2005). According to the Center of Disease Control and Prevention (CDC, 2012a), there are simple and complex carbohydrates. While simple carbohydrates include monosaccharides and disaccharides, complex carbohydrates are made of polysaccharides, which are chains of more than two sugars (Thompson & Manore, 2012). Digestion of carbohydrates leads to the breakdown of disaccharides and polysaccharides into the most common simple sugar – glucose (Dietary Reference Intakes, 2005). The body's brain cells and red blood cells rely on glucose constantly in order to maintain their function (Thompson & Manore, 2012). In addition, glucose can be converted into glycogen and stored within the muscles and liver in the body (Thompson & Manore, 2012). The Institute of Medicine states "glycogen is present in the muscles for storage and utilization and in the liver for storage, export, and maintenance of blood glucose concentrations" (Dietary Reference Intakes, 2005, p. 274). Such storage is important, especially when the body is undergoing extensive exercise. Physical activity that causes the body to sweat or breathe harder forces the body to withdraw more from the carbohydrate supply than the fat storage (Thompson & Manore, 2012).

Carbohydrates serve as a main source of energy for the average individual; however, in high caliber athletes, this macronutrient becomes more valuable in terms of providing quick energy for participation in energy-demanding athletic activities (Peterson & Peterson, 1988). Energy in the body comes from the basic combination of food and oxygen that result from digestion and breathing (Karinch, 2002). These two ingredients result in the products of carbon dioxide, water, and adenosine triphosphate (ATP) (Karinch, 2002). Adenosine Triphosphate (ATP) is the body's most direct supply of energy, and it is used for a majority of muscle activity (Campbell et al., 2012). ATP is formed from the breakdown of a glucose molecule. For every glucose molecule that goes through aerobic metabolism, approximately 36 to 38 ATP molecules are created for energy use (Thompson & Manore, 2012). Two of these molecules are produced during the first stage of cellular respiration, known as glycolysis (Campbell et al., 2012). Glycolysis also produces pyruvic acid, which is converted to lactic acid when oxygen availability is limited (Thompson & Manore, 2012). Energy developed from ATP is the body's direct supply for all of the muscular activity (Karinch, 2002). Despite its high caloric content, fat burns very slowly. The rate of ATP synthesis from carbohydrates yields about 1.0 mol/min whereas fats yield approximately 0.5 mol/min (Colgan, 1993). However, for athletes, it is just as important to time the consumption of carbohydrates as it is to know how much they need for energy (Colgan, 1993). According to the book *Practical Sports Nutrition*, pre-event meals that will help increase availability of carbohydrates before a prolonged exercise session should be 1-4g of carbohydrates per kilogram (kg) of body weight eaten 1-4 hours before exercise (Burke, 2007).

Sources of carbohydrates may come from liquids or food. The Colgan Institute suggests that athletes habitually consume 100 grams of a carbohydrate replacement drink 3 hours before training and continually resupply the body every hour with 40 additional grams (Colgan, 1993). During moderate-intensity or intermittent exercise lasting less than an hour, carbohydrate intake should be 0.5-1.0g/kg (Burke, 2007). The supply of glycogen in the muscles decreases during exercise and as the level of muscle glycogen declines, optimal performances also declines (Colgan, 1993). Studies indicate that many athletes, especially those undergoing high-intensity exercise or heavy training, may never achieve full levels of glycogen in their muscles (Colgan, 1993). Hydrolysis releases glucose from cells when the body's demand for sugar increases (Campbell et al., 2011). However, this stored fuel cannot sustain a human for long and must be replenished (Campbell et al., 2011). Therefore, consuming a 5-10% carbohydrate replacement beverage during training at a rate of one quart (35 oz.) per hour will help the body maintain its energy and performance (Colgan, 1993). During a competition, the amount of carbohydrates a drink has to offer can be essential to refueling effectively or can result in slowing down or cramping (Karinch, 2002). The best fluid replacement drinks are made "predominantly of glucose polymers or glucose plus a little fructose" (Colgan, 1993, p. 105).

The first twenty-four hours of recovery after exercise is when the body has its highest glycogen storage rates, and this is especially true within the first hour (Thompson & Manore, 2012). Recommended carbohydrate intake for post-exercise recovery of muscle glycogen is set at a value of 1-1.2 grams per kilogram of the athlete's body mass immediately after exercise and it is suggested that this amount is continued until one's meal schedule is resumed (Burke, 2007). Some advantages may result from consuming small carbohydrate snacks in intervals every 15-60 minutes early in the recovery phase (Burke, 2007). The reason for this is because glycogen synthesis occurs most rapidly "immediately after exercise because the low level of glycogen remaining in the muscles stimulates activity of an enzyme called glycogen synthase that controls glycogen storage" (Colgan, 1993, p. 103). Glycogen storage can be increased by ingesting foods with a high glycemic index for post-recovery (Thompson & Manore, 2012).

Low-intensity exercise or trainings that are primarily skill-based require a daily recovery or fuel need of 3-5 grams per kilogram of body mass of carbohydrates a day (Burke, 2007). Moderate exercise, lasting less than an hour, needs a daily recovery amount of about 5-7 g/kg a day (Burke, 2007). On the other hand, endurance athletes or people who undergo physical activity anywhere from 1-3 hours should consume 7-12 g/kg for daily recovery (Burke, 2007). Fuel needs for an athlete participating in an extreme exercise program lasting 4-5 hours are suggested to have an intake of at least 10-12 g/kg in order to meet daily recovery needs (Burke, 2007). Therefore, it is evident that both strength and endurance athletes require an adequate intake of carbohydrates to sustain their energy during physical performance and resupply their glycogen stores (Thompson & Manore, 2012).

Some athletes use carbohydrate loading as a technique to maximize their levels of glycogen in the body (Thompson & Manore, 2012). The process of carbohydrate loading is carried out by purposely depleting the glycogen stores in one's muscles to increase the production of glycogen synthase (Peterson & Peterson, 1988). Then the athlete will increase their intake of carbohydrates to 70-80% of their total calories approximately 3 days before a competition or race (Peterson & Peterson, 1988). Prior to this, during days 6-4, carbohydrate intake should be about 50-60% of one's daily calories paired with a normal training routine that is reduced to 60% (Colgan, 1993). However, carbohydrate loading does not always improve performance (Thompson & Manore, 2012). Unless the athlete is participating in events such as marathons, long-distance swimming, or triathlons, they may not benefit or gain performance benefits from this kind of practice (Thompson & Manore, 2012). This is because extra glycogen that is not used in our muscles is stored with water, which can leave an athlete feeling heavy or lethargic (Thompson & Manore, 2012). On top of this, switching to a high-carbohydrate diet before a competition does not produce glycogen loading unless the body had experienced training intense enough to deplete glycogen levels

(Colgan, 1993). Without sufficient depletion, excess carbohydrates turns into body fat, which adds unnecessary weight to an athlete (Colgan, 1993). Also, glycogen depletion and glycogen synthase production occur only in the muscles being used (Colgan, 1993). Studies have shown that over working one leg and not the other, followed by carbohydrate loading, results in double the glycogen levels in the leg driven to exhaustion and little to no change in the leg at rest (Colgan, 1993). Therefore, if an athlete chooses to use loading as a way to prepare their body for an event or competition, they should experiment with training sessions first and evaluate the outcome of this approach (Thompson & Manore, 2012).

Overall, carbohydrates are essential for providing the body its quick energy reserve. Found in cereals, fruits, vegetables, juices, and foods made of whole grains, complex carbohydrates have proven to be the best support for vigorous training sessions (Thompson & Manore, 2012). Guidelines suggest that simple sugars should make up less than 10% of one's diet (Thompson & Manore, 2012). Replenishing the body is important when it comes to physical activity. Without enough carbohydrates in the diet, the body turns to the breakdown of fats and proteins to sustain a certain level of activity (Colgan, 1993).

Fats

In addition to carbohydrates, the body utilizes fats as an additional energy source. Fats offer more than twice the amount of calories (energy) per gram than carbohydrates do (Thompson & Manore, 2012). While carbohydrates only contain about 4 kcal per gram, fats contain approximately 9 kcal per gram (Thompson & Manore, 2012). Fats, which fall under a large category of lipids, can be divided into several subsections, including: saturated fat, monounsaturated, and polyunsaturated fats (CDC, 2012b). The role of fats in the body is to provide fuel while it is at rest, aid in the fueling of physical activity, store energy within adipose tissue, facilitate the transportation of fat-soluble vitamins, develop cell membranes, cushion the body, and help prevent the body from always feeling hungry (Thompson & Manore, 2012). Outside the body, fats help flavor food and provide it with tastes appealing to humans (Dietary Reference Intakes, 2005). When fats are used for energy, fatty acids are "released from the adipose cell" and they venture to the muscles where the smaller components of fats are used to fuel the mitochondria (Thompson & Manore, 2012, p. 153). This facilitates the muscles ability to extend and contract allowing the body to move. Likewise, the components of fats, especially the fatty acids, are used to make phospholipids. Phospholipids create the structure of the cell membrane, which monitors everything that goes into and out of the cell (Campbell et al., 2012). Protecting the body is also an important function. Fats will contribute to the adipose tissue, which prevents serious injury to our organs when we fall (Thompson & Manore, 2012). Lastly, because fats are denser in calories, the stomach digests the food slower thereby making the body feel satiated (Thompson & Manore, 2012).

Fats serve as a fuel source that can be broken down under aerobic conditions in order to supply the body with energy during exercise that incorporates long duration or low intensity (Thompson & Manore, 2012). Fat stores in the body can supply up to 60% of needed energy during physical activity; however, it can take up to thirty minutes from the time a training session starts until fat is available to be used as fuel (Peterson & Peterson, 1988). In the diet, fats become fatty acids and glycerol after being digested (Campbell et al., 2012). Once absorbed into the body, the fatty acids and glycerol are combined to form triglycerides (Peterson & Peterson, 1988). Muscles, especially those in athletes, release the fat from adipose tissue to be oxidized when energy needs to be maintained (Peterson & Peterson, 1988). Also, fat directly from muscles serve as an advantage to the body during exercise when fat from adipose tissue is limited (Larson-Meyer, 2007). This way, carbohydrates can be reserved for periods of short bursts such as the sprint at the end of a race (Larson-Meyer, 2007). However, most athletes contain more energy reserve of fat than they will ever utilize; therefore, saturated fats are not a necessary part of an athlete's diet and should be lessened or eliminated (Colgan, 1993). Recently, a diet consisting of 20-30% fat is strongly suggested instead with 10% or less being from saturated fats (Thompson &

Manore, 2012).

Protein

Protein, the third macronutrient, plays an important role in the body. According to the CDC (2012c), proteins are combinations of amino acids that are a part of "every cell, tissue and organ in our bodies" (p. 1). Found in foods such as meats, eggs, nuts, and milk, proteins are the building blocks for body parts such as the bones, blood, and skin (Thompson & Manore, 2012). Bounded together by peptide bonds, the combination and structure of amino acids determine their function (Campbell et al., 2012). The purpose of proteins resides in their ability to contribute to cell growth and development, repair, and maintenance of the body (Dietary Reference Intakes, 2005). Many times they act as enzymes or hormones, maintain fluid/electrolyte or acid/base balance, and develop antibodies for the immune system (Thompson & Manore, 2012). Cells are constantly replacing themselves, allowing proteins to be recycled, which aids in the replacement process (Campbell et al., 2012). During acid-base balance, proteins serve as buffers to prevent a state of acidosis or alkalosis (Thompson & Manore, 2012). Buffers take away or contribute hydrogen atoms when needed. Lastly, proteins also serve as an energy reserve. To use proteins, they must undergo deamination, and the carbon and hydrogen are then converted into the glucose that the body needs (Thompson & Manore, 2012).

Proteins do not serve the body as a significant source of energy (Thompson & Manore, 2012). When protein is used by body as a source of fuel, its major functions, including its structural and regulatory roles, are dismissed (Peterson & Peterson, 1988). Amino acids are the building blocks of proteins and are specifically meant to be used for the building and repairing of muscles (Campbell et al., 2012). The Recommended Dietary Allowance (RDA) for protein is 0.8 g/kg of body weight per day (Volpe et al., 2007). As one of the most important monomers in the body, amino acids supply about 1-6% of the energy used during physical activity (Thompson & Manore, 2012). Despite claims made by supplement advertisements, the amount of protein one consumes does not control muscle growth; rather, the demand for growth is initiated by the trauma associated with intense exercise (Colgan, 1993). However, the timing of the consumption of protein does matter. Studies suggest that muscles benefit the most when protein is ingested immediately after exercise (Phillips et al., 2007). Previously, it was thought that muscles were sensitive to the provision of amino acids and other nutrients up to 3 hours following exercise, however longitudinal research has contradicted this (Phillips et al., 2007). Immediate consumption supports worked muscles the best (Thompson & Manore, 2012). On top of this, consuming protein in conjunction with carbohydrates promotes muscle protein synthesis (Benjamin et al., 2009). It is said to enhance training in the long run (Gibala, 2012). Low glycogen stores have the potential to metabolize twice as much protein than normal because amino acids are converted to glucose to sustain blood sugar levels (Larson-Meyer, 2007). Eating a small amount (about 10 to 20 grams) of protein will provide the body with what it needs to begin the rebuilding process post-workout (Gibala, 2012). According to the American College of Sports Medicine, athletes, like growing children, have protein requirements higher than the RDA (Stoler, 2013). These requirements include 1.2g/kg for endurance athletes and 1.7g/kg for strength athletes (Stoler, 2013). However, most athletes consume approximately 1.6g/kg a day already, meeting the daily recommendations without supplements (Stoler, 2013). Studies have shown no support for the assertion that ingesting more than 2g/kg of protein will improve muscle strength or performance (Thompson & Manore, 2012). Excess protein consumed by athletes will either be burned or stored in the body as fat (Stoler, 2013). A popular post-workout drink for athletes is chocolate milk (Colgan, 1993). Leucine, an essential amino acid and a key ingredient for the building of muscle, is found in both plain and chocolate milk (Volpe et al., 2007). Drinks like these offer some of the best recovery after resistance training (Volpe et al., 2007).

Overall, proteins are essential for the repair and building of the body's tissue, especially muscle. While carbohydrates and fats refuel the body, proteins help provide it with the strength it needs to compete.

Sports Drinks, Gels, and Jellybeans

Over the years, studies have shown that by consuming carbohydrates in the form of sports drinks, gels, and jellybeans, athletes are able to maintain blood glucose levels and, therefore, improve their exercise performance (Campbell et al., 2008). According to the *International Journal of Sport Nutrition and Exercise Metabolism*, "the ability to sustain moderate to high-intensity exercise for longer than one hour depends on the cardiovascular system's ability to deliver fuel and oxygen to the exercising muscle… convert that fuel into energy… and have adequate glycogen contents" (Campbell et al., 2008, p. 179). Carbohydrates, found in several advertised sources, provide the key to muscle fuel (Burke et al., 2005). Ingesting carbohydrates during exercise can help reduce fatigue in the muscles, and after exercise, they can improve recovery (Skinner, 2009).

Sports drinks were originally invented with three purposes in mind: (1) prevent dehydration, (2) replace electrolytes lost through sweat during a workout, and (3) provide the muscles with carbohydrates (Mayo & Kravitz, 2008). Although water can prevent dehydration, it lacks the ability to supply adequate amounts of electrolytes and carbohydrates to the body to supplement lost energy (Williams, 2010). Studies have demonstrated that the flavoring in sports drinks encourage individuals to consume more of the carbohydrate-electrolyte replacements as opposed to regular drinking water (Guest, 2007). The lack of taste associated with water can make it a poor hydrator, especially in young athletes (Guest, 2007). Athletes will often voluntarily dehydrate themselves by neglecting to consume plain water (Skinner, 2009). Sports drinks are primarily meant for use in athletic related activities or working out, which means they are not designed to be part of a balanced diet (Guest, 2007). A typical replacement drink contains 14-17 grams of carbohydrates for every 8 fluid ounces (Mayo & Kravitz, 2008). This 6-8% carbohydrate solution will allow for enhanced fluid absorption in the small intestine and quicker supply of energy to the muscles (Mayo & Kravitz, 2008). The drink becomes satisfactory when it includes a wide range of electrolytes including sodium, chloride, calcium, magnesium, and potassium (Williams, 2010). Sodium not only serves as an electrolyte found in sports drinks, but can also prompt the desire to drink more by increasing one's thirst (Skinner, 2009). However, it is important to avoid sports drinks that contain high-fructose corn syrup, sucrose, dextrose, or fructose as their only source of carbohydrate (Williams, 2010). Examples of acceptable workout replenishing drinks are Gatorade® and Powerade® (Skinner, 2009). While these drinks contain too many calories for an inactive individual, they satisfy the three purposes of a sports drink (Skinner, 2009). If consumed without working out, the extra carbohydrates can turn into body fat since they are being unused (Mayo & Kravitz, 2008). When exercise sessions become lengthy, meaning they span for a few hours at a time, it is recommended that blood glucose levels be replenished with 30 to 60 grams of carbohydrates per hour depending on the intensity (Mayo & Kravitz, 2008). To accomplish this goal 16-32 oz. of a sports drink is necessary every hour (Mayo & Kravitz, 2008). However, the carbohydrate and electrolyte needs can be aided by, or met through, the consumption of supplements such as gels or jellybeans as well (Campbell et al., 2008).

Products such as gels and jellybeans provide athletes with personal preference and portability (Campbell et al., 2008). In an experiment that compared these carbohydrate supplements to water, the study revealed that the carbohydrate supplements enabled the participants to complete a 10-km time trial in a faster time and work at a higher intensity for longer than with just water alone (Campbell et al., 2008). The same study used the 10-km time trial to compare the solid carbohydrate supplements (jellybeans) against the liquid carbohydrate supplements (sports drinks and gels) but concluded that there was no significant difference between the two different forms (Campbell et al., 2008). The average power output for the sports beans, sports drink and gel were 226.4 +/- 17.7W, 221.9 +/- 19.9W, and 225.3 +/- 20.9W, respectively (Campbell et al., 2008, p. 187). On the other hand, water yielded an average power output of only 208.1 +/- 18.1W (Campbell et al., 2008). Likewise, the timing for all three carbohydrate options were better (faster) than water. While water resulted in a 10-km timed-trial time of 17.8 +/- 0.7 minutes, sports beans were timed at 17.2 +/- 0.6, sports drinks at 17.3 +/- 0.6, and gel at 17.3 +/- 0.6 minutes (Campbell et al., 2008). As a result, any of the carbohydrate supplements were considered to be "effective nutritional aids" to combat the issue of "digestibility and portability faced during endurance training and competition" (Campbell et al., 2008, p. 189). In a similar study, the use of gels was tested again against water; however, this time, participants took part in a half marathon. The conclusion of this experiment revealed that the carbohydrates in gel form enhanced a runner's speed in the half marathon by only about 14 seconds (Burke et al., 2005). Although the study marks this as an insignificant value, it also points out that sometimes runners finish within seconds of each other emphasizing the importance of even the smallest aid (Burke et al., 2005).

Overall, there appears to be no significant difference between the different forms of carbohydrates – sports drinks, gels, or jellybeans. However, according to research, carbohydrates play a key role in maintaining power in our muscles for longer. Therefore, whether an individual consumes a rehydrating sports drink during a game or ingests a pack of gel during a race, the athlete is most likely to gain the benefits of the supplement (Williams, 2010).

Ergogenic Aids

Ergogenic aids, substances consumed in order to enhance athletic performance, are often used by athletes to build muscle, increase strength, or decrease fatigue in the body (Thompson & Manore, 2012). The drive toward success in sports and the desire to have an advantage over competition has led to the consumption of these chemicals, commonly known as "doping" (Greydanus & Patel, 2012). However, doping has been described as being contrary to sports morals (Mazzeo & Ascione, 2013). Several of these ergogenic aids include: anabolic-androgenic steroids, creatine, and caffeine.

Anabolic androgenic steroids (AAS), frequently shortened to "anabolic steroids" or just "steroids," are derivatives of testosterone designed with the purpose of promoting protein synthesis and muscle growth (Mazzeo & Ascione, 2013). Another function of anabolic steroids is their potential to reduce physical recovery time (Mazzeo & Ascione, 2013). Two examples of these derivatives are androstenedione and dehydroepiandrosterone (Thompson & Manore, 2012). Athletes such as weightlifters, football players, swimmers, and runners sometimes seek the benefits of this drug (Mazzeo & Ascione, 2013). Likewise, body builders ingest steroids to improve their size and enhance their muscular cosmetic appearance (Mazzeo & Ascione, 2013). According to the Romanian Sports Medicine Society, "the anabolic effect is determined by a local nitrogen increment with an increase of new formed proteins, by the rise of glycogen,… an accentuated oxygen consumption,… and increased water content in the muscle mass" (Mazzeo & Ascione, 2013, p. 2012). The 1940s introduced the first published reports of ergogenic effects, and since then, AAS have been abused at every Olympic competition since 1960 (Kersey et al., 2012). While AAS has the potential for increasing lean body mass and can greatly improve strength-and power-related performance, negative consequences may result from inappropriate dosage (Kersey et al., 2012). Misusing these drugs is discouraged due to their potential physical and/or psychological damage (Greydanus & Patel, 2010). Different types of AAS have been associated with cardiovascular disease, sudden cardiac death, renal and hepatic pathologies, and even some cancers (Sculthorpe et al., 2012). Some studies have shown that additional physical effects include pubertal voice alterations in males, increased density of facial/body hair, and induced hypertension (Sculthorpe et al., 2012). Steroid use can also result in infertility, liver damage, acne, and uncontrollable changes in mood (for example, anger) (Thompson & Manore, 2012). Anabolic androgenic steroids are illegal in the United States and are banned by all collegiate and professional sports programs across the nation (Thompson & Manore, 2012). In attempt to reduce the abuse of ergogenic aids, sports associations, for example the National Collegiate Athletic Association (NCAA), randomly test for drugs in participating athletes to ensure a fair environment (Kersey et al., 2012). Athletes are also tested using a urine sample before any form of competition in the Olympics (Kersey et al., 2012).

In addition to anabolic steroids, creatine, a supplement that has become popular among strength athletes, has been reported to improve high-intensity exercise capacity (Jagim et al., 2012). Studies have shown that creatine monohydrate (CrM) increases creatine and phosphocreatine concentrations by 15-40% in the body and enhances anaerobic exercise capacity (Jagim et al., 2012). Creatine is a compound formed in protein metabolism, is present in living tissue, and is involved in the supply of energy for muscle contraction (Jagim et al., 2012). According to one study, recent research indicates creatine supplementation in amounts of 0.1g/kg of body weight will improve training adaptations at both the cellular and sub-cellular levels (Cooper et al., 2012). As an oral supplement, CrM provides additional creatine to the body along with the 1 gram naturally consumed through a well-balanced diet containing meat (Cooper et al., 2012). The purpose of creatine is to replenish the ATP stores in the body, which helps maintain energy for intense workouts (Thompson & Manore, 2012). Although side effects such as dehydration or gastrointestinal discomfort may be associated with it, currently, creatine is not banned in the United States (Thompson & Manore, 2012).

Caffeine is the most widely used stimulant in the world and allows an individual to feel more alert (O'Mathúna, 2012). According to a statistic from *Integrative Medicine Alert*, 90% of all adults drink beverages that contain caffeine averaging about 227mg of caffeine daily (O'Mathúna, 2012). Athletes use caffeine in the form of energy drinks as an ergogenic aid for increasing energy levels and lowering feelings associated with muscle fatigue (Thompson & Manore, 2012). While one cup of coffee may contain 100mg of caffeine, energy drinks vary between 70-140 mg (Mayo & Kravitz, 2008). Examples of these central nervous system stimulants include Red Bull®, Monster®, and 5-Hour Energy® (Skinner, 2009). After examining the effects of several of these energy drinks and energy shots, one study came to the conclusion that consuming energy drinks 10-60 minutes before exercise can improve mental focus, alertness, and endurance performance (Campbell et al., 2013). However, side effects are also associated with excess caffeine. Individuals must be aware that caffeine toxicity is a possibility if energy drinks are consumed in large amounts (O'Mathúna, 2012). Age, weight, caffeine tolerance, and dose all play a role in the overall effect on the body (Mayo & Kravitz, 2008). If taken in amounts too large for the body to handle, agitation, tremors, heart palpitations, or other adverse affects dealing with the heart or brain can result (O'Mathúna, 2012). Although caffeine is not banned in the United States, athletes can be refused the right to participate in Olympic competition if caffeine levels are too high (Thompson & Manore, 2012).

It is not recommended for athletes to consume ergogenic aids, rather it is suggested they balance hard work and training with a nutritious diet to provide their muscles with the necessary ingredients for energy and power (Thompson & Manore, 2012). This is considered the safest way to improve one's body strength and physical ability (O'Mathúna, 2012).

Conclusion

Maintaining proper hydration and consuming adequate amounts of carbohydrates, fats, and proteins are key to developing healthy nutritional habits. Water, one of the most important liquids needed by the body, contains essential electrolytes and is critical to maintaining homeostasis. Without it, athletes pose the risk of dehydration or more severe consequences that could alter or hinder their performance. The electrolytes contained in the fluids we consume regulate fluid balance, help control nerve impulses, and carry out muscle contractions, which are necessary to compete. On top of this, carbohydrates and fats furnish athletes with energy for physical activity. While carbohydrates provide the body with ATP stores for short bursts of high-intensity intervals, fats breakdown to supply energy for longer intervals at lower intensity levels. Carbohydrates can be found in different forms to facilitate the amount that athletes ingest. Sports drinks, gels, and jellybeans are a few of those forms. Protein, the third macronutrient, allows the body to build, repair, and grow after an athlete trains. A correct balance of these three macronutrients will help the body perform to its best ability. Although athletes can utilize products to enhance their performance, ergogenic aids are not recommended and may be deemed illegal in the United States.

Nutrition is a key component to the success of athletes. Although it is often overlooked in favor of training sessions and workouts, the right foods and nutrients provide athletes with the fuel they need to supply their working body. By understanding what their bodies need in order to stay healthy, athletes will be able to perform at optimal levels.

References

Benardot, D. (2006). *Advanced Sports Nutrition: Fine-Tune Your Food and Fluid Intake for Optimal Training and Performance.* Champaign, IL: Human Kinetics.

Benjamin, L., Blandpied, P., & Lamont, L. (2009). "Dietary Carbohydrate and Protein Manipulation and Exercise Recovery in Novice Weight-Lifters." *Journal of Exercise Physiology*, 12, 33-39.

Burke, L. (2007). *Practical Sports Nutrition*. Champaign, IL: Human Kinetics.

Burke, L. M., Wood, C., Pyne, D. B., Telford, R. D., & Saunders, P. U. (2005). "Effect of Carbohydrate Intake on Half-Marathon Performance of Well-Trained Runners." *International Journal of Sport Nutrition and Exercise Metabolism*, 15, 573-589.

Campbell, B., Wilborn, C., LaBounty, P., Taylor, L., Nelson, M. T., Greenwood, M., Kreider, R. B. (2013). "International Society of Sports Nutrition Position Stand: Energy Drinks." *Journal of the International Society of Sports Nutrition*, 10, 2-16.

Campbell, C., Prince, D., Brown, M., Applegate, E., & Casazza, G. A. (2008). "Carbohydrate-Supplement Form and Exercise Performance." *International Journal of Sport Nutrition and Exercise Metabolism*, 18, 179-190.

Campbell, N. A., Reece, J. B., Taylor M. R., Simon, J. S., Dickey J. L. (2012). *Biology: Concepts and Connections* (7th ed.). San Francisco, CA: Pearson Education, Inc.

Campbell, N. A., Reece, J. B., Urry, L.A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. (2011). *Biology* (9th ed.) San Francisco, CA: Pearson Education, Inc.

Center for Disease Control and Prevention. (2012a). "Nutrition for Everyone." Retrieved from: http://www.cdc.gov/nutrition/everyone/.

Center for Disease Control and Prevention. (2012b). "Polyunsaturated Fats and Monounsaturated Fats." Retrieved from: http://www.cdc.gov/nutrition/everyone/basics/fat/unsaturatedfat.html.

Center for Disease Control and Prevention. (2012c). "Protein." Retrieved from: http://www.cdc.gov/nutrition/everyone/basics/protein.html.

Center for Disease Control and Prevention. (2013). "Water and Nutrition."Retrieved from: http://www.cdc.gov/healthywater/drinking/nutrition.html.

Colgan, M. (1993). *Optimum Sports Nutrition: Your Competitive Edge.* Ronkonkoma, NY. Advance Research Press.

Cooper, R., Naclerio, F., Allgrove, J., & Jimenez, A. (2012). "Creatine Supplementation with Specific View to Exercise/Sports Performance: An Update." *Journal of the International Society of Sports Nutrition*, 9, 1-9.

Gibala, M. J. (2012). "Protein and Exercise: What Does Science Say." *Handball*, 62, 1-4.

Greydanus, D. E. & Patel, D. R. (2010). "Sports Doping the Adolescent: The Faustian Conundrum of Hors de Combat." *Adolescents and Sports*. 3, 729-750.

Guest, N. (2007). "Sports Drinks – Who Needs Them Anyway?" *Fitness Business Canada*, 18, 46-47.

Institute of Medicine (2005). *Dietary Reference Intakes: For Energy, Carbohydrates, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington, D.C.: The National Academies Press.

Jagim, A. R., Olive, J. M., Sanchez, A., Gavan, E., Fluckey, J., Riechman, S., Kreider R. B. (2012). "A Buffered Form of Creatine Does Not Promote Greater Changes in Muscle Creatine Content, Body Composition, or Training Adaptations than Creatine Monohydrate." *Journal of the International Society of Sports Nutrition*, 9, 43.

Karinch, M. (2002). *Diets Designed for Athletes: How to Combine Foods, Fluids, and Supplements for Maximum Training and Performance*. Champaign, IL: Human Kinetics.

Kenefick, R. W. & Cheuvront S. N. (2012). *Hydration for Recreational Sport and Physical Activity* (Vol. 70). Hoboken, NJ: Blackwell Publishing.

Kersey, R. D., Elliot, D. L., Goldberg, L., Kanayama, G., Leone, J. B., Pavlovich, M., Pope, H. G. (2012). "National Athletic Trainers' Association Position Statement: Anabolic-Androgenic Steroids." *Journal of Athletic Training*, 47, 567-588.

Larson-Meyer, D. E. (2007). *Vegetarian Sports Nutrition: Food Choices and Eating Plans for Fitness and Performance.* Champaign, IL: Human Kinetics.

Mayo, J. J. & Kravitz, L. (2008). "Sports & Energy Drinks: Answers for Fitness Professionals." *IDEA Fitness Journal*, 5, 17.

Mazzeo, F. & Ascione, A. (2013). "Anabolic Androgenic Steroids and Doping in Sport." *Sports Medicine Journal*, 9, 2009-2018.

McCall, P. (2009). "What is High Intensity Interval Training (HIIT) and What are the Benefits?" Retrieved from: http://www.acefitness.org/acefit/healthy-living-article/60/104/what-is-high-intensity-interval-training-hiit/

O'Mathúna, D. P. (2012). "Energy Drinks to Improve Performance." *Integrative Medicine Alert*, 15, 133-137.

Peterson, M. & Peterson, K. (1988). *Eat to Compete: A Guide to Sports Nutrition.* St. Louis, MO: Mosby – Year Book, Inc.

Phillips, S.M., Moore, D. R., & Tang, J. E. (2007). "A Critical Examination of Dietary Protein Requirements, Benefits, and Excesses in Athletes." *International Journal of Sport Nutrition and Exercise Metabolism*, 17, 58-76.

Sculthorpe, N., Grace, F., Angell, P., Baker, J., & George, K. (2012). "Cardiovascular Risk and Androgenic Anabolic Steroids." *British Journal of Cardiac Nursing*, 7(6), 266-273.

Skinner, R. (2009). "Drink to Your Health." *Volleyball*. Quincy, MA: Madavor Media.

Skolnik, H. & Chernus, A. (2010). *Nutrient Timing for Peak Performance: The Right Food, the Right Time, the Right Results* Champaign, IL: Human Kinetics.

Stoler, F. (2013). "Sports Nutrition Unplugged." Retrieved from: http://www.acsm.org/access-public-information/acsm's-sports-performance-center/sports-nutrition-un-plugged

Stoppani, J. F. (2013). "Protein Powder." *Flex*. New York, NY: Weider Publications, Inc.

Thompson, J., & Manore, M. (2012). *Nutrition: An Applied Approach* (3rd ed.). San Francisco, CA: Pearson Education, Inc.

USADA (2010). "Optimal Dietary Intake Guide." Retrieved from: http://www.usada.org/diet

Volpe, S. L., Sabelawski, S. B., & Mohr, C. R. (2007). *Fitness Nutrition for Special Dietary Needs*. Champaign, IL: Human Kinetics.

Williams, E. Z. (2010). "Good Eats: Hydration and Sports Drinks." *Massage Magazine*. Ponte Vedra Beach, FL: Doyle Group.

Williams, M. H. (1995). *Nutrition for Fitness and Sport* (4th ed.). United States: The McGraw-Hill Companies, Inc.

Wolinsky, I. (1998). *Nutrition in Exercise and Sport* (3rd ed.) Boca Raton, FL: CRC Press LLC.