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Athletic Nutrition

Glenn M. Taira
University of North Dakota

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ATHLETIC NUTRITION

by

Glenn M, Taira
Bachelor of Science in Physical Therapy
University of North Dakota, 1996

Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1997
This Independent Study, submitted by Glenn Masao Taira in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Chairperson, Physical Therapy)

(Faculty Preceptor)

(Graduate School Advisor)
PERMISSION

Title Athletic Nutrition
Department Physical Therapy
Degree Master of Physical Therapy

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Date
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WE DID IT!

Nui Ka Pia . . . Nui Ka I'a - HUI O I'A
ABSTRACT

Science has broken down many of the barriers that once kept athletes from performing at their very best. This has been done through the scientific study of athletes and the development of a combination of proper training, technique, mental attitude, and nutrition. While training and technique are variables that come with time and practice, proper nutrition can produce positive changes in an athlete’s performance in a relatively short period of time. Eating the right kinds of foods, in the right proportions, for a given type of athletic event (i.e. aerobic, anaerobic, strength, and muscular definition) can provide an athlete the boost he or she needs to get to the next level of performance.

Athletic nutrition has been looked at as a "Cookbook" process in which the goals of the individual are overlooked or disregarded. Some clinical nutritionists believe that the Recommended Daily Allowance still covers the athletes’ daily nutritional requirements. The need for increased amounts of all nutrients are not seen to be necessary, despite the differing demands of occupation or increased demands of training for athletes. Yet, science has proven this to be wrong. Studies have shown that the nutritional needs of the working man and woman, not to mention athletes, are not satisfied by the Recommended Daily Allowance. The idea that the Recommended Daily Allowance is adequate for athletes has been perpetuated by big business and some health and sports organizations for many years.
The purpose of this literature review is to compile information that is currently available and provide a resource manual for clinicians. This review will discuss nutrient requirements for protein, carbohydrates, fats, vitamins, minerals, and water. The review will go further and discuss the role that supplements and sleep play in the athlete's diet.
CHAPTER I
INTRODUCTION

Participation in sporting events is becoming increasingly popular every year. As the number of people participating in these events has grown, so has the desire of each athlete to perform at his or her very best. Many people have turned to science to provide some of the answers with some margin of success.

Science has broken down many of the barriers that once kept athletes from performing at their very best. This has been done through the scientific study of athletes and the development of a combination of proper training, technique, mental attitude, and nutrition.

While training and technique are variables that come with time and practice, proper nutrition can produce positive changes in an athlete’s performance in a relatively short period of time. Eating the right kinds of foods, in the right proportions, for a given type of athletic event (i.e. aerobic, anaerobic, strength, and muscular definition) can provide an athlete the boost he or she needs to get to the next level of performance.

The nutritional requirements of the athlete were once thought to be covered by the Food and Drug Administration’s (FDA) Recommended Daily Allowance (RDA). The original intent of the RDA was to provide a baseline standard for the sedentary population. This means that the RDA is a broad view of the proportions of foods that should be consumed throughout the day. However, these standards fail to make any
adjustments for activity and stress levels of the individual. As a result, what the RDA suggests to be adequate falls far below the nutritional requirements (protein, carbohydrates, fats, nutrients, and water) of the athlete.

The athletic population is far from being sedentary. For example, when sleeping, a human burns approximately 80 kilocalories/hour (Kcal/hour) or when watching television he or she burns about 90 Kcal/hour. In contrast, running a marathon burns about 990 Kcal/hour or walking to class burns 300 Kcal/hour. Simple math shows that an athlete will burn up to ten times the amount of calories a sedentary individual will burn. Listed below are some other energy expenditures of different activities.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Energy Expenditure (Kcal/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleeping</td>
<td>80</td>
</tr>
<tr>
<td>Watching Television</td>
<td>90</td>
</tr>
<tr>
<td>Walking to Class</td>
<td>300</td>
</tr>
<tr>
<td>Singing</td>
<td>120</td>
</tr>
<tr>
<td>Running Marathon</td>
<td>990</td>
</tr>
<tr>
<td>Disco Dancing</td>
<td>450</td>
</tr>
<tr>
<td>Playing Basketball</td>
<td>560</td>
</tr>
<tr>
<td>Weight Training</td>
<td>550</td>
</tr>
</tbody>
</table>

Taking into consideration all of these factors, assuming that the athlete and the sedentary individual will have the same caloric needs is illogical.¹

Each athlete is an individual genetically and therefore biochemically. This means that the proportions of nutrients needed by each athlete varies from person to person. One example of biochemical individuality was displayed in a study which investigated the utilization of vitamin C. Subjects were given megadoses (5000 mg) of Vitamin C and their urinary excretion of the vitamin was monitored. Excretion rates are used to monitor the amount of a substance that is being utilized by the body. Increases in excretion would signify when tissues become saturated. Results in some individuals
were found to show a limited increase in urinary excretion while others showed an increase after a dose of only 1000 mg.\textsuperscript{2}

In addition to the physical variables that must be taken into consideration, environmental variables (i.e. humidity, temperature, and time of day) must also be considered since they also affect nutritional requirements of the athlete. One of the most well known influences is humidity. Increases in humidity decrease the body's ability to cool the system. As a result, an athlete would need to consume more cool liquids to regulate body temperature.

Based on these facts it would be wrong to assume that the RDA is adequate for every individual, let alone the athlete. This literature review will cover nutrition requirements for the athletic population and further try to tailor nutritional requirements to specific types of athletic events and goals. The review will further discuss the role sleep and supplements play in attaining optimal sports nutrition and therefore optimal performance.
CHAPTER II

PROTEIN

Optimal nutrition begins with six basic areas—protein, carbohydrates, fats, calories, vitamins, minerals, and water. These six areas form the building blocks of optimal nutrition and will be briefly discussed here and in the following chapters.

Proteins form the building block of all living things. All living organisms use proteins to build their structures and regulate normal body functions. In human beings approximately 15 to 20 percent of body weight is composed of protein, with the majority of it deposited in skeletal muscle. Proteins are the largest macromolecule used by the cell.

Protein Chemistry

Proteins are comprised of combinations of Amino Acids (AA) linked together by hydrogen bonds to form long chains. Each AA is formed by at least one Amino radical (-NH2) and an Organic Acid Complex (-COOH). Side chain groups designated by (CH3)x distinguish each AA from another. The basic chemical structure looks like this:

Amino Radical

<table>
<thead>
<tr>
<th>Organic Acid</th>
<th>O NH2</th>
</tr>
</thead>
<tbody>
<tr>
<td>C CH (CH3)x</td>
<td>OH</td>
</tr>
</tbody>
</table>

4
Currently there are twenty-three known AA used by the human body. Different combinations of these form different proteins and the sequence in which these AA are joined determines the primary structure of the protein. Plants are able to manufacture all of the AA they require to grow correctly by incorporating Carbon from the air, Nitrogen from the soil, and Hydrogen and Oxygen from water. Animals on the other hand are unable to produce certain AA at a sufficient rate to support proper growth and bodily functions. These AA are therefore termed essential because they must be ingested by animals. Animals and humans acquire these essential AA by eating meats and vegetables.

**Protein Deficiencies and Over Consumption**

Deficiencies in protein intake can result in growth abnormalities and impaired tissue development. In its severest form protein deficiency can result in a condition known as Kwashiorkor, which is characterized by lethargy, apathy, irritability, mental deficiency, inanition, decreased immune system function, dermatitis, edema, and liver enlargement.

An overabundance of protein is not good either. Protein contains approximately 5.65 Kcal per gram. An overabundance of protein will result in the liver metabolizing the excess and storing it as fat. Others believe that a protein excess is more detrimental than just an addition of fat to the body. Their concern is that high protein diets contribute to renal disease in some patients. These concerns are mostly unfounded due to the limited research in this area and the fact that the studies have involved subjects with pre-existing renal problems. At this time there is no adverse effect of excessive protein intake other than the addition of fat.
Protein Quality

Proteins are categorized by the ability of the body to assimilate them for use. One system that is currently being used is the Protein Efficiency Ratio or PER. This ratio is based on the availability of all 10 of the essential AA, the correct proportions of those AA, and the ability of the body to assimilate those AA. The best naturally occurring source of protein is egg white or albumin at 96 percent PER; the next would be milk at 60 percent PER, followed by meats at 40 percent PER, and vegetables at 15 percent PER.

An athlete wants to choose those proteins that will provide him or her with the highest PER rating. This will ensure that they are getting the right AA in the right proportions to remain in positive nitrogen balance.

Nitrogen Balance Studies

Establishing the recommended intake of protein has been done through the use of nitrogen balance studies. When proteins are consumed they are broken down to their individual AA. As AA are metabolized in the body they are converted to carbon dioxide, water, and ammonia (NH3). Ammonia is highly toxic, so the body converts it to a less toxic form called urea which is then excreted by the kidneys. Therefore, nitrogen concentrations found in urine are a good indicator of protein that is excreted by the body and nitrogen balance can be estimated.

The goal for the athlete is to remain in the "Anabolic zone" or positive nitrogen balance. Positive nitrogen balance occurs when nitrogen excretion through feces, sweat, and urine is less than nitrogen intake. This zone provides the body with the materials needed to function at peak levels and to excel at given tasks. Negative nitrogen balance occurs when nitrogen excretion is greater than nitrogen intake. This
means that protein is being cannibalized from the body's protein stores (mainly skeletal muscle) to maintain normal function. This could mean a decrease in muscle mass and immune function, and a host of different problems. When everything is taken into consideration, all athletes want to remain in the positive nitrogen zone.²

**Protein Requirement Theories**

Two schools of thought have emerged in the last decade relative to protein requirements of athletes. The conventional view states that the RDA is adequate for all populations (sedentary to athletic). The current RDA for protein is .80 g/Kg/day (grams of protein per kilogram of lean body mass per day) for adults 19 years and older. According to the National Research Council this should cover 80 to 90 percent of all healthy individuals under normal amounts of stress. Included in this recommended amount is a .45 g/Kg/day of protein to cover any nitrogen lost though feces, urine, or sweat and a .35 g/Kg/day of safety margin to cover any other losses. Therefore, because a safety margin has been included in this value, the National Research Council determined in 1984 that an increase in the amount of protein is not needed for different occupational demands or increases in training.¹⁰

While many believe this to be true, research has shown that exercise and diet affect muscle protein requirements. Exercise induced adaptations of muscle proteins are observed with all athletes. For example, heavy resistance training causes hypertrophy of muscles which increases the body's need for protein.¹² While aerobic or endurance training causes little or no change in the size of muscles, a vast number of subcellular changes do occur to provide the muscle the ability to perform aerobic activity. Both of these changes are a result of protein redistribution and metabolism, which in turn increases protein requirements.⁹,¹² These findings have led to the
emergence of a new school of thought which advocates that the athletic population requires higher amounts of protein to remain in the anabolic state and prevent protein catabolism.

**Current Recommendations**

Current research suggests that the current RDA of 0.8 g/Kg/day body weight/day is far too low for the athletic population. This is based on 1) positive nitrogen balance resulting from heavy exercise, and 2) the contribution of protein catabolism to fuel requirements of endurance exercise.\(^3,10\) In other words the increases in muscle mass and the role protein plays as a secondary energy source further support the increases in the RDA.

**Strength or Anaerobically Training Athletes**

Specifically for strength or anaerobic training athletes, the suggested values range form 1.3 g/Kg/day to 3.6 g/Kg/day.\(^1,6,7,9,10,12\) In comparison to the RDA, these values are up to three times the current RDA standards. Research established these values through nitrogen balance studies of weight lifters.\(^1,9\)

Another researcher suggests that by maintaining an optimal environment for growth (positive nitrogen balance which is achieved through increased protein consumption), protein synthesis can be enhanced. This is based on the known fact that muscular exercise increases AA absorption rates of skeletal muscle. Therefore, maintaining a high protein diet may be important for all athletes who participate in short duration high intensity events where muscular strength is important.\(^6\)

**Endurance or Aerobic Requirements**

For endurance athletes, researchers suggest 1.0 g/Kg/day to 2.00 g/Kg/day.\(^3,6,7,9,10,12\) These suggested values are also supported by nitrogen balance
studies which tested various levels of protein at a level of exercise. For example, in one study, well trained athletes were exercised on a treadmill at 75 percent of their \( \text{VO}^2 \) max for 75 minutes every day for six days. Nitrogen balance was assessed following each exercise session. Results showed that on days four, five, and six, nitrogen balance was negative when a diet of 0.86 g/Kg/day of protein was used. When the same study was done with athletes on 1.5 g/Kg/day of protein, nitrogen balance was found to be positive for all six days. This study clearly shows that the RDA is inadequate and that increases need to be made. Other studies have come to the same conclusion . . . that the RDA does not cover the needs of the athlete and that increases in protein intake are needed.\(^3\) The suggested level lies in the range specified earlier. Individual levels need to be personally adjusted by the athlete.

**Timing of Protein Intake**

Researchers have also suggested that there is particular time that the body requires protein intake. Studies suggest that protein intake is especially important immediately following exercise. This is based on the fact that for the first four to six hours following exercise muscle recovery is at its fastest rate. At this time, protein is required to assist in recovery. Based on this, if protein substrate is not available, the body cannibalizes its own protein stores, which is mainly found in skeletal muscle. Recovery is delayed for an extended period of time.\(^2\)

**Protein Supplementation**

The role of supplementing a diet is to provide additional nutrients that, for some reason, the athlete has been unable to consume through normal meals. Despite the recommendation that athletes require higher amounts of protein than the current RDA, it does not mean that an athlete needs to use a supplement. In many cases, normal
meals can provide adequate amounts of nutrients. Therefore, before an athlete begins a supplementation program, it is necessary to consider current dietary intake to see if they are receiving adequate amounts of each nutrient.  

There are two cases in which protein supplementation may be appropriate. First, in cases where the athlete is unable to consume adequate amounts of protein, supplementation with a high quality commercially prepared protein may be in order. However the athlete should monitor total protein intake so that recommended levels are not exceeded because excess protein may be stored as fat. Furthermore, there appears to be no ergogenic value in excessive protein intake: there is no increase in performance relative to excessive protein consumption.  

A second reason that protein supplementation may be advantageous to the athlete is that many normal dietary sources of protein, particularly dairy products, whole eggs, and meats, contain high amounts of fat, purine, and cholesterol. These substances are known to cause hardening of the arteries (arthrogenic) and should be consumed as little as possible. In contrast, protein supplements are able to control the amounts of these substances thereby making it a more pure source of protein. 

Conclusion  

Increases in protein intake have been found to be beneficial to athletes. Increases in performance have been attributed to the role that protein plays in building muscle structures and the role it plays as a secondary energy source. It is clear the RDA is inadequate for the athlete and that protein intake should be higher for this population. Supplementation of an athlete's diet may be needed in cases where the diet falls short of recommended levels. In these cases, a high quality protein supplement may be able to make up for the difference.
CHAPTER III
CARBOHYDRATES

First a distinction must be made between building nutrients and fuel nutrients. In the previous chapter protein was defined as a building nutrient. In addition, minerals, vitamins, and fats are also predominantly designated as building nutrients. Their main function is to provide the material needed to build the structures of the body. On the other hand carbohydrates (carbs) are predominantly designated a fuel source.

**Carbohydrate Metabolism**

Carbs are the primary source of energy the body needs to form Adenosine Triphosphate (ATP). ATP is a high energy storage molecule for all activities of the body.¹ Production of ATP begins in the digestive tract where carbs are broken down and converted to glucose. Glucose is then absorbed and enters the bloodstream. This triggers the release of the hormone insulin, which regulates blood glucose concentration. Insulin does this by facilitating the transport of glucose into cells of the liver, spleen, and muscles where glucose is converted to glycogen and stored.⁴

When blood glucose levels become too low, another hormone called glucagon is secreted causing the conversion of glycogen back to glucose. Glucagon then facilitates the transport of glucose back into the bloodstream. Between the actions of glucagon and insulin, blood glucose and glycogen levels are kept fairly consistent.¹ Problems arise when the regulatory mechanisms become faulty (i.e. diabetes).
Energy Production From Carbohydrates

Energy liberated from the breakdown of carbs is used to produce ATP which is then stored in the various organs of the body. Energy for the various activities of the body are produced by cleaving a phosphate molecule from ATP. Based on this it is logical to conclude that the amount of carbs that an athlete can carry predetermines the amount of readily available energy he or she can expend at any given time. The rate at which the muscles use carbs to produce ATP is dependent on various factors such as intensity of exercise, physical conditioning, exercise type, environmental factors, and pre-exercise diet.

Other Fuel Sources

Secondary and tertiary fuel sources are also available to the body. While protein can also be used as a fuel source, an athlete wants to delay burning protein for fuel as long as possible because this means that muscle is being cannibalized. Fats also play a role in energy storage but the body only uses this fuel source when carb stores are depleted. Many diets emphasize forcing the body to use fats for fuel but for the athlete this spells disaster. Studies have shown that if the athlete is exercised until carb levels are depleted, the body will primarily burn fats. The studies continued and tested athletic performance following carb depletion. Under the depleted conditions the researchers found that athletic performance dropped dramatically. This is the main reason carb levels should be maintained in athletes.

Carbohydrates as the Primary Fuel Source

Since the body looks for the least resistant and most economical path to function, carbs are the primary fuel source of the body. This is based on energy release studies in which both fats and carbs were studied. Fats and carbs are both
calorie dense, meaning that they both contain high amounts of calories per gram. When ATP yields were examined, fats yielded 0.5 mols/minute of ATP whereas carbs yielded 1.0 mols/minute of ATP.\(^1\) Simple math shows twice the ATP yield comes from carbs as compared to fats. Furthermore, the energy required to manufacture ATP from fats far exceeds that of carbs.

Other reasons why carbs are a preferred fuel source lies in fact that carbs are the only energy source that can be burned in an anaerobic environment or during events that require rapid energy release. Other sources of energy (fats and protein) need to be converted into glucose before they are ready for energy production.\(^1\) Carbs play a role in this conversion. As you can see, carbs play an integral part in all parts of the energy manufacturing.

Types of Carbohydrates

Carbs consist of various combinations of carbon, hydrogen, and oxygen.\(^5\) An example of a carb molecule is listed below:\(^1\)

\[ C_6H_{12}O_6 \] - Glucose Molecule

Carbohydrates fall into three categories:

- Simple Sugars: (glucose, fructose, galactose). Also known as Monosaccharides. Primarily found in fruits and honey.

- Sucrose: Also known as disaccharides.

- Complex Carbohydrates: Also known as polysaccharides. Starches (dextrins, cellulose, pectin, glycogen). Cellulose (dietary fiber). Found in vegetables, fruits, whole grains and legumes.
The RDA

While the National Research Council suggests a dietary carb intake of 44 to 65 percent of the daily calories for aerobic sports and 34 to 56 percent of calories for anaerobic sports, research has found a decreased performance level in athletes who consumed carbs at these levels. For example, cyclists consuming a 54% carb diet and participating in events lasting more than three hours, were tested to study the effect this diet had on performance. Results showed a decrease in performance in each case. The same decrease in performance was seen during a study with wrestlers (anaerobic) consuming a 55 percent carb diet; they showed a decrease in total power and average power output. No decreases in performance were seen in wrestlers who kept carb levels at 70 percent.

Concepts of Carb Intake

Since carbs play such a vital role in allowing athletes to perform at their best, it makes sense that these levels need to be increased appropriately and according to the exercise or sport type. While the FDA and other research suggests a recommended level of carbohydrates that should be ingested, this recommended level varies widely because of biological individuality, intensity and type of exercise, and environmental conditions.

Therefore the question must be asked, "How is the athlete to calculate the amount of carbohydrates to be consumed?" To answer this, there are guidelines by which sensible amounts can be calculated, but before this is done, the reader should first understand some concepts about the intake of carbs to take advantage of this premium fuel source. Among these concepts are the type, timing and amount of carbs that should be consumed.
The Insulin Response and the Glycemic Index

As previously stated there are three basic types of carbs. For the athlete, complex carbohydrates or polysaccharides such as whole grains, fruits, and dark leafy greens, provide some the best sources of carbs. The body digests these types of carbs over a longer period of time. This results in a long steady release of glucose into the blood stream, providing a steady source of energy. If simple sugars are consumed, glucose is dumped into the blood stream resulting in a quick burst of energy, or what has been called a "sugar high." This is followed by a sudden let down, and a resulting decrease in athletic performance.

The sudden drop in energy is caused by the response of the digestive system to the high levels of glucose in the blood stream. The body responds by releasing large amounts of insulin. As blood glucose levels rise insulin is also secreted to normalize the concentration. Initially the levels of insulin are low, then more and more is released. The result is that the level of insulin overshoots the amount of glucose, termed an insulin spike, causing too much glucose to be shuttled into the liver and the muscles leaving blood glucose levels low. Since the brain's energy comes primarily from blood glucose, the result is that you feel tired.

Here is where the glycemic index becomes useful to avoid the sudden energy drops. The index is a chart developed by Dr. David Jenkins, to help diabetic patients choose foods which keep their blood sugar levels at a constant level. This index itemizes foods according to the rate at which they are digested into blood glucose. Foods such as honey, carrots, white potatoes, and raw sugar (monosaccharides and disaccharides) have very high indices. Foods such as soybeans, apples, and whole grains (polysaccharides) have very low index values. Basically, the longer it takes for
foods to be digested and for glucose to move into the blood stream, the lower the index number. The index allows the athlete to classify carbs and select the right carb for the right time.

**Timing of Carb Intake**

Meals are divided into three different categories, Pre-exercise, During-exercise, and Post-exercise. Each category will discuss the type and amount of carbs that should be ingested.

**Basic Guidelines**

Specifically, for endurance athletes ideal carb intake levels are not truly known. Actual levels vary from athlete to athlete due to biochemical individuality, training intensity, and training duration. However researchers suggest an amount based on a percentage of calories consumed throughout the day. The recommendation is that no less than 65 percent of calories come from carbs, with ultra-endurance athletes (in events that last longer than three hours) requiring closer to 70 to 80 percent.

These calorie percentages are based on studies of athletes on high carb diets and their performances. Researchers tested cyclists on a 72 percent carb diet and a 13 percent carb diet. Results showed that cyclists on the 72 percent diet were able to exercise longer at 80 percent of their VO₂ max (113min). This is in contrast to the results of the same cyclist on the 13 percent carb diet who could maintain this level of exercise for 60 minutes. While the carb level used for the low carb diet (13 percent) may be abnormally low, other researchers have found that carb levels of 50 to 54 percent, a level commonly found among endurance athletes, to still be inferior to the higher carb diets. These diets were found inferior due to decreased performances of the athletes.
Studies suggest that the performance enhancement due to increased carb intake is linked to increased glycogen storage prior to the onset of exercise. This is further reflected in the longer time to exercise fatigue. Some studies do not support this theory, but can find no detrimental effects of increasing carb intake. These same researchers suggest that high carb diets may only benefit athletes that compete or exercise for periods longer than 90 minutes; this theory is still unproven.14

Studies of anaerobic training athletes have demonstrated increases in performance with athletes on high carb diets. Studies of weight lifters under three different diets may hold the answers. Weight lifters were randomly assigned to one of three types of diets, high carb (70 percent of calories)/moderate protein, moderate carb (50 percent of RDA)/high protein, and a control group. Results of the experiment show reduced performance of quads with the high protein/moderate carb diet. Researchers suggest that this result is due to glycogen depletion of muscles.14 Carb levels for anaerobically training athletes are suggested to be no less than 65 percent of the calories consumed throughout the day.

The particular mechanism by which high carb diets benefit the anaerobic athlete is not well understood. Researchers are sure that carbs do play a role in the increased performance of the athlete.14 One theory suggests that specific motor units are depleted of glycogen. By ingesting a high carb diet, glycogen stores are then replenished.14 Research of this theory by muscle biopsy has shown varied use of muscle glycogen from different fiber types as well as different muscular compartments following exercise. This would imply that the various sources of muscle glycogen may be called upon according the intensity and duration of exercise.16
Pre-Exercise

The Pre-exercise meal is designated as the meal eaten two to three hours prior to the onset of competition and meals eaten in between training sessions. Carb intake at these times should be in the low glycemic index category. This will insure a slow release of energy with no insulin spike, glycogen repletion, and no subsequent let down in energy.²

During Exercise

As the athlete begins to exercise, muscle glycogen is metabolized to produce ATP. Following 20 to 30 minutes of exercise, glycogen stores become depleted. As muscle glycogen becomes depleted, blood glucose and liver glycogen are shuttled into the muscle tissues to replace decreasing levels of muscle glycogen. When these sources begin to become depleted, fatigue begins to take place.¹

Logically then, if blood glucose levels can be maintained, glycogen levels will remain at an optimal level and fatigue will be kept in check. In actuality, fatigue can only be delayed because it appears that the body shuttles blood glucose into the muscle cells a bit slower than it metabolizes muscle glycogen. Studies suggest that improvements in performance following carb intake may be the result of decreased muscle glycogen utilization.¹⁶ Therefore, the idea is to minimize the amount of muscle glycogen used by maintaining blood glucose level during exercise.¹⁴

Most studies agree that carb intake during exercise or competition benefits athletes participating in endurance events (events lasting more than 90 minutes) due to the high energy expenditure of these events. Others feel that these findings should only apply to events that take place for periods longer than 60 minutes, because fatigue in short duration exercises like shot put and weight lifting are primarily caused
by the build up of metabolites. While this may be true in short events, in any case, all athletes practice for long periods. The energy that is required for this must come from a premium fuel source such as carbs.

**Post-Exercise**

Following exercise, carb intake becomes increasingly important. According to research, muscle glycogen resynthesis is at its highest rate for about four to six hours following the end of exercise. After that period, it begins to slow over the next 24 hours. Therefore the athlete should provide enough substrate to take advantage of this critical period.

In one of the few studies of anaerobic athletes, subjects were tested to see if carb intake following high power (anaerobic) exercises could replenish muscle glycogen. Following a 30 percent reduction in muscle glycogen, subjects were fed a carb beverage (15 g/kg) or plain water. Subjects who ingested water showed a muscle glycogen resynthesis of 75 percent, while the athletes who had the carb drink displayed a carb resynthesis of 91 percent. Both measures were taken six hours following the end of exercise. Although this study did reinforce carb supplementation following exercise, it did not address the effect it has on performance.

In a study in which performance was addressed, cyclists (endurance) were used to observe the effect post exercise carb supplementation had on performance. In this study muscle glycogen was measured prior to exercise to establish a base line and five hours after the ending of exercise. Following the muscle glycogen measurement, subjects were tested to find a base line for performance. Cyclist were given a carb drink of 71.4 percent or 77.5 percent randomly.
Muscle glycogen measurements following a five hour period, showed a rebound of 60 percent of initial levels. Following a 22 hour rest period, muscle glycogen and performance was tested again. While muscle glycogen levels were found to be at baseline measurements, performance was seven percent below baseline measurements. Researchers concluded that replacement of muscle glycogen is only a part of recovery and that full replacement of glycogen stores does not ensure full recovery.14

Factors Affecting Carb Demand

Other factors besides exercise type may contribute to carb demand. Some of these factors are hormones, gender, climate, emotional state, stress, fever, and temperature to name a few.4

Many of the variables listed above are unpredictable but temperature and climate are two that are fairly easy to plan for with the advances in weather forecasting. In general, researchers have found that as temperature and humidity go up, the body needs to work harder to cool the body and energy expenditure continues to rise. This has been reported to be approximately 76 percent increase in muscle glycogen energy use during 45 minutes of exercise (41 degrees Celsius, 15 percent humidity).17

Similar increases in glycogen utilization have been seen in cold temperatures. However, substrate for fuel relies more heavily on fat than carbs but the exact reason for this is not well understood. Researchers are quick to point out that if the athlete is dressed accordingly then increases in substrate utilization should remain similar to hot weather conditions.18
Carbohydrate Supplements

In many cases athletes fail to consume carbs during and following exercise or competition due to the fact that it is not always convenient to do so. In these cases a carb supplement in the form of a drink may provide adequate carbs to ensure proper glycogen resynthesis.

Specifically, researchers suggest that athletes consume carbs at a rate that will supply them with one gram of carbs per minute. This can be accomplished by ingesting 600 to 1000 milliliters per hour of a six to ten percent solution of glucose or glucose polymer.\textsuperscript{17} Researchers find no differences between glucose polymers (Malto dextrins), glucose, and sucrose relative to their ability to be metabolized and their effects on performance during exercise. The only difference between the three choices is that the glucose polymers tend to be less sweet, and that may make them more desirable than the others.\textsuperscript{14,17}

Carbohydrate Loading

Carbohydrate loading (carb loading) is a process in which the goal is to "super load" the muscle with glycogen in preparation for competition. The exact process of how this is done is beyond the scope of the this literature review and will not be discussed here.\textsuperscript{2}

Most research currently published suggests that carbohydrate loading is beneficial to athletes who participate in events that last longer than 80 to 90 minutes due to the high energy expenditure of their sports. However, current studies are investigating the possibility that carb loading may benefit short duration high intensity or anaerobically training athletes.
One current study looked at eight males who were placed on a medium carb diet or a carb loading program. Following the initiation of dietary treatments the subjects completed a 15 minute submaximal run and a performance run to exhaustion. Results of this experiment showed that performance increased when the subjects were on the carb loading diet.

While the number of subjects involved in this study was small, it does provide some insight to the effect that carb loading has on short duration high intensity events. Further studies in which a larger sample size is used are needed to provide more power for the use of carb loading for short duration high intensity athletes.

Conclusion

Carbs are the energy source through which athletes propel their bodies to perform. By understanding what role they play and how to manipulate the different types of carbs to different situations, athletic performance will not decline due to energy depletion. It is clear that the RDA falls short in providing athletes with an adequate carb stores and that athletes do need high amounts of carbs in both endurance and short duration high intensity events.
CHAPTER IV

FATS

Fats, also known as lipids, are nature's most calorie dense nutrient. One gram of fat contains nine calories in comparison to carbohydrates that contain four to five calories per gram. For athletes, fats play a role as a secondary source of energy after carbohydrates stores are depleted. This normally occurs following 30 to 45 minutes of exercise at 70 to 80 percent of maximal heart rate. However, fats have a much bigger role in the body than just energy production. Other than the production of energy, fats aid in the transport and absorption of fat-soluble vitamins, function in the cushioning of organs against trauma, and insulate the body from heat loss.

Sources and Types of Fats

Fats generally have the same chemical structure as carbohydrates. However, fats are characterized by one or more double bonds within the carbon to carbon bonds and the proportion of hydrogen to oxygen is higher in fats. An example of a fat molecule is stearin which has a chemical formula of \( \text{C}_{57} \text{H}_{110} \text{O}_6 \). All fats can be classified into one of three groups which are simple fats, compound fats, and derived fats. Fats are found in both animals and plants, are hydrophobic (insoluble in water), and generally have a greasy feel.

Simple Fats

Simple fats consist primarily of triglycerides. Triglycerides are the major form of fat storage in the body (95 percent of all body fat is in the triglyceride form). The
triglyceride molecule consists of a three carbon molecule called glycerol. Attached to that molecule are three clusters of carbon chains called fatty acids.\textsuperscript{1,4,20}

Two types of fatty acids can combine with the glycerol molecule. The first type is called an unsaturated fatty acid. These fatty acids are characterized by containing at least one double bond along the main carbon chain. The double bonds reduce the possible sites to which a hydrogen molecule might bond. If only one double bond is present the molecule is said to be monounsaturated. If there is more than one double bond present, the molecule is said to be polyunsaturated. Unsaturated fats are generally found in plants and tend to liquify at room temperature. As a rule, the less firm the fat is, the greater the degree of unsaturation.\textsuperscript{1,4,20}

Saturated fats contain only single bonds throughout the carbon chain leaving the remaining bonds available to link with hydrogen atoms. Saturated fats are named so because they carry the maximal hydrogen bonds possible. Saturated fats are mainly found in animals but can also be found in egg yolks, dairy products, and nuts.\textsuperscript{1,4,20}

Since unsaturated fats have empty spaces, other substances in the body are able to link up with these molecules. This makes these fats more biologically active meaning that they can have a variety of roles. In contrast, saturated fats are dedicated to the storage of energy and because most athletes already carry more than enough energy in the form of body fat, the ingestion of saturated fats is not warranted.\textsuperscript{2}

\textbf{Compound Fats}

Compound fats are composed of what is called a neutral fat in association with other chemical compounds. One class of compound fat is known as phospholipid, which consists of one or more fatty acid molecules, a phosphoric acid component and
a nitrogenous base. This type of compound fat is responsible for giving cell walls their structural integrity. In addition, compound fats are important elements in the formation of platelets and components of the insulation surrounding nerve fibers.¹,⁴,²⁰

Another class of compound fats is glucolipids, which are formed by a carbohydrate molecule and nitrogen. Glucolipids play a role in the structural form of the plasma membrane.⁴

Lipoproteins are the last class of compound fats. They are formed by a protein molecule linking with either triglycerides, phospholipids, or cholesterol. Lipoproteins are important in the shuttling of fats into the blood stream and keeping fats in a liquid form. Without lipoproteins, fat molecules would bunch together to form fatty nodules blocking blood flow.¹,⁴,²⁰

Two specific types of lipoproteins, high density lipoproteins (HDLs) and low density lipoproteins (LDLs) function in the blood stream. HDLs contain small amounts of fats, while LDLs contain the highest amount of fat. LDLs carry 60 to 80 percent of the total fat in the blood stream and have an affinity for arterial walls. LDLs have been linked to the deposition of fatty plaques on arterial walls, which leads to subsequent hardening of the arterial walls (atherosclerosis), and coronary artery disease.¹,² HDLs protect against atherosclerosis in two ways. The first is to compete with LDL fragments for entrance into the cells and binding to arterial walls. The second is to carry fat in the blood stream away from the arterial walls to be degraded by bile in the liver.¹,⁴,²⁰

Derived Fats

This class of fats are those that are produced from both the simple and compound fats. The most well known derived fat is cholesterol, which is a sterol
found only in animal tissues. Cholesterol contains no fatty acid yet it exhibits both chemical and physical characteristics of fat.¹

Cholesterol is obtained both from consumption of foods containing cholesterol and from cellular production. The liver is responsible for approximately 70 percent of cholesterol synthesis. The remainder is produced by the arterial walls and the intestines. An individual on a cholesterol free diet produces about 0.5 to 2.0 grams of cholesterol per day. That amount will increase if the individual consumes a diet high in saturated fats.¹ ¹⁴ Cholesterol is important in the building of cell membranes, synthesis of vitamin D, and the synthesis of hormones. The richest source of this type of fat is seen in egg yolks but it can also be found in meats; organs such as liver, kidneys, and brains; shell fish; and some dairy products.¹ ¹⁴ ⁸ ²⁰

Correlation of Body Fat Content to Sport Type

Studies have been performed to find the ideal body build (lean body mass to percent body fat) for different sports. For example, in swimming, a body that floats without the need for energy expenditure may provide an advantage in endurance swimming. Since fat is more buoyant than muscle and bone, an athlete participating in endurance swimming events, may do better by keeping his or her body fat content at a higher level than a sprint swimmer. Additional benefits of a higher body fat percentage for the endurance swimmer are increased insulation against cold temperatures and higher energy storage due to the inability to refuel with carbohydrate drinks.¹

In general, for athletes whose body weight tends to be supported by a medium, body fat percentages are higher than for those athletes who participate in extremely aerobic or extremely anaerobic events.²² ²³ The exception may be found in heavy
weight lifters. They believe that by adding large amounts of fat prior to competition, they will lower their center of gravity. This will in turn increase their lifting leverage and therefore increase their performance. No scientific studies have been performed to confirm this.\textsuperscript{13}

While the ideal body build for athletes is generally thought to be one of minimal body fat, the athlete should be aware of the effects of extremely low body fat levels, especially in the case of the female athlete. However, this goes beyond the scope of this review and the reader is directed to reference number one for a further discussion.

**Recommendations**

No dietary fat recommendations for athletes have been established due to the limited number of studies. However, a recommended fat intake exists for non-athletes. In 1989 the National Research Council recommended that diets should contain no more than 25 to 30 percent of their calories from fat. This value has been endorsed by the American Dietetic Association and the American Heart Association. However most researchers find that this value is still too high for athletes.\textsuperscript{1,2,10,24,25}

One researcher points to two reasons why this recommended level is too high. The first reason lies in the fact that when fat is consumed, it is directly deposited in body fat stores. This increases body weight which subsequently increases the energy required to propel the body. The second reason lies in the fact that extra body fat increases body temperature during exercise. This causes the body to work harder to cool the body down during exercise. In addition, fat is about 15 percent water, whereas muscle contains 75 percent water. Therefore, not only does fat increase
body temperature, it also decreases the potential amount of water that can be used for cooling.¹

In consideration of the factors listed above, the athlete should try to keep fat intake below 10 to 15 percent of the daily calories consumed. At this level requirements for essential fatty acids should be met.¹,5

Conclusion

Fats play many roles in the body. However, athletes need only a minimal amount of it in their diet due to the increase in energy demand it places on the body for both propulsion and cooling. Athletes only need enough fat to satisfy the requirements for essential fatty acid production.
CHAPTER V
VITAMINS AND MINERALS

For the athlete, vitamins and minerals are of particular interest due to the proposed idea that they play a role in enhancing physical performance. The average population probably takes a multivitamin with their breakfast every morning not knowing why they do it or if it is even necessary. To understand if athletes need higher amounts of vitamins and minerals, it is critical to understand their role in human body.

Role of Vitamins and Minerals

Vitamins are critical components of hormones and enzymes which regulate and catalyze reactions in the body. Vitamins act as coenzymes for energy metabolism, protein metabolism, synthesis of cells; act as antioxidants to protect other cells from damage; and help to maintain blood calcium levels. One specific example of the role that vitamins play is vitamin B1 or thiamine, which acts in decarboxylation reactions. This is a critical step in carbohydrate metabolism, which is critical for energy metabolism.

Minerals are necessary for normal biochemical and physiological processes that take place in the body. The important minerals are those that are components in enzymes, hormones and vitamins. An example of this is calcium which has many functions in the body. One is to combine with phosphorus to form the matrix for
skeletal bone and teeth. Without adequate calcium levels bones and teeth become brittle.

Categories of Vitamins and Minerals

Currently there are 13 compounds that are recognized as vitamins and 21 that are recognized as minerals. Vitamins are categorized in two groups, fat soluble and water soluble. RDAs have been set for all of the 13 compounds.

Minerals are also categorized into two groups, major minerals and trace minerals. Of the 21 minerals, 13 are designated as being essential. The RDA has been set for seven (calcium, phosphorus, magnesium, iron, iodine, and selenium).

Fat Soluble Vitamins

Fat soluble vitamins are those that are dissolved and stored in fat. These vitamins include A, D, E, and K. Since these vitamins are stored in fat, deficiencies in these vitamins normally take years to show any symptoms. In addition, since these vitamins can be stored in the body, toxic levels can be built up in the body, particularly in the liver. Therefore, these vitamins should carefully monitored for signs of toxicity.

Specific toxic effects are as follows:

Vitamin A toxic symptoms include headache, vomiting, peeling of skin, anorexia, and swelling of long bones.

Vitamin D toxic symptoms include vomiting, diarrhea, loss of weight, and kidney damage.

Vitamin E has no known toxic effects.

Vitamin K has no known toxic effects.
Water Soluble Vitamins

Water soluble vitamins are those that are not stored in the body for long periods of time. The concentration in the body is determined by the concentration in the foods that are consumed and the amount that is excreted by the body. These vitamins include the following: B6 (pyridoxine), B1 (thiamine), B2 (riboflavin), niacin (nicotinic acid), pantothenic acid, biotin, folic acid, cobalamin (B12), and C (ascobic acid). These substances are primarily involved in the metabolism of nutrients for energy. Other functions include DNA synthesis and red blood cell development.

In some cases, it may be difficult to obtain sufficient amounts of water soluble vitamins, in which case supplementation may be necessary. Toxicity of these vitamins is normally not a problem since the excess is normally excreted in urine. The only toxic effects known with these vitamins are found with vitamin B-3 (Niacin) and vitamin C. Symptoms of niacin poisoning are flushing, burning and tingling around the neck, face and hands. High doses of vitamin C have been related to the formation of kidney stones.

Major Minerals

If the body requires more than 100 milligrams per day of any particular element it is designated a major mineral. These minerals include calcium, phosphorus, sodium, magnesium, and potassium. Toxic symptoms related to excessive intake of these minerals are listed below.

- Calcium has no known toxic effects.
- Phosphorus in very high doses has been linked to erosion of bone.
- Sodium has been known to cause high blood pressure.
- Magnesium causes nausea, vomiting, and diarrhea.
Potassium causes irregular or fast heartbeat, paralysis of arms and legs, and convulsions.\textsuperscript{17}

**Trace Minerals**

Trace minerals are those that are required in amounts less than 100 milligrams per day. These minerals include iron, fluorine, zinc, copper, selenium, iodine, molybdenum, and chromium. Toxicity is more common with these minerals since they are required in smaller amounts.\textsuperscript{1} Symptoms of toxicity are listed below.

- Iron causes a condition called siderosis and cirrhosis of the liver.\textsuperscript{1}
- Fluorine causes increases in bone density, mottling of the teeth, and neurological disturbances.\textsuperscript{1}
- Zinc causes fever, nausea, vomiting and diarrhea.\textsuperscript{1}
- Copper causes a rare metabolic condition called Wilson's disease.\textsuperscript{1}
- Selenium causes gastrointestinal disorders, lung irritation, and hair loss.\textsuperscript{1}
- Iodine causes depressed thyroid activity in extremely high doses.\textsuperscript{1}
- Molybdenum inhibits enzyme activity.\textsuperscript{1}
- Chromium has relatively low toxicity. Most cases of toxicity occur with long term industrial exposure. Symptoms of toxicity include skin and kidney damage.\textsuperscript{1,27}

**Major Roles, Sources, Deficiency Conditions and the RDA**

The major roles, sources, conditions caused by deficiencies, and the RDA for healthy men and women will be discussed for fat soluble and water soluble vitamins as well as major and trace minerals.

**Fat Soluble Vitamins**

Vitamin A is a constituent of rhodopsin (visual pigment) and primarily plays a role in maintaining epithelial tissue and in mucopolysaccharide synthesis. Dietary sources
of this vitamin are found in dark leafy greens, dairy products, and liver to name a few. Deficiencies of this vitamin cause keratinization of ocular tissue, which may lead to night blindness and permanent loss of vision; dry rough skin; weak teeth; and poor bone growth. The Recommended Daily Allowance (RDA) for a healthy adult male is 1.0 mg; for a female it is 0.8 mg.\textsuperscript{1,27}

Vitamin D promotes growth and mineralization of bone and calcium absorption. Some sources of this vitamin are fish oil (especially high fat cold water fish), sunlight, eggs, and dairy products. Deficiencies may cause bone deformities (Ricketts) in young children and softening of bones in older adults (Osteomalacia). The RDA for a healthy adult male is 0.01 mg; for a female it is 0.01 mg.\textsuperscript{1,27}

Vitamin E primarily functions as an antioxidant protecting against the formation of free radicals in the body. It also promotes normal red blood cell formation. Sources include seeds, dark leafy greens, margarine, and grains. Deficiencies may cause anemia in adults and children but research is inconclusive. The RDA for a healthy adult male is 10 mg; for a female it is 8 mg.\textsuperscript{1,27}

Vitamin K is important in the formation of active prothrombin, a critical protein involved in blood clotting. Sources include dark leafy greens, fruits, meats and some cereals. Deficiencies have been associated with severe bleeding secondary to the inability to form clotting factors. The RDA for a healthy adult male is 0.08 mg; for a female it is 0.06 mg.\textsuperscript{1,27}

**Water Soluble Vitamins**

Vitamin B-1 or thiamine is a coenzyme involved with the removal of carbon dioxide and it maintains normal function of the nervous system, muscle and heart. Sources include meats, legumes, and whole grains. Deficiencies cause beriberi which
is characterized by peripheral nerve changes, edema and heart failure in severe
cases. The RDA for a healthy adult male is 1.5 mg; for a female it is 1.1 mg.\textsuperscript{1,27}

Vitamin B-2 or Riboflavin is a component of two flavonoid nucleotides coenzymes
involved in energy metabolism. It can be found in all types of foods. Deficiencies
cause reddening of the lips, cracking at the corner of the mouth, lesions of the eye,
and slow learning. The RDA for a healthy adult male is 1.7 mg; for a female it is 1.3
mg.\textsuperscript{1,27}

Vitamin B-3 or Niacin is a component of two coenzymes involved in
oxidation/reduction reactions of energy production. Sources include liver, lean meats,
grains, legumes, poultry (can be formed from tryptophan), and swordfish. Deficiencies
cause skin and gastrointestinal lesions, and nervous and mental disorders. The RDA
for a healthy adult male is 19 mg; for a female it is 15 mg.\textsuperscript{1,27}

Vitamin B-5 or Pantothenic acid is a component of a coenzyme involved in the
metabolism of nutrients for energy. Sources of this vitamin are found in many
different types of foods. Deficiencies cause nerve damage, fatigue, sleep disorders,
impaired coordination, gray hair, and birth defects. The RDA for a healthy adult male
is 4 to 7 mg; for a female it is 4 to 7 mg.\textsuperscript{1,27}

Vitamin B-6 or Pyridoxine is involved with glycogen and protein metabolism.
Sources of this vitamin include meats, dark leafy greens, whole grains, and cereals.
Deficiencies may cause irritability, convulsions, muscular contractions, kidney stones,
mental confusion, and poor coordination during walking. The RDA for a healthy adult
male is 2.0 mg; for a female it is 1.6 mg.\textsuperscript{1,27}

Vitamin B-9 or Folic acid is a coenzyme involved in metabolism of nucleic acids
and amino acids. Sources of this vitamin are legumes, dark leafy greens, and whole
wheat products. Deficiencies cause anemia, gastrointestinal disturbances, mild mental symptoms, and insomnia. The RDA for a healthy adult male is 0.02 mg; for a female it is 0.2 mg.\textsuperscript{1,27}

Vitamin B-12 is a coenzyme involved in nucleic acid metabolism. Sources include meats, eggs, and dairy products, it is not present in plant products. Deficiencies cause pernicious anemia. The RDA for a healthy adult male is 0.002 mg; for a female it is 0.002 mg.\textsuperscript{1,27}

Biotin is a coenzyme required for the fat synthesis and amino acid and glycogen metabolism. Sources include legumes, vegetable, and meats. Deficiencies result in fatigue, muscular pains, decreased muscular reflexes, and nausea. The RDA for a health adult male is 0.03 to 0.10 mg. No RDA has been set for females.\textsuperscript{1,27}

Vitamin C or Ascorbic Acid promotes healthy capillaries, gums, and teeth; aids in the formation of collagen; increases iron absorption; and blocks the synthesis of nitrosamines. Sources include citrus fruits, tomatoes, green peppers, and salad greens. Deficiencies cause degeneration of the skin, teeth and blood vessels, and epithelial hemorrhages. The RDA for a healthy adult male is 60 mg; for a female it is 60 mg.\textsuperscript{1,27}

**Major Minerals**

Calcium plays a role in bone and teeth formation, blood clotting, and nerve conduction. Sources include dairy products, dark green vegetables, and legumes. Deficiencies cause stunted growth, rickets, osteoporosis, and convulsions. The RDA for a healthy adult male is 1200 mg; for a female it is 1200 mg.\textsuperscript{1,27}

Phosphorus is involved in bone formation and acid/base regulation in the body. Sources include dairy products and meats, poultry, and grains. Deficiencies cause
weakness, demineralization of bone, and loss of calcium. The RDA of healthy adult male is 1200 mg; for a female it is 1200 mg. \(^1\,^27\)

Sodium functions to monitor acid/base balance and water balance, and it plays a role in nerve impulse conduction. Sources of this mineral are found in all food types. Deficiencies cause muscle cramps, mental apathy, and reduced appetite. No RDA has been established for this mineral. \(^1\,^27\)

Magnesium is involved in activating enzymes involved with protein synthesis. Sources include whole grains and dark green leafy vegetables. Deficiencies cause growth failure, behavioral disturbances, weakness, and spasms. The RDA for a healthy male is 350 mg; for a female it is 280 mg. \(^1\,^27\)

Potassium is involved mainly with nerve impulse conduction. Sources include fish, bananas, citrus fruits, milk, and whole grain cereals. Deficiencies cause weakness, low blood pressure, and a condition known as hypokalemia. No RDA has been established for this mineral. \(^2\,^27\)

Trace Minerals

Iron is a major component in hemoglobin and enzymes involved in energy metabolism. Sources include dark green leafy vegetables, grains, lean meats, and legumes. Deficiencies cause a condition known as anemia. The RDA for a healthy adult male is 10 mg; for a female it is 15 mg. \(^1\,^27\)

Fluorine is thought to be important in the maintenance of skeletal structures. Sources include drinking water, tea, and seafood. Deficiencies have been linked to higher incidences of tooth decay. No RDA has been set for this mineral. \(^1\,^27\)

Zinc is a component of enzymes involved in the process of digestion. Sources are widely distributed throughout all types of food. Deficiencies may cause growth
failures and small sex glands. The RDA for a healthy adult male is 15 mg; for a female it is 12 mg.\textsuperscript{1,27}

Copper is a component of enzymes involved with iron metabolism. Sources include meats and drinking water. Deficiencies may cause anemia and bone deformities. No RDA has been established for this mineral.\textsuperscript{1,27}

Selenium is thought to function in association with vitamin E in the elimination of free radicals. Sources include seafoods, meats, and drinking water. Deficiencies are rare but have been known to cause anemia. No RDA has been established for this mineral.\textsuperscript{1,2,27}

Iodine is a main component in thyroid hormones. Sources include seafood, dairy products, and many vegetables. Deficiencies cause a condition known as goiter. The RDA for both healthy males and females is 0.15 mg.\textsuperscript{1,27}

Molybdenum is a component of enzymes. Sources include legumes, cereals, and animal organs. No known cases of deficiencies are known. No RDA has been established for this mineral.\textsuperscript{1,27}

Chromium is known to be involved with glucose and energy metabolism. Sources include fats, vegetable oils, and meats. Deficiencies may impair the ability to metabolize glucose. No RDA has been established for this mineral.\textsuperscript{1,27}

The RDA

The RDAs for vitamins and minerals were derived using a statistical treatment of the minimum daily requirement. The minimum daily requirements were derived experimentally from depletion studies and epidemiological studies by the National Health and Medical Research Council in 1987. The minimum daily requirement
(MDR) is a level of a vitamin or mineral from foods sources needed to prevent a deficiency state or biochemical malfunction.\textsuperscript{11}

Assuming that the minimum daily requirement of the population is a normal distribution, the RDA was set to cover 97.5 percent of the healthy adult population.\textsuperscript{11} Due to the large margin of safety, most authorities suggest that supplementation is not necessary if a well balance diet is consumed.\textsuperscript{10,11,26,28,29,30}

\textbf{Research}

Current research has suggested that the athlete does have higher requirements for vitamins and minerals due to the physically demanding events in which they participate and vitamin and mineral losses due to increased perspiration. It has been suggested that the requirements of athletes rise in response to stressful environmental factors, such as hard training and competitive stress.\textsuperscript{31}

However, most researchers agree that if an athlete is consuming a well balanced diet and adequate caloric intake, vitamin requirements will be more than satisfied.\textsuperscript{11} If the athlete is falling short in one category or another, supplementation with a multivitamin should suffice. Furthermore, researchers have documented no increases in performance secondary to consuming amounts higher than the RDA.

Another concern of researchers is whether or not athletes need to supplement their diets with individual vitamins or minerals.\textsuperscript{29} One researcher suggests that all nutrients work in synergy with one another. The idea is that nutrients are required in certain proportions to work efficiently. Too much of one vitamin or mineral will interfere with the absorption of some other nutrient and an imbalance may occur.\textsuperscript{1}

In an example relative to proportions, vitamin E interacts with the mineral zinc to protect cell membranes from damage. In cases where vitamin E levels are deficient,
zinc is also found to be low. This is because the body requires more zinc to cover for the reduced amount of vitamin E. Instead of supplementing with one particular vitamin or mineral, it recommended the athletes supplement with a multivitamin.¹

**Conclusion**

Despite having higher requirements a well balanced diet with adequate calories should satisfy the athlete's requirements for vitamins and minerals. In cases where the athlete suspects deficiencies, a supplemental multivitamin should provide adequate amounts to keep levels within a satisfactory zone. However the athlete should be aware of the possible toxic effects of fat soluble vitamins and minerals.
CHAPTER VI

WATER

A human being can continue to survive without food for about two to three weeks. On the other hand, water is so important that a human being can only survive a few days without it. Everything in a living organism contains a certain amount of water. For example, the brain is approximately 76 percent water, blood is 82 percent water, the lungs are 90 percent water, and 40 to 60 percent of total body weight is water.\(^1\)\(^2\)

Functions of Water

While water contains no nutritional value, it can be thought of as a keystone ingredient in athletic nutrition. Without water none of the reactions needed to sustain life and build structures would occur because water provides the solvent through which all of these reactions take place. Water also functions as a cooling agent due to its high specific heat, facilitates nutrient and gas transport throughout the body, facilitates waste product elimination from the body, provides lubrication for all joints, and helps to maintain the shape of our bodies.\(^1\)

Water Loss and Intake

Water Loss

Water is lost in three basic ways: waste elimination, water vapor, and cooling. Waste elimination is urine and fecal elimination. Approximately 1000 ml to 1500 ml (1.5 quarts) of urine is excreted by the body each day. Urine is about 99 percent water and the other one percent is made up of toxic metabolites. In cases where
protein is used for energy, normal metabolism causes a build up of toxic substances (urea). Water is needed to dilute these substances which may result in an increased rate of dehydration.\textsuperscript{1,4}

Approximately 100 ml to 200 ml per day of water are lost through fecal elimination. About 70 percent of feces is composed of water while 30 percent is made up of digested materials. During illness water loss increases by 1500 ml to 5000 ml due to vomiting or diarrhea.\textsuperscript{1,4}

Water vapor is lost when moistened air is exhaled. The amount is thought to range from approximately 250 ml to 350 ml per day.\textsuperscript{4} Physically active people may lose up to two ml to five ml per minute due to increase perspiration rates. This value may vary due to environmental influences. For example in hot and humid environments less water is lost and in cold and dry air more water is lost.\textsuperscript{1}

Water loss through cooling is about 500 ml to 700 ml per day. This occurs while no activity is taking place. When strenuous activity begins, about 1.0 to 2.5 liters per hour may be lost. This type of water loss is also affected by the environment.

Total loss of water due to all the factors listed above is approximately 2550 ml of water. This value is used to calculate the water requirements of a sedentary individual.\textsuperscript{1,4,32}

**Water Intake**

Water is obtained in three ways: water, foods, and from metabolic reactions. The first way is the most obvious: when we need water we associate it with drinking. Normal intake is about 1200 ml or 41 oz of fluids per day. It should be noted that the value will increase with changes in the environment such as heat and humidity, and increases in physical activity.\textsuperscript{1}
Water is also obtained from foods, especially fruits and vegetables. Amounts of water obtained through foods is highly variable due to differing individual diets.¹

When nutrients are metabolized, by-products are produced. Two by-products of the reaction are carbon dioxide and water. Metabolism of 100 grams of carbohydrates, protein, and fat yields 55 g, 100 g, and 107 g of water respectively.¹

Influence of Water Loss On Performance

Researchers have shown that a water loss of only five percent of body weight will decrease performance by 2 to 48 percent.²,³²,³³ In one study track athletes were dehydrated by two or three percent of their body weight. For a 165 pound person that equals about three to five pounds. Most athletes feel that this is not significant because losses of seven to ten pounds are not uncommon in marathons. However when the slightly dehydrated athletes were asked to run timed trials at 1500 meters, 5K, and 10K, performance levels were severely affected. Researchers found the dehydrated athletes to be three percent slower than their normal time trials.¹,³⁴

Further studies by other researchers showed that the magnitude of performance impairment is correlated to the type of exercise (especially endurance exercise) and the environmental conditions.³²

Decreases in performance have been linked primarily to the effects of hyperthermia (high temperature) and dehydration on the cardiovascular response to exercise.¹² Exercise increases the body's core temperature in direct proportion to exercise load. The body expends energy to keep it at the optimal temperature of 98.6 degrees Fahrenheit by moving excess heat to the skin via the circulatory system. At the skin, the heat is dissipated into the air by radiation and convection. The medium for convection is perspiration, which is evaporated from the skin. Blood which is
about 82 percent water donates a large part of the fluid that is used for perspiration. Blood also carries nutrients and oxygen to the muscles. When blood volume is decreased, the efficiency of transport of these vital items decreased. This is followed by the resultant decrease in performance.\textsuperscript{1,2}

Not only is physical performance affected by dehydration, so too is mental performance. Studies have shown that indices of sustained attention, error rate, response time, and accuracy are negatively affected by dehydration induced heat.\textsuperscript{34} Dehydration induced heat is a result of the body's inability to control core temperature levels.

**Recommended Intake During Competition and Training**

Research has a simple solution to dehydration which occurs during training or competition. Replace whatever you lose. One suggested method of water replacement is to measure body weight hourly during training. Since one liter of water is about 2.2 pounds, any drop in body weight during training will be attributed to water loss. Based on this an athlete can calculate the approximate amount of water he or she needs to remain hydrated and initiate a water consumption schedule. Researchers suggest that water consumption of about 100 ml to 200 ml every five to ten minutes or 0.6 to 2.41 liters per hour will keep an athlete hydrated.\textsuperscript{2}

Some researchers have suggested that these amounts are excessive and recommend a different method. The athlete should begin by consuming eight ounces of water every 15 to 20 minutes one to four hours prior to the onset of training or competition. In theory, this allows for super hydration of the body. Following the onset of training or exercise, hydration continues at every stop or chance the athlete is given.\textsuperscript{2}
Variables Affecting Fluid Replacement

Four factors have been found to affect fluid replacement - taste, gastric emptying, intestinal absorption, and adaptation. Taste refers simply to the fact that if something tastes good, athletes will consume more of it. 34

Gastric emptying refers to the fact that if dehydration is allowed to occur, gastric emptying is reduced and the chance for gastrointestinal distress becomes more likely. This can be avoided by beginning training or competition with a large volume of fluid in the stomach and continued fluid intake in the manner listed above. 14

Intestinal absorption refers to the fact that if fluids are consumed with a small amount of carbs, absorption efficiency is increased and the urge to urinate is delayed for longer period. 14

Adaptation refers to the fact that the body adapts to the training environment by increasing voluntary fluid consumption. The reason for this is not known but it has been well documented in athletes training in hot climates. 14

By recognizing and understanding the way that these four variables affect the absorption of fluids, the athlete will be able to optimize his or her hydration program. In addition to optimizing absorption, the athlete will be able develop a tolerable hydration program.

Conclusion

Water plays a major role in normal biological functions of the body. If dehydration is allowed to occur, both physical and mental performances are affected negatively. Dehydration can be avoided by consuming water more frequently and in greater amounts. By following the guidelines listed above, reduction in performance due to dehydration will not be a problem.
CHAPTER VII

SLEEP

Proper nutrition is a vital component to achieving optimal performance but sleep also plays an important role. In all animals, a certain portion of a 24 hour period is dedicated to a dormancy time, or a period in which that animal sleeps. In humans, approximately one third of our lives are dedicated to sleep. In this period of time, we are vulnerable to attack, and unable to forage or consume food, propagate our species, or seek shelter. What then, is the function of this time period in relation to athletic nutrition? To answer this it is necessary to define sleep.

Defining Sleep

It somehow seems ridiculous to define what sleep is. Most would just define it as a period of time when the mind goes blank and a great feeling of calm is felt. However, researchers are quick to point out that it is much more than that. They have characterized sleep on many levels including a mental level as well as biological and physiological levels.

In the mental definition, sleep is defined either as a discrete state or as part of a continuous cycle of change in consciousness. The discrete state describes a reduced state of responsiveness to external stimuli, from which a person can be aroused if a stimulus of sufficient strength can be induced. The second definition describes sleep as a portion of the 24 hour cycle (circadian cycle) in which the subject is inactive. It can further be characterized in this definition by the electroencephalogram (EEG) and
physiological changes that take place. EEG activity is reduced to low levels and body temperature drops to about 97.5 degrees Fahrenheit. It is likely that sleep is composed of both definitions due to the fact that researchers have observed all of the phenomenon listed above.

**Stages of Sleep**

Sleep consists of four stages characterized by EEG activity and biological changes in the body. Each stage may occur many times during the same sleep cycle. Currently, researchers identify the different stages based upon the frequency and amplitude of the EEG readings.

**Stage One**

This is the lightest level of sleep. EEG levels are low voltage, high frequency, and desynchronized. Autonomic activities such as heart rate, blood pressure, and sweating begin to slow down. The sleeper is variably responsive to external stimuli at this time and may be difficult to awaken or may spontaneously wake. Dreams are most often remembered if the sleeper is aroused from this stage. Stage one progressively increases in length as sleep continues. The last of the four or five episodes of stage one sleep may last for about an hour. Stage one sleep occupies about two to five percent of sleep time in adults. When stage one sleep is extended, restorative sleep is delayed. As humans age, stage one sleep becomes longer.

**Stage Two**

Stage two sleep EEG activity is characterized by what is call 12 to 15 Hertz sleep spindles (EEG waveforms) and high voltage K complexes. Stage two first appears about 30 minutes following the first appearance of stage one. Later appearances of stage two alternate with stage one and stage three. Cognitive functions are short and
fragmented in stage two sleep. Research has yet to show any functional significance of stage two sleep other than the possibility that it may be a preparatory period for deeper sleep stages. When subjects are forced to reduce sleep length, they do so at the expense of stage two. This stage is not classified as a restorative type of sleep. Stage two occupies approximately 45 to 55 percent of total sleep time, making it the largest sleep period.

**Stages Three and Four**

Stages three and four are lumped together since the EEG wave forms that characterize this stage are similar. The EEG wave forms are called "Delta Waves" and are characterized by increasingly higher voltage amplitudes and slower frequency rates. Due to the fact that delta waves cycle slower than during stage one and two, this stage is also called "slow wave" sleep. Growth hormone secretion and cell division are at their highest rate while metabolism, heart rate, respiration, and core temperature are at their lowest. Delta sleep has been described as a restorative factor relative to the metabolic activity and energy expended by the subject during the day. It has been further observed that when total sleep time is restricted, delta wave sleep is maintained at the expense of the other stages. This may indicate the importance of delta wave sleep. The sleeper is very difficult to awaken from this stage and a feeling of being "dazed" is often reported by individuals. Delta wave sleep comprises about 15 to 20 percent of the total sleep time. As individuals age, delta wave sleep decreases.

**REM Sleep**

In some resources, REM or paradoxical sleep is a component of stage one sleep. For the purposes of this thesis, it will be discussed as a separate entity. REM sleep is
characterized by low amplitude and mixed frequency EEG readings, saw tooth EEG waveforms, rapid eye movements, and dramatic decreases in muscle tone. The decrease in muscle tone is what separates REM sleep from stage one sleep. REM sleep makes its first appearance approximately 70 to 90 minutes after the onset of sleep and normally lasts for about five to ten minutes. REM sleep time progressively increases as sleep continues and may last up to an hour in the last cycles of sleep. Physiological processes that occur at this time include increases in cerebral blood flow, brain temperature, brain protein synthesis, and heart rate. REM sleep has been associated with the consolidation of memories and learning. Increases in brain protein synthesis have been theorized to be a facilitating agent for memory and learning. Recent studies have confirmed this relationship. REM sleep occupies approximately 20 to 25 percent of total sleep time.

Control

Current knowledge about the control of sleep is very limited. Research suggests that the sleep-wake cycle revolves around a series of complex chemical reactions in the brainstem, particularly the reticular formation. These chemical reactions are mediated by neurotransmitters such as serotonin and noreadrenalin.

The sleep-wake cycle an example of a circadian rhythm which needs 24 hours to complete. Many physiological functions revolve around a 24 hour cycle. For example, body temperature fluctuates between 97.6 degrees Fahrenheit at sleep to 98.7 degrees Fahrenheit at peak activity. Other functions known to fluctuate around a circadian rhythm are endocrine secretions, metabolic rate, and digestive functioning. These bodily functions fluctuate at a fairly predictable rate and on a consistent basis.
The ultimate control of all circadian rhythms is monitored by a portion of the hypothalamus nicknamed the "body clock."15

**Relationship to Nutrition and Performance**

Optimal performance is the result of three things coming together. First is proper training or overload to promote growth. Second is good nutrition to provide the raw materials for construction. Last is adequate rest and sleep which is need to permit the growth and repair.4

Research has found that the secretion of growth hormone is highest in stage three and four sleep. In particular the highest concentration of this hormone is seen 60 to 90 minutes after the onset of these two stages.38,39 Growth hormone is responsible for the stimulation of new tissue synthesis, particularly muscle proteins.21 Studies with athletes using injectable growth hormone have demonstrated its positive effects on athletic performance.38,39

Further studies on anorexic patients found a positive correlation between decreased total sleep time and weight loss. By increasing total sleep time, the same anorexic patients increased body weight. Researchers hypothesized that sleep may be the way that the body maximizes its resources for growth.15

While the physical body is undergoing growth and repair, the brain is just as busy processing information that has been gathered throughout the day. Research hypothesizes that during REM sleep unnecessary memories are discarded and important ones are consolidated. Since protein synthesis is thought to occur during REM sleep and memory is associated with deposition of proteins within nerve cells, researchers linked REM sleep with memory storage, consolidation, and learning.15,36,37
In relation to the athlete, the skills that are learned throughout the day or during practice are mentally consolidated for future use should the situation require it.

Studies investigating the effect of sleep deprivation on memory have found that simple one step tasks are not affected significantly. However sleep deprivation does produce a decrease in the performance of complex tasks and in this way affects the athlete's performance. This is due to the fact that athletes rarely perform one step tasks. Athletes are required to analyze information and select the best possible reaction and this is by no means a simple one step task. Therefore, if the goal of the athlete is to perform his or her task correctly, adequate sleep is needed.

**Suggested Sleep Requirements**

Resources consulted for this study did not provide any information on sleep requirements with any scientific evidence. One resource however did suggest that an athlete requires 7.5 to 9.5 hours of sleep. No evidence for the values was provided.

**Variables Affecting Sleep**

Scientists have identified several variables which may affect the length of each stage and the total sleep time. Among these variables are age, fitness status, and travel.

Sleeping length and patterns both change as we age. When children are first born, they average approximately 17 to 18 hours of sleep per day and experience longer stage three and four sleep. In contrast 70 year old subjects need an average of 6.5 hours of sleep per day and delta wave sleep is decreased.

Some studies have found a positive correlation between fitness status and sleep. In particular, it seems that fitness status affects the type of sleep that the subject experiences. Researchers have found that fit athletes experience a longer period of
delta wave sleep. Researchers theorize that this is due to the increase in physical trauma athletes sustain through daily training regimens and competition.  

Sudden shifts in time zones are known to cause a disruption of sleep wake patterns. Studies have found that a change of three hours or more poses the largest adjustment problem. It has been further found that east bound travel affects travelers more than west bound travel. The particular changes in sleep are increases in REM sleep and a decrease in delta wave sleep. Since it takes several days for the body to adjust, athletes and coaches may want to consider an acclimatizing period after travel and prior to competition.

**Conclusion**

It is clear that sleep is a necessary component of the athlete's drive to optimal performance. If adequate amounts of sleep are not obtained the result will be little if any positive results of training. Sleep is when memories are consolidated and the only time when the body is able to repair and build tissues. Therefore it is necessary that the athlete obtain adequate amounts of sleep.
CHAPTER 8
CONCLUSION

It is clear that nutrition plays a major role in permitting the athlete to achieve peak performance. However the Recommended Daily Allowance (RDA) fails to cover the needs of the athlete, with fats being the exception (in many diets the RDA for fat is too high). It is illogical to expect an athlete to perform at his or her very best if the basic building blocks of performance are absent or lacking.

Specifically, protein requirements of athletes have been found to be higher than the RDA suggests. With increased intake of protein, increases in performance have been reported due to the role that protein plays in building muscular structures and the role it plays as a secondary fuel source.

Carbohydrate requirements have also been found to be higher than the RDA due to the rate that athletes burn this fuel. By understanding the concepts presented in this thesis, athlete will be able to sustain peak performance.

Fats play many roles in the body. However, the athlete requires only a minimal amount in his or her diet due to the increased energy demands that excess fat places on the body for propulsion and cooling. In addition, other health concerns such as the increased risk for cardiovascular disease, should be considered with a diet high in fat.

Despite having higher requirements than those suggested by the RDA, the athlete should be able satisfy vitamin and mineral daily requirements with a well balanced diet. In cases where a
deficiency may be suspected the athlete may consider taking a multivitamin supplement. However the athlete should be aware of possible toxic effects of fat soluble vitamins.

Adequate hydration plays a major role in allowing the athlete to continue to perform at peak levels. Both mental and physical performance are negatively affected if the athlete is allowed to become dehydrated. Dehydration can be avoided by consuming water more frequently and in greater amounts. Specific guidelines were provided in the body of this study.

Finally, sleep is the keystone that brings good nutrition and training together. If adequate amounts of sleep are not obtained, little if any positive effects of training will be seen. Sleep provides the time where memories are consolidated and the only time when the body is able to perform repairs and build new tissues.

In addition to the concepts and nutritional recommendations provided for athletes, further application of this study may be made to individuals in occupations in which hard physical labor is a requirement. For example, carpenters are often involved in physically intense activities for most of their work day and will probably benefit from an athletic diet and hydration program.

By following the recommendations and guidelines provide in this study, the foundation for optimal performance will be laid. Proper training and technique are still required to shape and mold the athlete.
REFERENCES


