Science of Strength and Conditioning Series

# NSCA's Guide to SPORT AND EXERCISE NUTRITION

NSCA™
National Strength and Conditioning Association

Bill I. Campbell • Marie A. Spano
EDITORS

# NSCA's Guide to Sport and Exercise Nutrition

**National Strength and Conditioning Association**

NSCA™



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**NSCA's Guide to Program Design**

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# Introduction

What is sport nutrition? Ask 10 different people this question, and you are likely to receive 10 different answers. At its most basic level, sport nutrition is the practice of ingesting nutrients in the correct amounts at specific times to improve exercise or sport performance. But while improving sport performance is a goal for some, many individuals are not competitive in their activities but rather are concerned with improving their body composition, 5K time, or maximum bench press, for example. An intriguing aspect of sport nutrition is that the same principles apply to the elite athlete as to the individual who has hired a personal trainer for the first time. One of the primary objectives of this book is to relay practical, scientific information to this diverse range of fitness enthusiasts and competitive athletes.

Scientific inquiry into the domain of sport nutrition has steadily increased over the past few decades. In fact, since 1990, the number of scholarly, peer-reviewed publications in the realm of sport nutrition has exponentially increased. It appears that almost each issue of every scientific journal in the fields of exercise science and nutrition includes at least one study or comprehensive review related to sport nutrition. Even though this research is answering a number of questions, many unanswered questions and divided opinions on fundamental aspects of nutrition intake, supplementation, and exercise performance remain. Examples include the amount of protein ingestion that will maximize training adaptations, the safety of creatine supplementation, and the best combinations of supplements to use to improve performance. It is these unanswered questions and differing opinions that drive the progression and growth of sport nutrition research. This research is pertinent to many populations, from mothers of teenagers playing multiple sports to Olympic athletes specializing in one particular movement pattern.

This book discusses how food and sport supplements interact with the body's biological functions. Pertinent research is cited to highlight specific nutrient intakes that have been shown to improve exercise and sport performance. Chapters also present information on assessing an athlete's nutritional status and developing a plan based on this assessment. As a whole, the book will give readers a better understanding of how ingested food is metabolized, stored, and oxidized for energy. The research presented demonstrates how the proper selection of these nutrients can improve performance.

This book is divided into 12 chapters. The first chapter overviews how nutrition affects training and performance. The next several chapters discuss the macronutrients (carbohydrate, protein, and fat), specifically how these nutrients are metabolized, stored, and oxidized for energy, and presents scientifically based recommendations for ingesting these macronutrients to improve aerobic, anaerobic, and strength training performance. Chapter 5 discusses fluids, including the fluid needs of aerobic endurance and strength athletes, and outlines common problems resulting from an inadequacy or overabundance of ingested fluids. Chapter 6 considers micronutrients and their role in metabolism and exercise. The next several chapters discuss specific nutrition techniques and nutritional ergogenic aids that have been shown to improve aerobic endurance, strength, and power performance, as well as nutrition techniques and nutritional ergogenic aids that may help improve body composition. The final two chapters provide important information on assessing nutrition status and developing a comprehensive plan based on the assessment.

*Sport nutrition* is an umbrella term that can encompass a great deal of information. It is our hope that through this book the reader will gain an enhanced understanding of how food, sport supplements, and their interactions with the body's biological systems can enhance exercise and sport performance.

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# Contents

# 1

# Foods and Fluids for Training and Sport Performance

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Many modifiable factors contribute to an athlete's success. The most important ones are a sound strength and conditioning program, sport psychology, sport-specific training, nutrition, supplementation, rest, and recovery. Not only do these factors affect long-term training and subsequent performance, but they can also play a major role in just one competition.

The science of nutrition and performance (and also of nutrition and physique changes) is growing by leaps and bounds. As this body of research expands and scientists scrutinize ever more closely the factors that can affect an athlete's performance and physique, the need for sport nutrition practitioners is also growing. At both the college and professional level, sport nutritionists use scientific research to make sound recommendations to athletes. They often work with coaches, strength and conditioning professionals, and trainers as part of a comprehensive team whose primary goal is to assist the athletes. Sport nutritionists help athletes make sound changes to their dietary intake, apply nutrient timing techniques, alter their supplementation regimen, and make sense of all the information related to supplements. Sport nutritionists also develop healthy training tables, measure body composition and bone density, help athletes navigate the grocery store, teach them the basics of preparing healthy meals, and work with a team of professionals to develop a treatment plan for athletes with eating disorders.

## New Developments in Nutrition Research

What are some of the hottest areas of research relevant to an athlete's diet? From macronutrients to electrolyte balance to supplements that mitigate fatigue, sport nutrition incorporates a multifaceted body of research. When it comes to macronutrients, the timing of consumption is just as important as the specific macronutrient consumed. **Nutrient timing**, the practice of consuming a specific nutrient in a given time period within proximity to training or performance, affects physique changes, glycogen replenishment, muscle protein synthesis, and performance.

➤ nutrient timing—The practice of consuming a specific nutrient in a given time period within proximity to training or performance to achieve a desired outcome.

Carbohydrate consumption is an area of nutrient timing that has a great impact on many athletes. Twenty years ago, carbohydrate research largely focused on aerobic endurance athletes. However, studies since then have examined the importance of pre- and postexercise carbohydrate consumption for resistance training as a means of restoring glycogen losses (Robergs et al. 1991; Tesch et al. 1998), altering hormone secretion, and influencing muscle protein synthesis (Volek 2004). In addition, the types of carbohydrate ingested play a critical role, with a glucose plus fructose beverage possibly the best means of staying hydrated (Jeukendrup and Moseley 2010) and potentially sparing endogenous carbohydrate during exercise (Currell and Jeukendrup 2008). And a unique, high molecular weight starch-based carbohydrate made from barley amylopectin may be preferable to low molecular weight carbohydrates such as monosaccharides and disaccharides for expediting glycogen replenishment (Stephens et al. 2008).

Protein research has evolved from studies of the amino acid profiles (**PDCAAS,** protein digestibility–corrected amino acid score) of various sources of protein to research on nutrient timing and on types of protein (i.e., whey) that may play a role in weight loss (Lockwood et al. 2008). In addition, researchers have determined when and how branched-chain amino acids (BCAAs) and to what extent essential amino acids (EAAs) increase muscle protein synthesis (Borsheim et al. 2002; Norton and Layman 2006; Shimomura et al. 2006; Tipton et al. 1999). The final macronutrient, fat, may play an important role in overall health, while some types of fat, such as conjugated linoleic acid (CLA) and medium-chain triglycerides, continue to spark interest for their potential role in improving exercise performance and enhancing weight loss.

➤ PDCAAS (protein digestibility–corrected amino acid score)—A method of evaluating protein quality based on the amino acid requirements of humans and ease of digestion; 100% is often used as the highest value (values above 100 are truncated) and 0 is the lowest (Schaafsma 2000).

Though the ingestion of **micronutrients** above and beyond the Recommended Dietary Intake (RDI) has not been shown to enhance performance, population-based studies are uncovering that many people do not consume the RDI of certain nutrients and that some individuals are deficient in one or more micronutrients. And, making up for a dietary deficiency by consuming a micronutrient may directly or indirectly enhance performance. For instance, taking extra iron even if you have enough in your diet will not help performance. However, individuals who are iron deficient should notice an improvement in their levels of fatigue and their athletic performance if they correct this deficiency through supplementation. When it comes to specific micronutrients, certain groups of people are more likely to experience a deficiency than others (women are more likely to be deficient in calcium and iron, for example, than men). In some cases, correcting micronutrient deficiencies may directly enhance performance (iron deficiency anemia, for example); and in others it may benefit overall health, help prevent injuries and illness (vitamin D, for example), or quicken the recovery process (sodium for enhancing thirst and therefore rehydration). Chapter 6 presents an in-depth analysis of the various micronutrients and their importance to exercise performance.

➤ micronutrient—A substance needed in small amounts by the body. All vitamins and minerals are micronutrients.

Possibly the hottest topic among athletes is supplements. In a society fascinated with finding "magic bullets," athletes are also in search of anything that will help them get stronger, faster, and leaner and possibly even concentrate better. Consequently, a wide variety of sport supplements fill up store shelves and the cabinets of physically active individuals. Fortunately, there is scientific research to substantiate marketing claims for some of these purported ergogenic aids. Creatine, protein, caffeine, amino acids, electrolyte replacement sport beverages, beta-alanine, and high molecular weight starch-based carbohydrates are among the most widely researched supplements to date (these are explored in more depth in chapters 7 and 8).

## Topics in Nutrition and Performance

In research on an athlete's diet, three of the top areas sport nutritionists hone in on are macronutrients, hydration, and ergogenic aids. The type and amount of macronutrients, as well as the timing of consumption, can have a major impact on performance, recovery, and overall health. And changing the variables related to macronutrient intake, including the type of macronutrient consumed, when it is consumed, and the amount consumed, can often have an immediate impact on how an athlete feels. Hydration encompasses more than just cooling the body. Hydration also affects electrolyte status and nutrient delivery. Finally, ergogenic aids are very popular among athletes looking for an edge on their competition. Ergogenic aids are a very large category of supplements and range from ineffective to effective, as well as from dangerous to very safe for intended use.

## Macronutrients

**Macronutrient** (carbohydrate, protein, and fat) ingestion is essential for a multitude of life-sustaining activities, including preservation of the structural and functional integrity of the human body. In the realm of sport nutrition, the macronutrients are often discussed in terms of energy production and their role in building skeletal muscle that can subsequently be trained or stimulated to enhance force production (table 1.1). Specifically, carbohydrate and fat are the primary nutrients used for energy production; protein contributes only a small amount of the total energy used (Lemon and Nagle 1981; van Loon et al. 1999).

➤ macronutrient—Substances required by the body in large amounts. Carbohydrate, protein, and fat are all macronutrients.

Adenosine triphosphate (ATP), the energy currency of the cell, allows the conversion of chemical energy into mechanical energy. The energy in food (chemical energy) does not transfer directly to the cells for biologic work. Rather, "macronutrient energy" funnels through the energy-rich ATP compound (McArdle, Katch, and Katch 2008). This process can be summarized in two basic steps: (1) the extraction of chemical energy from macronutrients and its transfer to the bonds of ATP; (2) the extraction and transfer of the chemical energy in ATP to fuel biologic work such as skeletal muscle contraction (McArdle, Katch, and Katch 2008). All three macronutrients are oxidized for energy during exercise. Several factors regulate the extent to which each of the macronutrients is oxidized, including nutrition status, exercise intensity, and training status. The following is a brief discussion of the major roles of the macronutrients in terms of fueling activity and their ability to build lean body mass.

### *Fuels for Aerobic and Anaerobic Exercise*

Carbohydrate and fat (in the form of fatty acids) are the two primary substrates oxidized by skeletal muscle to provide energy during prolonged exercise. As the exercise intensity increases, a greater percentage of fuel

**TABLE 1.1** Primary Roles of Macronutrients Relative to Exercise Performance

| Macronutrient | Role |
|---|---|
| Carbohydrate | Energy production (high intensity) |
| Fat | Energy production (low intensity) |
| Protein | Lean tissue accretion and maintenance |

used is from carbohydrate. As people near 100% of $\dot{V}O_2max$, they progressively use more carbohydrate and less fat (Mittendorfer and Klein 2003; van Loon et al. 1999). However, as exercise duration increases, fat metabolism is increased and carbohydrate metabolism decreased (Jeukendrup 2003). The main carbohydrate sources are muscle and liver glycogen, liver gluconeogenesis (the production of carbohydrate from noncarbohydrate sources), and ingested carbohydrate. Even though carbohydrate and fat are the major energy sources during aerobic exercise, athletes who consistently train aerobically alter the amounts of energy contribution from these macronutrients. Whole-body calorimetry measurements have clearly shown that aerobic endurance training leads to an increase in total fat oxidation and a decrease in total carbohydrate oxidation during exercise at a given intensity (Coggan et al. 1990; Friedlander et al. 1997; Hurley et al. 1986). Although amino acids are not a major contributor to energy production, several clinical investigations have demonstrated that their contribution to aerobic exercise energy production is linearly related to exercise intensity (Brooks 1987; Lemon and Nagle 1981; Wagenmakers 1998).

The energy to perform short-term, high-intensity anaerobic exercise comes from existing ATP-PC (ATP phosphocreatine) stores and carbohydrate oxidation via glycolysis (refer to chapter 2 for an in-depth discussion of carbohydrate metabolism and glycolysis) (Maughan et al. 1997). In fact, anaerobic energy transfer from the macronutrients occurs only from carbohydrate breakdown during glycolytic reactions (McArdle, Katch, and Katch 2008). Also, carbohydrate catabolism, or breakdown, is the fastest source of ATP resynthesis. Due to its rate and quantity of oxidation, carbohydrate is the main source for ATP resynthesis during maximal exercise tasks lasting approximately 7 seconds to 1 minute (Balsom et al. 1999; Mougios 2006).

### *Protein for Building Lean Body Mass*

The contribution of amino acid oxidation to the total energy production is negligible during short-term, high-intensity exercise. It likely accounts for 3% to 6% but has been reported to be as high as 10% of the total ATP supplied during prolonged exercise (Hargreaves and Spriet 2006; Phillips et al. 1993; Brooks 1987). The role that protein plays as a substrate during exercise is principally dependent on the availability of branched-chain amino acids and the amino acid alanine (Lemon and Nagle 1981). Protein has a limited role in energy production; its primary function is to increase and maintain lean body mass. One needs to consider many factors when determining an optimal amount of dietary protein for exercising individuals. These factors include protein quality, energy intake, carbohydrate intake, mode and intensity of exercise, and the timing of the protein intake (Lemon 2000). For an in-depth discussion of the various types of protein and specific protein intake recommendations, refer to chapter 3. A protein intake of 1.5 to 2.0 g/kg per day for physically active individuals not only is safe but also may improve the adaptations to exercise training (Campbell et al. 2007).

## Hydration

Hydration is not limited to the replenishment of body fluids but is also a vehicle for delivering electrolytes, sugar, and amino acids. Dehydration and hyponatremia (low blood sodium, often due to overhydration in the absence of sodium) still affect "weekend warriors" and experienced athletes alike. Further, dehydration can result in a dangerous increase in core body temperature leading to heat illness (Greenleaf and Castle 1971). However, even mild dehydration, which is more common, can lead to decreases in both strength and aerobic endurance and subsequently to impaired athletic performance (Bigard et al. 2001; Schoffstall et al. 2001; Walsh et al. 1994). The young and the elderly are the two groups at greatest risk for heat-related illness, including heat cramps, heat exhaustion, and heatstroke (Wexler 2002). Two major factors put young athletes at risk: (1) They do not sweat as much as adults (sweat helps dissipate heat); and (2) they have a greater surface area relative to their body mass, which increases their heat gain from the environment when ambient temperatures are elevated (Delamarche et al. 1990; Drinkwater et al. 1977).

In the elderly, age-related changes in thirst and thermoregulation contribute to dehydration. Elderly individuals experience a decreased thirst sensation in response to drops in blood volume, a reduction in renal water conservation capacity, and disturbances in fluid and electrolyte balance (Kenney and Chiu 2001). Some prescription medicines, as well as cardiovascular disease (still the number one cause of death in the United States), can impair fluid homeostasis (Naitoh and Burrell 1998).

The quest for enhanced hydration has led to the examination of hyperhydrating agents such as glycerol. In addition, nutrition scientists have investigated the effects of adding amino acids to sport beverages and regular electrolyte replacement beverages to improve hydration and mitigate muscle damage. Fortunately, beverage companies are continuing to sponsor research on the effectiveness of their products, which indicates a continued focus on hydration and its effects on health and performance. Companies that conduct studies on their products should hire independent labs with no financial interest in the company itself to conduct unbiased, well-designed clinical trials.

### *Ergogenic Aids*

Modern-day Olympic athletes are no different from high school athletes attempting to make their junior varsity basketball team—both groups are seeking to improve their athletic performance. Naturally, any athlete attempting to improve performance will continually manipulate his training regimen. Along with this focus on training methodology is often an equal attention on the use of ergogenic aids to improve performance. **Ergogenic aids** are nutritional, physical, mechanical, psychologic, or pharmacologic procedures or devices intended to improve exercise or sport performance. Since by definition, ergogenic aids are work-enhancing substances or devices believed to increase performance (McNaughton 1986), they may range from caffeine for the aerobic endurance athlete to eyewear for a skier or snowboarder. Nutritional ergogenic aids receive a lot of attention from athletes and others in the sport performance industry. They may directly influence the physiological capacity of a particular body system and thereby improve performance, or they may increase the speed of recovery from training and competition.

➤ ergogenic aid—A work-enhancing substance or device believed to increase performance. Examples include nutritional, physical, mechanical, psychologic, or pharmacologic procedures or aids to improve exercise or sport performance.

## *Macronutrients and Sport Supplements*

Nutritional ergogenic aids can be categorized into two broad categories: macronutrient intake manipulations (carbohydrate loading, increasing protein intake during a hypertrophic resistance training phase, etc.) and the ingestion of dietary supplements. Dietary supplements, products intended to make the diet more complete, contain one or more of the following ingredients: a vitamin, mineral, amino acid, herb, or other botanical; a dietary substance intended to supplement the diet by increasing the total dietary intake of certain macronutrients or total calories; a concentrate, metabolite, constituent, extract, or combination of any of the ingredients already mentioned and intended for ingestion in the form of a liquid, capsule, powder, softgel or gelcap, and not represented as a conventional food or as a sole item of a meal or the diet (Antonio and Stout 2001; U.S. Food and Drug Administration [FDA] 1994). Commonly used supplements such as vitamins and minerals are considered ergogenic aids only if the athlete is correcting a deficiency. Other ergogenic aids are not taken specifically to correct a deficiency but instead for a very specific benefit. For instance, a hockey player taking a time-released beta-alanine supplement for four to six weeks prior to preseason practice is doing so to zone in on one very specific component of training and recovery: buffering fatigue. Sport supplements and nutritional ergogenic aids are classified under the umbrella of dietary supplements. Often, sport supplements provide a substance that is a component of a normal physiological or biochemical process (creatine monohydrate, alpha ketoglutarate, etc.). Other nutritional ergogenic aids augment physiological or bioenergetic pathways to enhance energy production (e.g., creatine monohydrate, caffeine) or skeletal muscle mass (creatine monohydrate, leucine, etc.). Table 1.2 lists common sport supplements and their proposed benefits in relation to health and performance.

**TABLE 1.2** Proposed Benefits of Popular Sport Supplements

| Sport supplement | Proposed benefits |
|---|---|
| BCAAs (branched-chain amino acids) | Increase rates of protein synthesis |
| Caffeine | Improve aerobic endurance performance, mental alertness |
| Creatine | Increase strength and muscle mass |
| EFAs (essential fatty acids) | General health, weight loss |
| Energy drinks | Increase alertness and metabolism |
| Glycerol | Hyperhydration |
| HMB (β-hydroxy-β-methylbuteric acid) | Increase strength and muscle mass; anticatabolic |
| Hydration drinks | Improve aerobic endurance performance, improve hydration |
| Medium Chain Triglycerides | Improve aerobic endurance exercise performance |
| Multivitamins and multiminerals | General health |
| Nitric oxide boosters | Increase blood flow to active musculature |
| Protein | Increase strength and muscle mass; recovery |
| Patented, highly branched high molecular weight (HMW) glucose polymer solution | Increase aerobic endurance performance; recovery |

## *Prevalence of Ergogenic Aid Use*

Throughout history, athletes have experimented with nutritional ergogenic aids to improve performance. The ancient Greeks may have been the first to ponder how to gain a competitive edge through proper diet and supplementation (Antonio and Stout 2001). Greek warriors from the fifth century B.C. reportedly used such things as hallucinogenic mushrooms and deer liver for ergogenic purposes (Applegate and Grivetti 1997; McArdle, Katch, and Katch 2008). For a comprehensive review on the history of dietary practices of ancient athletes, refer to Grivetti and Applegate 1997 and Grandjean 1997.

A look at past practices of nutritional supplementation suggests that elite athletes in various civilizations ingested nutritional ergogenic aids. Modern times have seen a shift in the prevalence and types of individuals who consume nutritional ergogenic aids. Statistics on high school athletes are a sign of this shift (Hoffman et al. 2008). A self-report survey asking about dietary supplement intake was administered to approximately 3,000 students (with an approximately equal gender distribution) representing grades 8 through 12 in the United States. The results revealed that 71.2% of the adolescents reported use of at least one supplement. The most popular supplements used were multivitamins and high-energy drinks. The use of supplements to increase body mass and strength (e.g., creatine, protein powder, weight gain formulations) increased across grades and was more prevalent in males than females. The authors concluded, not surprisingly, that reliance on nutritional supplements and ergogenic aids increases during adolescence. Other survey-based investigations have yielded similar results (Bell et al. 2004; O'Dea 2003).

As greater numbers of adolescents and high school athletes ingest nutritional ergogenic aids, their coaches, athletic trainers, personal trainers, physicians, and parents need an increased knowledge base. Weekend warriors, mothers interested in the long-term effects of creatine on their high school children, and fitness enthusiasts striving to obtain a leaner physique—all must have a working knowledge of nutrition and ergogenic aids and how they affect the physiology of the human body. Given the increase in sport nutrition research, this information is becoming more available.

**Professional Applications**

The need for accurate nutrition and supplement information among athletes, coaches, strength and conditioning professionals, strength coaches, athletic trainers, and support staff is clear. Various surveys, including the General Nutrition Knowledge Questionnaire (GNKQ) and Eating Attitude Test (EAT-26), have been used to assess athletes' nutrition knowledge (Raymond-Barker, Petroczi, and Quested 2007). Most of these surveys reflect limitations in athletes' knowledge. Studies have found that formal education in nutrition or closely related subjects does not influence nutrition knowledge (Raymond-Barker, Petroczi, and Quested 2007). In addition, nutrition knowledge does not necessarily impact eating attitudes in females at risk for the female athlete triad (Raymond-Barker, Petroczi, and Quested 2007); adolescent females may have nutrition misconceptions (Cupisti 2002); and college athletes in general cannot identify the recommended intake for all macronutrients, and also many do not know what roles vitamins play in the body (Jacobson, Sobonya, and Ransone 2001). In addition, coaches often have a low level of knowledge of sport nutrition (Zinn, Schofield, and Wall 2006).

Filling the sport nutrition knowledge gap requires testing and education. After testing an athlete's body composition and bone density and analyzing food records and subjective data (how the athlete feels, energy levels, etc.), practitioners can use the results as a starting place for education. In addition, one-on-one consultations with athletes provide a great opportunity for each athlete to ask pertinent questions. A sport nutritionist's knowledge of the current research and how it can be applied to athletes is essential to helping athletes meet their goal of improved performance. Sport nutritionists use this knowledge to develop plans and progress charts for athletes, make sound recommendations, and help design the treatment plan for those with eating disorders.