Exercise & Sport Nutrition: A Balanced Perspective for Exercise Physiologists

Richard B. Kreider, PhD, MX, EPC, FACSM, FASEP; Anthony L. Almada, MSc; Jose Antonio, PhD, FACSM; Craig Broeder, PhD, FNAASO; Conrad Earnest, PhD, FACSM; Lori Greenwood, PhD, ATC, LAT; Mike Greenwood, PhD, CSCS*D; Thomas Incledon, MS, RD, LD/LN, NSCA-CPT, CSCS, RPT; Douglas S. Kalman MS, RD, FACN; Chad Kerksick, MS, CSCS, ATC, EPC; Susan M. Kleiner, PhD, RD, FACN; Brian Leutholtz, PhD, FACSM; Lonnie M. Lowery, PhD; Ron Mendel, PhD; Christopher J. Rasmussen, MS, MX, CSCS, EPC; Jeffrey R. Stout, PhD, FACSM, CSCS; Joseph P. Weir, Ph.D., EPC, FACSM; Darryn S. Willoughby, Ph.D., FACSM, FASEP, EPC, CSCS, CNS;
Tim N. Ziegenfuss, PhD, CSCS, EPC, FASEP

Author Affiliations:

Richard B. Kreider, PhD, MX, EPC, FACSM, FASEP
Past-President of ASEP and Member of ASEP Board of Directors
Professor and Chair
Department of Health, Human Performance & Recreation
Director of the Exercise & Sport Nutrition Laboratory &
Center for Exercise, Nutrition & Preventive Health Research
Baylor University
Richard_Kreider@baylor.edu

Anthony L. Almada, MSc
Chief Scientific Officer
IMAGINutrition
Former Co-founder and Chief Scientific Officer
Experimental & Applied Sciences

Jose Antonio, PhD, FACSM
Senior Manager of Sports Science
MET-Rx

Craig Broeder, PhD, FNAASO
Professor and Chair
Department of Exercise Science
St. Benedictine University

Conrad Earnest, PhD, FACSM
Director, Exercise Physiology Laboratory
The Cooper Institute

Lori Greenwood, PhD, ATC, LAT
Associate Professor and Coordinator of the Graduate Athletic Training and Sports Medicine Program
Department of Health, Human Performance & Recreation
Exercise & Sport Nutrition Laboratory
Center for Exercise, Nutrition & Preventive Health Research
Baylor University

Mike Greenwood, PhD, CSCS*D
Member of ASEP Board of Directors
Professor and Graduate Program Director & Research Coordinator
Department of Health, Human Performance & Recreation
Exercise & Sport Nutrition Laboratory
Center for Exercise, Nutrition & Preventive Health Research
Baylor University

Thomas Incledon, MS, RD, LD/LN, NSCA-CPT, CSCS, RPT
Director of Performance Research and Nutrition
Athletes' Performance

Douglas S. Kalman MS, RD, FACN
Director, Nutrition & Applied Clinical Research
Miami Research Associates

Chad Kerksick, MS, CSCS, ATC, EPC
Doctoral Research Associate
Exercise & Sport Nutrition Laboratory
Department of Health, Human Performance & Recreation
Baylor University

Susan M. Kleiner, PhD, RD, FACN
Affiliate Assistant Professor
Department of Medical History and Ethics
School of Medicine
University of Washington

Lonnie M. Lowery, PhD
Department Nutrition and Dietetics
Kent State University

Brian Leutholtz, PhD, FACSM
Professor, Department of Health, Human Performance & Recreation
Exercise & Sport Nutrition Laboratory
Center for Exercise, Nutrition & Preventive Health Research
Baylor University

Ron Mendel, PhD
President, Ohio Society of Exercise Physiology
Lab Director, Pinnacle Institute of Health & Human Performance

Christopher J. Rasmussen, MS, MX, CSCS, EPC
Research Coordinator
Exercise & Sport Nutrition Laboratory
Department of Health, Human Performance & Recreation
Baylor University

Jeffrey R. Stout, PhD, FACSM, CSCS
Chief Scientific Officer
Vitalstate USA

Joseph P. Weir, PhD, EPC, FACSM
Member of ASEP Board of Directors
Associate Professor and Research Coordinator
Division of Physical Therapy
Des Moines University-Osteopathic Medical Center

Darryn S. Willoughby, Ph.D., FACSM, FASEP, EPC, CSCS, CNS
President-Elect of ASEP and Member of ASEP Board of Directors
Associate Professor of Exercise & Molecular Physiology
Exercise Biochemistry and Molecular Biology Lab
Department of Kinesiology
Texas Christian University

Tim N. Ziegenfuss, PhD, CSCS, EPC
Member of ASEP Board of Directors
Chief Scientific Officer
Pinnacle Institute of Health & Human Performance

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Introduction

Over the last year or so several articles have appeared in PEP online suggesting that exercise physiologists who conduct research on exercise and nutrition and/or recommend that their clients/athletes consume special diets or take nutritional supplements are quacks [1]. More recent articles suggested that: 1.) sport nutrition research is often flawed from an ethical and scientific perspective; 2.) it is unethical and/or unprofessional for exercise physiologists to conduct performance enhancement research (particularly if it is funded by a supplement company); 3.) it is unethical and/or unprofessional for exercise physiologists to consult with supplement companies; 4.) it is unethical for athletes to consume nutrients and/or take performance enhancement supplements because it is a form of cheating; 5.) exercise physiologists and professors who conduct research in this area and/or teach their students how to optimize training and/or performance through scientific application of training and nutrition are unethical and contributing to a "win at all cost" mentality; and, 6.) if exercise physiologists recommend that people take nutritional supplements they are in violation of the ASEP Code of Ethics and should therefore be sanctioned in some manner by ASEP [1-5].

As leading researchers and educators in this area, we felt that it was time to provide our opinion on these articles. Although we have great respect for the authors and appreciate their commitment to ASEP and passion for the professionalization of exercise physiologists, it is our view that many of the comments made in these articles simply cannot be supported by the current scientific literature. Further, that much of the logic used to support these views is flawed. Members of ASEP should know that many leading sport nutrition researchers, ASEP members, and members of the ASEP Board of Directors (BOD) do not share these views. As an indication of this consensus, this paper is coauthored by a number of respected exercise physiology and sport nutrition professors, researchers, practitioners, and leading who have extensive experience working with athletes, teaching exercise physiology and sport nutrition, conducting research on dietary supplements, serving as consultants for nutrition companies, coordinating research and product development for nutrition companies, and/or educating the scientific and lay communities about the role of nutrition on exercise and performance. This list includes: the Past-President and President-Elect of ASEP; members of the ASEP Board of Directors; Certified Exercise Physiologists (EPC), Strength and Conditioning Specialists (CSCS), Certified Athletic Trainers (ATC), and registered dietitians (RD); Fellows of ASEP, the American College of Sports Medicine (ACSM), American College of Nutrition (ACN), and the North American Association for the Study of Obesity (NAASO); leaders of sport nutrition organizations; Chief Scientific Officers of leading supplement companies; and, a cofounder of a company founded on the principle of developing products based on science. While PEP Online provides an opportunity for exercise physiologists to raise issues relevant to the professional practice of exercise physiologists and sport nutrition is certainly a relevant issue for exercise physiologists, authors should be careful that the opinions are based on a thorough and comprehensive analysis of the literature so that unfounded conclusions are not made. It is our view that these articles have served to alienate exercise physiologists, divide ASEP members, and have reflected poorly upon ASEP within the broader scientific community due to a misrepresentation of available scientific literature. Consequently, we felt it was our responsibility to provide a more balanced perspective on the role of nutrition on exercise and performance.

In our view, it is the professional responsibility of an exercise physiologist to be up to date on current literature so the students, clients, and/or athletes are provided the latest information so they can make an informed decision about whether to try a particular training/rehab program, diet, and/or nutritional supplement. Moreover, they should teach their students about legal and illegal performance enhancement aids used by athletes so they understand the potential physiological mechanisms of action, potential benefits, and/or possible risks and side effects in order to properly educate their clients/athletes. If a proposed nutrient or diet lacks scientific support, then it is the responsibility of the exercise physiologist to inform their students, clients, and/or athletes that there is little to no data supporting a proposed benefit. If outrageous claims are made by marketing arms of supplement companies, then the best course of action for an exercise physiologist is to conduct research, publish the research findings, and inform their students and the public that there is no data to support the claims made. We concur that not doing so would be unethical. However, in our view it is equally unethical to suggest there are no data supporting the health and/or ergogenic value of a diet strategy or nutrient when there are indeed data supporting its use. It is our experience that many exercise physiologists and nutritionists unintentionally mislead and confuse the public because they simply are not familiar with the available scientific data. The area of exercise nutrition is rapidly advancing. Thousands of articles are published every year investigating the role of nutrition and exercise on health, disease, and performance. There have been enormous advancements in our understanding how diet, exercise, and specific nutrients can promote health, well-being, helps in disease management, and/or improve performance and training adaptations. For this reason, many grant agencies like the National Institutes of Health have called for an increase in funding to assess the interaction of exercise and nutrition on health, disease, and performance. In our view, not being aware of the scientific literature and/or making blatantly inaccurate or false statements about the role of nutrition and exercise is as unethical as supplement companies making unsupported claims about their products.

It is our view that although the articles by Boone and Birnbaum [1-5] raise some important questions that should be openly discussed as the exercise physiology profession develops, they are misleading in that they do not present a current and/or comprehensive view of the role of nutrition on exercise, performance, and training. For example, these articles indicated that there are *no data* to support a recommendation that athletes need to supplement their normal diet with protein, amino acids, vitamins, minerals, or many other purported ergogenic aids and even if there were data supporting their use it is unethical to do so. Moreover, if an exercise physiologist suggested that there were data to support these views, then they are "quacks" and/or are supporting unethical behavior among athletes. As several members of ASEP who reviewed some of these papers and/or provided comments regarding these positions at the recent ASEP national meeting indicated, these views are simply not supported by hundreds of articles reporting health, performance, and/or training benefits of various nutritional strategies, macronutrients, micronutrients, and ergogenic aids. It is our view that authors should be more careful before suggesting that a large segment of researchers, exercise physiologists, athletes, and members of the general public are unethical.

Boone and Birnbaum [1-5] also question the ethics of athletes attempting to enhance exercise capacity by using performance-enhancing supplements. It is our view that suggesting it is unethical and/or cheating for an athlete to follow a performance enhancement diet and/or take legal nutritional supplements shown in research to be safe and effective doesn't make sense. A similar argument can be made suggesting its unethical for athletes to: 1.) use the latest training methods shown in research to improve strength, speed, endurance, and/or agility; 2.) seek more experienced coaching to improve performance of an athletic skill; 3.) use the most technologically advanced athletic equipment; 4.) use protective sports medicine equipment to reduce risk of injuries; and/or, 5.) live at altitude in hopes of enhancing endurance performance at sea level. Using this line of thinking, it would be unethical for an athlete to consume a high carbohydrate diet, carbohydrate load or drink coffee prior to competition, and/or use sports drinks during prolonged exercise to maintain hydration and performance. Furthermore, it would be unethical for an athlete to consult with a sport psychologist, sport nutritionist, strength and conditioning specialist, and/or exercise physiologist to undergo assessments to gauge training and/or performance progress. After all, not all athletes have access good coaching, can eat a good diet, have strength and conditioning coaches, have access to the most technologically advanced equipment and training facilities, and/or can afford to take performance enhancing supplements. Using this logic, fairness in sport could only be achieved if athletes were required to follow the same training program, had access to the same training facilities, lived in the same environment, ate the same diet at the same time of day, slept the same amount each night, and had the same genetic endowment. Moreover, it would be unethical for anyone to recommend participating in a potentially dangerous sport or recreational activity (actually hundreds of people die each year from traumatic and non-traumatic sudden death during exercise and/or while participating in recreation and sporting events) or a sport that wasn't always "fun". Based on this logic, we should ban competitive and professional sport because sports shouldn't be that serious, athletes may not always be good "role models" to our youth, and/or participating in sport may not always impart proper "values" to our children. To us, this line of thinking makes little sense.

Many of us have been athletes and have worked extensively with young athletes (Junior High and High School), college athletes, Olympic athletes, and professional athletes. Many of us have made presentations to numerous professional societies and coaching groups in the U.S. and abroad. There are many reasons why people participate in exercise programs and sport. It's not always fun to run, lift weights, participate in sprint and conditioning drills, and/or endlessly practice to become good at a sport. It also isn't always easy to eat a well-designed diet and/or time nutrient intake to optimize performance and recovery. However, these are key principles of preparing individuals to perform to their best capability. Some people don't feel the discipline required to train hard, eat right, and optimize performance is worth the time and energy. Others strive to be the best they can be even though they don't have the genetic endowment for a particular sport. Still others who have the genetic predisposition and talent for a particular sport seek to reach the heights of athletic performance by becoming a national class, world class, or professional athlete. Optimizing training through provision of well-timed nutrients and/or use of various nutritional supplements research has shown can help optimize performance and/or training adaptations (e.g., sports drinks, energy bars, carbohydrate gels, carbohydrate/protein supplements, creatine, caffeine, etc) is not cheating – its smart training and preparation for competition. Application of performance enhancement nutritional strategies doesn't make it easier to train, it helps you train harder, recover faster from intense training, and may help reduce the incidence of overtraining. It helps optimize energy availability so you can exercise longer and/or at higher intensities. This is not a short-cut to training but a way to help the body tolerate higher levels of training. It is no different than applying the latest training principles to optimize performance. Athletes and coaches have many choices they can make about which training methods to employ, how much training is enough (or too much), how much rest the athlete needs to recover well, what type of diet to follow, and/or whether nutritional supplements can help them train and/or perform better. The exercise physiologist should help coaches and athletes base their decisions on available science. Some will listen to this advice while others will employ seemingly strange training techniques and methods. As long as athletes and coaches adhere to the rules of their sport, these decisions should not be viewed as unethical. To us, the question is not whether optimizing nutrition is ethical or not but what is the best way to help people optimize training adaptations, performance, and/or assist in the rehabilitation of injury or illness. Ultimately, this may help people see better results from training, improve exercise adherence, and help people achieve their training, rehabilitation, and/or performance goals.

Such a multitude of training and performance enhancements calls for some distinctions regarding legitimacy. It is unfair to conclude that simply because there is no literature on one ergogenic approach, then subsequently all strategies are equally unsupportable or unethical. Blanket statements regarding all ergogenic endeavors are inappropriate as we should strive to only make conclusions based upon existing data – not personal convictions. Some aspects of exercise augmentation provide substantially more published evidence than others. For example, not all sports supplements are technically nutritional in nature. Sports nutrition, *per se*, is a well-documented field of study that can be incongruent with sports supplements such as prohormones and many herbal substances. Supplements that are essential to human health (e.g. proteins/ EAAs, carbohydrates, fats, vitamins and minerals) or are common to humans' dietary intake (e.g. creatine, caffeine) are historically "nutrition" per se, and typically have far more data to support or refute their potential. Conversely, hormonal and herbal preparations – although legally "dietary supplements" - are more the realm of sports pharmacology. This does not preclude their investigation by exercise physiologists, but does make them a different entity, calling for a somewhat different educational background by those researching them.

There is a significant body of research that has evaluated the role of exercise and nutrition on performance. This research has served as a cornerstone in the development and advancement of exercise physiology. However, as Boone and Birnbaum [1-5] correctly point out, there is a significant amount of misinformation and marketing hyperbole about various training techniques, devices, nutritional strategies, and dietary supplements. But again, this is a large group of distinct ergogenic approaches. There have also been instances when quality research findings have been misrepresented or exaggerated in marketing materials. The answer is not to condemn all performance enhancement training techniques, devices, nutritional strategies, dietary supplements, ergogenic aids, and those who support the use of some of these techniques as unethical. The answer is to conduct research to determine whether there is a scientific basis to these purported aids and assist in educating the public about which ones are credible or not. Further, to recommend to researchers in this area that they incorporate safeguards in grant contracts regarding full publication rights, restrictions that data can only be described in marketing material after it has been published and/or presented at an appropriate scientific venue, disclose any conflicts of interest, and to inform the public if marketing materials describing results misrepresent the data. ASEP should not separate itself from one of the foundations of exercise physiology and/or condemn those who seek to determine the legitimate role of training and nutrition on performance. Rather, it should encourage the ethical conduct of research and dissemination of research so that its members and the general public can be appropriately informed as to the state of the science in this area. Moreover, it should call upon companies who sell training devices and/or nutritional supplements to develop research based products, to fund clinical trials to independently analyze the ergogenic value of their products, and to fully and accurately portray results of research findings in research publications and marketing material so that the public can make an informed decision about them. Finally, it should encourage exercise physiologists to stay current with the scientific literature and help interpret the literature for the scientific and lay public by writing scholarly reviews for academic journals, online publications, and/or fitness magazines so the public can be properly informed about the science that does or does not support various products.

Exercise physiologists need to be on the frontier of applying the scientific principles of training and nutrition. This requires a current and up-to-date understanding of the literature. In fact, the current professional climate provides a real niche for the exercise physiologist in this regard. Turning down the role of sports nutrition/ergogenic aid researcher as "unethical" would not only further relinquish certain authority of the exercise physiologist to other professions, but would itself be irresponsible to the public. There is published opinion that sports nutritionists need as little as one to two courses in exercise science, even as they are expected to "understand and explain the plethora of ergogenic aids and their marketing claims" and "be able to apply biochemistry principles and analyze research designs" [6]. It has also been suggested that these health professionals assuming the role of [sports] nutrition educator have been underdeveloped in their interpretation and/ or participation in the scientific literature [7, 8]. Thus, the opportunities and need for interdisciplinary interaction to protect the public are clear.

Exercise physiologists also need to know how to evaluate the scientific merit of articles and advertisements about exercise and nutrition products so they can separate marketing hype from scientifically based training and nutritional practices. In order to help educate ASEP members about sport nutrition, we have adapted several recent articles and chapters from Dr. Kreider's work regarding exercise, nutrition, and training. This paper provides an overview of: 1.) what are ergogenic aids and dietary supplements; 2.) how dietary supplements are legally regulated; 3.) how to evaluate the scientific merit of nutritional supplements; 4.) general nutritional strategies to optimize performance and enhance recovery; and, 5.) an overview of our current understanding of the ergogenic value weight gain, weight loss, and performance enhancement supplements. We have also categorized nutritional supplements into apparently effective, possibly effective, too early to tell, and apparently ineffective as well as describes our general approach to educating athletes about sport nutrition. While some exercise physiologists and nutritionists may not agree with all of our interpretations of the literature and/or categorization of a particular supplement, these interpretations are based on the current available scientific evidence and have been well received within the broader scientific community. Our hope is that ASEP members find this information useful in their daily practice and consultation with their clients.

What is an Ergogenic Aid?

An *ergogenic aid* is any training technique, mechanical device, nutritional practice, pharmacological method, or psychological technique that can improve exercise performance capacity and/or enhance training adaptations [9, 10]. This includes aids that may help prepare an individual to exercise, improve the efficiency of exercise, and/or enhance recovery from exercise. Ergogenic aids may also allow an individual to tolerate heavy training to a greater degree by helping them recover faster or help them stay healthy during intense training. Although this definition seems rather straightforward, there is considerable debate regarding the ergogenic value of various nutritional supplements. Some exercise physiologists only consider a supplement ergogenic if studies show that the supplement significantly enhances exercise performance (e.g., helps you run faster, lift more weight, and/or perform more work during a given exercise task). On the other hand, some feel that if a supplement helps prepare an athlete to perform or enhances recovery from exercise, it has the potential to improve training adaptations and therefore should be considered ergogenic. In our view, one should take a broader view about the ergogenic value of supplements. While we are interested in determining the performance enhancement effects of a supplement on a single bout of exercise, we also realize that one of the goals of training is to help people tolerate training to a greater degree. People who tolerate training better usually experience greater gains from training over time. Consequently, employing nutritional practices that help prepare people to perform and/or enhance recovery from exercise should also be viewed as ergogenic.

What are Dietary Supplements and How Are They Regulated?

According to the Food and Drug Administration (FDA), dietary supplements were regulated in the same manner as food prior to 1994 [11]. Consequently, the manufacturing processes, quality, and labeling of supplements were monitored by FDA. However, many people felt that the FDA was too restrictive in regulating dietary supplements. As a result, Congress passed the Dietary Supplement Health and Education Act (DSHEA) in 1994 which placed dietary supplements in a special category of "foods". In October 1994, DSHEA was signed into law by President Clinton. The law defined a "dietary supplement" as a product taken by mouth that contains a "dietary ingredient" intended to supplement the diet. “Dietary ingredients" may include vitamins, minerals, herbs or other botanicals, amino acids, and substances (e.g., enzymes, organ tissues, glandulars, and metabolites). Dietary supplements may also be extracts or concentrates from plants or foods. Dietary supplements are typically sold in the form of tablets, capsules, soft gels, liquids, powders, and bars. Products sold as dietary supplements must be clearly labeled as a dietary supplement.

According to DSHEA, dietary supplements are not drugs. Dietary supplement ingredients that were sold prior to 1994 are therefore not required to be shown to be safe and/or effective in clinical trials prior to being approved for sale by the FDA. However, new dietary supplement ingredients introduced after 1994 must undergo pre-market review for safety data by the FDA before it can be legally sold. Supplement companies are responsible for determining that the dietary supplements it manufactures or distributes are safe and that any representations or claims made about them are substantiated by adequate evidence to show that they are not false or misleading. Because of this, DSHEA requires supplement manufacturers to include on the label that *“This statement has not been evaluated by the FDA. This product is not intended to diagnose, treat, cure, or prevent any disease".* According to the 1994 Nutrition Labeling and Education Act (NELA), the FDA has the ability to review and approve health claims for dietary supplements and foods. However, since the law was passed, it has only reviewed a few claims. The delay in reviewing health claims of dietary supplements resulted in a law suit filed by Pearson & Shaw et al v. Shalala et al in 1993. After years of litigation, U.S. Court of Appeals for the District of Columbia Circuit ruled in 1999 that qualified health claims may now be made about dietary supplements with approval by FDA as long as the statements are truthful and based on science. Supplement companies wishing to make health claims about supplements can submit research evidence to the FDA for approval. Additionally, they must submit an Investigation of New Drug (IND) application to FDA if a research study on a nutrient is designed to treat an illness and/or medical affliction and/or the company hopes to one day obtain approval for making a qualified health claim if the outcome of the study supports the claim. Studies investigating structure and function claims, however, do not need to be submitted to the FDA as an IND.

Manufacturers and distributors of dietary supplements are not currently required to record, investigate or forward to FDA any reports they receive on injuries or illnesses that may be related to the use of their products. However, the FDA and other groups have established phone hotlines and online adverse event monitoring systems to report problems they believe may be a result of taking dietary supplements. While these reports are unsubstantiated, can be influenced by media attention to a particular supplement, and do not necessarily show a cause and effect, they are used by the FDA to monitor trends and "signals" that may suggest a problem. Once a dietary supplement product is marketed, the FDA has the responsibility for showing that a dietary supplement is unsafe before it can take action to restrict the product's use or removal from the marketplace. The Federal Trade Commission (FTC) is responsible to make sure manufacturers are truthful regarding claims they make about dietary supplements. The FDA has the power to remove supplements from the market if it has sufficient scientific evidence to show the supplement is unsafe. Additionally, the FTC has the power to act against companies who make false and/or misleading marketing claims about a specific product. This includes acting against companies if the ingredients found in the supplement do not match label claims. While this does not ensure the safety of dietary supplements, it does provide a means for governmental oversight of the dietary supplement industry if adequate resources are provided to enforce DSHEA. Since inception of DSHEA, the FDA has required a number of supplement companies to submit evidence showing safety of their products and acted to remove a number of products sold as dietary supplements from sale in the U.S. due to safety concerns. Additionally, the FTC has acted against a number of supplement companies for misleading advertisements and/or structure and function claims.

As can be seen, although some argue that the dietary supplement industry is "unregulated" and/or may have suggestions for additional regulation, manufacturers of dietary supplements must adhere to a number of federal regulations before a product can go to market. Further, they must have evidence that the ingredients sold in their supplements are generally safe if requested to do so by the FDA. For this reason, over the last 10-15 years, most quality supplement companies have employed a team of researchers (many of whom are MS or PhD prepared exercise physiologists) who help educate the public about nutrition and exercise, provide input on product development, conduct preliminary research on products, and/or assist in coordinating research trials conducted by independent research teams (e.g., university based researchers or clinical research sites). They also consult with marketing teams with the responsibility to ensure structure and function claims do not misrepresent results of research findings. This has increased job opportunities for exercise physiologists as well as enhanced opportunities for external funding for research groups interested in exercise nutrition research. While it is true that some companies use borrowed science, suppress negative findings, and/or exaggerate results from research studies, the trend in the nutrition industry is to develop scientifically sound supplements. This trend toward greater research support is the result of: 1.) attempts to honestly and accurately inform the public about results; 2.) efforts to have data to support safety and efficacy on products for FDA and the FTC; and/or, 3.) to provide scientific evidence to support advertising claims and increase sales. This trend is due in large part to greater scrutiny from the FDA and FTC as a result of increased consumer expectations and political pressure to ensure that companies sell quality products that have been shown to be safe and effective in clinical trials. In our experience, companies who adhere to these ethical standards prosper while those who do not struggle to adhere to FDA and FTC guidelines and lose consumer confidence. When this occurs, companies are often sued by consumers and/or are forced out of business because ultimately the consumer has the final word on whether a supplement or supplement company is credible or not.

How to Evaluate Nutritional Ergogenic Aids

When you evaluate the ergogenic value of a nutritional supplement or training device/method, we recommend that you go through a process of evaluating the validity and scientific merit of claims made. This can be accomplished by evaluating the theoretical rationale behind the supplement/technique and determining whether there is any well-controlled data showing the supplement/technique works. Training devices and supplements based on sound scientific rationale with supportive research showing effectiveness may be worth trying and/or recommending. However, those based on unsound scientific rationales and/or little to no data supporting the ergogenic value for people involved in intense training may not. The exercise physiologist should be a resource to help their clients interpret the scientific and medical research that may impact on their welfare and/or help them train more wisely. The following are the questions we recommend asking when evaluating the potential ergogenic value of a supplement.

Does the theory make sense?

Most supplements that have been marketed to improve health and/or exercise performance are based on theoretical applications derived from basic and/or clinical research studies. Based on these preliminary studies, a training device or supplement is often marketed to people proclaiming the benefits observed in these basic research studies. Although the theory may sound good, critical analysis of the theory often reveals flaws in scientific logic and/or that the claims made don't quite match up with the literature cited. If you do your homework, you can discern whether a supplement has been based on sound scientific evidence or not. To do so, we suggest you read reviews about the training method, nutrient, and/or supplement from researchers who have been intimately involved in this line of research and/or consult reliable references about nutritional and herbal supplements [12-16]. We also suggest doing a search on the nutrient/supplement on the National Library of Medicine's Pub Med Online [17]. A quick look at these references will often help you know whether the theory is plausible or not. In my experience, proponents of ergogenic aids often overstate claims made about training devices and/or nutritional supplements while opponents of nutritional supplements and ergogenic aids are either unaware and/or ignorant of research supporting their use. The exercise physiologist has the responsibility to know the literature and/or search available data bases to know whether there is merit or not to a proposed ergogenic aid.

Is there any scientific evidence supporting the ergogenic value?

The next question suggest asking is whether there is any well-controlled data showing the proposed ergogenic aid works as claimed in athletes or people involved in training. The first place we look is the list of references cited in marketing material supporting their claims. We look to see if the abstracts or articles cited are general references or specific studies that have evaluated the efficacy of the nutrient/supplement. We then critically evaluate the abstracts and articles by asking a series of questions.

- *Are the studies simply basic research done in animals/clinical populations or have the studies been conducted on athletes?* Studies reporting improved performance in rats may be insightful but research conducted on athletes is much more convincing.
- *Were the studies well controlled?* For ergogenic aid research, the study should be a placebo controlled, double blind, and randomized clinical trail if possible. This means that neither the

researcher's nor the subject's were aware which group received the supplement or the placebo during the study and that the subjects were randomly assigned into the placebo or supplement group. At times, supplement claims have been based on poorly designed studies (i.e., small groups of subjects, no control group, use of unreliable tests, etc) and/or testimonials which may make interpretation much more difficult. Studies that are well controlled clinical trials provide stronger evidence as to the potential ergogenic value than those that are not well controlled.

- *Do the studies report statistically significant results or are claims being made on non-significant means or trends reported?* Appropriate statistical analysis of research results allows for an unbiased interpretation of data. Although studies reporting statistical trends may be of interest and lead researchers to conduct additional research, studies reporting statistically significant results are obviously more convincing. With this said, exercise physiologist must be careful not to commit type II statistical error (i.e., indicating that no differences were observed when a true effect was seen but not detected statistically). Since many studies on ergogenic aids (particularly in high level athletes) evaluate small numbers of subjects, results may not reach statistical significance even though large mean changes were observed. In these cases, additional research is warranted to further examine the potential ergogenic aid before conclusions can be made.
- *Do the results of the studies cited match the claims made about the supplement?* It is not unusual for marketing claims to greatly exaggerate the results found in the actual studies. Therefore, you should compare results observed in the studies to marketing claims. Reputable companies accurately report results of studies so that consumers can make informed decisions about whether to try a product or not.
- *Were results of the study presented at a reputable scientific meeting and/or published in a peer-reviewed scientific journal?* At times, claims are based on research that has either never been published or only published in an obscure journal. The best research is typically presented at respected scientific meetings and/or published in reputable peer-reviewed journals.
- *Have the research findings been replicated at several different labs?* The best way to know an ergogenic aid works is to see that results have been replicated in several studies preferably by a number of researchers. The most reliable ergogenic aids are those in which a number of studies, conducted at different labs, have reported similar results.

Is the Supplement Legal and Safe?

The final question we ask is whether the supplement is legal and/or safe. Some athletic associations have banned the use of various nutritional supplements (e.g., prohormones, ephedra, etc). Obviously, if the supplement is banned, the exercise physiologist should discourage its use. In addition, many supplements have not been studied for long-term safety. People who consider taking nutritional supplements should be well aware of the potential side effects so that they can make an informed decision regarding whether to use a supplement or not. Additionally, they should consult with a knowledgeable physician to see if there are any underlying medical problems that may contraindicate use. When evaluating the safety of a supplement, we suggest looking to see if any side effects have been reported in the scientific or medical literature. In particular, we suggest determining how long a particular supplement has been studied, the dosages evaluated, and whether any side effects were observed. We also recommend consulting the PDR for nutritional supplements and herbal supplements to see if any side effects have been reported and/or there are any known drug interactions. If no side effects have been reported in the scientific/medical literature, we generally will view the supplement as safe for the length of time and dosages evaluated.

Classifying and Categorizing Supplements

Dietary supplements may contain carbohydrate, protein, fat, minerals, vitamins, herbs, and/or various plant/food extracts. Supplements can generally be classified as convenience supplements (e.g., energy bars, meal replacement powders, ready to drink supplements) designed to provide a convenient means of meeting caloric needs and/or managing caloric intake, weight gain supplements, weight loss supplements, and performance enhancement supplements. Based on the above criteria, we generally categorize nutritional supplements into the following categories:

I. **Apparently Effective.** Supplements that help people meet general caloric needs and/or the majority of research studies show is effective and safe.
II. **Possibly Effective.** Supplements that initial studies support the theoretical rationale but that more research is needed to determine how the supplement may affect training and/or performance.
III. **Too Early To Tell.** Supplements that the theory may make sense but there is insufficient research to support the use at this time.
IV. **Apparently Ineffective.** Supplements that the theoretical rationale makes little scientific sense and/or research has clearly shown to be ineffective.

When exercise physiologist's council people who train, they should first evaluate their diet and training program. They should make sure that the athlete is eating an energy balanced, nutrient dense diet and that they are training intelligently. This is the foundation to build a good program. Following this, we recommend that they generally only recommend supplements in category I. If someone is interested in trying supplements in category II, they should make sure that they understand that these supplements are more experimental and that they may or may not see the type of results claimed. We recommend discouraging people from trying supplements in category III because there isn't enough data available on whether they work or not. However, if someone wants to try one of these supplements, they should understand that although there is some theoretical rationale, there is little evidence to support use at this time. Obviously, we do not support athletes taking supplements in categories IV. We believe that this approach is a more scientifically supportable and balanced view than simply dismissing the use of all dietary supplements out of hand.

General Dietary Guidelines for Active Individuals

A well-designed diet that meets energy intake needs and incorporates proper timing of nutrients is the foundation upon which a good training program can be developed. Research has clearly shown that athletes that do not ingest enough calories and/or do not consume enough of the right type of macronutrients may impede training adaptations while athletes who consume a good diet can help the body adapt to training. Moreover, maintaining an energy deficient diet during training may lead to loss of muscle mass, increased susceptibility to illness, and increase prevalence of overreaching and/or overtraining. Incorporating good dietary practices as part of a training program is one way to help optimize training adaptations and prevent overtraining. The following overviews energy intake and major nutrient needs of active individuals.

Energy Intake. The first component to optimize training and performance through nutrition is to ensure the athlete is consuming enough calories to offset energy expenditure [9, 18-20]. People who participate in a general fitness program (e.g., exercising 30 - 40 minutes per day, 3 times per week) can generally meet nutritional needs following a normal diet (e.g., 1,800 – 2,400 kcals/day or about 25 - 35 kcals/kg/day for a 50 – 80 kg individual) because their caloric demands from exercise are not too great (e.g., 200 – 400 kcals/session) [9]. However, athletes involved in moderate levels of intense training (e.g., 2-3 hours per day of intense exercise performed 5-6 times per week) or high volume intense training (e.g., 3-6 hours per day of intense training in 1-2 workouts for 5-6 days per week) may expend 600 – 1,200 kcals or more per hour during exercise [9, 21]. For this reason, their caloric needs may approach 50 – 80 kcals/kg/day (2,500 – 8,000 kcals/day for a 50 – 100 kg athlete). For elite athletes, energy expenditure during heavy training or competition may be enormous. For example, energy expenditure for cyclists to compete in the Tour de France has been estimated as high as 12,000 kcals/day (150 - 200 kcals/kg/d for a 60 – 80 kg athlete) [21-23]. Additionally, caloric needs for large athletes (i.e., 100 – 150 kg) may range between 6,000 – 12,000 kcals/day depending on the volume and intensity of different training phases [21].

Although some exercise physiologists and nutritionists argue that athletes can meet caloric needs simply by consuming a well-balanced diet, it is often very difficult for larger athletes and/or athletes engaged in high volume/intense training to be able to eat enough food in order to meet caloric needs [9, 19, 21-23]. Maintaining an energy deficient diet during training often leads to significant weight loss (including muscle mass), illness, onset of physical and psychological symptoms of overtraining, and reductions in performance [20]. Nutritional analyses of athletes' diets have revealed that many are susceptible to maintaining negative energy intakes during training. Susceptible populations include runners, cyclists, swimmers, triathletes, gymnasts, skaters, dancers, wrestlers, boxers, and athletes attempting to lose weight too quickly [19]. Additionally, female athletes have been reported to have a high incidence of eating disorders [19]. Consequently, it is important for the exercise physiologist working with athletes to ensure that athletes are well-fed and consume enough calories to offset the increased energy demands of training and maintain body weight. Although this sounds relatively simple, intense training often suppresses appetite and/or alters hunger patterns so that many athletes do not feel like eating [19]. Some athletes do not like to exercise within several hours after eating because of sensations of fullness and/or a predisposition to cause gastrointestinal distress. Further, travel and training schedules may limit food availability and/or the types of food athletes are accustomed to eating. This means that care should be taken to plan meal times in concert with training as well as make sure athletes have sufficient availability of nutrient dense foods throughout the day for snacking between meals (e.g., drinks, fruit, carbohydrate/protein bars, etc) [9, 18, 19]. For this reason, sport nutritionists' often recommend that athletes consume 4-6 meals per day and snack in between meals in order to meet energy needs. Use of nutrient dense energy bars and high calorie carbohydrate/protein supplements provides a convenient way for athletes to supplement their diet in order to maintain energy intake during training.

Carbohydrate. The second component to optimizing training and performance through nutrition is to ensure that athletes consume the proper amounts of carbohydrate, protein and fat in their diet. Individuals engaged in a general fitness program can typically meet macronutrient needs by consuming a normal diet (i.e., 45-55% carbohydrate [3-5 grams/kg/day], 10-15% protein [0.8 – 1.0 gram/kg/day], and 25-35% fat [0.5 – 1.5 grams/kg/day]). However, athletes involved in moderate and high volume training need greater amounts of carbohydrate and protein in their diet to meet macronutrient needs. For example, in terms of carbohydrate needs, athletes involved in moderate amounts of intense training (e.g., 2-3 hours per day of intense exercise performed 5-6 times per week) typically need to consume a diet consisting of 55-65% carbohydrate (i.e., 5-8 grams/kg/day or 250 – 1,200 grams/day for 50 – 150 kg athletes) in order to maintain liver and muscle glycogen stores [9, 18]. Research has also shown that athletes involved in high volume intense training (e.g., 3-6 hours per day of intense training in 1-2 workouts for 5-6 days per week) may need to consume 8-10 grams/day of carbohydrate (i.e., 400 – 1,500 grams/day for 50 – 150 kg athletes) in order to maintain muscle glycogen levels [9, 18]. This would be equivalent to consuming 0.5 – 2.0 *kg* of spaghetti. Preferably, the majority of dietary carbohydrate should come from complex carbohydrates with a low to moderate glycemic index (e.g., grains, starches, fruit, maltodextrins, etc). However, since it is physically difficult to consume that much carbohydrate per day when an athlete is involved in intense training, many nutritionists and exercise physiologist recommend that athletes consume concentrated carbohydrate juices/drinks and/or consume high carbohydrate supplements to meet carbohydrate needs. While consuming this amount of carbohydrate is not necessary for the fitness minded individual who only trains 3-4 times per week for 30-60 minutes, it is essential for competitive athletes engaged in intense moderate to high volume training.

Protein. There has been considerable debate regarding protein needs of athletes [24-28]. Initially, it was recommended that athletes do not need to ingest more than the RDA for protein (i.e., 0.8 to 1.0 g/kg/d for children, adolescents and adults). However, research over the last decade has indicated that athletes engaged in intense training need to ingest about 1.5 – 2 times the RDA of protein in their diet (1.5 to 2.0 g/kg/d) in order to maintain protein balance [24-28]. If an insufficient amount of protein is obtained from the diet, an athlete will maintain a negative nitrogen balance which can increase protein catabolism and slow recovery. Over time, this may lead to lean muscle wasting and training intolerance [9, 20].

For people involved in a general fitness program, protein needs can generally be met by ingesting 0.8 – 1.0 grams/kg/day of protein. It is generally recommended that athletes involved in moderate amounts of intense training consume 1 – 1.5 grams/kg/day of protein (50 – 225 grams/day for a 50 – 150 kg athlete) while athletes involved in high volume intense training consume 1.5 – 2.0 grams/kg/day of protein (75 – 300 grams/day for a 50 – 150 kg athlete) [29]. This protein need would be equivalent to ingesting 3 – 11 servings of chicken or fish per day for a 50 – 150 kg athlete [29]. Although smaller athletes typically can ingest this amount of protein in their normal diet, larger athletes often have difficulty consuming this much dietary protein. Additionally, a number of athletic populations have been reported to be susceptible to protein malnutrition (e.g., runners, cyclists, swimmers, triathletes, gymnasts, dancers, skaters, wrestlers, boxers, etc). Therefore, care should be taken to ensure that athletes consume a sufficient amount of quality protein in their diet in order to maintain nitrogen balance (e.g., 1.5 - 2 grams/kg/day).

However, it should be noted that not all protein is the same. Proteins differ based on the source that the protein was obtained, the amino acid profile of the protein, and the methods of processing or isolating the protein [30]. These differences influence availability of amino acids and peptides that have been reported to possess biological activity (e.g., á-lactalbumin, ß-lactoglobulin, glycomacropeptides, immunoglobulins, lactoperoxidases, lactoferrin, etc). Additionally, the rate and metabolic activity of the protein [30]. For example, different types of proteins (e.g., casein and whey) are digested at different rates which directly affect catabolism and anabolism [30-33]. Therefore, care should be taken not only to make sure the athlete consumes enough protein in their diet but also that the protein is high quality. The best dietary sources of low fat and high quality protein are light skinless chicken, fish, egg white and skim milk (casein and whey) [30]. The best sources of high quality protein found in nutritional supplements is whey, colostrum, casein, milk proteins and egg protein [29, 30]. Although some athletes may not need to supplement their diet with protein and some exercise physiologists may not think that protein supplements are necessary, suggestions that it is unethical for an exercise physiologist to recommend that some athletes supplement their diet with protein in order to meet dietary protein needs and/or provide essential amino acids following exercise in order to optimize protein synthesis is clearly not supported by the literature.

Fat. The dietary recommendations of fat intake for athletes are similar to or slightly greater than those recommended for non-athletes in order to promote health. Maintenance of energy balance, replenishment of intramuscular triacylglycerol stores and adequate consumption of essential fatty acids are of greater importance among athletes and allow for somewhat increased intake [34]. This depends on the athlete's training state and goals. For example, higher-fat diets appear to maintain circulating testosterone concentrations better than low-fat diets [35-37]. This has relevance to the documented testosterone suppression which can occur during volume-type overtraining [38]. Generally, it is recommended that athletes consume a moderate amount of fat (approximately 30% of their daily caloric intake), while increases up to 50% of kcal can be safely ingested by athletes during regular high-volume training [34]. For athletes attempting to decrease body fat, however, it has been recommended that they consume 0.5 to 1 g/kg/d of fat [9]. The reason for this is that some weight loss studies indicate that people who are most successful in losing weight and maintaining the weight loss are those who ingest less than 40 g/d of fat in their diet [39, 40] although this is not always the case [41]. Certainly, the type of dietary fat (e.g. n-6 versus n-3; saturation state) is a factor in such research and could play an important role in any discrepancies [42, 43]. Strategies to help athletes manage dietary fat intake include teaching them which foods contain various types of fat so that they can make better food choices and how to how to count fat grams [9, 19].

Strategic Eating and Refueling. In addition to the general nutritional guidelines described above, research has also demonstrated that timing and composition of meals consumed may play a role in optimizing performance, training adaptations, and preventing overtraining [9, 18, 44, 45]. In this regard, it takes about 4 hours for carbohydrate to be digested and begin to be stored as muscle and liver glycogen. Consequently, pre-exercise meals should be consumed about 4 to 6 h before exercise [18]. This means that if an athlete trains in the afternoon, breakfast is the most important meal to top off muscle and liver glycogen levels. Research has also indicated that ingesting a light carbohydrate and protein snack 30 to 60 min prior to exercise (e.g., 50 g of carbohydrate and 5 to 10 g of protein) serves to increase carbohydrate availability toward the end of an intense exercise bout [46, 47]. This also serves to increase availability of amino acids and decrease exercise-induced catabolism of protein [44, 46, 47].

When exercise lasts more than one hour, athletes should ingest glucose/electrolyte solution (GES) drinks in order to maintain blood glucose levels, help prevent dehydration, and reduce the immunosuppressive effects of intense exercise [18, 48-53]. Following intense exercise, athletes should consume carbohydrate and protein (e.g., 1 g/kg of carbohydrate and 0.5 g/kg of protein) within 30 min after exercise as well as consume a high carbohydrate meal within two hours following exercise [9, 44, 45]. This nutritional strategy has been found to accelerate glycogen resynthesis as well as promote a more anabolic hormonal profile that may hasten recovery [54-56]. Finally, for 2 to 3 days prior to competition, athletes should taper training by 30 to 50% and consume 200 to 300 g/d of *extra* carbohydrate in their diet. This *carbohydrate loading* technique has been shown to supersaturate carbohydrate stores prior to competition and improve endurance exercise capacity [9, 18, 45]. Thus, the type of meal and timing of eating are important factors in maintaining carbohydrate availability during training and potentially decreasing the incidence of overtraining.

Vitamins. Vitamins are essential organic compounds which serve to regulate metabolic processes, energy synthesis, neurological processes, and prevent destruction of cells. There are two primary classifications of vitamins: fat and water soluble. The fat soluble vitamins include vitamins A, D, E, & K. The body stores fat soluble vitamins and therefore excessive intake may result in toxicity. Water soluble vitamins are B vitamins and vitamin C. Since these vitamins are water soluble, excessive intake of these vitamins are eliminated in urine. Table 1 describes RDA, proposed ergogenic benefit, and summary of research findings for fat and water soluble vitamins. Although research has demonstrated that specific vitamins may posses some health benefit (e.g., vitamin E, niacin, folic acid, vitamin C, etc), few have been reported to directly provide ergogenic value for athletes. However, some vitamins may help athletes tolerate training to a better degree by reducing oxidative damage (vitamin E, C) and/or help to maintain a healthy immune system during heavy training (vitamin C). Theoretically, this may help athletes tolerate heavy training leading to improved performance. The remaining vitamins reviewed appear to have little ergogenic value for athletes who consume a normal, nutrient dense diet. Since dietary analyses of athletes have found deficiencies in caloric and vitamin intake, many sport nutritionists' recommend that athletes consume a low-dose one a day multivitamin and/or a vitamin enriched post-workout carbohydrate/protein supplement during periods of heavy training. The American Medical Association also recently evaluated the available medical literature and recommended that Americans consume a one-a-day low-dose multivitamin in order to promote general health. Suggestions that there is no benefit of vitamin supplementation for athletes and/or it is unethical for an exercise physiologist to recommend that their clients take a one-a-day multi-vitamin and/or suggest taking other vitamins that may reduce cholesterol levels (niacin), serve as antioxidants (Vitamin E), decrease risk to heart disease (niacin, Vitamin E), or may help maintain a health immune system (Vitamin C) is not consistent with current available literature.

Minerals. Minerals are essential inorganic elements necessary for a host of metabolic processes. Minerals serve as structure for tissue, important components of enzymes and hormones, and regulators of metabolic and neural control. Some minerals have been found to be deficient in athletes or become deficient in response to training and/or prolonged exercise. When mineral status is inadequate, exercise capacity may be reduced. Dietary supplementation of minerals in deficient athletes has generally been found to improve exercise capacity. Additionally, supplementation of specific minerals in non-deficient athletes has also been reported to affect exercise capacity. Table 2 describes minerals that have been purported to affect exercise capacity in athletes. Of the minerals reviewed, several appear to possess health and/or ergogenic value for athletes under certain conditions. For example, calcium supplementation in athletes susceptible to premature osteoporosis may help maintain bone mass. There is also recent evidence that dietary calcium may help manage body composition. Iron supplementation in athletes prone to iron deficiencies and/or anemia has been reported to improve exercise capacity. Sodium phosphate loading has been reported to increase maximal oxygen uptake, anaerobic threshold, and improve endurance exercise capacity by 8 to 10%. Increasing dietary availability of salt (sodium chloride) during the initial days of exercise training in the heat has been reported to help maintain fluid balance and prevent dehydration. Finally, zinc supplementation during training has been reported to decrease exercise-induced changes in immune function. Consequently, somewhat in contrast to vitamins, there appear to be several minerals that may enhance exercise capacity and/or training adaptations for athletes under certain conditions. However, although ergogenic value has been purported for remaining minerals, there is little evidence that boron, chromium, magnesium, or vanadium affect exercise capacity or training adaptations in healthy individuals eating a normal diet. Suggestions that there is no benefit of mineral supplementation for athletes and/or it is unethical for an exercise physiologist to recommend that their clients take minerals that research has shown may affect health and/or performance is not consistent with current available literature.

Water. The most important nutritional ergogenic aid for athletes is water. Exercise performance can be significantly impaired when 2% or more of body weight is lost through sweat. For example, when a 70-kg athlete loses more than 1.4 kg of body weight during exercise (2%), performance capacity is often significantly decreased. Further, weight loss of more than 4% of body weight during exercise may lead to heat illness, heat exhaustion, heat stroke, and possibly death [53]. For this reason, it is critical that athletes consume a sufficient amount of water and/or GES sports drinks during exercise in order to maintain hydration status. The normal sweat rate of athletes ranges from 0.5 to 2.0 L/h depending on temperature, humidity, exercise intensity, and their sweat response to exercise [53]. This means that in order to maintain fluid balance and prevent dehydration, athletes need to ingest 0.5 to 2 L/h of fluid in order to offset weight loss. This requires frequent ingestion of 6-8 oz of cold water or a GES sports drink every 5 to 15-min during exercise [53, 57-60]. Athletes and should not depend on thirst to prompt them to drink because people do not typically get thirsty until they have lost a significant amount of fluid through sweat. Additionally, athletes should weigh themselves prior to and following exercise training to ensure that they maintain proper hydration [53, 57-60]. The athlete should consume 3 cups of water for every pound lost during exercise in order adequately rehydrate themselves [53]. Athletes should train themselves to tolerate drinking greater amounts of water during training and make sure that they consume more fluid in hotter/humid environments. Preventing dehydration during exercise is one of the most effective ways to maintain exercise capacity. Finally, inappropriate and excessive weight loss techniques (e.g., cutting weight in saunas, wearing rubber suits, severe dieting, vomiting, using diuretics, etc) are extremely dangerous and should be prohibited. Exercise physiologists can play an important role in educating athletes and coaches about proper hydration methods and supervising fluid intake during training and competition.

Dietary Supplements and Athletes

Most of the work we do with athletes regarding sport nutrition is to teach them and their coaches how to structure their diet and time food intake to optimize performance and recovery. Dietary supplements can play a meaningful role in helping athletes consume the proper amount of calories, carbohydrate, and protein in their diet. However, they should be viewed as supplements to the diet, not replacements for a good diet. While it is true that most dietary supplements available for athletes have little scientific data supporting their potential role to enhance training and/or performance, it is also true that a number of nutrients and/or dietary supplements have been shown to help improve performance and/or recovery. This can help augment the normal diet to help optimize performance. Exercise physiologists must be aware of the current data regarding nutrition, exercise, and performance and be honest about educating their clients about results of various studies (whether pro or con). With the proliferation of information available about nutritional supplements to the consumer, the exercise physiologist, nutritionist, and nutrition industry lose credibility when they do not accurately describe results of various studies to the public. The following overviews several classifications of nutritional supplements that are often taken by athletes and categorizes them into apparently effective, possibly effective, too early to tell, and apparently ineffective supplements based on my interpretation of the literature. It should be noted that this analysis will primarily focus on whether the proposed nutrient has been found to affect exercise and/or training adaptations based on the current available literature. Additional research may reveal it may or may not possess ergogenic value which may then change its classification. It should be also noted that although there may be little ergogenic value to some nutrients, there may be some potential health benefits that may be helpful for some populations. Therefore, just because a nutrient does not appear to affect performance and/or training adaptations, that does not mean it may not have possible health benefits.

Convenience Supplements

Convenience supplements are meal replacement powders (MRP's), ready to drink supplements (RTD's), energy bars, and energy gels. They currently represent the largest segment of nutrition industry representing 50 – 75% of most company's sales. They are typically fortified with 33 – 50% of the RDA for vitamins and minerals and typically differ on the amount of carbohydrate, protein, and fat they contain. They may also differ based whether they are fortified with various nutrients purported to promote weight gain, enhance weight loss, and/or improve performance. Most people view these supplements as a high quality snacks and/or use them to help control caloric intake when trying to gain and/or lose weight. In our view, MRP's, RTD's, and energy bars/gels can provide a convenient way for people to meet specific dietary needs and/or serve as good alternatives to fast food. Use of these types of products can be particularly helpful in providing carbohydrate, protein, and other nutrients prior to and/or following exercise in an attempt to optimize nutrient intake when an athlete doesn't have time to sit down for a good meal. However, they should be used to improve dietary availability of macronutrients – not as a replacement for a good diet. Care should also be taken to make sure they do not contain any banned or prohibited nutrients.

Muscle Building Supplements

The following provides an analysis of the literature regarding purported weight gain supplements and our general interpretation of how they should be categorized based on this information. Table 3 summarizes how we currently classify the ergogenic value of a number of purported performance-enhancing, muscle building, and fat loss supplements based on an analysis of the available scientific evidence.

Apparently Effective

Weight Gain Powders. One of the most common means athletes have employed to increase muscle mass is to add extra calories to the diet. Most athletes "bulk up" in this manner by consuming extra food and/or weight gain powders. Studies have consistently shown that simply adding an extra 500 – 1,000 calories per day to your diet will promote weight gain [28, 44]. However, only about 30 – 50% of the weight gained on high calorie diets is muscle while the remaining amount of weight gained is fat. Consequently, increasing muscle mass by ingesting a high calorie can help you build muscle but the accompanying increase in body fat may not be desirable for everyone. Therefore, we typically do not recommend this type of weight gain approach.

Creatine. In our view, the most effective nutritional supplement available to athletes to increase high intensity exercise capacity and muscle mass during training is creatine. Numerous studies have indicated that creatine supplementation increases body mass and/or muscle mass during training [61] Gains are typically 2 – 5 pounds greater than controls during 4 – 12 weeks of training [62]. The gains in muscle mass appear to be a result of an improved ability to perform high intensity exercise enabling an athlete to train harder and thereby promote greater training adaptations and muscle hypertrophy [63-65]. The only clinically significant side effect reported from creatine supplementation has been weight gain [61, 62, 66, 67] Although concerns have been raised about the safety and possible side effects of creatine supplementation [68, 69], recent long-term safety studies have reported no apparent side effects [67, 70, 71] and/or that creatine may lessen the incidence of injury during training [72-74]. Consequently, supplementing the diet with creatine and/or creatine containing formulations seems to be a safe and effective method to increase muscle mass.

b-hydroxy b-methylbutyrate (HMB). HMB is a metabolite of the amino acid leucine. Leucine and metabolites of leucine have been reported to inhibit protein degradation [75]. Supplementing the diet with 1.5 to 3 g/d of calcium HMB has been typically reported to increase muscle mass and strength particularly among untrained subjects initiating training [76-81] and the elderly [82]. Gains in muscle mass are typically 0.5 to 1 kg greater than controls during 3 – 6 weeks of training. There is also recent evidence that HMB may lessen the catabolic effects of prolonged exercise [83] and that there may be additive effects of co-ingesting HMB with creatine [84, 85]. However, the effects of HMB supplementation in athletes are less clear. Most studies conducted on trained subjects have reported non-significant gains in muscle mass possibly due to a greater variability in response of HMB supplementation among athletes [86-88] . Consequently, there is fairly good evidence showing that HMB may enhance training adaptations in individuals initiating training. However, additional research is necessary to determine whether HMB may enhance training adaptations in athletes.

Possibly Effective

Branched Chain Amino Acids (BCAA). BCAA supplementation has been reported to decrease exercise-induced protein degradation and/or muscle enzyme release (an indicator of muscle damage) possibly by promoting an anti-catabolic hormonal profile [44, 46, 89]. Theoretically, BCAA supplementation during intense training may help minimize protein degradation and thereby lead to greater gains in fat-free mass. There is some evidence to support this hypothesis. For example, Schena and colleagues [90] reported that BCAA supplementation (~10 g/d) during 21-days of trekking at altitude increased fat free mass (1.5%) while subjects ingesting a placebo had no change in muscle mass. Bigard and associates [91] reported that BCAA supplementation appeared to minimize loss of muscle mass in subjects training at altitude for 6-weeks. Finally, Candeloro and coworkers [92] reported that 30 days of BCAA supplementation (14 grams/day) promoted a significant increase in muscle mass (1.3%) and grip strength (+8.1%) in untrained subjects. Although more research is necessary, these findings suggest that BCAA supplementation may have some impact on body composition.

Essential Amino Acids (EAA). Recent studies have indicated that ingesting 3 to 6 g of EAA prior to [93, 94] and or following exercise stimulates protein synthesis [94-101]. Theoretically, this may enhance gains in muscle mass during training. To support this theory, a recent study by Esmarck and colleagues [102] found that ingesting EAA with carbohydrate immediately following resistance exercise promoted significantly greater training adaptations as compared to waiting until 2-hours after exercise to consume the supplement. Although more data is needed, there appears to be strong theoretical rationale and some supportive evidence that EAA supplementation may enhance protein synthesis and training adaptations.

Glutamine. Glutamine is the most plentiful non-essential amino acid in the body and plays a number of important physiological roles [44]. Glutamine has been reported to increase cell volume and stimulate protein [103-105] and glycogen synthesis [106]. Theoretically, glutamine supplementation prior to and/or following exercise (e.g., 6-10 g) may help to optimize cell hydration and protein synthesis during training leading to greater gains in muscle mass and strength [44, 107]. In support of this hypothesis, a recent study by Colker and associates [108] found that subjects who supplemented their diet with glutamine (5 grams) and BCAA (3 grams) enriched whey protein during training promoted about a 2 pound greater gain in muscle mass and greater gains in strength than ingesting whey protein alone. Although more data is needed, there appears to be a strong scientific rationale and some preliminary evidence to indicate that glutamine may help build muscle.

Protein. As previously described, research has indicated that people undergoing intense training may need additional protein in their diet to meet protein needs (i.e., 1.5 – 2.0 grams/day). People who do not ingest enough protein in their diet may slow recovery and training adaptations [44]. Protein supplements offer a convenient way to ensure that athletes consume quality protein in the diet and meet their protein needs. However, ingesting additional protein beyond that necessary to meet protein needs does not appear to promote additional gains in strength and muscle mass. The research focus over recent years has been to determine whether different types of protein (e.g., whey, casein, soy, milk proteins, colostrum, etc) and/or various biologically active protein subtypes and peptides (e.g., á-lactalbumin, ß-lactoglobulin, glycomacropeptides, immunoglobulins, lactoperoxidases, lactoferrin, etc) have varying effects on the physiological, hormonal, and/or immunological responses to training. In addition, whether timing of protein intake may play a role in protein synthesis and training adaptations [94-101]. Although more research is necessary in this area, research clearly indicates that protein needs of individuals engaged in intense training are elevated, that different types of protein have varying effects on anabolism and catabolism, that different types of protein subtypes and peptides have unique physiological effects, and that timing of protein intake may play an important role in optimizing protein synthesis following exercise. Therefore, it is simplistic and misleading to suggest that there is no data supporting contentions that athletes need more protein in their diet and/or there is no potential ergogenic value of incorporating different types of protein into the diet.

Too Early to Tell

a-ketoglutarate (a-KG). α-KG is an intermediate in the Krebs cycle that is involved in aerobic energy metabolism. There is some clinical evidence that α-KG may serve as an anticatabolic nutrient after surgery [109, 110]. However, it is unclear whether α-KG supplementation during training may affect training adaptations.

a-Ketoisocaproate (KIC). KIC is a branched-chain keto acid that is a metabolite of leucine metabolism. In a similar manner as HMB, leucine and metabolites of leucine are believed to possess anticatabolic properties [111]. There is some clinical evidence that KIC may spare protein degradation in clinical populations [112, 113]. Theoretically, KIC may help minimize protein degradation during training possibly leading to greater training adaptations. However, we are not aware of any studies that have evaluated the effects of KIC supplementation during training on body composition.

Ecdysterones. Ecdysterones (also known as ectysterone, 20 Beta-Hydroxyecdysterone, turkesterone, ponasterone, ecdysone, or ecdystene) are naturally derived phytoecdysteroids (i.e., insect hormones). They are typically extracted from the herbs *Leuza rhaptonticum* sp., *Rhaponticum carthamoides*, or *Cyanotis vaga*. They can also be found in high concentrations in the herb *Suma* (also known as Brazilian Ginseng or *Pfaffia*). Research from Russia and Czechoslovakia conducted over the last 30 years indicates that ecdysterones may possess some potentially beneficial physiological effects in insects and animals [114-118]. However, since most of the data on ecdysterones have been published in obscure journals, results are difficult to interpret. While future studies may find some ergogenic value of ecdysterones, it is our view that it is too early to tell whether phytoecdysteroids serve as a safe and effective nutritional supplement for athletes.

Growth Hormone Releasing Peptides (GHRP) and Secretogues. Research has indicated that growth hormone releasing peptides (GHRP) and other non-peptide compounds (secretagogues) appear to help regulate growth hormone (GH) release [119, 120]. These observations have served as the basis for development of nutritionally-based GH stimulators (e.g., amino acids, pituitary peptides, "pituitary substances", *macuna pruriens*, broad bean, alpha GPC, etc). Although there is clinical evidence that pharmaceutical grade GHRP's and some non-peptide secretagogues can increase GH and IGF-1 levels at rest and in response to exercise, it is currently unknown whether any of these nutritional alternatives would increase GH and/or affect training adaptations.

Isoflavones. Isoflavones are naturally occurring non-steroidal phytoestrogens that have a similar chemical structure as the ipriflavone (a synthetic flavonoid drug used in the treatment of osteoporosis) [121-123]. For this reason, soy protein (which is an excellent source of isoflavones) and isoflavone extracts have been investigated in the possible treatment of osteoporosis. Results of these studies have shown promise in preventing declines in bone mass in post-menopausal women as well as reducing risks to side effects associated with estrogen replacement therapy. More recently, the isoflavone extracts 7-isopropoxyisoflavone (ipriflavone) and 5-methyl-7-methoxy-isoflavone (methoxyisoflavone) have been marketed as "powerful anabolic" substances. These claims have been based on research described in patents filed in Hungary in the early 1970s [124, 125]. Although the data presented in the patents are interesting, there is currently no peer-reviewed data indicating that isoflavone supplementation affects exercise, body composition, or training adaptations.

Ornithine-a-ketoglutarate (OKG). OKG is another nutrient believed to possess anabolic/catabolic effect. Animal and clinical studies have suggested that patients administered OKG experienced improved protein balance [124, 125]. Theoretically, OKG may provide some value for athletes engaged in intense training. A recent study by Chetlin and colleagues [126] reported that OKG supplementation (10 grams/day) during 6-weeks of resistance training promoted greater gains in bench press. However, no significant differences were observed in squat strength, training volume, gains in muscle mass, or fasting insulin and growth hormone. Therefore, additional research is needed before conclusions can be drawn.

Sulfo-Polysaccharides (Myostatin Inhibitors). Myostatin or growth differentiation factor 8 (GDF-8) is a transforming growth factor that has been shown to serve as a genetic determinant of the upper limit of muscle size and growth [127]. Recent research has indicated that eliminating and/or inhibiting myostatin gene expression in mice [128] and cattle [129-131] promotes marked increases in muscle mass during early growth and development. The result is that these animals experience what has been termed as a "double-muscle" phenomenon apparently by allowing muscle to grow beyond its normal genetic limit. In agriculture research, eliminating and/or inhibiting myostatin may serve as an effective way to optimize animal growth leading to larger, leaner, and a more profitable livestock yield. In humans, inhibiting myostatin gene expression has been theorized as a way to prevent or slow down muscle wasting in various diseases, speed up recovery of injured muscles, and/or promote increases in muscle mass and strength in athletes [132]. While these theoretical possibilities may have great promise, research on the role of myostatin inhibition on muscle growth and repair is in the very early stages – particularly in humans. There is some evidence that myostatin levels are higher in the blood of HIV positive patients who have experience muscle wasting and that myostatin levels negatively correlate with muscle mass [127]. There is also evidence that myostatin gene expression may be fiber specific and that myostatin levels may be influenced by immobilization in animals [133]. Additionally, a recent study by Ivey and colleagues [132] reported that female athletes with a less common myostatin allele (a genetic subtype that may be more resistant to myostatin) experienced greater gains in muscle mass during training and less loss of muscle mass during detraining. No such pattern was observed in men with varying amounts of training histories and muscle mass. These early studies suggest that myostatin may play a role in regulating muscle growth to some degree. Recently, some nutrition supplement companies have marketed sulfo-polysaccharides (derived from a sea algae called *Cytoseira* canariensis) as a way to partially bind the myostatin protein in serum. Although this theory is interesting and studies examining this hypothesis are underway, there is currently no published data supporting the use of sulfo-polysaccharides as a muscle building supplement.

Smilax Officinalis (SO). SO is a compound which contains plant sterols purported to enhance immunity as well as provide an androgenic effect on muscle growth [9]. Some data supports the potential immune enhancing effects of SO. However, we are not aware of any data that show that SO supplementation increases muscle mass during training.

Zinc/Magnesium Aspartate (ZMA). ZMA formulations have recently become a popular supplement purported to promote anabolism at night. The theory is based on studies suggesting that zinc and magnesium deficiency may reduce the production of testosterone and insulin like growth factor (IGF-1). ZMA supplementation has been theorized to increase testosterone and IGF-1 leading to greater recovery, anabolism, and strength during training. In support of this theory, Brilla and Conte [134] reported that a zinc-magnesium formulation increased testosterone and IGF-1 (two anabolic hormones) leading to greater gains in strength in football players participating in spring training. While these data are interesting, more research is needed to further evaluate the role of ZMA on body composition and strength during training before conclusions can be drawn.

Apparently Ineffective

Boron. Boron is a trace mineral proposed to increase testosterone levels and promote anabolism. Several studies have evaluated the effects of boron supplementation during training on strength and body composition alterations. These studies indicate that boron supplement (2.5 mg/d) appears to have no impact on muscle mass or strength [135, 136].

Chromium. Chromium is a trace mineral that is involved in carbohydrate and fat metabolism. Clinical studies have suggested that chromium may enhance the effects of insulin particularly in diabetic populations. Since insulin is an anti-catabolic hormone and has been reported to affect protein synthesis, chromium supplementation has been theorized to serve as an anabolic nutrient. Theoretically, this may increase anabolic responses to exercise. Although some initial studies reported that chromium supplementation increased gains in muscle mass and strength during training particularly in women [137-139], most well-controlled that have been conducted since then have reported no benefit in healthy individuals taking chromium (200-800 mcg/d) for 4 to 16-weeks during training [140-146]. Consequently, it appears that although chromium supplementation may have some therapeutic benefits for diabetics, chromium does not appear to be a muscle-building nutrient for athletes.

Conjugated Linoleic Acids (CLA). Animal studies indicate that adding CLA to dietary feed decreases body fat, increases muscle and bone mass, has anti-cancer properties, enhances immunity, and inhibits progression of heart disease [147-149]. Consequently, CLA supplementation in humans has been suggested to help manage body composition, delay loss of bone, and provide health benefit. Although animal studies are impressive [150-152] and a some studies suggests benefit at some but not all dosages [153, 154], most studies conducted on humans show little to no effect on body composition or muscle growth.[155, 156]

Gamma Oryzanol (Ferulic Acid). Gamma oryzanol is a plant sterol theorized to increase anabolic hormonal responses during training [157]. Although data are limited, one study reported no effect of 0.5 g/d of gamma oryzanol supplementation on strength, muscle mass, or anabolic hormonal profiles during 9-weeks of training [158].

Anabolic Steroids & Prohormones. Testosterone and growth hormone are two primary hormones in the body that serve to promote gains in muscle mass (i.e., anabolism) and strength while decreasing muscle breakdown (catabolism) and fat mass [159-163]. Testosterone also promotes male sex characteristics (e.g., hair, deep voice, etc) [163]. Low level anabolic steroids are often prescribed by physicians to prevent loss of muscle mass for people with various diseases and illnesses [164-175]. It is well known that athletes have experimented with large doses of anabolic steroids in an attempt to enhance training adaptations, increase muscle mass, and/or promote recovery during intense training [159-163]. Research has generally shown that use of anabolic steroids and growth hormone during training can promote gains in strength and muscle mass [159, 169, 176-183]. However, a number of potentially life threatening adverse effects of steroid abuse have been reported including liver and hormonal dysfunction, hyperlipidemia (high cholesterol), increased risk to cardiovascular disease, and behavioral changes (i.e., steroid rage) [178, 184-188]. Some of the adverse effects associated with the use of these agents are irreversible, particularly in women [185]. For this reason, anabolic steroids have has been banned by most sport organizations and should be avoided unless prescribed by a physician to treat an illness.

Prohormones (androstenedione, 4-androstenediol, 19-nor-4-androstenedione, 19-nor-4-androstenediol, 7-keto DHEA, and DHEA, etc) are naturally derived precursors to testosterone or other anabolic steroids. Prohormones have become popular among body builders because they believe they are natural boosters of anabolic hormones. Consequently, a number of over-the-counter supplements contain prohormones. While there is a strong theoretical rationale that prohormones may increase testosterone levels, there is virtually no evidence that these compounds affect training adaptations in younger men with normal hormone levels. In fact, most studies indicate that they do not affect testosterone and that some may actually increase estrogen levels and reduce HDL-cholesterol [178, 189-195]. Consequently, although there may be some potential applications for older individuals to replace diminishing androgen levels, it appears that prohormones have no training value. Since prohormones are "steroid-like compounds", most athletic organizations have banned their use. Use of nutritional supplements containing prohormones will result in a positive drug test for anabolic steroids. Use of supplements knowingly or unknowingly containing prohormones have been believed to have contributed to a number of recent positive drug tests among athletes. Consequently, care should be taken to make sure that any supplement an athlete considers taking does not contain prohormone precursors particularly if their sport bans and tests for use of such compounds.

Tribulus Terrestris. Tribulus terrestris (also known as puncture weed/vine or caltrops) is a plant extract that has been suggested to stimulate leutinizing hormone (LH) which stimulates the natural production of testosterone [111]. Consequently, Tribulus has been marketed as a supplement that can increase testosterone and promote greater gains in strength and muscle mass during training. Several recent studies have indicated that Tribulus supplementation appears to have no effects on body composition or strength during training [196, 197].

Vanadyl Sulfate (Vanadium). In a similar manner as chromium, vanadyl sulfate is a trace mineral that has been found to affect insulin-sensitivity and may affect protein and glucose metabolism [111]. For this reason, vanadyl sulfate has been purported to increase muscle mass and strength during training. Although there may be some clinical benefits for diabetics, vanadyl sulfate supplementation does not appear to have any effect on strength or muscle mass during training in non-diabetic individuals [198, 199].

Weight Loss Supplements

Although exercise and proper diet remain the best way to promote weight loss and/or manage body composition, a number of nutritional approaches have been investigated as possible weight loss methods (with or without exercise). The following overviews the major types of weight loss products available and discusses whether any available research supports their use. See Table 3 for a summary.

Apparently Effective

Low Calorie Diet Foods & Supplements. Most of the products in this category represent low fat/carbohydrate, high protein food alternatives [200]. They typically consist of pre-packaged food, bars, MRP, or RTD supplements. They are designed to provide convenient foods/snacks to help people follow a particular low calorie diet plan. In the scientific literature, diets that provide less than 1000 calories per day are known as very low calorie diets (VLCD's). Pre-packaged food, MRP's, and/or RTD's are often provided in VLCD plans to help people cut calories. In most cases, VLCD plans recommend behavioral modification and that people start a general exercise program.

Research on the safety and efficacy of people maintaining VLCD's generally indicate that they can promote weight loss. For example, Hoie et al [201] reported that maintaining a VLCD for 8-weeks promoted a 27 lbs (12.6%) loss in total body mass, a 21 lbs loss in body fat (23.8%), and a 7 lbs (5.2%) loss in lean body mass in 127 overweight volunteers. Bryner and colleagues [202] reported that addition of a resistance training program while maintaining a VLCD (800 kcal/d for 12-weeks) resulted in a better preservation of lean body mass and resting metabolic rate compared to subjects maintaining a VLCD while engaged in an endurance training program. Kern and coworkers [203] reported that a medically supervised weight loss program involving behavioral modification and VLCD promoted a 51 lbs weight loss and that 61% of subjects maintained at least 50% of the weight loss at 12 and 18 months follow-up. Recent studies indicate that high protein/low fat VLCD's may be better than high carbohydrate/low fat diets in promoting weight loss [40, 204-207]. The reason for this is that typically when people lose weight about 40-50% of the weight loss is muscle which decreases resting energy expenditure. Increasing protein intake during weight loss helps preserve muscle mass and resting energy expenditure to a better degree than high carbohydrate diets [208]. These findings and others indicate that VLCD's (typically using MRP's and/or RTD's as a means to control caloric intake) can be effective particularly as part of an exercise and behavioral modification program. Most people appear to maintain at least half of the initial weight lost for 1-2 years but tend to regain most of the weight back within 2-5 years. Therefore, although these diets may help people lose weight on the short-term, it is essential people who use them follow good diet and exercise practices in order to maintain the weight loss.

Ephedra, Caffeine, and Silicin. Thermogenics are supplements designed to stimulate metabolism thereby increasing energy expenditure and promote weight loss. They typically contain the "ECA" stack of ephedra alkaloids (e.g., Ma Haung, 1R,2S Nor-ephedrine HCl, Sida Cordifolia), caffeine (e.g., *Gaurana, Bissey Nut, Kola*) and aspirin/salicin (e.g., *Willow Bark Extract*). More recently, other potentially thermogenic nutrients have been added to various thermogenic formulations. For example, thermogenic supplements may also contain synephrine (e.g., *Citrus Aurantum*, Bitter Orange), calcium &

sodium phosphate, thyroid stimulators (e.g., guggulsterones, L-tyrosine, iodine), cayenne & black pepper, and ginger root.

A significant amount of research has evaluated the safety and efficacy of EC and ECA type supplements. Studies show that use of synthetic or herbal sources of ephedrine and caffeine (EC) promote about 2 lbs of extra weight loss per month while dieting (with or without exercise) and that EC supplementation is generally well tolerated in healthy individuals [209-216]. For example, Boozer et al [210] reported that 8-weeks of ephedrine (72 mg/d) and caffeine (240 mg/d) supplementation promoted a 9 lbs loss in body mass and a 2.1 % loss in body fat with minor side effects. Molnar and associates [209] reported that overweight children treated for 20 weeks with ephedrine and caffeine observed a 14.4% loss in body mass and a 6.6% decrease in body fat with no differences in side effects. Interestingly, Greenway and colleagues [215]reported that EC supplementation was a more cost-effective treatment for reducing weight, cardiac risk, and LDL cholesterol than several weight loss drugs (fenfluramine with mazindol or phentermine). Finally, Boozer and associates [209] reported that 6-months of herbal EC supplementation promoted weight loss with no clinically significant adverse effects in healthy overweight adults. Less is known about the safety and efficacy of synephrine, thyroid stimulators, cayenne/black pepper and ginger root.

Despite these findings, the Food and Drug Administration (FDA) and the medical community have warned against use of ephedra containing supplements. In fact, the FDA has attempted to ban sale of supplements containing ephedra since the mid 1990s and a number of sport organizations prohibit the use of ephedra or ephedrine during competition (even from cold medicines). The rationale has been based on reports to adverse event monitoring systems and in the media suggesting a link between intake of ephedra and a number of severe medical complications (e.g., high blood pressure, elevated heart rate, arrhythmias, sudden death, heat stroke, etc) [217, 218]. Although results of available clinical studies do not show these types of adverse events, anyone contemplating taking thermogenic supplements should carefully consider the potential side effects, discuss possible use with a knowledgeable physician, and be careful not exceed recommended dosages.

Possibly Effective

High Fiber Diets. One oldest and most common methods of suppressing the appetite is to eat a high fiber diet. Ingesting high fiber foods (fruits, vegetables) or fiber supplements increase the feeling of fullness (satiety). They typically allow you to feel full while ingesting fewer calories. Theoretically, maintaining a high fiber diet may serve to help decrease the amount of food you eat. In addition, high fiber diets/supplements have also been purported to help lower cholesterol and blood pressure as well as help diabetics manage glucose and insulin levels. Some of the research conducted on high fiber diets indicates that they provide some benefit, particularly in diabetic populations. For example, Raben et al [219] reported that subjects maintaining a low fat/high fiber diet for 11 weeks lost about 3 lbs of weight and 3.5 lbs of fat. Other studies report either no significant effects or modest amounts of fat loss. High fiber/low fat diets have also been found to help reduce cholesterol. Consequently, although maintaining a low fat / high fiber diet may have some health benefits, they do not appear to promote a significant amount of weight or fat loss.

Calcium. Research has indicated that calcium modulates 1,25-diydroxyvitamin D which serves to regulate intracellular calcium levels in fat cells [220-222]. Increasing dietary availability of calcium reduces 1,25-diydroxyvitamin D and promotes reductions in fat mass in animals [220-222]. Dietary calcium has been shown to suppress fat metabolism and weight gain during periods of high caloric intake [220, 223, 224]. Further, increasing calcium intake has been shown to increase fat metabolism and preserve thermogenesis during caloric restriction [220, 223, 224]. In support of this theory, Davies and colleagues [225] reported that dietary calcium was negatively correlated to weight and that calcium supplementation (1,000 mg/d) accounted for an 8 kg weight loss over a 4 yr period. Additionally, Zemel and associates [220] reported that supplemental calcium (800 mg/d) or high dietary intake of calcium (1,200 – 1,300 mg/d) during a 24-week weight loss program promoted significantly greater weight loss (26-70%) and dual energy x-ray absorptiometer (DEXA) determined fat mass loss (38-64%) compared to subjects on a low calcium diet (400-500 mg/d). These findings and others suggest a strong relationship between calcium intake and fat loss.

Phosphates. The role of sodium and calcium phosphate on energy metabolism and exercise performance has been studied for decades [226]. These studies have revealed that sodium phosphate supplementation appears to possess ergogenic properties particularly in endurance exercise events [227, 228]. More recently, phosphate supplementation has also been suggested to affect energy expenditure. For example, Kaciuba-Uscilko and colleagues [229] reported that phosphate supplementation during a 4-week weight loss program increased resting metabolic rate (RMR) and respiratory exchange ratio (suggesting greater carbohydrate utilization and caloric expenditure) during submaximal cycling exercise. In addition, Nazar and coworkers [230] reported that phosphate supplementation during an 8-week weight loss program increased RMR by 12-19% and prevented a normal decline in thyroid hormones. Although the rate of weight loss was similar in this trial, results suggest that phosphate supplementation may influence metabolic rate possibly by affecting thyroid hormones. Consequently, it is possible that phosphate could serve as a potential thermogenic nutrient in non-ephedrine based supplements. Additional research is necessary to test this hypothesis.

Green Tea Extract. Green tea is one of the more interesting herbal supplements that has recently been suggested to affect weight loss. Green tea contains high amounts of caffeine and catechin polyphenols. Research suggests that catechin polyphenols possess antioxidant properties [231]. In addition, green tea has also been theorized to increase energy expenditure by stimulating brown adipose tissue thermogenesis. In support of this theory, Dulloo et al [232, 233] reported that green tea supplementation in combination with caffeine (e.g., 50 mg caffeine and 90 mg epigallocatechin gallate taken 3-times per day) significantly increased 24-hour energy expenditure and fat utilization in humans. The thermogenic effects of green tea supplementation were much greater than when an equivalent amount of caffeine was evaluated suggesting a synergistic effect. Theoretically, increases in energy expenditure may help individuals lose weight and/or manage body composition.

Calcium Pyruvate. Calcium Pyruvate is supplement that hit the scene about five or six years ago with great promise. The theoretical rationale was based on studies from the early 1990s that reported that calcium pyruvate supplementation (16 – 25 g/d with or without dihydroxyacetone phosphate [DHAP]) promoted fat loss in overweight/obese patients following a medially supervised weight loss program [234-236]. Although the mechanism for these findings was unclear, the researchers speculated that it might be related to appetite suppression and/or altered carbohydrate and fat metabolism. Since calcium pyruvate is very expensive, several studies have attempted to determine whether ingesting smaller amounts of calcium pyruvate (6-10 g/d) affect body composition in untrained and trained populations. Results of these studies are mixed. Kalman and colleagues [237] reported that calcium pyruvate supplementation (6 g/d for 6-weeks) significantly decreased body weight (-1.2 kg), body fat (-2.5 kg), and percent body fat (-2.7%). However, Stone and colleagues [238] reported that pyruvate supplementation did not affect hydrostatically determined body composition during 5-weeks of in-season college football training. These findings indicate that although there is some supportive data indicating that calcium pyruvate supplementation may enhance fat loss when taken at high doses (6-16 g/d), there is no evidence that ingesting the doses typically found in pyruvate supplements (0.5 – 2 g/d) has any affect on body composition.

Too Early to Tell

Gymnema Sylvestre. Gymnema Sylvestre is a relatively new supplement. It is purported to affect glucose and fat metabolism as well as inhibit sweet cravings. In support of these contentions, some recent data have been published by Shigematsu and colleagues [239, 240] indicating that short and long-term oral supplementation of gymnema sylvestre in rats fed normal and high-fat diets may have some positive effects on fat metabolism, blood lipid levels, and/or weight gain/fat deposition. Although these findings are interesting, we are aware of no published studies that have evaluated the effects of gymnema sylvestre supplementation on lipid metabolism or body composition in humans. Consequently, more research is needed before conclusions can be drawn.

Chitosan. Chitosan has been marketed as a weight loss supplement for several years. It is purported to inhibit fat absorption and lower cholesterol. Several animal studies report decreased fat absorption, increased fecal fat content, and/or lower cholesterol following chitosan feedings [241-244]. However, the effects in humans appear to be less impressive. For example, although there is some data suggesting that chitosan supplementation may lower blood lipids in humans,[245] other studies report no effects on fecal fat content [246]or body composition alterations [247, 248] when administered to people following their normal diet. It seems that people may be prone to eat more when they know they are taking a fat blocking supplement in a similar way people tend to eat more when the consume low-fat foods. Whether chitosan may promote greater amounts of fat loss when people are put on a controlled diet is unclear.

Non-Ephedra Containing Thermogenics. Since the safety of ephedra supplements has come into question, a number of supplement companies have been looking for alternatives to ephedra such as *Citrus Aurantum* or Bitter Orange (synephrine), thyroid stimulators, and various herbs and peppers (cayenne, black pepper, ginger root, etc) [200]. Of these, *Citrus Aurantum* (synephrine) appears to have the most promise [249, 250]. Some studies suggest that synephrine may increase metabolism without significantly affecting heart rate and blood pressure. However, it is unclear whether dietary supplementation of *Citrus Aurantum* may enhance weight loss. A number of thyroid stimulating supplements have also been marketed. Most contain nutrients (e.g., guggulsterones, 3, 5-Diiodo-L-Thyronine, etc.) believed to enhance the conversion of triidiothyronine (T3) to thyroxin (T4) or increase availability of T2 (diidiothyronine) or T3 which would theoretically increase basal metabolic rate (resting caloric expenditure) and promote weight loss [251, 252]. However, while thyroid medications can effectively increase metabolic rate [253], it is unclear whether these supplements can promote weight loss. Additionally, several of these types of supplements have been recently pulled by the FDA due to adverse health outcomes reported among people using these types of supplements particularly if they also contain usnic acid.

Phosphatidyl Choline (Lecithin). Choline is considered an essential nutrient that is needed for cell membrane integrity and to facilitate the movement of fats in and out of cells. It is also a component of the neurotransmitter acetylcholine and is needed for normal brain functioning, particularly in infants. For this reason, phosphatidyl choline (PC) has been purported as a potentially effective supplement to promote fat loss as well as improve neuromuscular function. There is some data from animal studies that supports the potential value of PC as a weight loss supplement [254]. There has also been some interest in determining the potential ergogenic value of choline supplementation during endurance exercise [255, 256]. However, it is currently unclear whether PC supplementation affects body composition in humans.

Betaine. Betaine is a compound that is involved in the metabolism of choline and homocysteine. A number of studies have evaluated the effects of betaine feedings on liver metabolism, fat metabolism, and fat deposition in animals [257, 258]. There has also been interest in determining whether betaine supplementation may help lower homocysteine levels which has recently been identified as a marker of risk to heart disease [259]. For this reason, betaine supplements have been marketed as a supplement designed to promote heart health as well as a weight loss. Although the potential theoretical rationale of betaine supplementation is interesting, it is currently unclear whether betaine supplementation may serve as an effective weight loss supplement in humans.

Coleus Forskohlii (Forskolin). Forskolin is another relatively new weight loss supplement. Forskolin is a plant native to India that has been used for centuries in traditional Ayurvedic medicine primarily to treat skin disorders and respiratory problems [260, 261]. A considerable amount of research has evaluated the physiological and potential medical applications of forskolin over the last 25 years. Forskolin has been reported to reduce blood pressure, increase the hearts ability to contract, help inhibit platelet aggregation, improve lung function, and aid in the treatment of glaucoma [260-262]. With regard to weight loss, forskolin has been reported to increase cyclic AMP and thereby stimulate fat metabolism [263-265]. Theoretically, forskolin may therefore serve as an effective weight loss supplement. In support of this theory, Sabinsa Corporation (the principle source for Forskolin in the U.S.) reported that forskolin supplementation (250 mg of a 10% forskolin extract taken twice daily for 8-weeks) administered in an open label manner to six overweight females promoted a 7.25 lbs loss in body weight and a 7.7% decrease bioelectrical impedance (BIA) determined body fat [266]. Although this was not a placebo controlled double blind study and BIA is not the most accurate method of assessing body composition, these preliminary findings provide some support to contentions that forskolin supplementation may promote fat loss. Another recent study suggested that supplementing the diet with coleus forskohlii in overweight women helped maintain weight and was not associated with any clinically significant adverse events [267]. Additional research is needed before conclusions can be drawn.

Dehydroepiandrosterone (DHEA) and 7-Keto DHEA. Dehydroepiandrosterone (DHEA) and its sulfated conjugate DHEAS represent the most abundant adrenal steroids in circulation [268]. Although, DHEA is considered a weak androgen, it can be converted to the more potent androgens testosterone and dihydrotestosterone in tissues. In addition, DHEAS can be converted into androstenedione and testosterone. DHEA levels have been reported to decline with age in humans [269]. The decline in DHEA levels with aging has been associated with increased fat accumulation and risk to heart disease [270]. Since DHEA is a naturally occurring compound, it has been suggested that dietary supplementation of DHEA may help maintain DHEA availability, maintain and/or increase testosterone levels, reduce body fat accumulation, and/or reduce risk to heart disease as one ages [268, 270]. Although animal studies have generally supported this theory, the effects of DHEA supplementation on body composition in human trials have been mixed. For example, Nestler and coworkers [271] reported that DHEA supplementation (1,600 mg/d for 28-d) in untrained healthy males promoted a 31% reduction in percentage of body fat. However, Vogiatzi and associates [272] reported that DHEA supplementation (40 mg/d for 8 wks) had no effect on body weight, percent body fat, or serum lipid levels in obese adolescents. More recently, 7-keto DHEA has been marketed as a potentially more effective form of DHEA. 7-keto DHEA is a precursor to DHEA that is believed to possess lypolytic properties. Although data are limited, Kalman and colleagues and coworkers [273] reported that 7-keto DHEA supplementation (200 mg/d) during 8-weeks of training promoted a greater loss in body mass and fat mass while increasing T3. No significant effects were observed on thyroid stimulating hormone (TSH), T4, or other hormones. Although more research is needed, these findings provide some support to contentions that 7-keto DHEA may serve as an effective weight loss supplement. However, additional research is needed before definitive conclusions can be made.

Psychotropic Nutrients/Herbs. This is a relatively new type of weight loss supplement category. Psychotropic nutrients/herbs often contain things like St. John's Wart, Kava, Ginkgo Biloba, Ginseng, and L-Tyrosine. They are believed to serve as naturally occurring antidepressants, relaxants, and mental stimulants. The theoretical rationale regarding weight loss is that they may help people fight depression or maintain mental alertness while dieting. Although a number of studies support potential role as naturally occurring psychotropics or stimulants, the potential value in promoting weight loss is unclear.

Apparently Ineffective

Chromium. Interest in chromium as a potential body composition modifier emanated from studies suggesting that chromium may enhance insulin sensitivity/glucose disposal in diabetics. Initial studies reported that chromium supplementation during resistance training improved fat loss and gains in lean body mass [137-139]. However, recent studies using more accurate methods of assessing body composition have mostly reported no effects on body composition in healthy non-diabetic individuals [140-146]. For example, Walker and colleagues [141] reported that chromium supplementation (200 µg/d for 14-weeks) did not affect body composition alterations during training in healthy wrestlers. Likewise, Lukaski et al [145] reported that 8-weeks of chromium supplementation during resistance training did not affect strength or DEXA determined body composition changes. Therefore, chromium supplementation does not appear to promote fat loss.

Conjugated Linoleic Acids (CLA). CLA is a term used to describe a group of positional and geometric isomers of linoleic acid that contain conjugated double bonds. Adding CLA to the diet has been reported to possess significant health benefits in animals [147, 274]. In terms of weight loss, CLA feedings to animals have been reported to markedly decrease body fat accumulation [147, 148, 152]. Consequently, CLA has been marketed as a health and weight loss supplement since the mid 1990s. Although basic research in animals is very promising, the effect of CLA supplementation in humans is less clear. There are some data suggesting that CLA supplementation may modestly promote fat loss and/or increases in lean mass [275-280]. However, other studies indicate that CLA supplementation (1.7 to 12 g/d for 4-weeks to 6-months) has limited to no effects on body composition alterations in untrained or trained populations [155, 156, 275, 279, 281-283]. The reason for the discrepancy in research findings has been suggested to be due to differences in purity and the specific isomer studied. For instance, early studies in humans showing no effect used CLA that contained all 24 isomers. Today, most labs studying CLA use 50-50 mixtures containing the trans-10,cis-12 and cis-9,trans-11 isomers, the former of which being recently implicated in positively altering body composition. In our view, although CLA supplementation may have promise to promote general health, additional research is needed to determine if specific isomers of CLA may affects body composition in humans before conclusions can be made.

Garcinia Cambogia (HCA). HCA is a nutrient that has been hypothesized to increase fat oxidation by inhibiting citrate lyase and lipogenesis [284]. Theoretically, this may lead to greater fat burning and weight loss over time. Although there is some evidence that HCA may increase fat metabolism in animal studies, there is little to no evidence showing that HCA supplementation affects body composition in humans. For example, Ishihara et al [285] reported that HCA supplementation spared carbohydrate utilization and promoted lipid oxidation during exercise in mice. However, Kriketos and associates [286] reported that HCA supplementation (3 g/d for 3-days) did not affect resting or post-exercise energy expenditure or markers of lipolysis in healthy men. Likewise, Heymsfield and coworkers [287] reported that HCA supplementation (1.5 g/d for 12-weeks) while maintaining a low fat/high fiber diet did not promote greater weight or fat loss than subjects on placebo. Finally, Mattes and colleagues [288] reported that HCA supplementation (2.4 g/d for 12-weeks) did not affect appetite, energy intake, or weight loss. These findings suggest that HCA supplementation does not appear to promote fat loss in humans.

L-Carnitine. Carnitine serves as an important transporter of fatty acids from the cytosol into the mitochondria of the cell. Theoretically, increasing cellular levels of carnitine would thereby enhance transport of fats into the mitochondria and fat metabolism. For this reason, L-carnitine has been one of the most common nutrients found in various weight loss supplements. Over the years, a number of studies have been conducted on the effects of L-carnitine supplementation on fat metabolism, exercise capacity and body composition. Although there is some data showing that L-carnitine supplementation may be beneficial for some patient populations, most well controlled studies indicate that L-carnitine supplementation does not affect muscle carnitine content, fat metabolism, and/or weight loss in overweight or trained subjects [289]. For example, Villani et al [290] reported that L-carnitine supplementation (2 g/d for 8-weeks) did not affect weight loss, body composition, or markers of fat metabolism in overweight women.

Herbal Diuretics. This is a new type of supplement recently marketed as a natural way to promote weight loss. There is limited evidence that *taraxacum officinale*, *verbena officinalis, lithospermum officinale, equisetum arvense, arctostaphylos uva-ursi, arctium lappa* and *silene saxifraga* infusion may affect diuresis in animals [291, 292]. Two studies presented at the 2001 American College of Sports Medicine meeting [293, 294] indicated that although herbal diuretics promoted a small amount of dehydration (about 0.3% in one day), they were not nearly as effective as a common diuretic drug (about 3.1% dehydration in one day). Consequently, although more research is needed, the potential value of herbal diuretics as a weight loss supplement appears limited.

Performance Enhancement Supplements

A number of nutritional supplements have been proposed to enhance exercise performance. Some of these nutrients have been described above. Table 3 categorizes the proposed ergogenic nutrients into apparently safe and effective, possibly effective, too early to tell, and apparently ineffective. Weight gain supplements purported to increase muscle mass may also have ergogenic properties if they also promote increases in strength. Similarly, some sports may benefit from reductions in fat mass. Therefore, weight loss supplements that help athletes manage body weight and/or fat mass may also posses some ergogenic benefit. The following describes which supplements may or may not affect performance that were not previously described. Based on this analysis, Table 4 summarizes the general nutritional recommendations for athletes and which dietary supplements may help power and endurance athletes.

Apparently Effective

Water and Sports Drinks. Preventing dehydration during exercise is one of the keys of maintaining exercise performance (particularly in hot/humid environments). People engaged in intense exercise or work in the heat need to frequently ingest water or sports drinks (e.g., 1-2 cups every 10 – 15 minutes). The goal should be not to lose more than 2% of body weight during exercise (e.g., 180 lbs x 0.02 = 3.6 lbs). Sports drinks contain salt and carbohydrate. Studies show that ingestion of sports drinks during exercise in hot/humid environments can help prevent dehydration and improve endurance exercise capacity [295]. Consequently, frequent ingestion of water and/or sports drinks during exercise is one of the easiest and most effective ergogenic aids.

Carbohydrate. General nutritional needs were discussed earlier. However, one of the best ergogenic aids available for active people is carbohydrate. Athletes and active individuals should consume a diet high in carbohydrate (e.g., 55 – 65% of calories or 5-8 grams/kg/day) in order to maintain muscle and liver carbohydrate stores [9]. Additionally, ingesting a small amount of carbohydrate and protein 30-60 minutes prior to exercise and use of sports drinks during exercise can increase carbohydrate availability and improve exercise performance. Finally, ingesting carbohydrate and protein immediately following exercise can enhance carbohydrate storage and protein synthesis [9].

Creatine. Earlier we indicated that creatine supplementation is one of the best supplements available to increase muscle mass and strength during training. However, creatine has also been reported to improve exercise capacity in a variety of events [62]. This is particularly true when performing high intensity, intermittent exercise such as multiple sets of weight lifting, repeated sprints, and/or exercise involving sprinting and jogging (e.g., soccer) [62]. Although studies evaluating the ergogenic value of creatine on endurance exercise performance are mixed, endurance athletes may also theoretically benefit in several ways. For example, increasing creatine stores prior to carbohydrate loading (i.e., increasing dietary carbohydrate intake before competition in an attempt to maximize carbohydrate stores) has been shown to improve the ability to store carbohydrate [296-298]. Further, coingesting creatine with carbohydrate has been shown to optimize creatine and carbohydrate loading [299]. Most endurance athletes also perform interval training (sprint or speed work) in an attempt to improve anaerobic threshold. Since creatine has been reported to enhance interval sprint performance, creatine supplementation during training may improve training adaptations in endurance athletes [300, 301]. Finally, many endurance athletes lose weight during their competitive season. Creatine supplementation during training may help people maintain weight.

Sodium Phosphate. We previously mentioned that sodium phosphate supplementation may increase resting energy expenditure and therefore could serve as a potential weight loss nutrient. However, most research on sodium phosphate has actually evaluated the potential ergogenic value. A number of studies indicated that sodium phosphate supplementation (e.g., 1 gram taken 4 times daily for 3-6 days) can increase maximal oxygen uptake (i.e., maximal aerobic capacity) and anaerobic threshold by 5-10% [227, 228, 302, 303]. These finding suggest that sodium phosphate may be highly effective in improving endurance exercise capacity. Other forms of phosphate (i.e., calcium phosphate, potassium phosphate) do not appear to possess ergogenic value.

Sodium Bicarbonate (Baking Soda). During high intensity exercise, acid (H+) and carbon dioxide (CO_2) accumulate in the muscle and blood. One of the ways you get rid of the acidity and CO_2 is to buffer the acid and CO_2 with bicarbonate ions. The acid and CO_2 are then removed in the lungs. Bicarbonate loading (e.g., 0.3 grams per kg taken 60-90 minutes prior to exercise or 5 grams taken 2 times per day for 5-days) has been shown to be an effective way to buffer acidity during high intensity exercise lasting 1-3 minutes in duration [304-307]. This can improve exercise capacity in events like the 400 - 800 m run or 100 – 200 m swim [308]. Although bicarbonate loading can improve exercise, some people have difficulty with their stomach tolerating bicarbonate as it may cause gastrointestinal distress.

Caffeine. Caffeine is a naturally derived stimulant found in many nutritional supplements typically as *Gaurana*, Bissey Nut, or Kola. Caffeine can also be found in coffee, tea, soft drinks, energy drinks, and chocolate. Studies indicate that ingestion of caffeine (e.g., 3-9 mg/kg taken 30 – 90 minutes before exercise) can spare carbohydrate use during exercise and thereby improve endurance exercise capacity [305, 309]. People who drink caffeinated drinks regularly, however, appear to experience less ergogenic benefits from caffeine [310]. Additionally, some concern has been expressed that ingestion of caffeine prior to exercise may contribute to dehydration although recent studies have not supported this concern [311-313]. Caffeine doses above 9 mg/kg can result in urinary caffeine levels that surpass the doping threshold for many sport organizations. Suggestions that there is no ergogenic value to caffeine supplementation is not supported by the preponderance of available scientific studies.

Possibly Effective

Post-Exercise Carbohydrate and Protein. Ingesting carbohydrate and protein following exercise enhances carbohydrate storage and protein synthesis. Theoretically, ingesting carbohydrate and protein following exercise may lead to greater training adaptations. In support of this theory, Esmarck and coworkers [314] found that ingesting carbohydrate and protein immediately following exercise doubled training adaptations in comparison to waiting until 2-hours to ingest carbohydrate and protein. Additionally, Tarnopolsky and associates [315] reported that post-exercise ingestion of carbohydrate with protein promoted as much strength gains as ingesting creatine with carbohydrate during training. These findings underscore the importance of post-exercise carbohydrate and protein ingestion.

Glutamine. As described above, glutamine has been shown to influence protein synthesis and help maintain the immune system. Theoretically, glutamine supplementation during training should enhance gains in strength and muscle mass as well as help athletes tolerate training to a better degree. Although there is some evidence that glutamine supplementation with protein can improve training adaptations, more research is needed to determine the ergogenic value in athletes.

Essential Amino Acids (EAA). Ingestion of 3-6 grams of EAA following resistance exercise has been shown to increase protein synthesis [93-101]. Theoretically, ingestion of EAA after exercise should enhance gains in strength and muscle mass during training. While there is sound theoretical rationale, it is currently unclear whether following this strategy would lead to greater training adaptations and/or whether EAA supplementation would be better than simply ingesting carbohydrate and a quality protein following exercise.

Branched Chain Amino Acids (BCAA). Ingestion of BCAA (e.g., 6-10 grams per hour) with sports drinks during prolonged exercise would theoretically improve psychological perception of fatigue (i.e., central fatigue). Although there is strong rationale, the effects of BCAA supplementation on exercise performance is mixed with some studies suggesting an improvement and others showing no effect [66]. More research is needed before conclusions can be drawn.

Calcium b-HMB. HMB supplementation has been reported to improve training adaptations in untrained individuals initiating training as well as help reduce muscle breakdown in runners. Theoretically, this should enhance training adaptations in athletes. However, most studies show little benefit of HMB supplementation in athletes.

Glycerol. Ingesting glycerol with water has been reported to increase fluid retention [316]. Theoretically, this should help athletes prevent dehydration during prolonged exercise and improve performance particularly if they are susceptible to dehydration. Although studies indicate that glycerol can significantly enhance body fluid, studies are mixed on whether it can improve exercise capacity [60, 317-322].

Ephedrine/Caffeine. Most research has evaluated the effects of ingesting ephedrine and caffeine (EC) supplements on weight loss. However, since ephedra and caffeine are stimulants and caffeine has been shown to have ergogenic properties, there has also been interest in the potential ergogenic value of EC. Recent research has shown that ingestion of low to moderate amounts of synthetic EC supplements generally improves endurance and high intensity exercise performance with no apparent adverse effects [323-327]. However, it is unclear whether dietary supplements containing *botanical* ephedrine (i.e., ephedra) and caffeine (e.g., kola nut) have similar effects on performance. Further, since most sport organizations ban use of ephedrine and ephedra and concern has been raised regarding the safety of EC supplementation during intense exercise in hot/humid environments, the potential use in athletes appears limited.

Too Early to Tell

A number of supplements purported to enhance performance and/or training adaptation fall under this category. This includes the weight gain and weight loss supplements listed in Table 3 as well as the following supplements not previously described in this category.

Medium Chain Triglycerides (MCT). MCT's are shorter chain fatty acids that can easily enter the mitochondria of the cell and be converted to energy through fat metabolism [328]. Studies are mixed as to whether MCT's can serve as an effective source of fat during exercise metabolism and/or improve exercise performance [329-333].

Ribose. Ribose is a 3-carbon carbohydrate that is involved in the synthesis of adenosine triphosphate (ATP) in the muscle (the useable form of energy). Clinical studies have shown that ribose supplementation can increase exercise capacity in heart patients [334-338]. For this reason, ribose has been suggested to be an ergogenic aid for athletes. Although more research is needed, most studies show no ergogenic value of ribose supplementation on exercise capacity in health untrained or trained populations [339-341].

Apparently Ineffective

Inosine. Inosine is a building block for DNA and RNA that is found in muscle. Inosine has a number of potentially important roles that may enhance training and/or exercise performance [342]. Although there is some theoretical rationale, available studies indicate that inosine supplementation has no apparent affect on exercise performance capacity [343-345].

Supplements to Promote General Health

In addition to the supplements previously described, several nutrients have been suggested to help athletes stay healthy during intense training. For example, the American Medical Association recently recommended that all Americans ingest a daily low-dose multivitamin in order to ensure that people get a sufficient amount of vitamins and minerals in their diet. Although one-a-day vitamin supplementation has not been found to improve exercise capacity in athletes, it may make sense to take a daily vitamin supplement for health reasons. Glucosomine and chondroitin have been reported to slow cartilage degeneration and reduce the degree of joint pain in active individuals which may help athletes postpone and/or prevent joint problems [346, 347]. Vitamin C, glutamine, Echinacea, and zinc have been reported to enhance immune function [348-351]. Consequently, some sport nutritionists recommend that athletes who feel a cold coming on take these nutrients in order to enhance immune function [348-351]. Similarly, nutrients such as vitamins E and C may help restore overwhelmed anti-oxidant defenses exhibited by athletes and reduce the risk of numerous chronic diseases [352]. Creatine, calcium ß-HMB, BCAA, and L-carnitine have been shown to help athletes tolerate heavy training periods [66, 89, 90, 92, 353-357]. Finally, omega-3 fatty acids, in supplemental form, are now endorsed by the American Heart Association for heart health in certain individuals [358]. This supportive supplement position stems from: 1.) an inability to consume cardio-protective amounts by diet alone; and, 2.) the mercury contamination sometimes present in whole-food sources of DHA (docosahexaenoic acid) and EPA (eicosapentaenoic acid) found in fatty fish. Consequently, prudent use of these types of nutrients at various times during training may help athletes stay healthy and/or tolerate training to a greater degree [45].

Summary

Numerous nutritional and herbal products are marketed to promote weight gain, weight loss, and/or improve performance. Most have a theoretical basis for use but little data supporting safety and efficacy in athletes. A number are heavily marketed despite data indicating that they do not affect body composition, performance, and/or training adaptations at the dosages recommended. It is in these particular situations that unsupported claims explicitly or implicitly endorsed by exercise physiologists constitute fraud and/ or "quackery". Prudent training, maintaining an energy balance and nutrient dense diet, proper timing of nutrient intake, and obtaining adequate rest are the cornerstones to enhancing performance and/or training adaptations. Use of a limited number of nutritional supplements that research has supported can help improve energy availability (e.g., sports drinks, carbohydrate, creatine, caffeine, etc) and/or promote recovery (carbohydrate, protein, essential amino acids, etc) can provide additional benefit in certain instances. The exercise physiologist should stay up to date regarding the role of nutrition on exercise so they can provide honest and accurate information to their students, clients, and/or athletes about the role of nutrition and dietary supplements on performance and training. Furthermore, the exercise physiologist should actively participate in exercise nutrition research; write unbiased scholarly reviews for journals and lay publications; help disseminate the latest research findings to the public so they can make informed decisions about appropriate methods of exercise, dieting, and/or whether various nutritional supplements can affect health, performance, and/or training; and, disclose any commercial or financial conflicts of interest during such promulgations to the public. Finally, exercise physiologists can challenge companies who sell exercise equipment and/or nutritional supplements to develop scientifically based products, conduct research on their products, and honestly market the results of studies so consumers can make informed decisions. To us, that is the ethical and proper position to take and certainly not that of "quacks".

Table 1. Proposed Nutritional Ergogenic Aids – Vitamins

Nutrient	RDA (mg/d)	Proposed Ergogenic Value	Summary of Research Findings
Vitamin A	Males 1.0 Females 0.8	Constituent of rhodopsin (visual pigment) and is involved in night vision. Some suggest that Vitamin A supplementation may improve sport vision.	No studies have shown that Vitamin A supplementation improves exercise performance [359-361].
Vitamin D	0.01	Promotes bone growth and mineralization. Enhances calcium absorption. Supplementation with calcium may help prevent bone loss in osteoperotic populations.	Co-supplementation with calcium may help prevent bone loss in athletes susceptible to osteoporosis [362]. However, Vitamin D supplementation does not enhance exercise performance [359-361].
Vitamin E	Males 10.0 Females 8.0	As an antioxidant, Vitamin E has been shown to help prevent the formation of free radicals during intense exercise and prevent the destruction of red blood cells, improving or maintaining oxygen delivery to the muscles during exercise. Some evidence suggests that it may reduce risk to heart disease or decrease incidence of recurring heart attack.	Numerous studies show that Vitamin E supplementation can decrease exercise-induced oxidative stress [363-370]. However, most studies show no effects on performance at sea level. At high-altitudes, Vitamin E may improve exercise performance [359, 371]. Additional research is necessary to determine whether long-term supplementation may help athletes tolerate training to a better degree.
Vitamin K	Males 0.08 Females 0.06	Important in blood clotting. There is also some evidence that Vitamin K may affect bone metabolism in post-menopausal women.	Vitamin K supplementation (10 mg/d) in elite female athletes has been reported to increase calcium-binding capacity of osteocalcin and promoted a 15-20% increase in bone formation markers and a 20-25% decrease in bone resorption markers suggesting an improved balance between bone formation and resorption [372].
Thiamin (B_1)	Males 1.2 Females 1.1	Coenzyme (thiamin pyrophosphate) in the removal of CO_2 from decarboxylic reactions from pyruvate to acetyl CoA and in TCA. Supplementation is theorized to improve anaerobic threshold and CO_2 transport. Deficiencies may decrease efficiency of energy systems.	Dietary availability of thiamin does not appear to affect exercise capacity when athletes have a normal intake [362, 373].
Riboflavin (B_2)	Males 1.3 Females 1.7	Constituent of flavin nucleotide coenzymes involved in energy metabolism. Theorized to enhance energy availability during oxidative metabolism.	Dietary availability of riboflavin does not appear to affect exercise capacity when athletes have a normal intake [362, 373].
Niacin (B_3)	Males 16 Females 14	Constituent of coenzymes involved in energy metabolism. Theorized to blunt increases in fatty acids during exercise, reduce cholesterol, enhance thermoregulation, and improve energy availability during oxidative metabolism.	Studies indicate that niacin supplementation (100 to 500 mg/d) can help decrease blood lipid levels and increase homocysteine levels in hypercholesteremic patients [374-378]. However, niacin supplementation (280 mg) during exercise has been reported to decrease exercise capacity by blunting the mobilization of fatty acids [379].
Pyridoxine (B_6)	1.3	Pyridoxine has been market as a supplement that will improve muscle mass, strength and aerobic power in the lactic acid and oxygen systems. It also may have a calming effect that has been linked to an improved mental strength.	In well-nourished athletes, pyridoxine failed to improve aerobic capacity, or lactic acid accumulation [362, 373]. (39-40). However, when combined with vitamins B_1 and B_{12}, it may increase serotonin levels and improve fine motor skills that may be necessary in sports like pistol shooting and archery [359, 380, 381].

Cyano-cobalamin (B_{12})	2.4 mcg/d	Cyanocobalamin is a coenzyme involved in the production of DNA and serotonin. DNA is important in protein and red blood cell synthesis. Theoretically it would increase muscle mass, the oxygen-carrying capacity of blood and decrease anxiety.	In well-nourished athletes, no ergogenic effect has been reported. However, when combined with vitamins B_1 and B_6, cyanocobalamin has been shown to improve performance in pistol shooting [359, 380, 381]. This may be due to increased levels of serotonin, a neurotransmitter in the brain, which may reduce anxiety.
Folacin	400	Folic acid functions as a coenzyme in the formation of DNA and red blood cells. An increase in red blood cells could improve oxygen deliver to the muscles during exercise. Believed to be important to help prevent birth defects and may help increase homocysteine levels.	Studies suggest that increasing dietary availability of folic acid during pregnancy can lower the incidence of birth defects in children [382-385]. Additionally, that it may decrease homocysteine levels (a risk factor to heart disease) [383, 385-388]. In well-nourished and folate deficient athletes, folic acid did not improve exercise performance [359].
Pantothenic Acids	5-9	Pantothenic acid acts as a coenzyme for Acetyl Coenzyme A (Acetyl CoA). This may benefit aerobic or oxygen energy systems.	Research has reported no improvements in aerobic performance with Acetyl CoA supplementation, however, one study reported a decrease in lactic acid accumulation, without an improvement in performance [359, 389].
Beta Carotene	None	Serves as an antioxidant. Theorized to help minimize exercise-induced lipid perioxidation and muscle damage.	Research indicates that beta carotene supplementation with or without other antioxidants can help decrease exercise-induced perioxidation. Over time, this may help athletes tolerate training. However, it is unclear whether antioxidant supplementation affects exercise performance [367].
Vitamin C	Males 90 Females 75	Vitamin C is used in a number of different metabolic processes in the body. It is involved in the synthesis of epinephrine, iron absorption and is an antioxidant. Theoretically, it could benefit exercise performance by improving metabolism during exercise. There is also evidence that vitamin C may enhance immunity.	In well-nourished athletes, Vitamin C supplementation does not appear to improve physical performance [390-393]. However, there is some evidence that vitamin C supplementation following intense-exercise (e.g., 500 mg/d) may decrease the incidence of upper respiratory tract infections [390-398].

Recommended Dietary Allowances (RDA) based on the 2002 Food & Nutrition Board, National Academy of Sciences-National Research Council recommendations.

Table 2. Proposed Nutritional Ergogenic Aids – Minerals

Nutrient	RDA (mg/d)	Proposed Ergogenic Value	Summary of Research Findings
Boron	None	Boron has been marketed to athletes as a dietary supplement that may promote muscle growth during resistance training. The rationale was primarily based on an initial report that boron supplementation (3 mg/d) significantly increased β-estradiol and testosterone levels in post-menopausal women consuming a diet low in boron.	Studies which have investigated the effects of 7-wks of boron supplementation (2.5 mg/d) during resistance training on testosterone levels, body composition, and strength have reported no ergogenic value [135, 136]. There is no evidence at this time that boron supplementation during resistance-training promotes muscle growth.
Calcium	1,200 for 15 years and older	Involved in bone and tooth formation, blood clotting and nerve transmission. Stimulates fat metabolism. Diet should contain sufficient amounts especially in growing children/adolescents, female athletes, and post-menopausal women. Vitamin D needed to assist absorption.	Calcium supplementation may be beneficial in populations susceptible to osteoperosis [399-402]. Additionally, calcium supplementation has been shown to promote fat metabolism and help manage body composition [220-224, 403]. However, calcium supplementation provides no ergogenic effect on exercise performance.
Chromium	Males 0.035 Females 0.025	Chromium, commonly sold as Chromium Picolinate has been marketed with claims that the supplement will increase lean body mass and decrease body fat levels.	Animal research indicates that chromium supplementation increases lean body mass and reduces body fat. Early research on humans reported similar results [138], however more recent, well-controlled studies reported that chromium supplementation (200 to 800 mcg/d) does not improve lean body mass or reduce body fat [44, 143-145, 404-407].
Iron	Males 8 Females 18	Iron supplements are used to increase aerobic performance in sports that use the oxygen system. Iron is a component of hemoglobin in the red blood cell, which is a carrier of oxygen.	Most research shows that iron supplements do not appear to improve aerobic performance unless the athlete is iron-depleted and/or has anemia [408-411].
Magnesium	Males 420 Females 320	Activates enzymes involved in protein synthesis. Involved in ATP reactions. Serum levels decrease with exercise. Some suggest that magnesium supplementation may improve energy metabolism/ATP availability.	Most well-controlled research indicates that magnesium supplementation (500 mg/d) does not affect exercise performance in athletes unless there is a deficiency [412-417].
Phosphorus (Phosphate Salts)	700	Phosphate has been studied for its ability to improve all three energy systems, primarily the oxygen system or aerobic capacity.	Recent well-controlled research studies reported that sodium phosphate supplementation (4 g/d for 3-d) improved the oxygen energy system in endurance tasks [227, 228, 302, 303]. There appears to be little ergogenic value of other forms of phosphate (i.e., calcium phosphate, potassium phosphate). More research is needed to determine the mechanism for improvement.
Potassium	2000	An electrolyte that helps regulate fluid balance, nerve transmission, and acid-base balance. Some suggest excessive increases or decreases in potassium may predispose athletes to cramping.	Although potassium loss during intense exercise in the heat has been anecdotal associated with muscle cramping, the etiology of cramping is unknown [418-420]. It is unclear whether potassium supplementation in athletes decreases the incidence of muscle cramping [421-424]. No ergogenic effects reported.

Selenium	0.055	Selenium has been marketed as a supplement to increase aerobic exercise performance. Working closely with vitamin E and glutathione peroxidase (an antioxidant), Selenium may destroy destructive free radical production of lipids during aerobic exercise.	Although selenium may reduce lipid peroxidation during aerobic exercise, improvements in aerobic capacity have not been demonstrated [425, 426].
Sodium	500	An electrolyte that helps regulate fluid balance, nerve transmission, and acid-base balance. Increased dietary availability during intense training in the heat has been proposed to help maintain hydration, prevent hyponatremia, and reduce incidence of muscle cramping.	During the first several days of intense training in the heat, a greater amount of sodium is lost in sweat. Additionally, prolonged ultraendurance exercise may decrease sodium levels leading to hyponatremia. Increasing salt availability during heavy training in the heat has been shown to help maintain fluid balance and prevent hyponatremia [421, 423, 427]. .
Vanadium	None	Vanadium may be involved in reactions in the body that produce insulin-like effects on protein and glucose metabolism. Due to the anabolic nature of insulin, this has brought attention to vanadium as a supplement to increase muscle mass, enhance strength and power.	Limited research has shown that noninsulin-dependent diabetics may improve their glucose control, however there is no scientific proof that vanadyl sulfate has any effect on muscle mass, strength or power [198, 199].
Zinc	Males 11 Females 8	Constituent of enzymes involved in digestion. Associated with immunity. Theorized to reduce incidence of upper respiratory tract infections in athletes involved in heavy training.	Studies indicate that zinc supplementation (25 mg/d) during training minimized exercise-induced changes in immune function [395, 428-434].

Recommended Dietary Allowances (RDA) based on the 2002 Food & Nutrition Board, National Academy of Sciences-National Research Council recommendations.

Table 3. Categorization of the Ergogenic Value of Performance Enhancement, Muscle Building, and Weight Loss Supplements

Category	Muscle Building Supplements	Weight Loss Supplements	Performance Enhancement
*I.. **Apparently Effective and Generally Safe***	• Weight Gain Powders • Creatine • HMB (Untrained Individuals Initiating Training)	▪ Low calorie foods, MRP's and RTD's that help individuals maintain a hypocaloric diet ▪ Ephedra, caffeine, and salicin containing thermogenic supplements taken at recommended doses in appropriate populations	▪ Water & Sports Drinks ▪ Carbohydrate ▪ Creatine ▪ Sodium Phosphate ▪ Sodium Bicarbonate ▪ Caffeine
II. ***Possibly Effective***	• Post-exercise carbohydrate & protein • BCAA • Essential Amino Acids (EAA) • Glutamine • Protein • HMB (Trained Subjects)	• High fiber diets • Calcium • Phosphate • Green Tea Extract • Pyruvate/DHAP (at high doses)	• Post-exercise CHO/PRO • Glutamine • EAA • BCAA • HMB (Trained Subjects) • Glycerol • Low Doses of Ephedrine/Caffeine
III. ***Too Early To Tell***	• α-ketoglutarate • α-ketoisocaproate (KIC) • Ecdysterones • Growth Hormone Releasing Peptides (GHRP) and Secretogues • HMB (Trained Athletes) • Isoflavones • Smilax Officinalis (SO) • Sulfo-polysaccharides (Myostatin Inhibitors) • Zinc/Magnesium Aspartate (ZMA)	• Appetite Suppressants & Fat Blockers (Gymnema Sylvestre, Chitosan) • Thermogenics (Synephrine, Thyroid Stimulators, Cayenne Pepper, Black Pepper, Ginger Root) • Lipolytic Nutrients (Phosphatidyl Choline, Betaine, Coleus Forskohlii, 7-keto DHEA) • Psychotropic Nutrients/Herbs	• Medium Chain Triglycerides • Ribose
IV. Apparently Not Effective and/or Dangerous	• Boron • Chromium • Conjugated Linoleic Acids (CLA) • Gamma Oryzanol (Ferulic Acid) • Prohormones • Tribulus Terrestris • Vanadyl Sulfate (Vanadium) • Yohimbine (Yohimbe)	• Chromium (non-diabetics) • CLA • HCA • L-Carnitine • Pyruvate (at low doses) • Herbal Diuretics • High doses of Ephedrine/Caffeine	• Inosine • High doses of Ephedrine/Caffeine

Table 4. Summary of Performance Enhancement Nutrition Program for Athletes

General Recommendations

- Stress high carbohydrate, nutrient dense, and isoenergetic diet designed to maintain weight.
- Take a low-dose daily multi-vitamin (with iron for women).
- Taper training intensity and carbohydrate load before competition.
- Consume a pre-practice or pre-workout carbohydrate/protein snack 30-60 minutes before exercise.
- Consume plenty of water and sports drinks during exercise (particularly in the heat).
- Consume a post-practice carbohydrate/protein snack within 30 minutes of exercise.
- If you have to train in the morning, ingest an evening snack prior to going to bed.
- Only consider sport specific use of effective and legal ergogenic aids

Potentially Effective Supplements for Strength/Power/Sprint Athletes

- Water/Sports Drinks
- Carbohydrate
- Creatine
- Bicarbonate Loading
- Sodium Phosphate
- Glycerol (to counteract dehydration)

Potentially Effective Supplements for Endurance Athletes

- Water/Sports Drinks
- Carbohydrate
- Caffeine
- Sodium Phosphate
- Glycerol (to counteract dehydration)
- Creatine

Possible Anticatabolic Nutrients Which May Help Athletes Tolerate Training

- Sports Drinks
- Carbohydrate
- Post-exercise carbohydrate, protein, EAA & glutamine
- Creatine
- HMB

Possible Nutrients to Enhance the Immune System

- Post-exercise carbohydrate, protein, and EAA
- Vitamin C
- Zinc
- Glutamine
- Echinacea

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