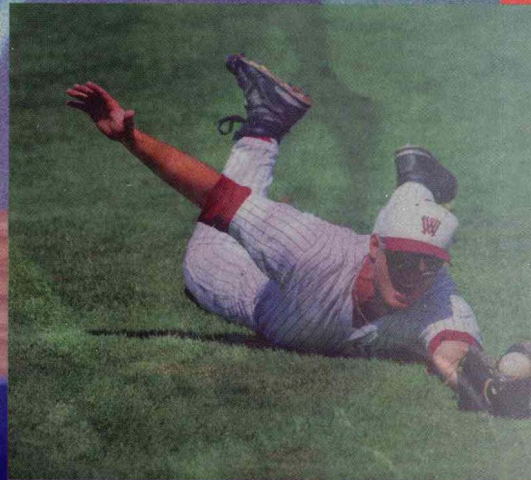
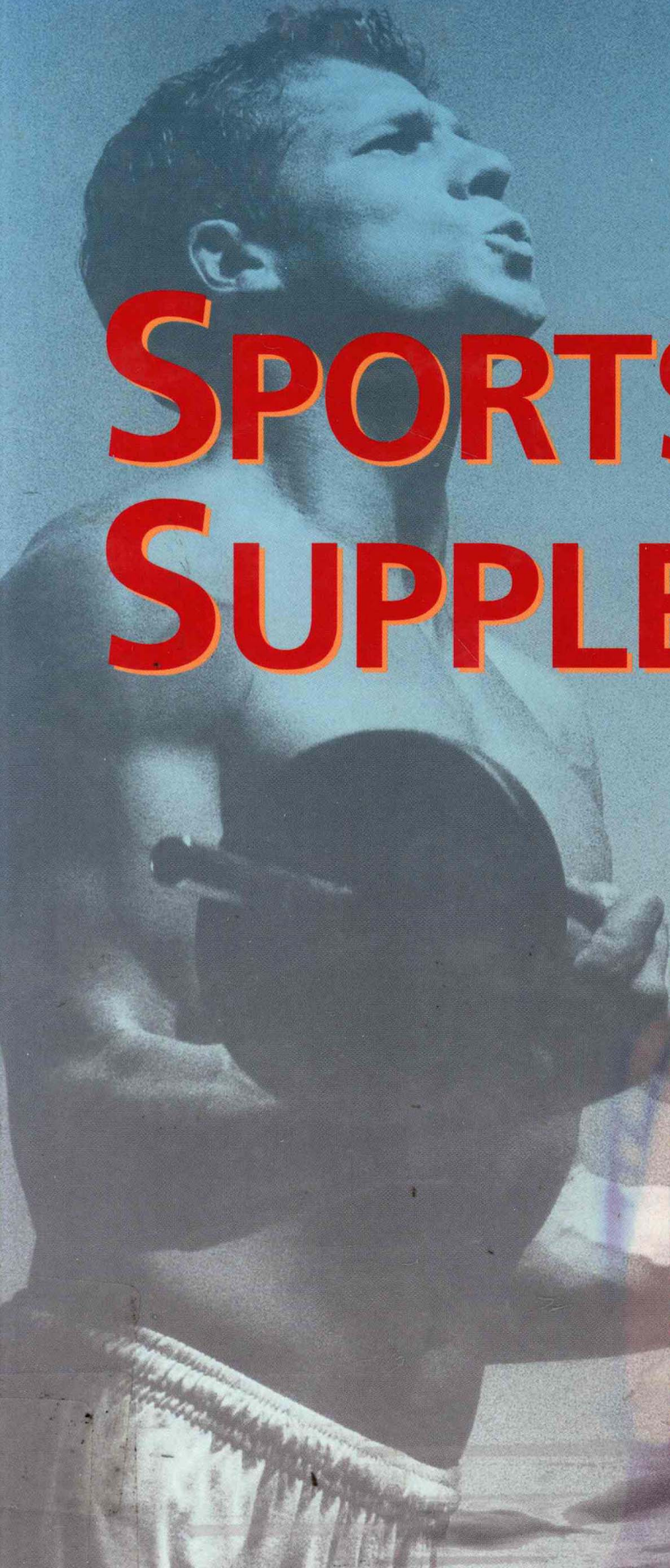


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SPORTS SUPPLEMENTS



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Dedication

To the most important people,
Our wives Karla and Martha and children Brooke, Brandi, Jeffrey and Nicole

Foreword

The sports supplement industry, primarily in the past few years, has experienced an unprecedented expansion involving the introduction and availability of ergogenic aids (substances that may enhance athletic performance or improve body composition). What was once considered an industry inundated with useless and even fraudulent products, now offers an abundance of effective compounds that are supported by research and “real-world” success. The heightened national interest in the area of sports supplementation has also been controversial, because the circulation of accurate, reputable information is lacking. Much of the information disseminated in popular fitness magazines is often a result of user trial and error. Only recently have the standards of science been used to assess the efficacy of various supplements; however, many popular fitness magazines still tend to hyperbolize the usefulness of various supplements. The proper selection and administration of supplements for desired benefits is an area of ambiguity for both the layperson and qualified personnel in the field of exercise and nutritional counseling. Accordingly, increased awareness in the fitness industry, as well as public and media interest, has led to the need of a book that addresses key issues of natural ergogenic compounds. To date, no publication exists that effectively summarizes the research behind these supplements, as well as offers expert opinion and experience from scientists in the field of ergogenic aids. The text, *Sports Supplements*, offers the clinician, professor, or educated layperson applicable information regarding ergogenic aids. The book covers the entire spectrum of supplements and their effectiveness (or lack thereof), including proper dosages and applications to specific goals, as well as recommendations from the author(s). As a clinician who works daily with athletes, this text could not have come at a better time. I know my fellow colleagues in sports medicine will find this an invaluable resource.

Eric Serrano, MD
Associate Clinical Professor
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Preface

**"Sure, not every piece of research is in . . .
[But] men buy companies, run political campaigns,
wage wars . . . all based on the best available—but incomplete—data."
—Bob Arnot, M.D., Medical Correspondent, in his book
*"The Prostate Cancer Protection Plan."***

The above quote is in response to Dr. Arnot's dietary advice concerning prostate cancer. As with any book related to diet or supplementation, a healthy dose of criticism always follows. Certainly, we have attempted to provide similar advice to athletes regarding the use of dietary supplements. Yes, we *know* that the data are incomplete. Yes, we *know* that they are often inconclusive. And yes, we *know* that more data are needed. In fact, as scientists, we make a living in part by convincing others (i.e., those with research dollars) that more data are always needed. And we've become so good at it that we *still* have studies that are funded showing that exercise is needed for permanent weight loss. (Is that still a mystery?) Of course, the same cannot be held true for the field of nutrition, particularly sports nutrition.

So, we admittedly have incomplete and inconclusive data regarding sports nutrition and supplements. Does that mean we should hide behind the ivory tower and refrain from giving practical advice to athletes? We think not. Yet, from our experience, that seems to be the case with many scientists. As scientists, we are often caught between those seeking practical advice (athletes) and our colleagues (fellow scientists) who are very disinclined to give an opinion regarding supplementation other than "eat a balanced diet and drink plenty of water." In fact, several of our colleagues subscribe to the notion that taking dietary supplements is largely ineffectual, costly, and a waste of time. On the other hand, it is clear that many common foods we eat are in fact "supplemented." We have orange juice fortified with vitamin C and calcium. We have refined bread fortified with B vitamins, milk fortified with vitamin D, and so on.

So why does the use of dietary supplements by athletes provoke such a negative response? As scientists, is it wrong to provide opinions based on incomplete data? And if scientists are the "experts" who the public seeks advice from, then should we not provide such information? Or should we leave that to the teenage boy working behind the counter at your local health food store? From whom would *you* seek advice?

We realize this book might contain controversial statements, but we also realize that an attempt to please everyone is a formula for failure. However, as academicians ourselves, we realize how insular our field can be. The lay public is often more confused concerning dietary supplements when the "experts" themselves cannot agree. Should you take supplemental vitamin C or not? Does creatine harm you or not? With such confusion, is it any wonder that athletes might be averse to listening to scientists who refuse to give practical "how-to" advice?

There is a tremendous need for scientists to bridge the gap (and it can be a wide one) between laboratory findings and real-world athletics. As we've stated previously, the data are far from complete. But we believe it would be irresponsible not to provide information to athletes regarding supplement use. Leaving such advice to the untrained salesman behind the health food store counter is sheer folly. We certainly will not lay claim to a monopoly on sports supplement knowledge, far from it. Indeed, it is far better to try to give well-intentioned advice, rather than hiding behind the clichéd "more research is needed" answer.

As you know, more research is *always* needed. That isn't new.

Nonetheless, we hope that you will find this book a valuable resource. We have attempted to provide an extensive literature review on a wide variety of dietary supplements. However, we know that new information on dietary supplements is published at an astonishing rate. Thus, some of you may view this text as being slightly behind the times.

We also hope that this text will be a great resource for the undergraduate and graduate student in the exercise sciences and nutrition as well as academicians and clinicians (i.e., physicians, dietitians).

For many of the chapters, we have attempted to cover *in vitro* and animal data (where appropriate) related to various dietary supplements (as well as human work). Though many in the exercise science community might cringe at the use of non-human data to “support” the claims made concerning certain supplements, it is clear that the best way to understand the purported mechanism of action regarding these supplements is via animal/*in vitro* studies. Regardless of how many human studies are performed, it is highly unlikely that one will get to a mechanistic understanding of the interplay between dietary supplementation (and nutrition in general) and exercise performance/body composition alterations.

Of interest to the athlete and coach is the section of each chapter entitled “Author(s) Recommendations.” This section will set this book apart from other similar texts. In spite of the limited data, we have attempted to provide something useful . . . a take-home message. We believe that, without such a section, those in the “real world” (i.e., those who actually incur the benefits or costs of choosing to use [or *not use*] dietary supplements) might find the text just another pointless academic exercise.

We hope that you find this text useful. Because of the rapidity of change in this field, you may find recent, cutting-edge research missing. Such is the nature of print publishing.

Jose Antonio, PhD
Jeffrey R. Stout, PhD

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We would also like to thank our mentors (Peter Lemon, William J. Gonyea, Terry Housh) who helped in our development as scientists. They laid the foundation for our future success. For that we are especially grateful.

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1



Sports Supplements: Evolution and Revolution

Greg Bradley-Popovich, Jeffrey R. Stout, and Jose Antonio



Introduction

By nature, athletics demand a competitive attitude. The athlete may desire to outperform the opponent, or the athlete may compete with oneself while striving to maximize personal potential. This drive to succeed has fueled the development of several performance-enhancing resources. Tools intended to enhance athletic performance are referred to as “ergogenic aids,” a term derived from the Greek words “ergon,” meaning “work,” and “gennan” meaning “to produce.” Ergogenic aids may take several forms, including nutritional, pharmacological, physiological, biomechanical, and psychological.¹ The purpose of this book is to provide an in-depth treatment of the dynamic field of nutritional ergogenic aids, which is rapidly accumulating new scientific evidence.

Origin and Successful Evolution of Sports Supplementation

The quest for reaching the pinnacle of physical performance and aesthetics can be traced to ancient times. Long before the pervasive use of illicit drugs in modern sports, or the popularity of surgical augmentation techniques such as implants or liposuction, our ancestors also sought ancillary means to achieving a body that was ideal in form and function.

The Primitive Beginnings: Mythology, Mysticism, and Mushrooms

The earliest use of natural preparations can be traced to the Chinese, who have used various concoctions for over 5,000 years. The Babylonians and Egyptians documented drug use approximately 4,000 years ago. In these cultures, using such substances was usually accompanied by rituals, chanting, and superstition.²

The ancient Greeks may have first pondered how to gain a competitive athletic “edge” through proper diet and supplementation. Indeed, a keen interest in the physique and athletic prowess may have best been exemplified by the ancient Greeks, who embraced and celebrated athletic competition, and who speculated about the ideal diet for optimum athletic performance.³

Greek trainers and athletes sought nutritional aids and may have believed that certain animal organs held special properties. For example, gladiators may have thought a lion’s heart conferred courage upon those who consumed it.^{1,4} Use of such substances, however, was scrutinized by athletic officials. Similar to the controversy surrounding some modern dietary supplements, in 300 BC three

Olympic athletes were banned from competing for ingesting mushrooms and animal protein.⁵

A well-known Greek athlete of mythological proportions was Milo of Croton. Milo, a champion wrestler, was said to have built tremendous strength by lifting a calf daily until it was fully mature. What may not be as well known was Milo’s voracious appetite. One version of the story tells of Milo parading around the stadium at Olympia while holding the bull above him. Milo’s relationship with the bull is said to have ended when he butchered the animal and devoured it in a single day! This feat may not be so surprising because the legend is that Milo’s typical daily diet included 20 pounds of meat, 20 pounds of bread, and 8 quarts of wine.³

Although we may laugh at such superstition and exaggeration, some of the advice from this period still applies today. For instance, writings of antiquity (circa 400 AD) reveal a suspected incompatibility of overeating and excessive alcohol consumption with athletic performance. Also, athletes of this period were advised to shy away from desserts.³

The Turning Point

Despite its early beginnings, the science of sports nutrition evolved little over the next millennium because the primary interest of those knowledgeable in medicine and nutrition was the prevention of debilitating or life-threatening nutrient deficiencies. By the mid-1800s, surprisingly little was known about the most fundamental aspects of sports nutrition. For example, the German researcher von Liebig wrote in 1842 that protein was the primary energy source for muscular work, when in fact, it is not.⁴

The isolation of vitamins in the early 1900s marked an exciting, dramatic turning point in nutrition science. Several studies would demonstrate in the next few decades an ergogenic, or work-enhancing benefit to dietary supplementation. Around the same time that vitamins were discovered, caffeine was recognized as possessing fatigue-masking qualities, and protein provided a minimal contribution to the body as a fuel for physical activity.⁴

In the 1920s, scientists began testing the effects of dietary carbohydrate manipulation on performance. One such experiment was conducted by Harvard Medical School on participants in the Boston Marathon. The researchers found that a supplemental carbohydrate—partly in the form of sugary candy—helped to decrease fatigue among the participants when consumed before and during the event.⁴

By the 1940s, it was well established that protein was not a significant source of energy during exercise and did not enhance endurance performance. However, supplemental protein was found to enhance muscle mass gains in strength athletes.⁴ It was outside the scientific community, however, where supplemental protein would gain an enthusiastic endorsement. This resounding endorsement from the

forefathers of a fledgling sport would have far-reaching implications for the future of the supplement industry.

Industry experts recognize that it was the niche of strength training and body building that espoused the special dietary needs of athletes. York Barbell Company founder Bob Hoffman (1899–1985) ushered in the sports supplement movement. Hoffman began publishing *Strength & Health* in 1932, followed by the successful *Muscular Development* in 1964, which still thrives today. Another icon of the physical culture movement was Joe Weider. In the late 1930s, Joe Weider (1923–) began publishing his newsletter, *Your Physique*, which evolved into the well-known *Muscle & Fitness* magazine. Both Hoffman and Weider began using their publications to market sports nutrition supplements, particularly protein supplements.⁶ Although scientific evidence supporting the use of these early nutrition supplements, like wheat germ oil and bee pollen, was minimal to nonexistent, such propaganda helped plant the seeds from which a prosperous sports supplement industry would grow.

The next big boost for the use of nutritional ergogenic aid occurred not as the result of a single person, but rather, a concept. Based on Scandinavian research that showed the fatigue-delaying qualities of carbohydrates, Gatorade created a new market in sports beverages in the 1960s.^{4,7} In addition to supplying carbohydrates to combat fatigue, the beverage was designed to be absorbed quickly to prevent dehydration. Gatorade was developed by researchers at the University of Florida at Gainesville to improve the performance of the “Gators” football team. Because of the research behind its development and the specificity of its objective, Gatorade may be regarded as the first sports nutrition product.⁴

The marketing of sports supplements continued through the 1970s and 1980s, but was still limited to the narrow weight training niche. New products abounded with endorsements from popular body builders, yet most were without scientific merit. In addition to the ever-present wheat germ products and bee pollen, protein supplements were still heavily marketed. Eventually, protein supplements were first chemically digested and then sold as their building blocks under the alias of *amino acid* or *peptide* capsules and pills. During this era, high-calorie, weight-gain powders flourished as did *steroid replacement kits* and a questionable assortment of miscellaneous products such as smilax, dibenzozide, gamma-oryzanol, and inosine.

The late 1980s was also characterized by the misrepresentation of scientific studies to market products. Before this point, consumers bought supplements on good faith. Now, supplement companies sought to develop an advantage by creating the illusion that their products were backed with science. Perhaps the best example of such a product is the fraudulent marketing of the mineral boron, which was shown in a study to increase testosterone production in undernourished menopausal women, but which was marketed to weight training enthusiasts.^{2,8}

The 1990s, a breakthrough decade for nutritional ergogenic aids, was the period during which sports supplement companies retained their hard-core devotees, but expanded the consumer base to include endurance athletes, casual athletes, and people living an active lifestyle.⁷ This broadening of audience was shown in the advertisement of a sports nutrition bar during the last episode of the popular television series *Seinfeld*. In addition to the expanding consumer base, some companies attempted to expand the research base by voluntarily offering grants to fund university research.

The advent of “engineered foods,” spearheaded by Met-Rx in the early 1990s, provided fitness enthusiasts and athletes with a useful meal-replacement supplement that was quick, relatively palatable, and nutrient dense without many calories. Though initial expectations and claims were somewhat unrealistic, the practicality and convenience of meal-replacement products were undeniable for a bustling health and appearance-conscious society. The engineered-food movement began as powders but has spawned several different products, most notably meal-replacement bars. Also during this time, creatine emerged from obscurity to become the most popular and most studied ergogenic aid of all time. In 1997, better products and aggressive marketing led the way to a record \$1.27 billion in sales of sports nutrition supplements in the United States alone.⁷

If there was ever a golden age of nutritional ergogenic aids, it is now. Increasingly well-researched products and a better-educated public have led to nothing less than a supplement explosion. However, this revolution has not yet stamped out bogus supplements completely. For example, one of the most exotic nutritional supplements ever consumed by athletes was ground bull testes, which claimed to enhance testosterone production. What is remarkable about this unfounded supplement is that it was marketed to athletes as recently as the 1990s!²

The Future Illuminated

Realizing how much the field has progressed in recent years, what are the exciting possibilities for sports supplementation in the future? Unfortunately, it is likely that less scrupulous companies will continue to manufacture an endless array of ill-conceived, ineffective supplements that will come and go, eventually ending up in the supplement graveyard like countless others before them. However, there is much to look forward to as more university research focuses on sports nutrition, proving the worth of many new and exciting supplements while ironing out the details of many effective supplements already in use.

Industry experts anticipate a continued broadening of the market, including using vending machines to dispense certain products. The number of middle-age users will likely increase as a result of men becoming concerned with cardiac health and women, with preventing

osteoporosis. In addition, supplement regimens will likely be designed to fit the needs of particular activities.⁷ Specifically, endurance athletes will see many new supplement options appear because endurance athletes outnumber strength athletes by at least 3 to 1.

In the future, look for a decrease in endorsements from big-name athletes; progressively more enlightened consumers are interested in science rather than hype. Any future endorsements may instead recruit medical professionals and researchers.⁷

Expect the medical community to become more accepting of sports supplements and to implement use of these supplements within certain patient populations, such as cardiac patients, given that current creatine research has already veered in that direction. Following the trend in Europe, American pharmaceutical companies, with their great financial resources, may become a powerful force in the development and marketing of new ergogenic aids. These progressive pharmaceutical companies may develop their own ergogenic aid division, or may acquire well-established sports nutrition companies. This widespread growth of the industry will lead to a greater public awareness, which will in turn result in more growth within the industry.

Legal Aspects of Nutrition Supplementation

What would a supplement revolution be without a change in government policy? The Nutrition Labeling and Education Act (NLEA), followed by the Dietary Supplement Health and Education Act (DSHEA) had a significant impact on the sports supplement industry.

The Nutrition Labeling and Education Act (NLEA)

President Bush signed the NLEA on November 8, 1990; it took effect 2 years later. The NLEA brought many changes for not only packaged foods, but also nutritional supplements; nutrition labels have appeared on nearly all packaged foods. United States recommended dietary allowances (USRDA) have been replaced by reference daily intakes (RDIs) and daily reference values (DRVs); RDIs and DRVs have been combined on labels as daily values (DVs); the nutrition label format has been standardized and simplified; previously vague terms such as *low*, *light*, *have been reduced*, and *good source of* defined; and disease-specific claims have been authorized.⁹ Disease-specific claims will be addressed later in this chapter.

The NLEA also modified the definition of “dietary supplement.” Traditionally, the Food and Drug Administration (FDA) regarded nutritional supplements to contain only

essential nutrients such as vitamins, minerals, and protein. The NLEA amended this definition of dietary supplement to include “herbs, or similar nutritional substances.”

The Dietary Supplement Health and Education Act (DSHEA)

Even more influential with regard to dietary supplements, the DSHEA, legally known as Public Law 103-417, was signed by President Clinton on October 25, 1994 in response to concerned nutritional supplement consumers and manufacturers who needed reassurance that safe dietary supplements would remain available to those who want to use them.^{10,11} In fact, for the 2 years preceding the DSHEA, many congressmen reported that they received more correspondence and phone calls regarding dietary supplements than on any other subject, including the national deficit, healthcare reform, and abortion. Consequently, members of Congress approved the measure unanimously.⁹

The DSHEA basically allows supplement manufacturers the freedom to market more products as dietary supplements and to provide information about product benefits so that consumers can make informed choices.¹² Although the DSHEA was welcomed by manufacturers and consumers alike, in the eyes of some consumer advocates, it “weakened” the enforcement ability of the FDA, but not as much as its original sponsors had intended.^{9,13}

Ingredient and Nutrition Information Labeling

The most visible DSHEA-mediated change is written on the packaging of nutritional supplements. Through requirements of the DSHEA, dietary supplement labels have been redesigned to be more consumer friendly. A dietary supplement is easy to recognize because the product label reads “dietary supplement.” Among other requirements, supplement labels will provide a “Supplement Facts” panel, a clear identity statement, and a complete list of ingredients. Supplement labels will be further described in this chapter under “Consumer Savvy.”

Distinguishing Among Foods, Food Additives, and Nutritional Supplements

Historically, the FDA regulated dietary supplements as foods for several decades. This was done to ensure that their labeling was accurate and that the supplements were safe and “wholesome.” Under the 1958 Food Additive Amendments to the Federal Food, Drug, and Cosmetic Act (FD&C Act), any new dietary ingredients for use in food or supplements were evaluated for safety. Frequently, the FDA previously viewed ingredients contained within dietary supplements as being analogous to substances that are added to foods. This perspective was problematic for supplement manufacturers because if a substance was not

recognized as safe (GRAS) based on ample scientific literature, then the substance was categorized as a food additive; categorizing it in this way had several consequences for a dietary supplement.

According to the FD&C Act, to market a food additive required petitioning the FDA for permission. To successfully petition often required much new research, money, and patience; it sometimes took the FDA more than 5 years to approve a new food additive. Because this previous system seemed unnecessarily complex, Congress amended the FD&C Act with the DSHEA to incorporate many provisions for dietary supplements. One major provision of the DSHEA is the precise clarification that the term “food additive” does not apply to dietary supplements. Hence, the DSHEA excludes the ingredients in dietary supplements (and therefore sports supplements) from the premarket safety assessment that is mandated for food additives or for new uses of previously established food ingredients. Binders, fillers, diluents (substances used to dilute), preservatives, and colors that may be used in nutritional supplements are still subject to food additive regulations.⁹ (New and old ingredients are defined by the FDA with respect to whether they were marketed for nutritional supplement use in the U.S. before or after October 15, 1994.)

The Supplement Police

With the new legislation, the regulatory role of the FDA was changed from that of evaluating premarket safety to policing the industry.⁹ Essentially, the FDA went from playing the role of the teacher granting a hall pass to assuming the role of the principal patrolling the hallways for violators. Thus, the burden of proof now rests on the FDA. However, dietary supplements are not exempt from all safety provisions.¹⁰

What is a “Safe” Supplement?

The DSHEA categorizes a nutritional supplement as *adulterated* (impure, or of questionable safety) if it or one of its ingredients poses “a significant or unreasonable risk of illness or injury” when used as indicated on its label. If there are no directions on the label, then the supplement must not present a risk when used under normal conditions. Also, any new ingredient may be considered unsafe if there is inadequate information from which to draw conclusions about its safety.¹⁰

The government did receive some new authorization as a result of the DSHEA. For example, the Secretary of Health and Human Services may proclaim a dietary supplement “to pose an imminent hazard to public health or safety,” which would effect an immediate ban on sales of the product.⁹

Using Literature to Inform Consumers

Before the DSHEA, any publications used to promote dietary supplements could be regulated by the FDA as

labels when used at the time of a prospective sale. Literature that claimed any role in the cure, mitigation, treatment, or prevention of any disease was particularly targeted. These claims, though not made on the product itself, would have made the supplement subject to regulation as a drug. So according to the old statutes, supplement salesclerks should not have promoted products by showing customers any publications that claimed disease-prevention benefits.⁹ This restriction was even true of scientific publications. Despite these restrictions, however, these marketing strategies were widely practiced.

The new legislature offers significant freedom to those who wish to use literature to market nutritional supplements. The DSHEA says that a “third-party” publication, such as “an article, a chapter in a book, or an official abstract of a peer-reviewed publication,” “shall not be defined as labeling” and may be “used in connection with the sale of a dietary supplement to consumers” if the literature is “reprinted in its entirety.” Furthermore, the publication must meet several criteria: it must not be false or misleading; it must not promote a particular brand or manufacturer; it must be presented with similar material in a balanced fashion that illustrates the sum of the available scientific literature; when displayed, it must be physically separate from the supplements; it must not have any additional information, such as product promotional literature, affixed to it.^{9,10} Given these amendments, a supplement salesclerk may now legally promote supplements by showing consumers scientific literature detailing the health benefits of particular supplements.⁹

What is the Difference Between a Supplement and a Drug?

What exactly is a dietary supplement, and how does it differ from a drug? Generally, a nutritional supplement provides a substance that is a component of a normal physiological or biochemical process. In contrast, a drug alters a physiological or biochemical process. Of course, more complex legal definitions have been established to distinguish between these two entities.

As previously mentioned, the NLEA expanded the traditional definition of “dietary supplement” to include not just essential nutrients, but also to encompass “herbs, or similar nutritional substances.” The DSHEA further expanded the definition of dietary supplements to include nonessential nutrients to encompass substances such as garlic, ginseng, fish oils, enzymes, psyllium (a fiber laxative), glandulars (extracts from animal glands or tissues), and combinations of these.¹⁰

The following is an abbreviated, nontechnical definition of “dietary supplement” provided by the Office of Dietary Supplements at the National Institutes of Health (NIH), an office itself established as stipulated by the DSHEA: “The Dietary Supplement Health and Education Act defines dietary supplements as a product (other than tobacco) intended to supplement the diet that bears or