ROUTLEDGE

Dietary Supplementation in Sport and Exercise

Evidence, Safety and Ergogenic Benefits

Edited by Jay R Hoffman

DIETARY SUPPLEMENTATION IN SPORT AND EXERCISE

Dietary Supplementation in Sport and Exercise removes the myths associated with many dietary supplements. It provides an evidence-based approach to the physiological mechanisms related to popular supplements and examines the ergogenic benefits in both competitive and recreational athletes.

This text covers a variety of supplements, including vitamins and minerals, carbohydrates, protein and amino acids, beta-alanine, creatine and guanidinoacetic acid, caffeine and probiotics, as well as emerging ergogenic aids. Information on dosage, ceiling effects and washout periods is discussed, along with safety and legality for different sporting organizations. The book also offers an insight into the efficacy of certain dietary supplements in unique populations, like children and the elderly.

Dietary Supplementation in Sport and Exercise is an important resource for advanced undergraduate and graduate students on exercise science, health and nutrition courses, as well as strength coaches, athletic trainers, nutritionists and personal trainers, and medical professionals who consult with patients on dietary supplementation.

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DIETARY SUPPLEMENTATION

Prevalence of use, regulation and safety

Jay R Hoffman

Introduction

The dietary supplement industry is a multi-billion-dollar enterprise that continues to grow annually. From the 1990s until the turn of the twenty-first century dietary supplement sales increased by more than 80% to nearly $16 billion dollars annually (3). Growth has not slowed and the market for dietary supplements continues to expand. Popularity for dietary supplement use is attributed to various reasons including a desire to reverse nutritional deficiencies that may pose a risk for disease (52). A large segment of the population also consumes dietary supplements to enhance athletic performance or improve aesthetics (e.g., weight loss or lean muscle gain) (23, 24). A recent increase has also been seen in the use of dietary supplementation for healthy ageing (15, 49). Recent investigations have focused on the potential role that various nutrients have on improving brain health (45, 55), reducing risk of sarcopenia (22) and improving functional performance (8, 39) in older adults. Despite numerous studies demonstrating positive outcomes associated with dietary supplement intervention, there is still much debate and concern over the health and safety associated with many supplements (41, 42). This is largely a function of an industry whose regulation and oversight has been questioned (11). As such, this chapter will focus first on the prevalence of dietary supplement use in various population groups including adolescents, adults, competitive athletes and military personnel. This chapter will then provide some insight into the regulatory and safety aspects of dietary supplement use.

Dietary supplement use in adolescents

A number of investigations have examined the pattern of dietary supplement use in adolescents. These studies, primarily examining American population groups,

have reported dietary supplement use in adolescents ranging from 23% to 74% (2, 5, 21, 25). These studies did not focus on young, competitive athletes, but rather the general population. Hoffman and colleagues (25) surveyed adolescent males (n = 1559) and females (n = 1689) in the 8th to 12th grades within the continental United States. Results from their investigation indicated that 71% of students surveyed reported using at least one dietary supplement. These numbers are greater than that seen in European, Asian and Middle-Eastern countries (16, 29, 47, 54) and may be a function of cultural differences regarding the acceptance of dietary supplementation in various adolescent populations. Figure 1.1a–c depicts the self-reported use of various supplements by all students combined (Figure 1.1a), males only (Figure 1.1b) and females only (Figure 1.1c) collapsed across grades. The most popular supplement used by high school students appears to be multivitamins (59%). This is consistent with a more recent investigation by Evans and colleagues (13) indicating that 95% of adolescents that report using a dietary supplement use a multivitamin supplement. The second most popular supplement in high school students reported by Hoffman et al. (25) was high energy drinks (32%). Male adolescents were noted to consume high energy drinks significantly more than females (38% versus 25%, respectively). In addition, the use of weight gain supplements (e.g., protein powders, amino acids, weight gain powders and creatine) was reported by 15% of all students surveyed (this includes students consuming more than one supplement), while the use of weight loss supplements (e.g., fat burners, high energy drinks, ephedra and caffeine pills) was reported by 35% of all students surveyed. Supplements associated with body mass and body fat reduction (e.g., fat burners, ephedra and caffeine pills) appear to be favoured more by females, whereas male adolescents tend to favour muscle-building supplements (2, 10, 14).

Nutritional supplementation use by grade

Figure 1.2 displays dietary supplement use by grade. As adolescents mature they tend to increase their use of dietary supplements, and this is more prevalent in males than in females. Protein powder use increases in both adolescent males and females throughout high school. The use of weight gain powders also increases from the 8th to 11th grades, where it then plateaus. An increase in the use of high energy drinks occurs from the 8th (29%) to 10th grades (34%), while creatine use also increases in both males and females as they mature from the 8th (0.6%) to 12th grades (12.2%). As students mature the number of supplements used to enhance muscle mass and strength increases significantly. These changes are greater in males than females (see Figures 1.3 and 1.4). The use of supplements with a primary goal to reduce body weight increases throughout high school (34.6% in 8th grade students to 56.4% in 12th grade students).

Supplementation habits of male and female high school students appear to differ. Adolescent males appear to be more interested in supplements that increase muscle size, strength and body mass than adolescent females (25). The tendency for

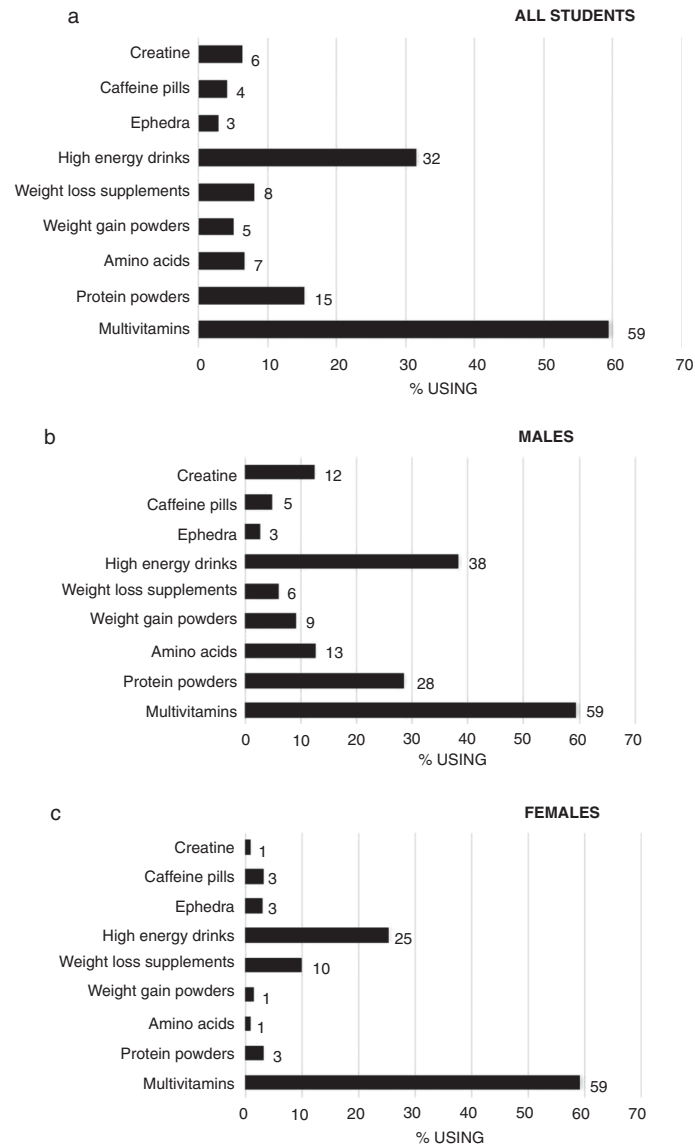

FIGURE 1.1 Supplement use by adolescents
Source: Data from (25).

males to supplement with protein, amino acids, weight gain powders and creatine increases from the middle school grades (8th and 9th grade) to the upper grades of high school. The primary reason associated with supplement use among very active adolescents appears to be enhancement of sports performance (57). For adolescents that are less active the primary reasons for supplement use still appear to be related

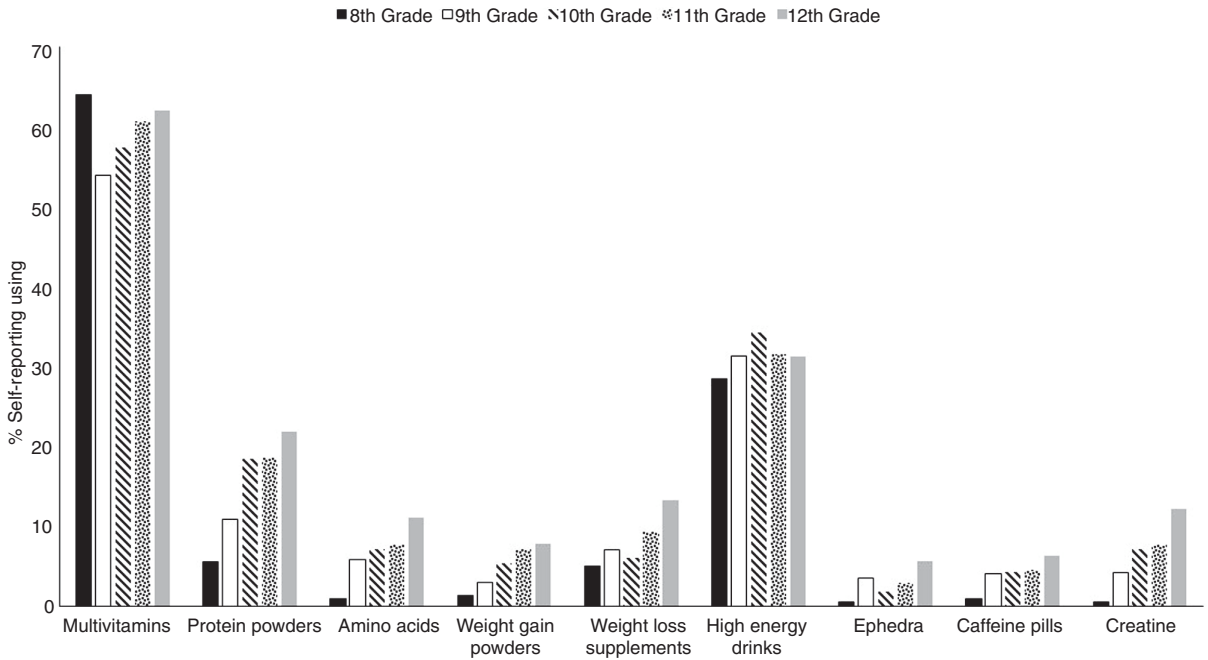

FIGURE 1.2 Supplement use by grade

Source: Data from (25).

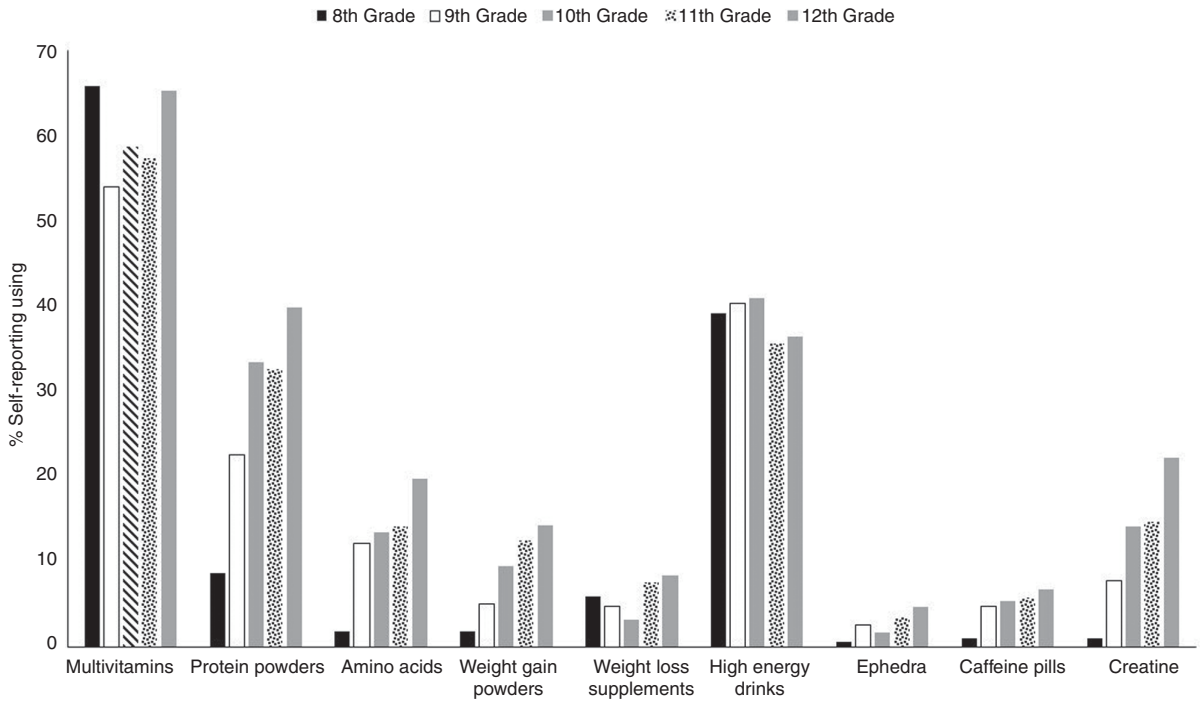

FIGURE 1.3 Supplement use by male adolescents across grade

Source: Data from (25).

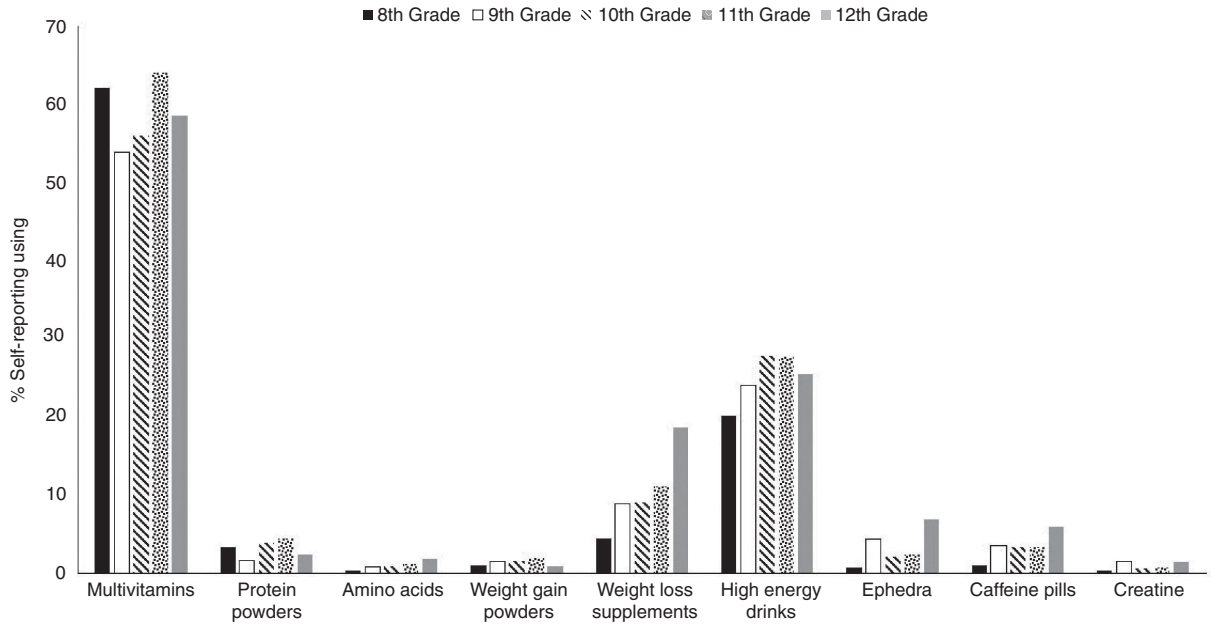

FIGURE 1.4 Supplement use by female adolescents across grade

Source: Data from (25).

to sport performance and body image among males, whereas improvements in health (e.g., enhanced immune function, bone health and compensation for inadequate diet) are the primary reasons provided by females (57).

Dietary supplementation use in adults

The most thorough survey of dietary supplement use of the American population comes from the National Health and Nutrition Examination Survey (NHANES). Initial studies indicated that supplement use in the general adult population from the 1980s through the turn of the century tended to increase (5, 32). However, the most recent survey, which collected data from 1999 to 2012, suggested that supplement use in the United States has plateaued (~52%) over the past decade (30). Supplement use among adults in the United States is similar (~53%) to that reported in Danish adults (46), but greater than that reported in Australian adults (~41%) (6). However, the focus of these surveys has been on multivitamin and mineral use and not on the range of supplements that are generally associated with muscle mass gains, weight loss and energy. The primary reasons indicated why adults use dietary supplements is a desire to "feel better" (~41% of supplement users), "improve energy" (~41% of supplement users) or enhance immune function (~35% of supplement users) (4). Interestingly, reasons for supplement use such as "building muscle" or "improving sport performance" still exists (~14% and ~11% of supplement users, respectively), but at much lower priorities than seen in young adults. Women tend to use dietary supplements to a greater extent than men and adults that use supplements appear to have a higher level of education than individuals that do not (30, 46). Adults who believe they are in excellent health tend to use dietary supplements more than adults who self-report their health status as being fair to poor (30).

A recent study examining young adults (e.g., American college students) indicated that 66% of the students surveyed consumed at least one dietary supplement per week and ~12% indicated that they consumed five dietary supplements per week (37). The most popular supplement consumed was vitamins and minerals. More than 40% of college students (both males and females) that were consuming at least one dietary supplement indicated that they used either a multivitamin or mineral. Protein and amino acids were consumed by 17% of the college students supplementing, but this pattern was significantly different between males and females. Males tended to consume protein and amino acids to a far greater extent than females (~34% versus ~8%, respectively). Lieberman and colleagues (37) also indicated that the prevalence of dietary supplementation was similar between males and females (both at 66%) and that college students that were more active (exercising between 2.5–5 hours per week) and trying to gain weight were more apt to consume a dietary supplement (72% and 74%, respectively) than less active students (exercising less than 30 minutes per week) and those that were trying to maintain their weight (58% and 64%, respectively). A desire to enhance health was the primary reason college students indicated for using a dietary supplement (see Figure 1.5).

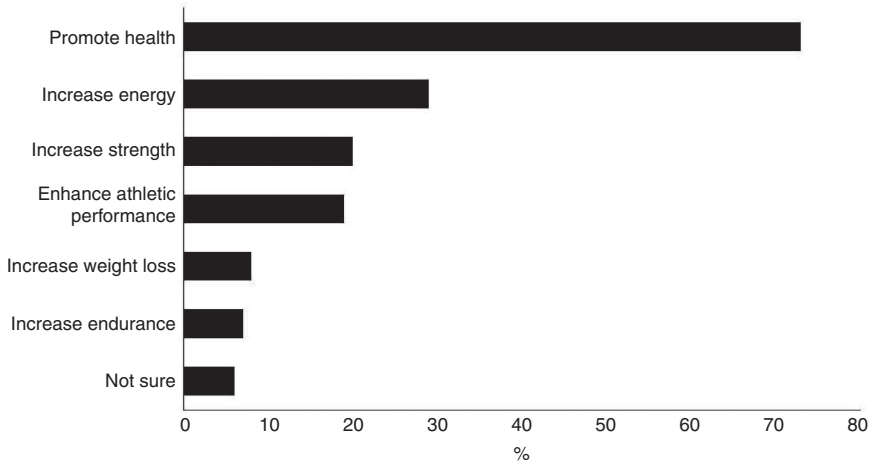

FIGURE 1.5 Reasons for supplement use by college students
Source: Data from (37).

The prevalence of dietary supplement use among college students in other countries has also been examined. Barnes and colleagues (1) examined patterns of dietary supplement use in Australian college students and reported that 74% of students surveyed indicated using at least one dietary supplement in the previous six months. The most common supplement used was a vitamin or mineral (69% of the students surveyed). The most common non-vitamin or mineral consumed was fish oils. American and Australian students appear to use dietary supplements to a much greater extent than Japanese students. Kobayashi and colleagues (36) reported that the prevalence of dietary supplement use in male and female Japanese students was 17.1% and 16.7%, respectively. Similar to American students, the primary purpose for using dietary supplements in Japanese students was to promote health. In addition, the most popular supplement being used by Japanese students was vitamins and minerals. This appears to be consistent in all counties surveyed.

Dietary supplement use by competitive athletes

The intense training common to competitive athletes frequently pushes the athlete to their physiological limitations. This may result in various nutritional deficiencies. Many sport science and nutritional organizations believe that the greater metabolic demand common to athletes can be met with appropriate adjustments to the athletes' diet, but do acknowledge that dietary supplementation can be of benefit in a number of circumstances (51). However, the use of dietary supplementation by competitive athletes is not just related to maintaining appropriate macro- and micronutrient intakes, but on maximizing athletic performance by creating a competitive advantage (33). One of the largest issues raised by professionals

regarding supplement use in competitive athletes is that more than half of athletes surveyed used supplements in a manner inconsistent with recommendations (31), highlighting the lack of education on evidence-based recommendations.

Maughan and colleagues (43) reported that 86% of elite track and field athletes (n = 307) use a dietary supplement for training. The prevalence of supplement use appeared to be greater in endurance athletes (91%) compared to sprint athletes (76%). The primary reason for using a supplement was to aid in recovery from training (71%) followed by improving health (52%), improving performance (46%), treating or preventing illness (40%) or balancing an unbalanced diet (29%). The most common supplements used by these athletes were vitamins and antioxidants (84%) followed by minerals (73%), muscle-building ingredients (i.e., protein and creatine) (53%) and several others that were grouped together including coenzyme Q, caffeine, ginseng and ephedrine (52%). In a study on approximately 600 elite Canadian athletes a similar pattern of dietary supplement use (88% of all athletes surveyed) was reported (12). In the study, the investigative team surveyed athletes from the national training center, university level and a national sports school for adolescents. The average age of athletes surveyed was 20.0 ± 3.9 y and they participated in a range of endurance and strength/power sports with the most frequent sport participation being ice hockey (12.7%), soccer (9.6%) and football (9.1%). The most popular supplements used by these athletes, separated by age, can be observed in Figure 1.6. The mean age (± SD) of the athletes surveyed in the high

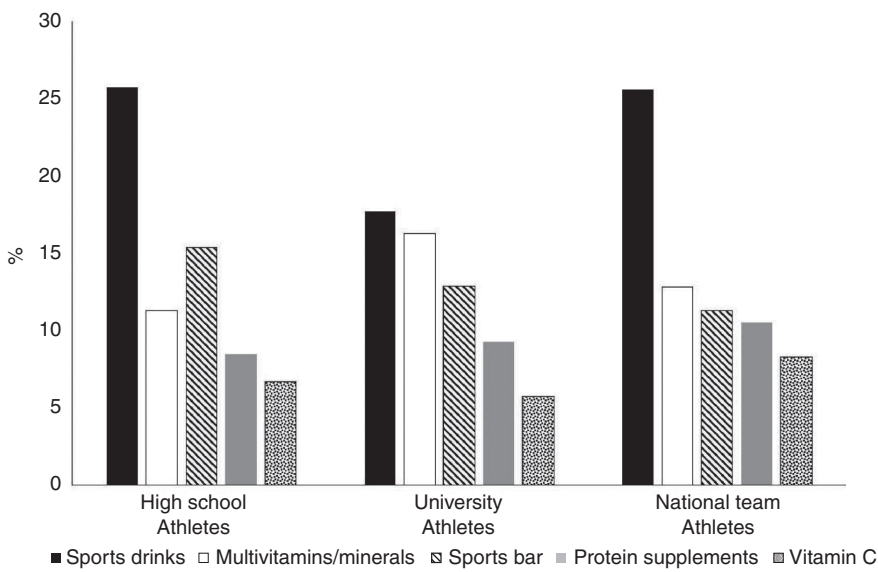

FIGURE 1.6 Supplement use comparison between Canadian high school, college and national team athletes

Source: Data from (12).

school, university and national team training centres was 16.4 ± 1.2 y; 20.8 ± 5.5 y; 20.4 ± 2.1 y, respectively. Interestingly, in contrast to other studies, the athletes surveyed in this investigation used sports drinks as their primary supplement. It was not clear from the authors whether this sports drink was an electrolyte drink, protein shake or energy drink. However, the use of creatine (2.4%) and amino acids (0.2%) was low and may reflect the popularity of those supplements and knowledge available at that time.

Younger athletes appear to consume dietary supplements at a level slightly lower than that observed in older athletes. Petróczi and colleagues (47) surveyed patterns of dietary supplement use in 403 elite, young athletes (17.7 ± 2.0 y, range 12–21 y) within the United Kingdom. A total of 48.1% of the athletes surveyed admitted to using at least one dietary supplement, with energy drinks being the most popular supplement (41.7% of all athletes, but approximately 87% of all athletes that used at least a single dietary supplement). The primary reason for using energy drinks was to enhance endurance. The type of athletes that completed the survey were comprised of a number of different sports; 27.8% were rugby union players, 13.9% were soccer players and 6.7% were swimmers. Smaller numbers of athletes were surveyed from approximately 20 additional sports. Besides energy drinks, the next most popular supplements used by these athletes were multivitamins (22.8%), protein (21.3%) and creatine (13.4%).

In a comparison of Finnish Olympic athletes between 2002 (n = 446) and 2009 (n = 372), the use of at least a single dietary supplement was noted by 81% of the athletes in 2002, but reduced to 73% in 2009 (20). This decrease in dietary supplement use was statistically different and was thought to reflect a greater awareness of purity issues and contamination of supplements among the athletes (this will be discussed in more detail later). However, this may also reflect the younger age of Olympic athletes surveyed in 2009 (21.2 ± 4.3) compared to 2002 (23.0 ± 4.5). Consistent with previous studies, older athletes (> 24 y) used dietary supplements more frequently than younger athletes. In addition, men used dietary supplements more frequently than women in both 2002 and 2009. Interestingly, despite the trend towards a decrease in dietary supplement use during these years, the percentage of athletes that were using dietary supplements were still greater than that reported by Canadian athletes in both the 1996 (69% of the athletes reported using a dietary supplement) and 2000 (74% of the athletes reported using a dietary supplement) Olympic games (27). Consistent among all investigations examining Olympic athletes, the most popular dietary supplements used are multivitamins (ranging from 44% to 57%) and protein (ranging from 38% to 47%).

The use of dietary supplements is also popular among Paralympic athletes (40). Madden and colleagues (40) surveyed 40 Paralympic athletes (ranging in age from 20.5 to 33.5 y). Eighty-seven percent of these athletes competed at international level and the majority of these athletes participated in wheelchair basketball (67.5%). The remainder of the athletes were evenly distributed in eight other sports. All of the male athletes (100%) reported using at least one dietary supplement, while 91% of the female athletes reported using at least one dietary supplement.

Sports bars (38.9%), protein powders (38.9%) and energy drinks (33.3%) were the most popular supplements used by men, while vitamin D (40.9%), protein powder (22.7%) and fatty acids (18.2%) were the most popular supplement used by women. These athletes indicated that staying healthy (50%), increasing energy levels (42.5%), medical reasons (40.0%), enhancing athletic performance (37.5%) and improving recovery (37.5%) were the primary reasons for using dietary supplements. No differences in the reasons for supplement use were observed between male and female Paralympic athletes.

Dietary supplement use by military personnel

The prevalence of dietary supplement use in military personnel has become a major topic of interest for a number of military scientists. Lieberman and colleagues (38) reported that 53% of American soldiers based at various military installations around the world (outside of the combat theatre) use at least one dietary supplement on a regular basis. A follow-up study estimated the prevalence of dietary supplement use in the United States Army, Navy, Air Force and Marine Corps to be 55%, 60%, 60% and 61%, respectively for men and 65%, 71%, 76% and 71%, respectively for women (34). Cassler and colleagues (7) reported that up to 72% of the United States Marines deployed to Afghanistan used a dietary supplement.

In a longitudinal study that is being conducted over a 20-year period, the Naval Health Research Center of the United States military has interviewed more than 100,000 military personnel since 2001 (28). Nearly half of all soldiers (46.7%) indicated using at least one dietary supplement. Dietary supplement use was more common in men than women, except for weight-loss supplements. Energy drinks were the most popular dietary supplement used by both male (40.5%) and female soldiers (35.5%). Amino acids, weight-gain products, creatine and supplements promoting muscle and strength gains were the most popular supplements used by male soldiers (22.8%). Weight-loss supplements (e.g., energy drinks, pills or energy-enhancing herbs) were the most popular supplements used by female soldiers (26.9%). Jacobson and colleagues (28) reported that deployment was a strong predictor of dietary supplement use. The investigators suggested that soldiers who deployed were more likely to use weight-loss supplements to maintain or achieve "fit-for-duty standards" and were also likely to use dietary supplements to increase muscle mass and strength. In addition, the use of energy supplements was also popular in deployed soldiers for reasons relating to increasing and maintaining alertness.

In a recent study on United States Navy and Marine Corps personnel Knapik and colleagues (35) reported that 72.6% of the soldiers surveyed (n = 1683) indicated they consumed at least one dietary supplement. Dietary supplement use appeared to be more prevalent in older soldiers (30–39 y) compared to younger soldiers (18–24 y; 75.9% versus 66.8%, respectively). In contrast to the Jacobson study (28) female soldiers were more likely to use dietary supplements (~76%) compared to male soldiers (~72%). No differences were noted in dietary supplement use between

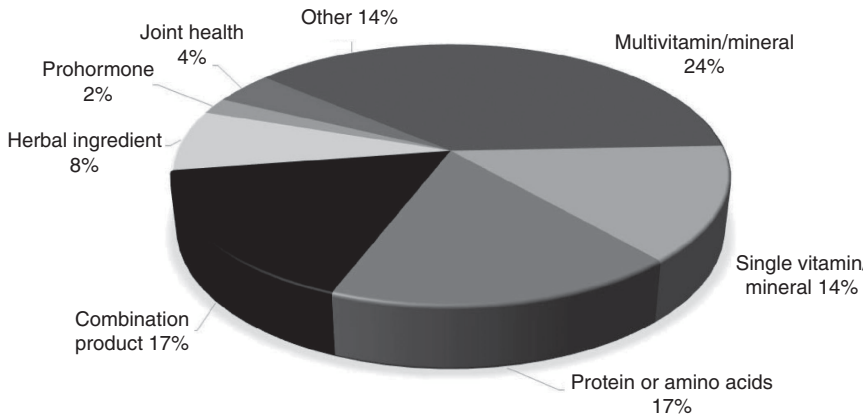

FIGURE 1.7 Type of supplements used by Navy and Marine Corps personnel
Source: Data from (35).

combat soldiers, combat support or combat service support. However, the type of exercise training program soldiers participated in did appear to impact supplement use. Soldiers that performed resistance training more than 136 minutes per week were more likely to use at least one dietary supplement (~79%) significantly more than soldiers performing resistance training less than 135 minutes per week (range 65–75%). No differences were noted in supplement use among various durations of weekly endurance training. The type of supplements used by the participants in this survey are depicted in Figure 1.7. Similar to most other dietary supplement surveys, the use of a multivitamin or multimineral was the most popular supplement used. Interestingly, more than half of the soldiers surveyed indicated that they take more than one dietary supplement and 31% of the soldiers indicated they consume at least five dietary supplements. No differences were noted in supplement use in married versus single soldiers, but soldiers with college experience appear to supplement more than soldiers with only a high school educational background. Interestingly, 22% of the soldiers using dietary supplements reported one or more adverse events. For supplements deemed a combination product, 29% of users reported one or more adverse events.

Combination products were reported to be those dietary supplements that contained a number of different ingredients generally seen in weight loss and/or muscle-building supplements. However, the specific ingredients within these supplements were not clearly defined. The authors though did suggest that many of the supplements within this classification contained banned or illegal ingredients such as 1,3 dimethylamylamine or ephedra alkaloids (35). When not including combination products the magnitude of adverse events associated with dietary supplement use dropped to approximately 13%. The use of prohormone supplements resulted in a 9.4% adverse event occurrence, while herbal supplements appeared to be associated with at least one adverse event in 8.9% of users.

Safety profiles and adverse events associated with dietary supplementation

In 2003 the Federal Drug Administration (FDA) officially began to monitor adverse events associated with the food, cosmetic and dietary supplement industry (56). In 2018, Timbo and colleagues (56) estimated the adverse event rate of dietary supplements for the first time covering a ten-year period from 2004 to 2013. During that time a total of 154,430 adverse event reports were filed within the United States. Women tended to report adverse events at a greater rate (64.4%) than men (31.6%), about 4% of the adverse events reports did not indicate a gender. Of the adverse event reports filed 32% did not provide an age, however 59.6% of the individuals filing an adverse event (6247/10,487) were above the age of 50. The most common serious outcome arising from these adverse events was hospitalization (25.4% of all serious outcomes) and 7.9% of these outcomes were considered life-threatening conditions. The need for surgery to prevent permanent impairment occurred in 5.1% of the individuals reporting an adverse event and 339 deaths (2.2%) were associated with adverse events from dietary supplement use. The most common supplements contributing to adverse events are depicted in Figure 1.8. Vitamins and minerals contributed to the overwhelming number of adverse events. Interestingly, supplements common to athletic or active populations (e.g., energy products and bodybuilding) contributed to about 9% of the adverse events reported. A recent study examining supplement toxicity indicated that Ma

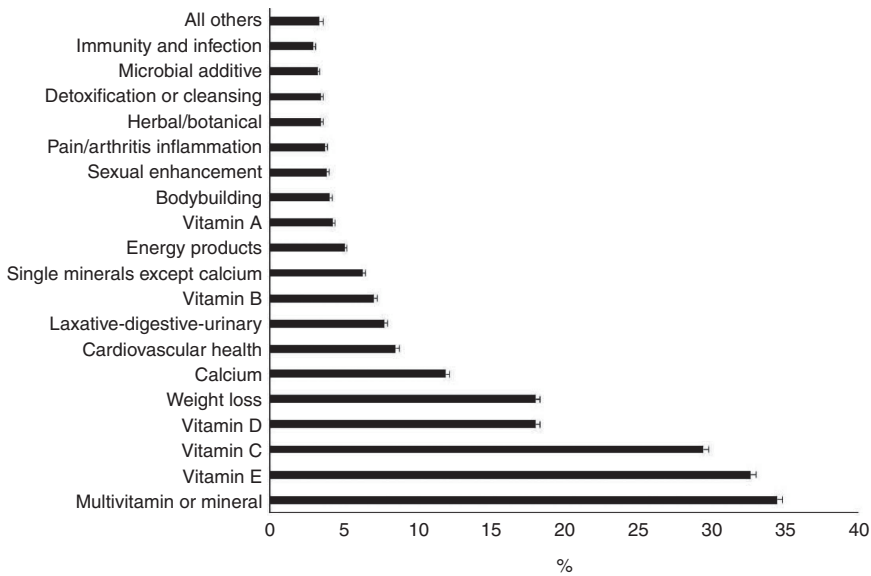

FIGURE 1.8 Dietary supplement adverse event reports from 2004–2013

Note: Data are reported as mean ± SE.

Source: Data from (56).

huang products (also known as Ephedra), yohimbe and energy products were the categories associated with the greatest toxicity (50).

Issues of adverse events are an important part of the safety profile for each specific dietary supplement. Although specific safety issues for the dietary supplements discussed in the book will be covered in each of the chapters, most safety profiles do not focus on supplement–supplement or supplement–drug interactions. This is a major concern for the weight loss supplement industry in which a host of ingredients with varying physiological effects are often combined together in a "cocktail" for consumer use. This is often referred to as a combination supplement. Although efficacy for individual ingredients may exist through scientific investigation, how these individual ingredients interact physiologically with each other (e.g., synergistically, antagonistically or exacerbating a physiological response) is rarely examined. Investigations of combination supplements are difficult to design with sufficient statistical power to truly understand ingredient interactions. If scientific studies are conducted with a combination supplement, it is often examined by investigating study participants consuming the combination supplement compared to study participants provided with a placebo. Without understanding the physiological effect of ingredient interaction, there are limitations to understanding the role of each ingredient. Also, it may increase the risk for an adverse event because of potential synergies or an additive effect. This may pose a significant medical risk for some supplement users. Further, a weakness of many supplement investigations is that it is often conducted in apparently healthy populations. How individuals with known medical conditions respond to a specific dietary supplement ingredient is often not understood. Further, how these ingredients interact with prescription drugs is also largely left to chance.

Issues regarding combination supplements are not just limited to synergies or additive effects, but whether the dose of each ingredient is consistent with the evidence supporting its efficacy. For instance, a supplement containing the alanine-glutamine dipeptide using a low and high dose (0.05 $g \cdot kg^{-1}$ body mass and 0.2 $g \cdot kg^{-1}$ body mass, respectively) was demonstrated to enhance fluid absorption and time to exhaustion in dehydrated college students (26). Based on the results of this study, the average male (70 kg body mass) would need to consume at least 3.5 g of this dipeptide (70 kg person × 0.05 g per kg [i.e., minimum dose showing efficacy]) for the supplement to be efficacious. In a follow-up study, investigators compared low (300 $mg \cdot L^{-1}$) and high doses (1 $g \cdot L^{-1}$) of this dipeptide mixed in a commercially available sports drink and compared to the sports drink alone, or a control trial in which no drink was provided (44). Study participants ran for one hour at 70% of their maximal aerobic capacity (VO_2max) following by a run to exhaustion at 90% of their VO_2max. Hydration (either the two supplement doses or the sports drink alone) was permitted in 15-minute intervals during the hour long run. No hydration was permitted in the control trial. Results indicated significant differences between trials in which participants consumed the dipeptide in both low and high concentrations compared to the no hydration trials. Interestingly, no significant differences were noted between the sports drink alone and the controlled trial. When the sponsoring

company attempted to market this to commercial sports drink companies they were met with the same response that the added cost of this ingredient, even using its lowest effective dose, would put it at a competitive disadvantage regarding retail price. This story is important because it highlights the decision-making factors that supplement companies consider when determining the final dose of their supplements. The cost factor of ingredients determines to a large degree how much of a specific ingredient goes into a supplement. So, if a company decided to include this dipeptide as part of a "ready-to-drink" rehydration supplement at doses lower than what has been determined to be efficacious, the actual dose used would have no impact on performance. Any marketing claims made by the company towards the potential impact of this supplement would be frowned upon by the United States Federal Trade Commission (FTC). Unfortunately, this hasn't stopped many unscrupulous supplement companies from making unsupported claims. To offset costs of expensive ingredients companies may "sprinkle" (e.g., small dose – less than what is considered to be efficacious) an ingredient as part of a combination supplement, or even a single ingredient supplement, to take advantage of research performed by others using appropriate dosages. Companies do this so they can state on their label or marketing materials that a specific ingredient is in a supplement even though it is not provided as an effective dose.

Although claiming a particular ingredient is in a dietary supplement, but at a dose that is not effective can be considered as deceptive advertising; not notifying the public of all the ingredients that are in a supplement is another major concern. To boost the effectiveness of various dietary supplements, especially those with ergogenic potential, some companies have added illegal and/or banned substances. This occurs both knowingly and inadvertently. Some companies adulterate their dietary supplements with illegal and/or dangerous ingredients such as hormones or prohormones to augment the desired effect of the supplement. Others may offer banned substances such as prohormones as a separate product line and, following a run on their production line, will then begin a run of a different supplement without thoroughly cleaning their machines. This may result in contamination from the previous ingredients getting into the next batch of supplements. These issues have gained media attention as numerous high-profile athletes have tested positive for illegal and banned substances claiming they did not fully understand what was in the supplement they were provided with. Regardless, the athlete may be suspended and/or may be forced to give up victories or medals.

Contamination issues of dietary supplements

In 2004, Dr. Hans Geyer and colleagues from the Institute of Biochemistry in the German Sport University in Cologne, Germany examined 634 non-hormonal dietary supplements purchased in 13 different countries from 215 different suppliers (18). Forty-six percent of the supplements examined were from companies that sell prohormones (substances that are precursors of anabolic hormones such as testosterone). Of the 634 samples analyzed 14.8% (n = 94) contained prohormones of

either testosterone, nandrolone and/or boldenone, which were not declared on the label. The vast majority of these positive tests were from prohormone-selling companies (21.1%), while only 9.6% of the supplements from companies not selling prohormones were positive. Banned substances were found in tablets, powders and capsules. Although companies originating from the United States had the most positive tests (45 positive tests from 240 samples), samples of supplements originating from both the Netherlands (25.8%) and Austria (22.7%) had the greatest relative percentage of samples producing a banned substance. Since 2004, the issue of contaminated substances appeared to get worse, as the increase in trade and availability of anabolic steroids and β2 agonists from Chinese companies resulted in a greater expansion of illegal supplements and cross-contaminated dietary supplements (17).

Considering that most of the evidence published on dietary supplement contamination is focused on the use of precursors of anabolic hormones, the assumption is that contamination is limited to muscle-building supplements. However, contamination has been reported in a variety of products. Contaminants have been found in weight loss and energy supplements, strength and muscle bulk enhancers, sexual performance enhancers, cognitive enhancers and supplements to enhance the immune system and aid in recovery (48). Regardless, the most common contaminant found in dietary supplements has been anabolic steroids (48).

To assist athletes and other dietary supplement users on choosing safe supplements a number of dietary supplement certifying organizations were developed. These organizations, such as NSF International and Informed-Choice are quality assurance program for suppliers to the sports nutrition industry and supplement manufacturing facilities. It certifies that samples of a specific supplement product and/or raw material that bears the organization's logo has been tested for banned substances by a certified world-class sports anti-doping lab. It is important to note that certified supplements are certified that they contain no banned substances, they are not certified that they work! Further, the certification is for the lot number tested only and not for each lot manufactured.

Regulation of the dietary supplement industry

Dietary supplements in the United States have always been regulated as a category of foods (9). In the 1980s and early part of the 1990s the FDA had discussed the reclassification of vitamins and minerals as drugs and also made known a desire to limit the amount of vitamins and minerals in dietary supplements (9, 53). In addition, the FDA also noted that amino acids were illegal food additives and should not be permitted in supplements (9). This obviously created turmoil within the dietary supplement industry and led to congressional intervention to define what a dietary supplement is and provide some clarity. In 1990, The United States Congress passed the Nutrition Labeling and Education Act (NLEA). This law required the FDA to change the food label into a guide to promote more informed and healthier eating. It also required the FDA to provide definitions for terms used on labelling such as "free," "low," "light or lite," "reduced," "less" and "high" (53). With respect

to vitamins, minerals, herbs and other similar dietary supplements, the FDA had to establish final rules to establish the validity of health claims made by these products. The NLEA permitted the FDA to authorize a health claim that previously might have subjected the product to regulation as a drug (19). As the time for enactment of these rules came to be, congress was also working on legislation that would change dietary supplements and their regulation that was unprecedented.

In October 1994 the United States congress passed the Dietary Supplement Health Education Act (DSHEA). This law recognized the importance that the public placed on dietary supplements (53). The primary goal of this law was to have the government hold accountable companies that manufacturer unsafe and adulterated dietary supplements. On the other hand, congress provided some protection to the supplement industry as DSHEA provided a broad definition of a dietary supplement as something that contained a vitamin, mineral, herb or other botanical, amino acid or another substance used to increase a person's total dietary intake. In addition, companies were somewhat protected by forcing the onus on the government to prove that the dietary supplement was adulterated. It was suggested that the rationale for the burden being placed on the government was in part related to the belief that the risk of withholding the supplement compared to the potential benefit of their use justified a rapid assimilation into the marketplace (53). DSHEA permitted companies to market their dietary supplement for nutritional support and indicate a benefit to compensate for a nutrient deficiency that could prevent disease. Dietary supplement companies were also permitted to state the potential role and mechanism that the nutrient has in affecting structure or function in humans. However, the company would have to provide scientific evidence to support all statements and marketing claims needed to be truthful and not misleading. In addition, DSHEA also recognized the problem manufacturers of supplements were having with purity and warned that their products would be considered misbranded if they failed to provide 100% of the claimed ingredients or if they failed to have the quality they were represented to have (9). DSHEA also authorized FDA to develop Good Manufacturing Practice (GMP) regulations for dietary supplements.

When DSHEA was enacted there were approximately 600 manufacturers of supplements in the United States producing an estimated 4000 products but, within a decade that number rose to nearly 30,000 products (11). The numbers today are staggering worldwide. Canada has issued more than 100,000 product licenses since their Natural Health Products program was created and it has been suggested that there are more than 85,000 products in the American Market alone (11). The goal of DSHEA was to provide access for the consumer and demand quality from the manufacture. In this endeavour DSHEA has succeeded in expanding the market for dietary supplements and informing the consumer regarding what is in the supplement and what it does. Modifications required in dietary nutrition supplement labelling provided to the consumer information about the identity and quantity of the ingredients and their active components. However, issues with regulation is still a major problem within the dietary supplement industry. This is likely a result of enforcement occurring once the product has already been released to the public.

To provide better protection for the consumer, the use of pre-release approvals for dietary supplements should be considered. This would require the FDA to create an organization to provide a rigorous review process that results in a stamp of approval regarding the supplement's safety, purity and efficacy. This could be a function of the FDA's Office of Dietary Supplements, which was created in 1995. Its creation was a function of DSHEA and it resides within the National Institute of Health in the Office of Disease Prevention. Although many manufacturers of dietary supplements have medical and scientific departments and/or advisory panels that provide scientific and medical oversight of supplement formulation, research and marketing claims, many do not. Expectations for the dietary supplement industry need to become standardized in a fashion that is similar to the pharmaceutical industry. Pharmaceutical manufacturers invest millions of dollars towards the development of their drug pipeline to scientifically demonstrate and prove safety and efficacy. However, in contrast to the pharmaceutical industry the dietary supplement industry does not have the same patent protection of their products. For pharmaceutical companies there is a period of exclusivity in which they can earn their profits without the drug being duplicated by generic companies. Likewise, the dietary supplement industry also needs protection to allow for sufficient research and development to be committed, without the product being copied by other companies seeking to reap the benefits of those investments. This is an area in which the FDA needs to provide some assistance and assurances. This pre-release oversight of dietary supplements would raise safety, purity and efficacy expectations from these manufacturers.

Conclusion

This chapter showed the prevalence and popularity of dietary supplement use in a variety of population groups. Dietary supplements use is common across all age ranges and among competitive, recreational and sedentary adults. Multivitamins and minerals are the most popular dietary supplements being used across all population groups. The use of high energy drinks is becoming very popular, especially in competitive and tactical athletes. One of the biggest concerns for dietary supplement use in competitive athletes is the risk for contamination from companies adulterating their products either knowingly or unknowingly. This led to several certification programs to help identify products that are certified against banned substances. However, supplement users need to understand that this certification program does not certify efficacy of the product. This issue of contamination, purity of product and truth in reporting has been addressed by the DSHEA, but there is still much to do with issues related to regulation of dietary supplements.

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