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Strength, Conditioning, and Nutritional Considerations for High-Level Performers

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Strength, conditioning, and nutrition play an important role in preparing athletes to perform to the best of their ability. For this reason, nearly all competitive teams employ strength and conditioning specialists to prepare their athletes for competition, and most teams have sport dietitians and/or nutrition consultants as part of their performance-enhancement team. Academic and professional preparation of strength and conditioning and sport-nutrition specialists in kinesiology programs has opened up a number of career opportunities for students and scholars. In addition, advances in technology have enhanced the ability of strength and conditioning specialists and sport nutritionists to monitor athletes during training and competition. This paper provides an overview of the history, professional preparation, program components, and general principals of strength and conditioning and sport nutrition and the impact they have had on high-level performance, as well as future trends in these fields.

Keywords*:* sport nutrition, performance enhancement, ergogenic aid

We often marvel when we see athletes break world records and do what was once thought impossible. We are also amazed when we see sustained excellence of teams and athletes who win championships year after year. While the public sees the athletes and coaches, they may not know that behind every athlete, team, and victory there are professionals who spend countless hours helping the athletes, coaches, and teams succeed (see Figure 1). This includes strength and conditioning coaches, sport nutritionists, athletic trainers and physical therapists, sports-medicine and specialty physicians, biomechanists, data-analytics professionals, and sport psychologists from a performance standpoint (Dijkstra, Pollock, Chakraverty, & Alonso, 2014). In addition, athletic administrators, operations and facilities managers, equipment managers, travel and logistics personnel, videographers, and academic-support, communications, and marketing personnel provide team support (Smith & Smolianov, 2016). In high-level sport, success is often determined by how effective the performance-enhancement team is in applying the latest sport science and psychology to help athletes achieve peak performance so they can effectively execute the coach's game plan. For this reason, many teams have developed a multidisciplinary performance-enhancement team to optimize performance and athlete care. Strength, conditioning, and nutrition play a vital role in helping athletes perform to their potential. Consequently, nearly all competitive teams employ strength and conditioning specialists and sport dietitians or sport-nutrition consultants to help prepare their athletes. This paper provides and overview of the history and primary roles that strength and conditioning specialists and sports nutritionists play on the performance-enhancement team, how improvements in facilities and technology have improved performance, and future directions in these fields.

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Strength and Conditioning

History of Strength and Conditioning

Strength training has been reported to date back to 3,600 B.C.E. when Chinese emperors made subjects exercise daily and pass weight-lifting tests to enter the military (Fry & Newton, 2000; Heffernan, 2014). There is also evidence that weight training was part of life in ancient Greece and India (Fry & Newton, 2000; Heffernan, 2014). Weight-training books began to be published in the 16th century (Heffernan, 2018). Moreover, training methods of "strongmen" like Eugen Sandow and Dr. Vladislav Krayevsky from Russia in the 19th century and the popularity of bodybuilders and fitness leaders in the early to mid-20th century helped popularize strength training and bodybuilding (Heffernan, 2014, 2018).

Up to 1969, many coaches discouraged athletes from strength training for fear it was detrimental to athletic performance (Shurley & Todd, 2012). Although some athletes lifted on their own, there were relatively few strength coaches working with athletic teams, and many were volunteers (Shurley & Todd, 2012). In 1969, Boyd Epley was hired as the University of Nebraska's first full-time strength coach, and he quickly gained national notoriety for his success at it (Shurley & Todd, 2012), particularly after Nebraska won national championships in football in 1970 and 1971. Soon thereafter, several other universities and a few professional teams began hiring strength coaches. However, there was a need to share experiences and further develop the profession of strength and conditioning, so Boyd Epley and 76 other strength coaches from across the United States met at the University of Nebraska and founded the National Strength and Conditioning Association (NSCA) in 1978. The NSCA's mission is to serve as worldwide authority on strength and conditioning and disseminate research-based knowledge and its practical application to improve athletic performance and fitness. Today, there are over 30,000 NSCA members in 72 countries. In 2000, the Collegiate Strength and Conditioning Coaches Association was founded to serve as a dedicated organization to meet the needs and challenges of college

Figure 1 — Components of performance enhancement.

strength and conditioning coaches. Most full-time strength and conditioning coaches belong to the NSCA and/or Collegiate Strength and Conditioning Coaches Association.

Professional Development

In 1979, the NSCA launched the *Strength and Conditioning Journal* (SCJ) as a professional journal for strength coaches, personal trainers, physical therapists, athletic trainers, and other health professionals. The journal's mission is to publish articles that report both the practical applications of research findings and the knowledge gained by experienced professionals. In 1987, the NSCA founded the *Journal of Strength and Conditioning Research* (JSCR) to advance knowledge about strength and conditioning through research. These publications have served as important outlets to educate professionals in the field, as well as for research specifically focused on strength and conditioning. In 1993, the NSCA's Certified Strength Conditioning Specialist certification earned accreditation from the National Commission for Certifying Agencies. It represented the first nationally accredited strength training and conditioning certification program. In 1996, the NSCA-CPT became the first certified personal trainer program accredited by the National Commission for Certifying Agencies. In 2014 the Tactical Strength and Conditioning Facilitator program was the first of its kind to earn National Commission for Certifying Agencies accreditation. In concert with these efforts, many academic programs in kinesiology began offering strength and conditioning courses preparing students for certifications and/or academic programs in strength and conditioning. The NSCA Education Recognition Program recognizes and distinguishes schools with standardized, approved strength and conditioning or personal-training curricula at the undergraduate and/or graduate levels that lead to NSCA certifications. These efforts have led to significant advancements in strength and conditioning research and the number of academically trained and certified professionals in the field.

Components of a Strength and Conditioning Program

Strength and conditioning programs are generally based on principles of specificity, overload, progression, and variation with an understanding that there are diminishing returns as training adaptations occur and that they are reversible (Clayton et al., 2016; Haff & Tripplett, 2016; Sands, Wurth, & Hewit, 2012). Specificity of training involves designing programs that target the muscle groups, energy systems, movement patterns, speed of movement, and muscle actions needed for a specific sport or athletic competition (Clayton et al., 2016; Haff & Tripplett, 2016). Overload is achieved by modifying load, sets, repetitions, and/or rest periods of various exercises, while progression involves the systematic increase of a training stimulus over time to promote positive training adaptations (Clayton et al., 2016; Haff & Tripplett, 2016). Planned variation of types of training and exercises performed is also an important component in preventing plateaus in training adaptations and overtraining (Clayton et al., 2016; Evans, 2019).

Strength and conditioning programs are typically organized into periodized training phases based on the general stress-adaptation theory initially described by Selye (1951, 1976). Periodization is the systematic process of planned variation in a training designed to optimize training and help athletes reach their peak as needed for competition (Cunanan et al., 2018; Harries, Lubans, & Callister, 2015). The annual training program is commonly referred to as a macrocycle (Clayton et al., 2016; Haff & Tripplett, 2016; Sands et al., 2012). Mesocycle training phases (i.e., 2- to 8-week phases) are organized in concert with a team's competitive season and generally consist of a general physical preparation phase, specific preparation phase, precompetitive phase, competitive phase, and peak phase (e.g., conference or national championships). Microcycles of smaller training phases (e.g., 1–2 weeks), different types of training, and individual training sessions with different types of training (see Table 1) provide variation to training. Individual training sessions typically involve mobility and flexibility training (e.g., dynamic warm-up, flexibility training), resistance training, cardiovascular conditioning, core/stability training, and/or speed and agility training (Clayton et al., 2016; Evans, 2019; Haff & Tripplett, 2016; Sands et al., 2012). Conditioning programs typically involve speed (e.g., linear, sprinting technique, reactive, active acceleration, frequency, complex speed drills), agility training (e.g., perceptual/decision-making drills, technical-agility drills), plyometrics (e.g., exercises with eccentric, amortization/transition, and concentric contraction phases), deceleration and jump training (e.g., jumping in place, multiple hops, distance jumps, etc.), interval training (repeated sprints of varying lengths with recovery periods), and classical repeated-sprint training with progressively decreasing work-to-rest ratios (e.g., 1:10, 1:8, 1:6) as training adaptations occur. Strength and conditioning specialists are typically responsible for assessing training and conditioning levels and planning all phases of training before and during the competitive season.

Impact of Strength and Conditioning

Numerous studies indicate that incorporating these types of conditioning programs into the annual training program increases strength, power, speed, agility, and muscle mass in male and female athletes (Anzell, Potteiger, Kraemer, & Otieno, 2013; Evans, 2019; Kerksick et al., 2009; Kraemer et al., 2003; Vantarakis et al., 2017). For example, Kraemer et al. (2003) reported that 9 months of resistance training resulted in significant increases in fat-free mass; anaerobic power; grip strength; jump height; 1-repetition-maximum leg press, bench press, and shoulder press; serve, forehand, and backhand ball velocities; and resting serum insulin-like growth factor-1, testosterone, and cortisol concentrations in female tennis players. In addition,

Table 1 Types of Resistance Training

Type	Description
Accommodating resistance	Using bands or chains attached to a bar that adds variable resistance throughout the range of motion
Circuit training	Performing 1 set each of a series of exercises with limited rest recovery and repeating the circuit 2 or 3 times
Cluster sets	Performing of 1–3 repetitions with 10–30 s rest recovery to maximize power and quality of each repetition lifted
Complex set	Performing a strength-focused exercise followed by a power or plyometrics exercise (e.g., squats followed by depth jumps)
Compound set	Performing 2 or 3 exercises for a given muscle group in a row to promote greater fatigue on a muscle group
Drop sets	Performing a set to muscle failure at a load followed by dropping the weight and performing the next set with minimal rest recovery
Forced repetitions	Lifting to failure and performing additional repetitions past volitional fatigue with the assistance of a spotter
Heavy negatives	Lifting more than 1-repetition maximum and performing eccentric-only exercise with assistance of a spotter
High-intensity interval training	Alternating short periods of high-intensity exercise followed by lower-intensity exercise or recovery periods
Multiple-set program	Performing multiple sets of the same exercise with rest recovery before moving to the next exercise
Partial range of motion	Performing an exercise with a limited range of motion to promote gains in strength at that joint angle
Pyramid loading	Lifting multiple sets at progressively increasing loads and reduced repetitions
Single sets	Performing 1 set of each exercise
Supersets	Performing alternating exercises for opposing muscle groups

Note. Adapted from Clayton et al. (2016).

that periodization of resistance training over 9 months was superior for enhancing strength and motor performance in college women tennis players compared with nonperiodized training. Davis, Wood, Andrews, Elkind, and Davis (2008) reported that female college athletes performing serial integrated concurrent exercise training (aerobics, resistance exercises at high heart rate achieved by cardioacceleration before each set, and range-of-motion cooldown) performed 3 days/week for 11 weeks experienced increases in lower- (23.3%) and upper- (17.8%) body muscle strength, lower-body muscle endurance (27.8%), fat-free mass (3.3%), and lower-body flexibility (8.4%) and a decline in fat mass (–4.5%) and percentage body fat (–5.7%). Smith et al. (2014) reported that use of a nonlinear resistance training model that prioritized training to specific athletic goals during off-season training in American football players promoted significant improvements in strength and power. Finally, Vatarakis et al. (2017) reported that 8 weeks of resistance training in naval academy cadets promoted significant improvements in bench-press and squat 1-repetition maximum, push-ups, abdominal crunches, time to complete a 30-m distance, and time to complete the Navy Obstacle Course.

Advances in Strength and Conditioning

Recent advances in wearable monitoring technology providing feedback to athletes and coaches during training sessions and/or data for sport scientists to analyze training and performance have also significantly advanced strength and conditioning (Gilgien, Kroll, Sporri, Crivelli, & Muller, 2018; Macadam, Simperingham, Cronin, Couture, & Evison, 2017; Orange et al., 2019). Most teams use these types of devices to not only track performance gains but also assess intensity, load volume, and rest recovery needed in order to optimize player readiness before important competitions and prevent overtraining. This includes training in power platform systems that have force plates and cameras providing instant feedback to athletes and their coaches regarding the amount of power and force generated during lifts, monitoring and displaying heart rate of those training, and the ability to monitor training volume lifted on each exercise. The advances in methods of training and data analytics of athlete performance over recent years have no doubt greatly contributed to athletes' increased size, speed, agility, and career longevity. In addition, strength and conditioning is now recognized as an important contributor to youth fitness and athletic development, promoting general health and fitness in adults and providing a way to maintain strength and prevent sarcopenia with aging (Faigenbaum et al., 2009; Fragala et al., 2019; Kraemer et al., 2002; Lloyd et al., 2016).

Sport Nutrition

History of Nutrition in Sport

While sport nutrition is thought to be a young field in kinesiology, there is evidence that athletes practiced various nutritional strategies leading up to performance for centuries. For example, athletes in ancient Greece and Rome purportedly ingested whole grains, fruits, cheese, wine, and meat and fish (Applegate & Grivetti, 1997; Harris, 1966; Juzwiak, 2016). The Spartan athlete Charmis purportedly consumed dried figs, and the distance runner Dromeus of Stymphalos purportedly ingested meat before competition (Juzwiak, 2016). Moreover, wrestler Milo of Croton purportedly consumed 9 kg of meat, 9 kg of bread, and 9 L of wine before competition (Juzwiak, 2016). While some believe this to be mythical, given that beef contains about 4–5 g/kg (Balsom, Soderlund, & Ekblom, 1994), it may represent one of the first creatine-loading protocols unknowingly practiced by an athlete. Finally, the winner of the marathon in the second modern Olympic Games reportedly consumed egg whites, brandy, and strychnine (as a stimulant in small quantities) during the run.

Research linking nutrition to athletic performance began appearing in the literature in the mid-1800s. For example, Michel Eugène Chevreul discovered creatine in muscle in 1832 (Heffernan, 2015). Justus von Liebig suggested that protein was the primary source of energy fuel during exercise in 1842 and, in 1847, that creatine increased in muscle 10-fold after exercise (Büttner, 2000). He also proposed that consuming a meat extract that he developed in the mid-1800s could increase strength, performance, and health (Juzwiak, 2016). The first studies showing that creatine ingestion (with and without carbohydrate) increased muscle creatine, weight gain, and/or exercise capacity were published in the early 1900s (Brown & Cathcart, 1909; Paton & Mackie, 1912; Thompson, Wallace, & Clotworthy, 1913). Scandinavian studies in the 1920s and 1930s reported that diet influenced carbohydrate and fat utilization at rest and during exercise (Christensen & Hansen, 1939; Krogh & Lindhard, 1920). During the 1940s through 1960s an extensive amount of research assessed the role of vitamins and minerals in health (Applegate & Grivetti, 1997; Williams, 1989).

While this work provided a basis for understanding the role of nutrition in metabolism and health, the development of the muscle-biopsy technique by Bergstrom in 1962 paved the way for studies to understand how macronutrient ingestion affects muscle glycogen, phosphagens, exercise capacity, recovery, and training (Bergstrom & Hultman, 1969; Hultman & Bergstrom, 1967). In addition, Robert Cade and colleagues created Gatorade and showed that ingesting a glucose electrolyte solution (GES) helps prevent dehydration and improve performance (Cade, Spooner, Schlein, Pickering, & Dean, 1972). This work spawned numerous studies evaluating the effects of GESs on fluid and electrolyte balance and dehydration. Studies conducted by Hultman, Bergstrom, Harris, and others (Bergstrom & Hultman, 1969; Bergstrom, Hultman, & Roch-Norlund, 1972; Harris, Hultman, & Nordesjo, 1974; Hultman & Bergstrom, 1967); Costill and colleagues (Costill, Bowers, Branam, & Sparks, 1971; Costill, Coyle, Fink, Lesmes, & Witzmann, 1979; Costill, Gollnick, Jansson, Saltin, & Stein, 1973; Costill, Jansson, Gollnick, & Saltin, 1974; Foster, Costill, Daniels, & Fink, 1978); and others in the 1970s provided the scientific foundation of the role of exercise, diet, and nutrition in metabolism. Over the last 50 years, an enormous amount of research has been conducted on the role of nutrition in exercise, performance, recovery, and body composition.

Professional Development of Sport Nutrition

While there have been many valuable contributions to the development of the field of sport nutrition, several stand out. In 1976, Dr. Mel Williams published a book on nutritional aspects of human physical athletic performance that extensively and eloquently synthesized the literature (Williams, 1976). This book was used as a graduate text in a number of doctoral programs and helped establish sport nutrition as a scholarly area of research and academic focus in kinesiology. During the 1980s, a number of academic programs added sport nutrition courses to their curriculum rather than simply having students take general nutrition courses. In 1991, Human Kinetics launched the *International Journal of Sport Nutrition,* which was renamed the *International Journal of Sports Nutrition and Exercise Metabolism* https://journals.humankinetics.com/view/journals/ijsnem/ijsnem-overview.xml in 2001. This was the first academic journal dedicated to publishing sport-nutrition-related research and reviews. In early to mid-1990s, several teams and universities hired full-time sport dietitians and/or collaborated with sport-nutrition-related research groups to provide performance nutrition support. In 2003, the International Society of Sports Nutrition (ISSN) was founded—an academic society dedicated to promoting the science and application of evidence-based sport nutrition and supplementation. The ISSN holds an annual meeting and a number of conferences in the United States and abroad. In addition, a number of ISSN international societies have been established and hold their own annual meetings. The ISSN also founded the *Journal of the International Society of Sports Nutrition* in 2004, which has been instrumental in publishing original research, exercise and sport nutrition reviews (Kerksick et al., 2018; Kreider et al., 2004, 2010), and a number of position stands to help scientists and practitioners synthesize and apply research in the field (Aragon et al., 2017; Campbell et al., 2013; Goldstein et al., 2010; Jäger et al., 2017; Kerksick et al., 2008; Kreider et al., 2017; La Bounty et al., 2011; Trexler et al., 2015; Wilson et al., 2013). Together with the Academy of Nutrition and Dietetics, Dietitians of Canada, and American College of Sports Medicine position stand on nutrition and athletic performance (Thomas, Erdman, & Burke, 2016), these publications provide a comprehensive assessment of the state of sport-nutrition-related literature.

In addition, several universities launched exercise and nutrition–related PhD programs and/or sport nutrition master's programs in the early 2000s. The ISSN also developed the certified sports nutritionist certification in 2007 for individuals with at least a bachelor's degree in the field. The certification is recognized as the premier certification in the field of sport nutrition and supplementation. More recently, the ISSN launched an entry-level sport nutrition specialist certification for individuals who are working in the field but have not yet earned a 4-year degree. Finally, the Collegiate and Professional Sports Dietitians Association was founded in 2010 to specifically meet the needs of sport dietitians working in the field, with a mission to create leaders who elevate the profession of sport nutrition through ethical, science-based, cutting-edge care. Because of these cumulative efforts, the profession of sport nutrition has made significant advancements.

Components of Sport Nutrition

Performance nutrition programs typically provide assessment of diet, body composition, and/or energy expenditure to help sport dietitians and/or strength coaches set goals for athletes. They typically design diets for athletes and counsel them about proper weight-gain and weight-loss methods. Since eating disorders are common in some sports, sport dietitians may also counsel athletes about negative eating behaviors. Sport nutritionists provide general nutrition education to help athletes understand the importance of diet for performance and help them make wise food selections. Many sport dietitians take athletes to the grocery store to teach them how to purchase healthy foods, as well as teaching them how to prepare meals. They also teach athletes about the importance of hydration and nutrient timing and provide education about dietary supplements.

Sport-nutrition dietitians and/or specialists are typically responsible for planning training-table meals. In this regard, they often select and order food used to prepare meals, train cooking staff on how to prepare low-fat meal options, prepare and approve menus, post nutritional information about meal options, and order catered meals and snacks as needed. In addition, sport-nutrition specialists often travel ahead of teams to make sure that the hotel chefs prepare food as directed and the team has access to fluids, meals, and snacks. They are also responsible for pre-game-day nutrition and hydration, postgame meals, and recovery nutrition practices and typically are responsible for purchasing the energy bars, drinks, foods, and supplements available in the weight room. Finally, they often review the dietary supplements athletes take on their own to make sure the athletes understand what they are taking and that they do not contain any banned or ergolytic substances. If a team does not have a full-time sport dietitian, specialist, or consultant, strength coaches and/or athletic trainers are typically responsible for these tasks.

Nutritional Needs of Athletes

Table 2 shows recommended energy and macronutrient intake for active individuals and athletes. Energy, carbohydrate, and protein needs generally increase as training intensity, duration, and volume increase. In addition, larger athletes have higher energy needs than smaller athletes. Strength and power athletes typically expend 2,700–7,200 kcal/day (45–60 kcal/kg/day) while generally needing to ingest 5–8 g/kg/day of carbohydrate and 1.7–2.2 g/kg/day of protein during heavy training. Endurance athletes may expend 2,500–6,400 kcal/day (50–80 kcal/kg/day) and need to consume 7–13 g/kg/day or carbohydrate and 1.5–2.0 g/kg/day of protein. For elite athletes, energy expenditure during heavy training or competition may be greater (Barrero, Erola, & Bescos, 2014). For example, energy expenditure for cyclists competing in the Tour de France has been estimated as high as 12,000 kcal/day (150–200 kcal/kg/day for a 60–80-kg athlete; Brouns et al., 1989a, 1989b). In addition, caloric needs for large athletes (i.e., 100–150 kg) may range between 6,000 and 12,000 kcal/day depending on the volume and intensity of different training phases (Heydenreich, Kayser, Schutz, & Melzer, 2017).

Athletes engaged in heavy training should (a) eat enough calories to offset energy expenditure (typically 50–80 kcal/kg/day); (b) consume the proper amount of carbohydrate (e.g., 5–8 g/kg/day during normal training and 8–10 g/kg/day or more during heavy training) and protein (1.5–2.0 g/kg/day) while maintaining a relatively low-fat diet (1.0–1.5 g/kg/day); (c) ingest meals and snacks at appropriate time intervals before, during, and/or after exercise to provide energy, as well as promote recovery after exercise; (d) ensure that they are properly hydrated prior to exercise and competition; (e) incorporate rest and nutritional strategies to optimize recovery; and (f) only consider using nutritional supplements that have been found to be an effective and safe means of improving performance capacity and/or enhancing recovery (Kerksick et al., 2018; Kreider, 2019).

Although some argue that athletes can meet caloric needs simply by consuming a well-balanced diet, it is often very difficult for larger athletes and athletes engaged in high-volume intense training to eat enough food on a daily basis to meet caloric needs (Kerksick et al., 2018; Kreider, 2019). In reviewing the literature, Burke (2001) concluded that carbohydrate needs are largely unmet by high-level athletes. Furthermore, intense training often suppresses appetite and/or alters hunger patterns so that many athletes do not feel like eating (Burke, 2007; Burke & Deakin, 2015). For example, some athletes prefer not to exercise for several hours after eating because of sensations of fullness and/or a predisposition to cause gastrointestinal distress. Travel and training schedules may limit food availability or the types of food athletes are accustomed to eating. For this reason, sport nutritionists often recommend that athletes consume 4–6 meals/day and snack between meals to meet energy needs. Due to these practical concerns, nutrient-dense energy foods, energy bars, and high-calorie carbohydrate/protein supplements provide a convenient way for athletes to supplement their diet to maintain energy intake during training (Kerksick et al., 2018; Kreider, 2019).

Nutritional Ergogenic Aids

An ergogenic aid is any training technique, mechanical device, nutritional ingredient or practice, pharmacological method, or psychological technique that can improve exercise performance capacity or enhance training adaptations (Kerksick et al., 2018; Williams, 1976). Ergogenic aids may help prepare an individual to exercise, improve exercise efficiency, enhance recovery from exercise, and/or assist in injury prevention during intense training (Kerksick et al., 2018; Kreider, 2019). The study of nutritional strategies to enhance exercise performance and/or recovery has been a major research focus over the last 50 or so years.

A number of nutrients and/or nutritional strategies have been purported to promote gains in muscle mass during training and/or performance. Table 3 presents the current ISSN classification of muscle-building supplements. There is strong evidence demonstrating that creatine monohydrate (Kreider et al., 2017) and protein or essential amino acids (Jäger et al., 2017) promote gains in fat-free mass during training. There is also evidence that calcium β-HMB supplementation in untrained and elderly individuals initiating training may promote gains in muscle mass (Wilson et al., 2013). There is limited to mixed evidence that adenosine-5′-triphosphate, branched-chain amino acids, calcium β-HMB (trained individuals), and phosphatidic acid may enhance muscle mass during training. Finally, while there may be some health and/or performance benefits, there is little to no evidence that the other nutrients listed in Table 3 promote gains in muscle mass during training.

Table 4 presents the ISSN's current classification of performance-enhancement supplements. There is strong evidence that

Table 2 General Caloric Intake and Macronutrient Needs for Active Individuals

	General fitness training (50–90 kg)	Moderate training (50–100 kg)	Power athletes (60–120 kg)	Endurance athletes (50–80 kg)
Energy intake (kcal/day)	1,500–3,150	2,000–5,000	2,700–7,200	2,500–6,400
Carbohydrate				
%	45–55%	50–60%	40–50%	55–65%
g/kg/day	3–5	5–8	5–8	7–13
Protein				
%	11–14%	10–16%	10–15%	10–12%
g/kg/day	0.8–1.2	1.2–2.0	1.7–2.2	1.5–2.0
Fat				
%	<30%	22–30%	<30%	25–30%
g/kg/day	1.0–1.2	1–1.5	1.5–2.0	1.5–2.2

Note. Adapted from Kreider (2019).

Table 3 International Society of Sports Nutrition Classification of the Efficacy of Nutrients Purported to Promote Muscle-Mass Gains During Training

Strong evidence	Limited to mixed evidence	Little to no evidence
Creatine monohydrate	Adenosine-5′-triphosphate	Agmatine sulfate
Essential amino acids (EAAs)	Branched-chain amino acids	α-glycerylphosphorylcholine
Protein	Calcium HMB (trained)	α-ketoglutarate
Calcium HMB (untrained)	(Trained individuals)	α-ketoisocaproate
	Phosphatidic acid	Arginine
		Boron
		Chromium
		Conjugated linoleic acids
		D-aspartic acid
		Ecdysterones
		Fenugreek extract
		Gamma oryzanol
		Glutamine
		GHRPs and secretagogues
		Smilax officinalis/sarsaparilla
		Isoflavones
		Ornithine-a-ketoglutarate
		Prohormones
		Sulfopolysaccharides (myostatin inhibitors)
		Tribulus terrestris
		Vanadyl sulfate
		Yohimbine
		Zinc magnesium aspartate

Note. Adapted from Kerksick et al. (2018) and Kreider (2019).

Table 4 International Society of Sports Nutrition Classification of the Efficacy of Various Nutrients Purported to Enhance Performance

Strong evidence	Limited to mixed evidence	Little to no evidence
β-alanine	L-alanyl-L-glutamine	Arginine
Caffeine	Arachidonic acid	Carnitine
Carbohydrate	Branched-chain amino acids	Gamma aminobutyric acid
Creatine monohydrate	Citrulline	Glutamine
Sodium bicarbonate	Phosphatidic acid	Hydroxyisoleucine
Sodium phosphate	Essential amino acids	Inosine
Water and glucose electrolyte solution	Glutathione	Medium-chain triglycerides
Energy drinks and preworkout supplements	Glycerol	Ribose
	Glycine-L-arginine-alpha-keotoisocaproic acid	Theanine
	β-hydroxy-β-methylbutyrate	
	Nitrates	
	Postexercise carbohydrate and protein	
	Quercetin	
	Taurine	

Note. Adapted from Kerksick et al. (2018) and Kreider (2019).

β-alanine (Trexler et al., 2015), caffeine (Goldstein et al., 2010), carbohydrate (Mata et al., 2019), creatine monohydrate (Kreider et al., 2017), sodium bicarbonate (Christensen, Shirai, Ritz, & Nordsborg, 2017), sodium phosphate (Buck, Wallman, Dawson, & Guelfi, 2013), water and GES drinks (Evans, James, Shirreffs, & Maughan, 2017), and energy drinks (Campbell et al., 2013) improve exercise and/or cognitive performance. There is limited to mixed data supporting the efficacy and safety of a number of other nutrients. Of these, glycerol, branched-chain amino acids, nitrates, and citrulline have the greatest potential to improved endurance-exercise capacity, while phosphatidic acid, glycine-L-arginine-alpha-keotoisocaproic acid, nitrates, quercetin, and taurine may affect greater applicability for high-intensity intermittent-exercise performance (Kreider, 2019). There is little to no evidence that arginine, carnitine, gamma aminobutyric acid, glutamine, hydroxyisoleucine, inosine, ribose, or theanine provides ergogenic benefit (Kerksick et al., 2018; Kreider, 2019). Individuals considering enhancing their diet with nutritional supplements should consider the evidence on safety and efficacy and whether the supplement is legal in their sport (Kerksick et al., 2018). In addition, competitive athletes should only consume supplements that are tested by third parties for banned substances (Kerksick et al., 2018). While this additional testing does not guarantee that the dietary supplement does not contain trace levels of banned substances, it reduces the risk of unknowingly consuming a banned substance.

Summary and Future Directions

Strength, conditioning, and nutrition have become important components of optimizing performance of high-level performers and military personnel. Nearly all competitive teams employ strength and conditioning specialists, and most teams have sport dietitians and/or nutrition consultants on their performance-enhancement team. Science-based training and nutritional strategies have played an important role in improving sport performance, military readiness, recovery and extending careers of high-level performers. For this reason, sport nutrition is a growing field for researchers and practitioners. As the field moves forward, strength, conditioning, nutrition, and data analytics will play an increasingly important role in optimizing performance of high-level athletes. There will be a greater emphasis on using strength, conditioning, and nutrition principles to develop young athletes, expedite improvements in health and fitness in apparently healthy populations, and, in elderly populations, maintain strength and muscle mass, strengthen bones, improve balance, and promote recovery from illness and surgery. Finally, there will be expanded interest in nutrigenomics and nutraceutical development to promote physical and cognitive health and performance, as well as nutritional strategies to reduce risk of concussion, traumatic brain injury, and chronic traumatic encephalopathy.

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