Nutritional Strategies for Optimizing Performance in Athletes

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Abstract

Different nutrition is necessary to athletes for performing optimally, recovering and being healthy. There are so many factors, as energy is needed in the sport, intensity, age, sex and metabolism. We have demonstrated that there is a crucial need for 'accurate' nutrient timing necessary for winning in aerobic and in anaerobic exercise. Carbohydrates are by far the main fuel for muscle, endurance performance is based on a continuous supply of energy from fats, while protein supplies the muscle repair and growth. Among micronutrients that help bone health, metabolism, muscle function are B vitamins, vitamin D, iron and calcium. Without water and electrolyte, you will become dehydrate, lose performance and endurance. Likewise, training cycles that combined with nutrient timing improve adaptation and recovery. Certain athletes should take creatine, caffeine and beta-alanine to enhance their strength and endurance. Endurance level is increased, the chances of injury are minimized and the athlete is also able to perform to the best of their ability in competition as well as practice with a structured diet with wisdom in nutritional planning.

Keywords: Sports Nutrition; Performance Optimization; Energy Metabolism; Macronutrient Intake; Hydration Strategies

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Introduction

Nutrition is a key element in an athlete's training and performance regimen, balancing energy intake with energy demands to enhance training, recovery, and overall performance (Smith et al., 20). Exercise-induced adaptations are influenced not only by exercise duration, intensity, and type but also by the quality and quantity of nutrition consumed pre- and post-exercise. Proper nutrition can amplify or dampen these adaptations (Jeukendrup, 2017).

Energy Requirements for Athletes

Components of Energy Expenditure

Resting Energy Expenditure (REE) (60-75%)

It's the resting energy expenditure (REE) or the energy that the body needs just to keep breathing, circulating, and staying warm. It is measured after 8–12 hours of fasting by indirect calorimetry determining oxygen consumption and carbon dioxide production (Schlein & Coulter, 2014). Doubly Labled water can also be used to measure it. (Hills et al., 2014). Due to accuracy, the Cunningham equation considering both fat-free mass (FFM) and fat mass, with FFM factoring in about 70% of total energy expenditure, is often preferred. BMR:500+22 x lean body mass (kcal/day). Generally, the FFM of athletes is higher and the REE higher as a result (Haaf & Weijs, 2014).

Factors Affecting REE

- **Body Composition**: Athletes have higher FFM, which significantly elevates REE, making them more metabolically active than non-athletes.
- **Gender**: Male athletes typically possess more muscle mass and a higher metabolic rate than females of similar size, although training can help female athletes offset this difference.
- **Age**: While RMR naturally declines with age, athletes may experience a slower decline due to ongoing muscle maintenance and fitness efforts (Frings-Meuthen et al., 2021).

Physical Activity (15-30%)

Physical activity, which encompasses bodily movements by skeletal muscles, is a variable component of total energy expenditure (TEE). Two broad categories exist for assessing physical activity: subjective methods (self-reported activities) and objective methods (wearable monitors) (Strath et al., 2013).

Activity levels range as follows:

- **Sedentary or Light Activity (1.4 - 1.69)**: Minimal training, typical for off-season athletes.
- **Moderate Activity (1.7 - 1.99)**: Regular training sessions (2-3 times per week).
- **Vigorous Activity (2.0 - 2.4)**: Intense exercise for several hours, common among endurance athletes.
- **Very Vigorous Activity (≥2.5)**: Professional or Olympic-level athletes (Thompson & Manore, 1996).

Total Energy Expenditure (TEE) can be calculated as:

$TEE = BMR \times PAL$ (Kapri et al., 2023)

Thermic Effect of Food (TEF)

Digestive and metabolization energy, or TEF, is an estimated 10% of TEE and refers to the energy expended to get nutrients digested, absorbed, and metabolized.(Binns et al., 2015). More meals, more carbohydrates, and more protein had the effect of raising TEF. The Respiratory Quotient (RQ), calculated as CO_2 produced divided by O_2 consumed, varies by macronutrient: 1.0 carbohydrates, 0.7 fats, and 0.8 proteins (Delsoglio et al., 2020).

Differentiating Energy Needs by Sport Type

Table 1 presents comparison of nutritional needs between endurance and strength athletes.

Table 1: Comparison of Nutritional Needs Between Endurance and Strength Athletes(Frączek et al., 2019; Fritzen et al., 2019; Ravindra et al., 2022)

Nutrient	Endurance Athletes	Strength Athletes
Caloric Intake	Higher (up to 4,518 kcal/day)	Lower (around 4,459 kcal/day)
Primary Fuel Source	Carbohydrates	Protein and carbohydrates
Protein Needs	Moderate (for muscle maintenance)	Higher (to promote muscle growth)
Training Duration	Long sessions (>90 minutes)	Short, high-intensity sessions

A balanced diet with 45 – 55% carbohydrates, 10 – 15% protein, and 25 – 35% fat is enough to get people with general fitness in most cases

Energy Systems in Exercise

Anaerobic and aerobic metabolism produces energy in sports depending on the activity intensity and duration (Artioli et al., 2012). High-intensity exercises use anaerobic systems: Used for up to 10 seconds with ATP-PC energy and up to 40 seconds with lactic acid. Low-intensity activities that take up to 3 hours and are sustained between 2 minutes and 3 hours require an understanding of human aerobic systems which rely on oxygen to break down glycogen (Tuliao, 2021).

ATP-PC System

ATP and phosphocreatine stored in muscle cells are used to provide energy associated with high-intensity, short-duration efforts through an ATP-PC (phosphagen) system. This system supplies energy for 8-10 seconds of maximal effort, crucial for activities like sprinting and weightlifting. The enzyme creatine kinase breaks down phosphocreatine, regenerating ATP from ADP. The ATP-PC pathway works without oxygen, delivering rapid energy but depletes quickly due to limited muscle ATP and PC stores. Post-exercise, phosphocreatine levels replenish in 3-5 minutes, with about 75% restored in the first minute (MacLaren & Morton, 2024).

Anaerobic Glycolysis

Anaerobic glycolysis produces ATP from glucose and muscle glycogen without oxygen, generating 2 ATP per glucose molecule. The process results in pyruvate, which converts to lactate, preventing glycolysis inhibition. This pathway is crucial for high-intensity activities lasting 30 seconds to 2 minutes, but can extend up to 3 minutes in trained athletes. Lactate buildup lowers muscle pH, contributing to fatigue, though lactate can be recycled into glucose via the Cori cycle during recovery. Despite its limitations, anaerobic glycolysis provides quick energy for activities like sprinting and resistance exercises (Table 2) (Facey et al., 2013).

Oxidative Phosphorylation (Aerobic System)

Oxidative phosphorylation (OXPHOS) occurs in mitochondria, producing 32-34 ATP molecules per glucose through the Krebs cycle and electron transport chain. This system fuels prolonged exercise beyond 90-120 seconds, with muscle glycogen and fats providing ATP depending on intensity. Carbohydrates dominate during high-intensity efforts, while fat oxidation becomes prominent at lower intensities (Conley, 2016; Hargreaves & Spriet, 2020).

Table 2: Energy Systems

Energy System	Duration	Fuel Source	Limitation
Mitochondrial ATP	0-2s	ATP	Limited Stores
ATP-PCr	2-10s	Phosphocreatine	Limited Stores
Anaerobic Glycolysis	30s-2min	Glycogen, Glucose	Lactic Acid Buildup
Oxidative Phosphorylation	>2min	Glycogen, Fat	Oxygen Availability

Role of Macronutrients

Nutrition Periodization

Periodized nutrition is a planned, purposeful, and strategic use of particular nutritional interventions to augment the training-specific adaptations produced by a set of exercise sessions or a segment of a periodized training plan or, again, produce other beneficial effects on performance in the longer term (Table 3) (Jeukendrup, 2017; Stellingwerff et al., 2019).

Table 3: Nutrition Across Training Phases

Periodization Phase	Duration	Nutritional Focus	Macronutrient Recommendations
Preparatory Cycle	Pre-season	Build foundational fitness and energy stores	- Carbohydrates: 3-7 g/kg body weight - Protein: 1.2-2.5 g/kg body weight - Fat: 0.8-1.3 g/kg body weight
Competition Cycle	In-season	Support performance and recovery during competitions	- Carbohydrates: 5-12 g/kg body weight - Protein: 1.4-2.0 g/kg body weight - Fat: 1.0-1.5 g/kg body weight
Transition Cycle	Off-season	Recovery and maintenance of fitness	- Carbohydrates: Moderate intake - Protein: 1.2-2.0 g/kg body weight - Fat: Moderate intake, focus on healthy fats
Short-Term Periodization	1-4 weeks	Cyclical structure of refeeds and diet breaks	- Varies based on training load; typically includes refeeding days with higher carbohydrate intake
Long-Term Periodization	12-18 months	Structured approach to achieve long-term goals	- Adjust macronutrient ratios according to specific training phases (e.g., higher carbs during intense training)

Carbohydrates

But carbohydrates (CHO) are an essential energy source, particularly for athletes doing endurance or high-intensity sports. Exercise breaks down glycogen (stored in muscles and the liver) as a source of energy. CHO before and during exercise prevents blood glucose decline, spares liver glycogen, and enhances performance (Podlogar & Wallis, 2022). That's called carbohydrate loading: loading up on carbohydrates in the days before a competition to get the most glycogen (the glucose stored in muscle cells) into the muscles. Exhaustive exercise, followed by 24–48 hours, results in increased consumption of carbohydrates. Nevertheless, excess consumption can cause gastrointestinal problems such as constipation and diarrhea (Moraes et al., 2019).

Carbohydrate Recommendations

- **Before Exercise**: Before an intense competition, athletes should eat a carbohydrate-rich meal to allow glycogen stores to be optimized, and foods of high glycemic index for rapid absorption (König et al., 2019). Before exercise: High fiber foods can lead to slow gastric emptying and gastrointestinal discomfort during physical activity, playing an athlete (Moitzi et al., 2024).
- **During Exercise**: For prolonged exercise (>45 minutes), a CHO intake of 20-60 g per hour is recommended to prevent glycogen depletion and sustain performance (Marquet et al., 2016). A glucose-fructose combination enhances carbohydrate oxidation and prolongs endurance (Jeukendrup, 2014).
- **After Exercise**: Replenishing glycogen stores is critical. Consuming 1-1.2 g/kg BW/h within the first 2-4 hours post-exercise is recommended for rapid glycogen resynthesis (König et al., 2019). High-glycemic carbohydrates are preferred for faster recovery (Podlogar & Wallis, 2022).

Practical Guidelines for Endurance and Strength Athletes

Endurance athletes typically require 6-12 g/kg BW/d of carbohydrates due to the high energy demands of their sport (Table 4) (König et al., 2019). Strength athletes, however, may need lower amounts (3-5 g/kg BW/d) as their activities rely more on short bursts of energy (Marquet et al., 2016). Both groups benefit from tailored carbohydrate strategies based on sport, intensity, and recovery needs (Jeukendrup, 2014; Mata et al., 2019).

Table 4: Carbohydrate Recommendations

Carbohydrate Needs	Endurance Athletes	Strength Athletes
Daily CHO (g/kg BW)	6-12	3-5
During Exercise CHO (g/hr)	20-60	Not necessary (for <60 min)
Post-exercise CHO (g/kg BW)	1-1.2 (first 2-4 hrs)	1-1.2 (first 2-4 hrs)

Proteins

Muscle repair, growth, and recovery all depend on protein. The daily protein needs vary depending on the athlete's training style: For strength athletes, 1.2 - 1.7 g/kg BW/d; whereas for endurance athletes it needs a little more 1.4 - 1.7 g/kg BW/d to prevent muscle breakdown due to prolonged activity (Table 5) (Kitchen, 2018).

Fats

Fats are a critical macronutrient, providing energy and supporting various physiological functions. Athletes should aim for 20-35% of their daily caloric intake from fats, focusing on healthy sources like omega-3 fatty acids. Endurance athletes often require higher fat intake than strength athletes due to their prolonged energy demands (Table 6) (Puglisi, 2019; Stephanie Magill, 2023).

Table 5: Protein Recommendations(Phillips, 2012; Schoenfeld et al., 2013; Kitchen, 2018).

Protein Needs	Endurance Athletes	Strength Athletes
Daily Protein (g/kg BW)	1.4-1.7	1.2-1.7
Pre-workout Protein (g)	15-20	20-30
Post-workout Protein (g)	0.25-0.3 (kg BW)	20-40

Table 6: Fat Recommendations(Kerksick et al., 2017; Schek et al., 2019; Stephanie Magill, 2023).

Fat Needs	Endurance Athletes	Strength Athletes
Daily Fat (% of total calories)	20-35%	20-35%
Pre-workout Fat (g)	10-20	10-20
Post-workout Fat (g)	10-30	10-30

Optimal nutrition strategies for athletes vary based on the type of sport, training intensity, and individual needs (Fritzen et al., 2019). Carbohydrates are essential for energy and recovery, protein supports muscle repair and growth, while fats provide long-lasting energy and aid in recovery (Phillips & Loon, 2013). Tailoring these macronutrient strategies ensures peak performance and effective recovery across different types of athletic disciplines.

Micronutrients

Micronutrients, including vitamins and minerals, are essential for energy metabolism, bone health, and recovery in athletes. B vitamins aid in converting food into energy, while vitamin D supports bone strength. Iron is crucial for oxygen transport, and enhancing endurance, and calcium and magnesium help maintain muscle function and prevent cramps. While most needs can be met through a balanced diet, supplements should only be taken when necessary and under professional guidance (Table 7) (Heffernan et al., 2019; Beck et al., 2021; Brancaccio et al., 2022).

Table 7: Summary of Micronutrient Role in Exercise Performance

Type of Micronutrient	DRI	Top Rich Food Sources	Role in Exercise Performance	Deficiency Effect on Performance	Citations
Vitamin A	900 µg for males; 700 µg for females	Beef liver, sweet potatoes, carrots	Protects against oxidative stress, aids in muscle recovery, and supports immune function.	Deficiency not directly linked to performance impairment but may affect recovery and health.	(Ghazzawi et al., 2023)
Vitamin C	90 mg for males; 75 mg for females	Citrus fruits, tomatoes, green peppers	Supports immune function and aids in collagen synthesis for muscle repair.	Increased risk of illness and slower recovery from exercise.	(Beck et al., 2021)
Vitamin D	600 IU (15 µg)	Fortified milk, fatty fish, sunlight exposure	Essential for calcium absorption and bone health; supports muscle function.	Deficiency can lead to weakened bones and increased injury risk.	(Nichols et al., 2023)
B Vitamins (e.g., B6, B12)	Varies (e.g., B6: 1.3 mg; B12: 2.4 µg)	Whole grains, meats, dairy products	Involved in energy metabolism and red blood cell formation; crucial for endurance and recovery.	Deficiencies can lead to fatigue, anemia, and impaired performance.	(Nichols et al., 2023)
Iron	8 mg for males; 18 mg for females	Lean meats, beans, fortified cereals	Critical for oxygen transport in the blood; essential for energy production during exercise.	Deficiency can lead to fatigue, decreased endurance, and impaired performance.	(Ghazzawi et al., 2023)
Calcium	1000 mg	Dairy products, leafy greens	Important for muscle contraction and bone health; low levels increase risk of stress fractures.	Deficiency can lead to muscle cramps and increased risk of fractures.	(Nichols et al., 2023; Beck et al., 2021)
Magnesium	400 mg for males; 310 mg for females	Whole grains, nuts, leafy vegetables	Supports muscle function and reduces inflammation; involved in over 300 biochemical reactions.	Deficiency can lead to muscle cramps, weakness, and decreased performance.	(Nichols et al., 2023)
Zinc	11 mg for males; 8 mg for females	Meat, seafood, legumes	Important for immune function and recovery; supports protein synthesis.	Deficiency can reduce endurance, impair recovery, and increase fatigue risk.	(Ghazzawi et al., 2023; Beck et al., 2021)
Potassium	3400 mg for males; 2600 mg for females	Bananas, potatoes, beans	Regulates fluid balance and muscle contractions; essential for cardiovascular health during exercise.	Deficiency can lead to muscle weakness and cramping during physical activity.	(Ghazzawi et al., 2023)

Hydration and electrolytes

Maintaining hydration and electrolyte balance is crucial for athletic performance and recovery. Athletes should aim to limit fluid loss during exercise to less than 2% of body weight, with sodium and potassium playing key roles in muscle function and preventing cramps. Proper sodium intake is essential, especially during endurance events, to prevent exercise-associated hyponatremia, while individualized hydration plans help avoid over-drinking and electrolyte imbalances (Table 8) (Beck et al., 2015; Meyer et al., 2016).

Table 8: Summary of Hydration and Electrolyte Strategies for Athletes

Aspects	Details	Citations
Importance of Hydration	Hydration is critical for athletes to maintain performance, prevent fatigue, and support overall health.	(Casa et al., 2019)
Fluid Loss Mechanisms	Athletes lose fluids through sweat and respiration during exercise, which can lead to dehydration if not replenished.	(Garth & Burke, 2013)
Effects of Dehydration	A loss of 2% body weight can impair performance; 3-5% loss significantly decreases exercise capacity and increases injury risk.	(Hillyer et al., 2015)
Hydration Strategies	Athletes should consume fluids before, during, and after exercise to maintain hydration levels.	(Casa et al., 2019)
Recommended Fluid Intake	- Before Exercise: 500-600 mL (17-20 fl oz) 2-3 hours prior; 200-300 mL (7-10 fl oz) 10-20 minutes before.	(Thomas et al., 2016)
	- During Exercise: 200-300 mL (7-10 fl oz) every 10-20 minutes; adjust based on sweat rate and intensity.	(Thomas et al., 2016)
	- After Exercise: Replace lost fluids based on body weight changes; ~1.5 liters for each kg lost.	(Thomas et al., 2016)
Electrolyte Needs	Sodium and chloride are primarily lost in sweat; replenishing these electrolytes is vital for recovery and performance.	(Clifford & Maloney, 2015)
Electrolyte Replacement Timing	- Before Workout: Consider electrolyte beverages if sweating heavily or exercising in hot conditions.	(McDermott et al., 2017)
	- During Workout: Use sports drinks with sodium and carbohydrates to replace lost electrolytes effectively.	(Maughan, 2013; Zoorob et al., 2013)
	- After Workout: Consume foods rich in electrolytes (e.g., fruits, vegetables, salted snacks) for recovery.	(Evans et al., 2017; Armstrong, 2021)
Hydration Monitoring	Check urine color and body weight changes to assess hydration status; dark urine indicates dehydration.	(McKenzie et al., 2015; Webb et al., 2016)
Risks of Overhydration	Excessive fluid intake can lead to hyponatremia, causing symptoms like headache, confusion, and fatigue.	(Hew-Butler et al., 2017; Hew-Butler, 2019)

Supplements in Athletic Performance

Table 9 provides summary of sports supplements; mechanism, efficacy, and safety.

Table 9: Summary of Sports Supplements: Mechanism, Efficacy, and Safety

Supplement	Proposed Mechanism of Action	Evidence of Efficacy	Evidence of Safety
Caffeine	Improves endurance capacity and reduces perceived exertion.	Average performance benefit of ~3.2% in endurance tasks; effective in various modalities (running, cycling) (Peeling et al., 2018; Jodra et al., 2020; Kreutzer et al., 2022)	Generally safe; excessive intake can lead to side effects like jitteriness and insomnia (Souza et al., 2022).
Creatine	Increases phosphocreatine stores, enhancing ATP production during high-intensity exercise.	Performance benefits in short-duration, high-intensity efforts; increases muscle mass (Peeling et al., 2018).	Safe for most; may cause water retention and gastrointestinal issues (Peeling et al., 2018; Kim, 2019).
Beta-Alanine	Increases carnosine levels in muscles, buffering acid during high-intensity exercise.	Effective for improving performance in high-intensity exercise lasting 1-4 minutes (Bellinger, 2014; Quesnele et al., 2014; Peeling et al., 2018)	Generally well-tolerated; may cause tingling at high doses (Ko et al., 2014).
Nitrate	It Increases production of nitric oxide glasses that improve blood flow and oxygen delivery to the muscles.	Given the acutely and chronically active doses between 8–16 mmol nitrate acutely or 4–16 mmol/day nitrate chronically (with the final dose ingested 2–4 h pre-exercise), athletes will derive the greatest benefits (Jones, 2014; Shannon et al., 2022).	Most (16 mmol) is believed to be safe; excessive consumption may lead to gastrointestinal discomfort (Jones, 2014; Shannon et al., 2022).

Protein	Supports muscle repair and growth post-exercise.	Essential for recovery; adequate intake improves muscle protein synthesis (Huecker et al., 2019; Kårlund et al., 2019; Pasiakos et al., 2014).	Safe; excessive protein intake can strain kidneys in susceptible individuals(Kårlund et al., 2019).
Branched-Chain Amino Acids	May reduce muscle soreness and fatigue during exercise.	Some evidence for reducing muscle soreness foe the dose of 255 mg/kg/day; mixed results on performance enhancement (Fedewa et al., 2019; Khemtong et al., 2021;Weber et al., 2021).	Generally safe; excessive intake may lead to imbalances in amino acid levels (Holeček, 2022).
Beta-Hydroxy Beta-Methylbutyrate	May reduce muscle breakdown and enhance recovery.	Limited evidence on performance enhancement; more research needed HMB appears to work best when used for 2 weeks before the exercise bout (Wilson et al., 2013; Holland et al., 2022).	Safe at recommended doses; long-term effects not well-studied (Wilson et al., 2013).
Antioxidants (Vitamin C, E)	Reduces oxidative stress from exercise-induced free radicals.	No significant evidence that they improve performance; may hinder muscle adaptation (Taghiyar et al., 2013; Higgins et al., 2020).	Generally safe; excessive doses can have adverse effects. The recommended dietary pattern for an athlete contains a diet rich in fruits and vegetables, providing vitamins and minerals phytochemicals bioactive compounds, that help meet recommended intakes of vitamin E and C (Oliveira et al., 2019; Li et al., 2022).

Conclusion

There is nothing more important to an athlete than proper nutrition as this mostly determines one's performance, rate of recovery, and health status. Energy needs depend on the sport type, the intensity of the exercising, and the athlete's needs, and meeting the energy requirement allows for continuous training and performance. A good example of macronutrient partitioning involves outlining the role of carbohydrates as energy sources, proteins as muscles-rebuilding foods, and fats as energy reserve foods. Consuming nutrients properly, before, during, and after a training/competition, improves performance and recovery. Vitamins are necessary cofactors that have decided roles in a broad variety of metabolic and immunological processes; minerals are important in maintaining bone health; water and electrolytes are important in a broad variety of functions including heat dissipation and maintaining energy homeostasis. Supplementation may also be advantageous during competition for athletes in need of supplementation- if the supplementation is done correctly and the research is solid. Through systematic cyclical and individualist nutrition, it will be possible to develop optimal physical and mental accomplishments that would reduce the chances of injuries and accomplish superior performance in athletics.

References

Armstrong, L. E. (2021). Rehydration during endurance exercise: Challenges, research, options, methods. *Nutrients*, *13*(3), 887.

Artioli, G. G., Bertuzzi, R. C., Roschel, H., Mendes, S. H., Jr, A. H. L., & Franchini, E. (2012). Determining the Contribution of the Energy Systems During Exercise. *Journal of Visualized Experiments (JoVE)*, *61*, e3413.

Beck, K. L., von Hurst, P. R., O'Brien, W. J., & Badenhorst, C. E. (2021). Micronutrients and athletic performance: A review. *Food and Chemical Toxicology*, *158*, 112618.

Bellinger, P. M. (2014). β-Alanine supplementation for athletic performance: An update. *The Journal of Strength & Conditioning Research*, *28*(6), 1751–1770.

Binns, A., Gray, M., & Di Brezzo, R. (2015). Thermic effect of food, exercise, and total energy expenditure in active females. *Journal of Science and Medicine in Sport*, *18*(2), 204–208.

Brancaccio, M., Mennitti, C., Cesaro, A., Fimiani, F., Vano, M., Gargiulo, B., Caiazza, M., Amodio, F., Coto, I., D'Alicandro, G., Mazzaccara, C., Lombardo, B., Pero, R., Terracciano, D., Limongelli, G., Calabrò, P., D'Argenio, V., Frisso, G., & Scudiero, O. (2022). The Biological Role of Vitamins in Athletes' Muscle, Heart and Microbiota. *International Journal of Environmental Research and Public Health*, *19*(3).

Casa, D. J., Cheuvront, S. N., Galloway, S. D., & Shirreffs, S. M. (2019). Fluid needs for training, competition, and recovery in track-and-field athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *29*(2), 175–180.

Clifford, J., & Maloney, K. (2015). Nutrition for athletes. *Colorado State: University Extension*.

Conley, K. E. (2016). Mitochondria to motion: Optimizing oxidative phosphorylation to improve exercise performance. *Journal of Experimental Biology*, *219*(2), 243–249.

de Oliveira, D. C., Rosa, F. T., Simões-Ambrósio, L., Jordao, A. A., & Deminice, R. (2019). Antioxidant vitamin supplementation prevents oxidative stress but does not enhance performance in young football athletes. *Nutrition*, *63*, 29–35.

de Souza, J. G., Del Coso, J., Fonseca, F. de S., Silva, B. V. C., de Souza, D. B., da Silva Gianoni, R. L., Filip-Stachnik, A., Serrão, J. C., & Claudino, J. G. (2022). Risk or benefit? Side effects of caffeine supplementation in sport: a systematic review. *European Journal of Nutrition*, *61*(8), 3823–3834.

Delsoglio, M., Dupertuis, Y. M., Oshima, T., van der Plas, M., & Pichard, C. (2020). Evaluation of the accuracy and precision of a new generation indirect calorimeter in canopy dilution mode. *Clinical Nutrition*, *39*(6), 1927–1934.

Evans, G. H., James, L. J., Shirreffs, S. M., & Maughan, R. J. (2017). Optimizing the restoration and maintenance of fluid balance after exercise-induced dehydration. *Journal of Applied Physiology*, *122*(4), 945–951.

Facey, A., Irving, R., & Dilworth. (2013). Overview of Lactate Metabolism and the Implications for Athletes. *American Journal of Sports Science and Medicine*, *1*, 42–46.

Fedewa, M. V., Spencer, S. O., Williams, T. D., Becker, Z. E., & Fuqua, C. A. (2019). Effect of branched-Chain Amino Acid Supplementation on Muscle Soreness following Exercise: A Meta-Analysis. *International Journal for Vitamin and Nutrition Research*, *89*(5–6), 348–356.

Frączek, B., Grzelak, A., & Klimek, A. (2019). Energy expenditure of endurance and strength athletes in the light of the Polish energy intake standards. *International Journal of Occupational Medicine and Environmental Health*.

Frings-Meuthen, P., Henkel, S., Boschmann, M., Chilibeck, P. D., Alvero Cruz, J. R., Hoffmann, F., Möstl, S., Mittag, U., Mulder, E., & Rittweger, N. (2021). Resting energy expenditure of master athletes: Accuracy of predictive equations and primary determinants. *Frontiers in Physiology*, *12*, 641455.

Fritzen, A. M., Lundsgaard, A.-M., & Kiens, B. (2019). Dietary Fuels in Athletic Performance. *Annual Review of Nutrition*, *39*, 45–73.

Garth, A. K., & Burke, L. M. (2013). What Do Athletes Drink During Competitive Sporting Activities? *Sports Medicine*, *43*(7), 539–564.

Ghazzawi, H. A., Hussain, M. A., Raziq, K. M., Alsendi, K. K., Alaamer, R. O., Jaradat, M., Alobaidi, S., Aqili, R. A., Trabelsi, K., & Jahrami, H. (2023). Exploring the Relationship between Micronutrients and Athletic Performance: A Comprehensive Scientific Systematic Review of the Literature in Sports Medicine. *Sports*, *11*(6), 109.

Haaf, T. ten, & Weijs, P. J. M. (2014). Resting Energy Expenditure Prediction in Recreational Athletes of 18–35 Years: Confirmation of Cunningham Equation and an Improved Weight-Based Alternative. *PLOS ONE*, *9*(10), e108460.

Hargreaves, M., & Spriet, L. L. (2020). Skeletal muscle energy metabolism during exercise. *Nature Metabolism*, *2*(9), 817–828.

Heffernan, S. M., Horner, K., De Vito, G., & Conway, G. E. (2019). The Role of Mineral and Trace Element Supplementation in Exercise and Athletic Performance: A Systematic Review. *Nutrients*, *11*(3).

Hew-Butler, T. (2019). Exercise-associated hyponatremia. *Disorders of Fluid and Electrolyte Metabolism*, *52*, 178–189.

Hew-Butler, T., Loi, V., Pani, A., & Rosner, M. H. (2017). Exercise-associated hyponatremia: 2017 update. *Frontiers in Medicine*, *4*, 21.

Higgins, M. R., Izadi, A., & Kaviani, M. (2020). Antioxidants and Exercise Performance: With a Focus on Vitamin E and C Supplementation. *International Journal of Environmental Research and Public Health*, *17*(22).

Hills, A. P., Mokhtar, N., & Byrne, N. M. (2014). Assessment of Physical Activity and Energy Expenditure: An Overview of Objective Measures. *Frontiers in Nutrition*, *1*.

Hillyer, M., Menon, K., & Singh, R. (2015). The Effects of Dehydration on Skill-Based Performance. *International Journal of Sports Science*.

Holeček, M. (2022). Side effects of amino acid supplements. *Physiological Research*, *71*(1), 29.

Holland, B. M., Roberts, B. M., Krieger, J. W., & Schoenfeld, B. J. (2022). Does HMB Enhance Body Composition in Athletes? A Systematic Review and Meta-analysis. *The Journal of Strength & Conditioning Research*, *36*(2), 585.

Huecker, M., Sarav, M., Pearlman, M., & Laster, J. (2019). Protein Supplementation in Sport: Source, Timing, and Intended Benefits. *Current Nutrition Reports*, *8*(4), 382–396.

Jeukendrup, A. (2014). A Step Towards Personalized Sports Nutrition: Carbohydrate Intake During Exercise. *Sports Medicine*, *44*(1), 25–33.

Jeukendrup, A. E. (2017). Periodized Nutrition for Athletes. *Sports Medicine*, *47*(1), 51–63.

Jodra, P., Lago-Rodríguez, A., Sánchez-Oliver, A. J., López-Samanes, A., Pérez-López, A., Veiga-Herreros, P., San Juan, A. F., & Domínguez, R. (2020). Effects of caffeine supplementation on physical performance and mood dimensions in elite and trained-recreational athletes. *Journal of the International Society of Sports Nutrition*, *17*(1), 2.

Jones, A. M. (2014). Dietary Nitrate Supplementation and Exercise Performance. *Sports Medicine*, *44*(1), 35–45.

Kapri, E., Dey, S., Mehta, M., Deshpande, N., & Zemková, E. (2023). Analysis of Daily Activity Pattern to Estimate the Physical Activity Level and Energy Expenditure of Elite and Non-Elite Athletes. *Applied Sciences*, *13*, 2763.

Kårlund, A., Gómez-Gallego, C., Turpeinen, A. M., Palo-oja, O.-M., El-Nezami, H., & Kolehmainen, M. (2019). Protein Supplements and Their Relation with Nutrition, Microbiota Composition and Health: Is More Protein Always Better for Sportspeople? *Nutrients*, *11*(4).

Kerksick, C. M., Arent, S., Schoenfeld, B. J., Stout, J. R., Campbell, B., Wilborn, C. D., Taylor, L., Kalman, D., Smith-Ryan, A. E., Kreider, R. B., Willoughby, D., Arciero, P. J., VanDusseldorp, T. A., Ormsbee, M. J., Wildman, R., Greenwood, M., Ziegenfuss, T. N., Aragon, A. A., & Antonio, J. (2017). International society of sports nutrition position stand: Nutrient timing. *Journal of the International Society of Sports Nutrition*, *14*, 33.

Khemtong, C., Kuo, C.-H., Chen, C.-Y., Jaime, S. J., & Condello, G. (2021). Does branched-chain amino acids (BCAAs) supplementation attenuate muscle damage markers and soreness after resistance exercise in trained males? A meta-analysis of randomized controlled trials. *Nutrients*, *13*(6), 1880.

Kim, J. (2019). Nutritional Supplement for Athletic Performance: Based on Australian Institute of Sport Sports Supplement Framework. *Exercise Science*, *28*(3), 211–220.

Kitchen, S. (2018). Protein for Endurance Athletes—Quantity, Timing, and Sources Explained. *Race Smart*. https://www.racesmart.com/blog/2018/09/protein-for-endurance-athletes-explained/

Ko, G.-J., Rhee, C. M., Kalantar-Zadeh, K., & Joshi, S. (2020). The effects of high-protein diets on kidney health and longevity. *Journal of the American Society of Nephrology*, *31*(8), 1667–1679.

Ko, R., Low Dog, T., Gorecki, D. K., Cantilena, L. R., Costello, R. B., Evans, W. J., Hardy, M. L., Jordan, S. A., Maughan, R. J., & Rankin, J. W. (2014). Evidence-based evaluation of potential benefits and safety of beta-alanine supplementation for military personnel. *Nutrition Reviews*, *72*(3), 217–225.

König, D., Braun, H., Carlsohn, A., Großhauser, M., Lampen, A., Mosler, S., Nieß, A., Oberritter, H., Schäbethal, K., & Schek, A. (2019). Carbohydrates in sports nutrition. Position of the working group sports nutrition of the German Nutrition Society (DGE). *Ernahrungs Umschau*, *66*(11), 228–235.

Kreutzer, A., Graybeal, A. J., Moss, K., Braun-Trocchio, R., & Shah, M. (2022). Caffeine supplementation strategies among endurance athletes. *Frontiers in Sports and Active Living*, *4*, 821750.

Li, S., Fasipe, B., & Laher, I. (2022). Potential harms of supplementation with high doses of antioxidants in athletes. *Journal of Exercise Science & Fitness*, *20*(4), 269–275.

MacLaren, D., & Morton, J. (2024). *Biochemistry for Sport and Exercise Metabolism*. John Wiley & Sons (Eds), *Endurance Exercise*, *10*(p 241-243).

Marquet, L.-A., Hausswirth, C., Molle, O., Hawley, J. A., Burke, L. M., Tiollier, E., & Brisswalter, J. (2016). Periodization of Carbohydrate Intake: Short-Term Effect on Performance. *Nutrients*, *8*(12).

Mata, F., Valenzuela, P. L., Gimenez, J., Tur, C., Ferreria, D., Domínguez, R., Sanchez-Oliver, A. J., & Martínez Sanz, J. M. (2019). Carbohydrate Availability and Physical Performance: Physiological Overview and Practical Recommendations. *Nutrients*, *11*(5).

Maughan, R. J. (2013). Fluid and electrolyte loss and replacement in exercise. *Foods, Nutrition and Sports Performance*, 147–178.

McDermott, B. P., Anderson, S. A., Armstrong, L. E., Casa, D. J., Cheuvront, S. N., Cooper, L., Kenney, W. L., O'Connor, F. G., & Roberts, W. O. (2017). National Athletic Trainers' Association Position Statement: Fluid Replacement for the Physically Active. *Journal of Athletic Training*, *52*(9), 877–895.

McKenzie, A. L., Munoz, C. X., & Armstrong, L. E. (2015). Accuracy of urine color to detect equal to or greater than 2% body mass loss in men. *Journal of Athletic Training*, *50*(12), 1306–1309.

Meyer, F., Szygula, Z., & Wilk, B. (2016). *Fluid balance, hydration, and athletic performance* (p. 457). Taylor & Francis (Eds), *Sodium Balance during Exercise and Hyponatremia*, *2*(p 23-31)

Moitzi, A. M., Krššák, M., Klepochova, R., Triska, C., Csapo, R., & König, D. (2024). Effects of a 10-Week Exercise and Nutritional Intervention with Variable Dietary Carbohydrates and Glycaemic Indices on Substrate Metabolism, Glycogen Storage, and Endurance Performance in Men: A Randomized Controlled Trial. *Sports Medicine - Open*, *10*(1), 36.

Moraes, W. M. A. M. de, Almeida, F. N. de, Santos, L. E. A. dos, Cavalcante, K. D. G., Santos, H. O., Navalta, J. W., & Prestes, J. (2019). Carbohydrate Loading Practice in Bodybuilders: Effects on Muscle Thickness, Photo Silhouette Scores, Mood States and Gastrointestinal Symptoms. *Journal of Sports Science & Medicine*, *18*(4), 772.

Nichols, Q. Z., Ramadoss, R., Stanzione, J. R., & Volpe, S. L. (2023). Micronutrient supplement intakes among collegiate and masters athletes: A cross-sectional study. *Frontiers in Sports and Active Living*, *5*.

Peeling, P., Binnie, M. J., Goods, P. S., Sim, M., & Burke, L. M. (2018). Evidence-based supplements for the enhancement of athletic performance. *International Journal of Sport Nutrition and Exercise Metabolism*, *28*(2), 178-187.

Phillips, S. M. (2012). Dietary protein requirements and adaptive advantages in athletes. *British Journal of Nutrition*, *108*(S2), S158–S167.

Phillips, S. M., & Van Loon, L. J. (2013). Dietary protein for athletes: from requirements to optimum adaptation. *Food, Nutrition and Sports Performance III*, 29-38.

Podlogar, T., & Wallis, G. A. (2022). New Horizons in Carbohydrate Research and Application for Endurance Athletes. *Sports Medicine*, *52*(S1), 5–23.

Puglisi, M. (2019). Chapter 47—Dietary Fat and Sports Performance. In D. Bagchi, S. Nair, & C. K. Sen (Eds.), *Nutrition and Enhanced Sports Performance (Second Edition)* (pp. 555–569).

Quesnele, J. J., Laframboise, M. A., Wong, J. J., Kim, P., & Wells, G. D. (2014). The effects of beta-alanine supplementation on performance: A systematic review of the literature. *International Journal of Sport Nutrition and Exercise Metabolism*, *24*(1), 14–27.

Ravindra, P. V., Janhavi, P., Divyashree, S., & Muthukumar, S. P. (2022). Nutritional interventions for improving the endurance performance in athletes. *Archives of Physiology and Biochemistry*, *128*(4), 851–858.

Schek, A., Braun, H., Carlsohn, A., Großhauser, M., König, D., Lampen, A., Mosler, S., Nieß, A., Oberritter, H., Schäbethal, K., Stehle, P., Virmani, K., Ziegenhagen, R., & Hesekr, H. (2019). Fats in sports nutrition. Position of the working group sports nutrition of the German Nutrition Society (DGE). *Ernahrungs Umschau*, *66(9)*, 181–188.

Schlein, K. M., & Coulter, S. P. (2014). Best Practices for Determining Resting Energy Expenditure in Critically Ill Adults. *Nutrition in Clinical Practice*, *29*(1), 44–55.

Schoenfeld, B. J., Aragon, A. A., & Krieger, J. W. (2013). The effect of protein timing on muscle strength and hypertrophy: A meta-analysis. *Journal of the International Society of Sports Nutrition*, *10*, 53.

Shannon, O. M., Allen, J. D., Bescos, R., Burke, L., Clifford, T., Easton, C., Gonzalez, J. T., Jones, A. M., Jonvik, K. L., Larsen, F. J., Peeling, P., Piknova, B., Siervo, M., Vanhatalo, A., McGawley, K., & Porcelli, S. (2022). Dietary Inorganic Nitrate as an Ergogenic Aid: An Expert Consensus Derived via the Modified Delphi Technique. *Sports Medicine*, *52*(10), 2537–2558.

Smith, J. W., Holmes, M. E., & McAllister, M. J. (2015). Nutritional Considerations for Performance in Young Athletes. *Journal of Sports Medicine*, *2015*(1), 734649.

Stellingwerff, T., Morton, J. P., & Burke, L. M. (2019). A framework for periodized nutrition for athletics. *International Journal of Sport Nutrition and Exercise Metabolism*, *29*(2), 141–151.

Stephanie Magill (2023). Importance of fats for athletes. *Soccer Mom Nutrition*. https://soccermomnutrition.com/importance-of-fats-for-athletes/

Strath, S. J., Kaminsky, L. A., Ainsworth, B. E., Ekelund, U., Freedson, P. S., Gary, R. A., Richardson, C. R., Smith, D. T., & Swartz, A. M. (2013). Guide to the assessment of physical activity: Clinical and research applications: a scientific statement from the American Heart Association. *Circulation*, *128*(20), 2259–2279.

Taghiyar, M., Darvishi, L., Askari, G., Feizi, A., Hariri, M., Mashhadi, N. S., & Ghiasvand, R. (2013). The effect of vitamin C and e supplementation on muscle damage and oxidative stress in female athletes: A clinical trial. *International Journal of Preventive Medicine*, *4*(Suppl 1), S16.

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Nutrition and athletic performance. *Med. Sci. Sports Exerc*, *48*(3), 543–568.
Tuliao, R. (2021). *Effects of a Ten-Week Training and Nutritional Intervention with Variable Carbohydrate Content and Glycemic Index on Oxidative DNA Damage* (Master's Thesis, University of Vienna)
Webb, M. C., Salandy, S. T., & Beckford, S. E. (2016). Monitoring hydration status pre- and post-training among university athletes using urine color and weight loss indicators. *Journal of American College Health*, *64*(6), 448–455.
Weber, M. G., Dias, S. S., De Angelis, T. R., Fernandes, E. V., Bernardes, A. G., Milanez, V. F., Jussiani, E. I., & De Paula Ramos, S. (2021). The use of BCAA to decrease delayed-onset muscle soreness after a single bout of exercise: A systematic review and meta-analysis. *Amino Acids*, *53*(11), 1663–1678.
Wilson, J. M., Fitschen, P. J., Campbell, B., Wilson, G. J., Zanchi, N., Taylor, L., & Antonio, J. (2013). International society of sports nutrition position stand: beta-hydroxy-beta-methylbutyrate (HMB). *Journal of the International Society of Sports Nutrition*, *10*(1), 6.
Zoorob, R., Parrish, M.-E. E., O'Hara, H., & Kalliny, M. (2013). Sports nutrition needs: Before, during, and after exercise. *Primary Care: Clinics in Office Practice*, *40*(2), 475–486