Sports Nutrition: Supplements & Ergogenic Aids

Ergogenic aids are applications or techniques that increase performance capacity work efficiency, and enable easy recovery after exercises or easy adaptation to difficult training. Nutritional support strategies before and during exercise are thought to replenish building block stores, maintain fluid balance, and facilitate regeneration between competitions. The use of ergogenic support can provide an advantage in terms of sportive performance by increasing the ability to perform intermittent high-intensity activity and/or motor skills (Dziedzic & Higham, 2014). Ergogenic supplements are often sold as tablets, capsules, soft gels, liquids, powders, and sticks (Kreider et al., 2010). It is reported that ergogenic nutritional supplements actually increase performance in a very small part, however, they can cause different health problems (Di Luigi, 2008; Maughan, 2005). Using uncontrolled ergogenic nutritional supplements can reduce the bioavailability of many nutrients or the effectiveness of other drugs used (Millen et al., 2004). Athletes turn to sportive nutritional products in order to meet the energy they lose. In this article, information is given about the use of supplements and ergonomic supports and their effects on athlete performance.

Figure 1. Sports nutrition supplement on shelf.
www.123rf.com (n.d.)
Protein powders are ergogenic supplements that are widely used among athletes to increase muscle mass. In particular, casein is thought to have positive effects in long-term resistance exercises. One of the commonly used proteins in sports nutrition is whey protein. Whey protein helps weight loss by reducing appetite and increasing satiety through various mechanisms such as regulation of satiety hormones and hepatic gluconeogenesis (Wirunsawanya et al., 2018). In addition, it has been reported that these protein supplements contribute to the reduction of body weight and total fat mass in overweight and obese patients

and to the elimination of cardiovascular risk factors (Wirunsawanya et al., 2018). Studies show that it reduces muscle loss, protects body composition, increases protein synthesis, creates hypertrophy in muscle, repairs muscle damage and increases fat burning (Keri Marshall, 2004; Cooke et al., 2009; Burd et al., 2011; Tsutsumi & Tsutsumi, 2014). Whey protein supplementation helps to repair muscle damage caused by exercise (Buckley et al., 2010). There are studies that predict a positive effect on creatine kinase and blood concentration levels with six-week whey protein supplementation (Philpott et al., 2018). Whey protein supplementation can improve exercise performance in trained men (West et al.,2017).

Sports drinks are products that are produced for the maximum efficiency of the athletes and provide them with benefits in the acute period. For short-term intense workouts, sports drinks can be a good support before and during exercise, while sports drinks can be highly effective for long and intermittent workouts. In addition, it has been emphasized that low-carbohydrate drinks can contribute to performance in order to prevent both the emptying of carbohydrate stores and the loss of fluid-electrolyte in long-term endurance exercises (Coombes, 2000). Sports and energy drinks can be consumed by athletes to replace energy, fluid and electrolytes lost during exercise and to increase performance. However, the composition, active ingredients, effects on sports performance as risk factors of both products are different from each other. When sports drinks are used and are correctly adjusted to the type of sport and the individual, they help to significantly improve physical performance due to their carbohydrate, electrolyte and fluid contents. It has been reported that drinking protein-containing sports drinks during exercise increases endurance, reduces dehydration-induced weight loss, and supports reducing muscle damage after exercise compared to those containing only carbohydrates and electrolytes (Naclerio, 2014). Sports drinks contain different types of carbohydrates (sucrose, fructose, glucose polymers, glucose) and they consist of colorant, and electrolytes. At the same time, if they contain 6-8% glucose and sucrose, they are absorbed as fast as water in the body, and they also provide energy to the working muscles. Since those with a carbohydrate ratio of 6-10% are quickly absorbed and mixed with the blood, they are recommended to be used during activity. Those with a carbohydrate ratio of 10-25% can be used during rest, since absorption is completed in a longer time. In addition, drinks containing more than 10% carbohydrates can cause nausea, diarrhea and cramps in some individuals. This may be due to increased insulin sensitivity after exercise. Sports drinks also contain sodium and potassium electrolytes. Drinks containing sodium trigger the thirst mechanism and encourage fluid intake. Sodium also improves absorption and retention. It also helps athletes who sweat excessively and salty to replenish salt. While the drinks containing sodium do not isolate the feeling of thirst, the ones that do not (including drinking water) cause a decrease in the desire to drink water and, consequently, insufficient fluid intake, as it isolates thirst. When glucose and sodium are added to water, fluid absorption is accelerated because glucose and sodium accelerate osmosis (Naclerio, 2014). Despite strategies that may be effective, improper use can lead to diabetes and tooth decay, and if they contain more potassium and calcium than is lost through sweat, they can put pressure on skeletal and cardiac muscles during exertion and cause pulse irregularities. In addition, these sugar-containing fluids can cause problems due to the displacement of blood for the digestion of sugar during strenuous exercise, insufficient blood flow to other organs, and consequent cramping and increased temperature (Naclerio, 2014). With the use of glutamine in endurance sports, there was a decrease in the incidence of disease reported after exercise (Castell, 1996).

Figure 2: Studies Show Little Benefit in Supplements. Paul Rogers (2016).
www.nytimes.com

BCAA (leucine, isoleucine, valine) is an essential amino acid for protein synthesis (Dudgeon et al., 2016; Platt et al., 2016). BCAAs are found in high amounts in skeletal muscle, where are also oxidized, while other amino acids are predominantly catabolized in the liver. They help prevent protein breakdown and increase protein synthesis. Many studies have shown that BCAAs reduce muscle soreness and muscle damage during exercise, but also play a key role in recovery. Such an ingredient preserves muscle mass when protein loss and catabolism occur, and helps to reduce muscle damage and accelerate recovery after heavy endurance training. They are also important for maintaining the normal functioning of body performance and ideal body composition (Dudgeon et al., 2016; Shimomura, 2004). According to studies, it has been shown that taking BCAAs before and after exercise has positive effects on reducing exercise-induced muscle damage and increasing muscle protein synthesis (Howatson et al., 2012). Muscle damage causes delayed muscle soreness that occurs 24-48 hours after intense exercise and inhibits athletic performance. Other studies have shown that BCAA supplementation improves plasma glutamine concentration as well as mononuclear cell proliferation in peripheral blood in response to mitogens after prolonged intense exercise. By directing the lymphocyte immune response towards Th1, BCAAs change the cytokine production sequence released by exercise (Bassit et al., 2002). In line with these findings, BCAAs can be considered as a useful supplement because of their positive effects on muscle recovery and immune regulation (Bassit et al., 2002; Negro et al., 2008). In addition to BCAA's, ZMA supplements can aid muscle growth by enhancing athletic performance; especially in people with zinc or magnesium deficiency, they can provide this increase more clearly. ZMA is a supplement consisting of Zinc, Vitamin B6 and Magnesium. It can strengthen their anabolic hormonal profile, affect and slow down the catabolic process, strengthen the immune level and improve adaptation to resistance exercises. Because of these features, it is preferred by athletes (Wilborn et al., 2004).
Caffeine and creatine are two of the most commonly employed ergogenic aids. Studies have shown that creatine increases strength, power output, sprint performance, total work to fatigue, peak power, and peak power exhibited during multiple sets of maximal effort contractions (Liddle & Connor, 2013). In a study conducted with cyclists, it was shown that creatine supplementation decreased blood lactate levels and increased the lactate threshold (Oliver et al.,2013). Creatine is predicted to be effective in repetitive short bursts of power between 6 seconds and 4 minutes, mainly sprinting and weight lifting, high-intensity activity (Terjung et al., 2000; Branch & Williams, 2002; Branch, 2003; Insel et al., 2004; Burke, 2006; Dunford, 2006). There are studies on the potential ergogenic effects of caffeine, the mobilizing of free fatty acids, and

its role in sparing of muscle glycogen (Dunford, 2006; Graham & Moisey, 2005). Caffeine is known to be a powerful ergogenic aid. It has also been widely suggested to increase exercise capacity by promoting fat oxidation and inhibiting carbohydrate oxidation through feedback mechanisms in active muscle (Tarnopolsky 1994; Graham 2001). It has been suggested that this action results in reduced dependence on muscle glycogen stores, and glycogen subsequently promotes increased endurance. This theory was supported by Costill et al. (Costill et al. 1978; Ivy et al. 1979; Essig et al. 1980).

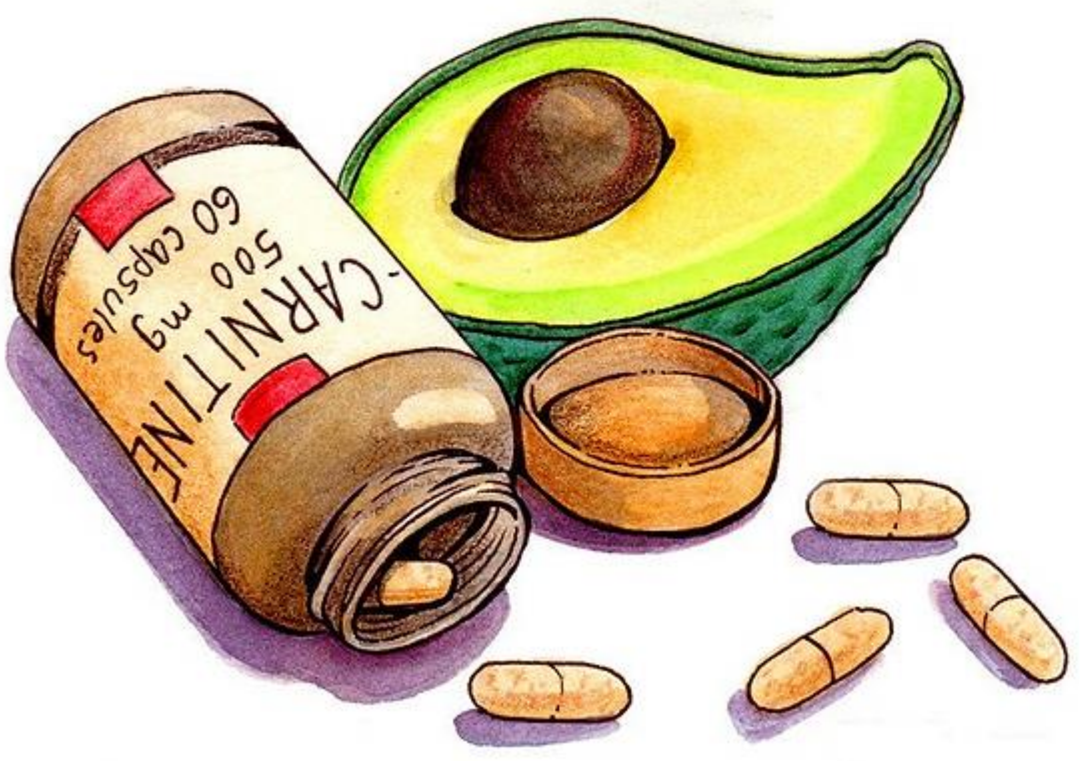

Figure 3: Carnitine. Donato, (2021).
www.mskcc.org
Carnitine is present in sufficient amount in muscle cells. In other words, it can be said that a situation such as carnitine deficiency will not occur. Much more can be obtained from the diet than the carnitine excreted in the urine. The body also stores excess carnitine. It can be said that in a healthy body (including professional athletes) there is no carnitine problem and it finds enough carnitine. When carnitine is taken orally, only the rate of carnitine in the blood increases, it does not reach the muscles and is excreted from the body with urine. L-carnitine is required for the transport of long-chain fatty acids from the cytosol to the mitochondrial matrix. ATP is produced by the oxidation of long-chain fatty acids in the mitochondrial matrix. L-carnitine is thought to play a key role in muscle energy metabolism by increasing fatty acid oxidation and energy expenditure. There are studies indicating that L-carnitine improves endurance capacity by increasing oxygen uptake or fatty acid oxidation (Pandareesh & Anand, 2013).

Figure 4: What's Really in Supplements? Mark Matcho, (2009).
www.wsj.com

Phosphate salts are one of the basic elements to be taken in the human body and are important for both nutrition and other functions of the body. Since it cannot be synthesized in the body, it must be taken from the outside through food. To date, few studies have supported the benefits of phosphate salt supplementation on exercise performance. In these studies, maximum oxygen consumption (Kreider et al., 1992; Czuba et al., 2009) and increase in anaerobic threshold (Kreider et al., 1992), time trial performance (Brewer et al., 2015) and improvement in repeated sprint ability (Buck et al. ., 2015; Kopec et al., 2016) and a number of mechanisms have been proposed to explain the ergogenic effects of phosphate loading, including increased oxidative metabolism and increased ATP synthesis, faster restoration of ATP and phosphocreatine in muscles. Phosphate supplementation was predicted to positively affect the cardiorespiratory system and gross efficiency in elite cyclists in a hypoxic environment. Sodium salts can be used to eliminate the effect of lactic acid, which is produced in the organism by the use of glycogen in an anaerobic environment and accumulates in the muscles according to the action mechanisms of the buffering systems. Specifically, sodium bicarbonate buffers anaerobic exercises to reduce the oxidant effect on muscle tissue (Lindh et al., 2008).

Figure 5: Hepatitis C Drugs Boost Remdesivir's Antiviral Activity Against COVID-19. Jenna Luecke (2021).
news.utexas.edu

Apart from performance, various supplements may also be effective in preventing certain diseases (Klein, 2011). Caffeine is widely used in sports as a performance-enhancing or ergogenic supplement, often in the form of caffeinated tablets, gels, or chewables. The ergogenic effects of caffeine on exercise performance are generally explained by its ability to bind to adenosine receptors. Caffeine metabolic rate varies between individuals depending on genetic variations (Pickering & Kiely, 2018). Apart from this, related to athlete performance, short-term folate supplementation in aerobic exercise is predicted to strengthen the immune system and reduce cardiovascular risk. It is thought to be applicable as a short-term ergogenic supplement due to the low cost of folate (Grigoletti et al., 2018). As another ergonomic support, athletes use ginseng to increase aerobic performance and energy level. Its possible mechanism of action is that it increases the response to cortisol during strenuous sports and decreases lactic acid production by keeping creatine phosphate levels high in the body. It is also known that ginseng has anti-inflammatory, antioxidant, stimulating brain function and performance enhancing effects (Sellami et al., 2018). It has been determined that ginseng increases muscle stimulation and muscle strength in athletes, and accelerates the healing of muscle damage (Cristina-Souza et al., 2022). In addition, ginseng supplementation positively affects bodybuilders' anabolic indices, muscle strength and body composition (Azizi & Moradi, 2021).

In summary, maintaining health and achieving high sportive performance can only be achieved through balanced, regular and purposeful nutrition. A well-structured, periodic training program tailored to the athlete's goal, an appropriate nutrition plan, and the right balance between exercise and recovery are essential to achieving personal athletic goals. However, the correct use of supplements is very important to increase performance, balance body fat ratio and activate protein synthesis. Ergogenic aids can be used to continuously increase strength, endurance, speed and dexterity.

Bibliographical References

Azizi, E., & Moradi, F. (2021). The effect of ginseng supplementation on anabolic index, muscle strength, body composition, and testosterone and cortisol response to acute resistance exercise in male bodybuilders. *Science & Sports*, *36*(5), 383-389.

Bassit, R. A., Sawada, L. A., Bacurau, R. F., Navarro, F., Martins Jr, E., Santos, R. V., & Rosa, L. F. C. (2002). Branched-chain amino acid supplementation and the immune response of long-distance athletes. *Nutrition*, 18(5), 376-379.

Branch, J., & Williams, M. (2002). Creatine as an ergogenic supplement. Performance-Enhancing Substances in Sport and Exercise. Champaign (IL): *Human Kinetics*, 175-96.

Branch, J. D. (2003). Effect of creatine supplementation on body composition and performance: a meta-analysis. *International Journal of Sport Nutrition and Exercise Metabolism*, 13(2), 198-226. Brewer, C. P., Dawson, B., Wallman, K. E., & Guelfi, K. J. (2015). Effect of sodium phosphate supplementation on repeated high-intensity cycling efforts. *Journal of Sports Sciences*, *33*(11), 1109-1116. Buck, C., Guelfi, K., Dawson, B., McNaughton, L., & Wallman, K. (2015). Effects of sodium phosphate and caffeine loading on repeated-sprint ability. *Journal of Sports Sciences*, *33*(19), 1971-1979.

Buckley, J. D., Thomson, R. L., Coates, A. M., Howe, P. R., DeNichilo, M. O., & Rowney, M. K. (2010). Supplementation with a whey protein hydrolysate enhances recovery of muscle force-generating capacity following eccentric exercise. *Journal of Science and Medicine in Sport*, 13(1), 178-181.

Burd, N. A., West, D. W., Moore, D. R., Atherton, P. J., Staples, A. W., Prior, T., & Phillips, S. M. (2011). Enhanced amino acid sensitivity of myofibrillar protein synthesis persists for up to 24 h after resistance exercise in young men. *The Journal of Nutrition*, 141(4), 568-573.

Burke, L., Cort, M., Cox, G., Crawford, R., Desbrow, B., Farthing, L., & Warnes, O. (2006). Supplements and sports foods. *Clinical Sports Nutrition*, 3, 485-580.

Castell, L. M., Newsholme, E. A., & Poortmans, J. R. (1996). Does glutamine have a role in reducing infections in athletes?. *European Journal of Applied Physiology and Occupational Physiology*, 73(5), 488-490.

Cooke, M. B., Rybalka, E., Williams, A. D., Cribb, P. J., & Hayes, A. (2009). Creatine supplementation enhances muscle force recovery after eccentrically-induced muscle damage in healthy individuals. *Journal of the International Society of Sports Nutrition*, 6(1), 13.

Coombes, J. S., & Hamilton, K. L. (2000). The effectiveness of commercially available sports drinks. *Sports Medicine*, *29*(3), 181-209.

Cristina-Souza, G., Santos-Mariano, A. C., Lima-Silva, A. E., Costa, P. L., Domingos, P. R., Silva, S. F., & Osiecki, R. (2022). Panax ginseng Supplementation Increases Muscle Recruitment, Attenuates Perceived

Effort, and Accelerates Muscle Force Recovery After an Eccentric-Based Exercise in Athletes. *Journal of Strength and Conditioning Research*, *36*(4), 991-997.

Czuba, M., Zajac, A., Poprzecki, S., Cholewa, J., & Woska, S. (2009). Effects of sodium phosphate loading on aerobic power and capacity in off road cyclists. *Journal of Sports Science & Medicine*, *8*(4), 591.

Di Luigi, L. (2008). Supplements and the endocrine system in athletes. *Clinics in sports medicine*, *27*(1), 131-151.

Dudgeon, W. D., Kelley, E. P., & Scheett, T. P. (2016). In a single-blind, matched group design: branched-chain amino acid supplementation and resistance training maintains lean body mass during a caloric restricted diet. *Journal of the International Society of Sports Nutrition*, *13*(1), 1.

Dunford, M. (2006). Sports nutrition: A practice manual for professionals. *American Dietetic Association*. Chicago, Ill. : American Dietetic Association. Dunford, M., & Smith, M. (2006). Dietary supplements and ergogenic aids. *Sports Nutrition: A Practice Manual for Professionals. Chicago (IL): American Dietetic Association*, 116-41. Dziedzic, C. E., Higham, D. G. (2014). Performance nutrition guidelines for international rugby sevens tournaments. *International Journal of Sport Nutrition and Exercise Metabolism*, 24(3), 305-314. Graham, T. E. (2001). Caffeine, coffee and ephedrine: impact on exercise performance and metabolism. *Canadian journal of applied physiology*, *26*(S1), S186-S191.

Graham, T. E., & Moisey, L. L. (2005). Caffeine, creatine, and food–drug synergy: ergogenics and applications to human health. In Food-drug synergy and safety (pp. 375-409). *CRC Press*.

Grigoletti, S. S., Ribeiro, J. P., Sprinz, E., & Ribeiro, P. A. (2018). Short-term folinic acid supplementation and aerobic exercise improve vascular reactivity in HIV-infected individuals. *HIV Clinical Trials*, *19*(4), 148-151.

Howatson, G., Hoad, M., Goodall, S., Tallent, J., Bell, P. G., & French, D. N. (2012). Exercise-induced muscle damage is reduced in resistance-trained males by branched chain amino acids: a randomized, double-blind, placebo controlled study. *Journal of the international Society of Sports Nutrition*, *9*(1), 20.

Insel, P., Turner, R. E., & Ross, D. (2004). *Nutrition. ed. Sudburry,* Massachusetts: Jones and Bartlett Publishers.

Keri Marshall, N. (2004). Therapeutic applications of whey protein. *Alternative Medicine Review*, 9(2), 136-156.

Klein, E. A., Thompson, I. M., Tangen, C. M., Crowley, J. J., Lucia, M. S., Goodman, P. J., ... & Baker, L. H. (2011). Vitamin E and the risk of prostate cancer: the Selenium and Vitamin E Cancer Prevention Trial (SELECT). *Jama*, *306*(14), 1549-1556.

Kopec, B. J., Dawson, B. T., Buck, C., & Wallman, K. E. (2016). Effects of sodium phosphate and caffeine ingestion on repeated-sprint ability in male athletes. *Journal of science and medicine in sport*, 19(3), 272-276.

Kreider, R. B., Miller, G. W., Schenck, D., Cortes, C. W., Miriel, V., Somma, C. T., & Hill, D. (1992). Effects of phosphate loading on metabolic and myocardial responses to maximal and endurance exercise. *International Journal of Sport Nutrition and Exercise Metabolism*, 2(1), 20-47.

Kreider, R. B., Wilborn, C. D., Taylor, L., Campbell, B., Almada, A. L., Collins, R., ... & Antonio, J. (2010). ISSN exercise & sport nutrition review: research & recommendations. *Journal of the international society of sports nutrition*, *7*(1), 7.

Liddle, D. G., & Connor, D. J. (2013). Nutritional supplements and ergogenic AIDS. *Primary Care: Clinics in Office Practice*, 40(2), 487-505.

Lindh, A. M., Peyrebrune, M. C., Ingham, S. A., Bailey, D. M., & Folland, J. P. (2008). Sodium bicarbonate improves swimming performance. *International Journal of Sports Medicine*, 29(06), 519-523.
Maughan, R. J. (2005). Contamination of dietary supplements and positive drug tests in sport. *Journal of sports sciences*, *23*(9), 883-889.
Millen, A. E., Dodd, K. W., & Subar, A. F. (2004). Use of vitamin, mineral, nonvitamin, and nonmineral supplements in the United States: the 1987, 1992, and 2000 National Health Interview Survey results. *Journal of the American Dietetic Association*, *104*(6), 942-950.
Naclerio, F., Larumbe-Zabala, E., Cooper, R., Jimenez, A., & Goss-Sampson, M. (2014). Effect of a carbohydrate-protein multi-ingredient supplement on intermittent sprint performance and muscle damage in recreational athletes. *Applied Physiology, Nutrition, and Metabolism*, 39(10), 1151-1158.

Negro, M., Giardina, S., Marzani, B., & Marzatico, F. (2008). Branched-chain amino acid supplementation does not enhance athletic performance but affects muscle recovery and the immune system. *Journal of Sports Medicine and Physical Fitness*, 48(3), 347.
Oliver, J. M., Joubert, D. P., Martin, S. E., & Crouse, S. F. (2013). Oral creatine supplementation's decrease of blood lactate during exhaustive, incremental cycling. *International Journal of Sport Nutrition and Exercise Metabolism*, 23(3), 252-258.

Pandareesh, M. D., & Anand, T. (2013). Ergogenic effect of dietary L-carnitine and fat supplementation against exercise induced physical fatigue in Wistar rats. *Journal of Physiology and Biochemistry*, 69(4), 799-809.
Philpott, J. D., Donnelly, C., Walshe, I. H., MacKinley, E. E., Dick, J., Galloway, S. D., ... & Witard, O. C. (2018). Adding fish oil to whey protein, leucine, and carbohydrate over a six-week supplementation period attenuates muscle soreness following eccentric exercise in competitive soccer players. *International Journal of Sport Nutrition and Exercise Metabolism*, 28(1), 26-36.
Pickering, C., & Kiely, J. (2018). Are the current guidelines on caffeine use in sport optimal for everyone? Inter-individual variation in caffeine ergogenicity, and a move towards personalised sports nutrition. *Sports Medicine*, *48*(1), 7-16.
Platt, K. M., Charnigo, R. J., Shertzer, H. G., & Pearson, K. J. (2016). Branched-chain amino acid supplementation in combination with voluntary running improves body composition in female c57bl/6 mice. *Journal of dietary supplements*, *13*(5), 473-486.
Sellami, M., Slimeni, O., Pokrywka, A., Kuvačić, G., D Hayes, L., Milic, M., and Padulo, J., (2018). Herbal medicine for sports: a review. *Journal of the International Society of Sports Nutrition*, 15, 14.

Shimomura, Y., Murakami, T., Nakai, N., Nagasaki, M., & Harris, R. A. (2004). Exercise promotes BCAA catabolism: effects of BCAA supplementation on skeletal muscle during exercise. *The Journal of nutrition*, *134*(6), 1583S-1587S.

Tarnopolsky, M. A. (1994). Caffeine and endurance performance. *Sports medicine*, *18*(2), 109-125.

Terjung, R. L., Clarkson, P., Eichner, E. R., Greenhaff, P. L., Hespel, P. J., Israel, R. G., ... & Williams, M. H. (2000). American College of Sports Medicine roundtable. The physiological and health effects of oral creatine supplementation. *Medicine and Science in Sports and Exercise*, 32(3), 706-717.

Tsutsumi, R., & Tsutsumi, Y. M. (2014). Peptides and proteins in whey and their benefits for human health. *Austin Journal of Nutrition and Food Sciences*, 1(1), 1002.

West, D. W., Abou Sawan, S., Mazzulla, M., Williamson, E., and Moore, D. R. (2017). Whey Protein Suplement ation Enhances Whole Body Protein Metabolism and Performance Recovery After Resistance Exercise: A double-blind crossover study. *Nutrients*, 9(7), 735.

Wilborn, C. D., Kerksick, C. M., Campbell, B. I., Taylor, L. W., Marcello, B. M., Rasmussen, C. J., ... & Kreider, R. B. (2004). Effects of zinc magnesium aspartate (ZMA) supplementation on training adaptations and markers of anabolism and catabolism. *Journal of the International Society of Sports Nutrition*, 1(2), 12.

Wirunsawanya, K., Upala, S., Jaruvongvanich, V., & Sanguankeo, A. (2018). Whey protein supplementation improves body composition and cardiovascular risk factors in overweight and obese patients: A systematic review and meta-analysis. Journal of the American College of Nutrition, 37(1), 60-70. **Visual Sources**

Figure 1: Anonymous, (n.d.). *Sports nutrition supplement on shelf*. [Photo]. Retrieved from https://www.123rf.com/photo_126028588_sports-nutrition-supplement-on-shelf-fitness-protein-shakers-energy-drinks-vector-illustration-healt.html?vti=n92d7mm723x1fhni5q-1-6
Figure 2: Rogers, P. (2016). *Studies Show Little Benefit in Supplements*. The New York Times. [Photo]. Retrieved from https://www.nytimes.com/2016/11/15/well/eat/studies-show-little-benefit-in-supplements.html

Figure 3: Donato (2021). *Carnitine*. Memorial Sloan Kettering Cancer Center. [Photo]. Retrieved from https://www.mskcc.org/cancer-care/integrative-medicine/herbs/carnitine

Figure 4: Matcho, M. (2009). What's Really in Supplements? The Wall Street Journal. [Photo]. Retrieved from https://www.wsj.com/articles/SB10001424052970204731804574390840811949538

Figure 5: Luecke J., (2021). Hepatitis C Drugs Boost Remdesivir's Antiviral Activity Against COVID-19. [Photo]. Retrieved from https://news.utexas.edu/2021/04/27/hepatitis-c-drugs-boost-remdesivirs-antiviral-activity-against-covid-19/