

The Effects of Sodium Bicarbonate and Caffeine Intake on Athletic Performance in Combat Sports

Mücadele Sporlarında; Sodyum Bikarbonat ve Kafein Alımının Atletik Performansa Etkisi

Büşra DİLER¹, Pınar GÖBEL²

ABSTRACT

Combat sports; it defines individual competitive sports between two athletes within certain rules. Although the main energy systems work with phosphogen and anaerobic glycolysis pathways, the aerobic system may also be partially involved in the mechanism. Due to the technical benefits and energy mechanism of the branch, the requirements differ from other branches. Especially during the competition, strength, explosiveness, balance and speed parameters gain importance and ergogenic needs take shape. Sodium-bicarbonate; it is a highly effective ergogenic support that has been studied for years. Due to its buffering properties, it affects acidosis and blood pH, and studies have been conducted mostly in endurance sports branches and it increases performance. Sodium-bicarbonate, which can act in a short time when taken orally; it contributes to increased performance in combat sports by accelerating recovery and slowing down burnout. Caffeine's ability to enhance performance through its explosiveness-supporting mechanism has made its use widespread in combat sports in recent years. Purpose of current use; In short-term and repetitive competitions seen in combat sports, using sodium-bicarbonate and caffeine together is a possible effect on performance. In the study, an evaluation was made by scanning the current literature on the subject. Although the co-administration of sodium-bicarbonate and caffeine as synergistic drugs is quite positive in theory, more studies are needed in different branches to evaluate them in practical use.

Keywords: Caffeine, Ergogenic, Performance, Sodium-bicarbonate, Sports.

ÖZ

Mücadele sporları; iki sporcu arasında belirli kurallar dahilinde, bireysel rekabetçi spor dallarını tanımlar. Ana enerji sistemleri fosfojen ve anaerobik glikoliz yolları ile çalışmasına rağmen, kısmen aerobik sistem de mekanizmaya dahil olabilmektedir. Branşın teknik getirileri ve enerji mekanizması sebebiyle, gereksinimler diğer branşlardan ayrılmaktadır. Özellikle müsabaka esnasında; kuvvet, patlayıcılık, denge, hız parametreleri önem kazanmakta ve ergojenik ihtiyaçlar şekillenmektedir. Sodyum-bikarbonat; yıllardır çalışılan yüksek etkili bir ergojenik destektir. Tamponlayıcı özelliği sebebiyle asidozu ve kan pH'sını etkilemesi ile daha çok dayanıklılık spor branşlarında çalışmalar yapılmış ve performansı yükseltmiştir. Oral alımı ile kısa sürede etki gösterebilen sodyum-bikarbonat; mücadele sporlarında toparlanmayı hızlandırması ve tükenmişliği yavaşlatması ile performans artışına katkı sağlamaktadır. Kafeinin de patlayıcılığı destekleyici mekanizması ile performans yükseltmesi, son yıllarda mücadele sporlarında kullanımını yaygınlaştırmaktadır. Mevcut çalışmanın amacı; mücadele sporlarında görülen kısa süreli ve tekrarlı müsabakalarda sodyum-bikarbonat ve kafeinin birlikte kullanımının performansa olan olası etkilerini incelemektir. Çalışmada, konu ile ilgili güncel literatür taranarak değerlendirme yapılmıştır. Sodyum-bikarbonat ve kafeinin birlikte kullanımının sinerjik etkileri, teorik açıdan oldukça olumlu olsa da pratik kullanımda etkisini değerlendirebilmek için farklı branşlarda yapılması gereken daha fazla çalışmaya ihtiyaç vardır.

Anahtar Kelimeler: Ergojenik, Kafein, Performans, Sodyum-bikarbonat, Spor.

¹ Uzm. Dyt., Büşra DİLER, Sporcu Beslenmesi Uzmanı, Gençlik ve Spor Bakanlığı, nesibebusradiler@gmail.com, ORCID: 0000-0003-0849-3236

² Doç. Dr., Pınar GÖBEL, Spor ve Egzersiz Beslenmesi, Sağlık Bilimleri Üniversitesi, Gülhane Sağlık Bilimleri Fakültesi, Beslenme ve Diyetetik Bölümü, pinar.gobel@sbu.edu.tr, ORCID: 0000-0001-7152-1581

INTRODUCTION

Combat sports account for approximately 25% of all medals awarded in the Olympic games. The most popular combat sports, such as wrestling, judo, kickboxing, mixed martial arts, boxing, karate, and taekwondo, require a high level of skill and dedication from their athletes, making them the pinnacle of athletic competition. In combat sports, athletes are classified based on their body mass to minimize differences between competitors in terms of body size, strength, and agility.¹

These sports are high-intensity and intermittent, requiring short bursts of maximum intensity actions and lower intensity actions. The energy demand is primarily met through aerobic metabolism.^{1,2} High-intensity actions require the anaerobic production of ATP and phosphocreatine, as well as the ability to produce energy through anaerobic glycolysis. The energy systems utilized vary depending on the type of sport being performed, including punching, kicking, and the use of upper and lower extremities at different intensities. Athletes who rely on piercing movements require exceptional explosive power and overall strength, whereas those who use grappling movements benefit from isometric and concentric muscle strength.³ To optimize athletic performance, it is crucial to recognize the varying demands of different movement types. By tailoring training and nutrition plans with confidence and expertise, athletes can achieve their full potential. Da Silva, V. et al. (2019) state that athletes who perform piercing movements require greater total strength and explosive power, while those who perform grappling movements require more emphasis on isometric and concentric muscle strength. Athletes' physiological responses and emerging requirements vary depending on the type of sport they engage in. The nutritional, supplementary, and ergogenic models used in endurance sports differ significantly from those used in combat sports.⁴ Ergogenic aids are techniques, devices, or approaches that enhance training adaptations and exercise performance capacity.

Nutritional ergogenic aids not only significantly enhance athletic performance but also help mitigate adverse effects such as excessive fatigue, dehydration, and loss of physical capacity.⁵

It is advised that athletes use Group A ergogenic aids, which are approved for effectiveness and have been categorized based on safety, legality, and effectiveness by leading organizations like the International Olympic Committee (IOC), Australian Institute of Sport (AIS), World Anti-Doping Agency (WADA), and International Society of Sports Nutrition (ISSN).⁶ Scientifically established supplements including sports beverages, liquid nutritional support, whey protein, calcium, iron, probiotics, creatine, caffeine, and sodium bicarbonate can help athletes perform at a much higher level. Therefore, athletes can confidently incorporate them into their training regimen to achieve their desired results.⁶

Reducing or neutralizing the negative effects of H^+ byproducts of anaerobic glycolysis can enhance exercise performance and improve burnout time. Blood lactate concentration (BL) serves as a key indicator of glycolytic metabolism.⁷ The increase in lactate causes an acid-base imbalance within the cell, which negatively impacts the speed of strength and power development, ultimately reducing performance. During anaerobic exercise, myofibers produce large amounts of H^+ ions, which are buffered by various molecules in the circulation. Blood pH levels are maintained by sodium bicarbonate ($NaHCO_3$), an efficient extracellular buffer that neutralizes H^+ ions.⁷ Intake of $NaHCO_3$ prior to high-intensity activity can dramatically accelerate glycolytic metabolism and improve performance during simulated taekwondo, according to research by Lopes-Silva et al. (2018).⁹ Exercise-induced acidity can be lessened and weariness can be postponed by consuming $NaHCO_3$, which enhances performance.⁹ As noted by McNaughton et al. (2016), it is crucial to remember that these advantages are exclusive

to improved physical performance and do not affect cognitive or mental performance.¹⁰

Low ATP content, muscle acidosis, elevated extracellular potassium, low muscle glycogen content, insufficient muscle PCr reserves, and central nervous system (CNS) fatigue are some of the variables that impact performance during competition in dual combat sports.¹¹ By acting on adenosine receptors, caffeine (CAF) is a stimulant that lowers perceived effort (RPE) and weariness. Owing to its central nervous system properties, it's a helpful aid for improving athletic performance. Research conducted by López-González et al. (2018) and Santos et al. (2014) shows that caffeine can increase the glycolytic contribution to energy metabolism during simulated and actual martial arts.^{1, 12} These studies also revealed improved reaction time and delayed weariness following multiple taekwondo bouts. Research has shown that caffeine intake during combat sports can improve reaction times, delay fatigue, increase endurance, and increase the production of catecholamines. For instance, Santos et al. (2014) demonstrated improved response time and delayed fatigue during sequential taekwondo fights; López-González et al. (2018) found that coffee can enhance the glycolytic contribution to energy metabolism during simulated and actual combat sports.^{1, 12}

Theoretically, by reducing extracellular potassium accumulation, minimizing CNS depletion, and increasing extracellular buffering capacity, combining CAF and NaHCO₃ can improve combat sports performance.¹³ The combined and individual effects of CAF and NaHCO₃ on athletic performance are evaluated in this study, with a focus on combat sports.

Sodium Bicarbonate (NaHCO₃)

Studies on the connection between exercise performance and sodium bicarbonate have been conducted on a large scale since the 1930s. Dennig and associates at Harvard University carried out the initial investigation in this field.¹⁴ The authors of this single-subject study discovered that by putting the body in an alkaline state before exercise, consuming 10 g of sodium bicarbonate before

jogging on a treadmill enhanced performance. Among the other buffers that have been tested, including sodium citrate, sodium phosphate, and sodium lactate, researchers have consistently discovered that sodium bicarbonate (NaHCO₃) is the most effective agent for enhancing exercise performance.^{15,17}

Supplementing with sodium bicarbonate works better during exercise that increases the production of H⁺ and is more reliant on glycolysis. Supplementing with sodium bicarbonate is not as beneficial for exercise that is either too short or too lengthy to result in a major acidosis.⁶ Fatigue is the term for the transient loss of muscle strength and power brought on by intense contractile action. It is generally acknowledged that the buildup of metabolites and ions is a causative factor in fatigue, even though the precise reasons of the condition are still up for question.¹⁸ There is disagreement on the impact of acidosis and the distribution of associated ions (such Ca²⁺, K⁺, and Cl⁻) on contractile performance. The precise processes underlying this effect remain mostly unclear. However, it is widely accepted that the ergogenic effect of sodium bicarbonate is due to an increase in extracellular buffering capacity. Changes in the blood's acid-base equilibrium brought on by metabolism are linked to elevated pH and the base excess that characterizes alkalosis. However, it is widely accepted that the ergogenic effect of sodium bicarbonate is due to an increase in extracellular buffering capacity. Elevated pH and the base excess associated with alkalosis are related to changes in the blood's acid-base equilibrium caused by metabolism. Da Silva et al.'s (2019) study evaluated the whole-body contribution of energy systems during exercise after sodium bicarbonate administration and found an increased glycolytic contribution, which may help to explain increases in high-intensity performance over time.³ It has been demonstrated that administering continuous sodium bicarbonate (NaHCO₃) supplements before to high-intensity interval training (HIIT) significantly improves anaerobic performance and increases blood lactate levels after anaerobic exercise.¹⁹ The study found that supplementation with 0.2 g/kg

NaHCO₃ before HIIT training also resulted in an improved clearance rate.¹⁹

Short bursts of high-intensity activity are mixed with brief rest intervals in martial arts competitions. Many martial sports, including judo and wrestling, mostly rely on glycolysis because of their structural makeup.²⁰ This explains why scientists are interested in finding out how supplementing with sodium bicarbonate affects athletes' ability to complete exercise demands related to various sports. In a study with thirty individuals, the effects of sodium bicarbonate ingestion after high-intensity intermittent exercise were evaluated using the yo-yo recovery test.²¹ The outcomes demonstrated that supplementation reduced perceived exertion while increasing performance and recovery. In a study involving judo athletes, the impact of sodium bicarbonate on the quantity of shots in the three sections of the "Special Judo Fitness Test" was examined.²² The outcomes demonstrated that supplementation increased the quantity of shots in the second and third sessions significantly. Analogous research has been carried out involving athletes participating in wrestling, taekwondo, and karate. Rezaei et al. (2019) found that supplementation extended the time to fatigue during a karate-specific aerobic measurement in a study testing the sodium bicarbonate consumption of eight karate athletes.¹¹ The impact of sodium bicarbonate consumption on the quantity of strikes in a simulated throwing test was investigated in a group of top-tier competitive wrestlers. Therefore, it was observed that when utilized in a graduated regimen, sodium bicarbonate supplementation had no ergogenic impact.²³ Even however, only male participants demonstrated a substantial improvement in the number of rounds fired in the same fake shooting test using the same enhancement methodology in a follow-up study conducted by the same research group.²⁴ Overall, the majority of research points to sodium bicarbonate as a useful supplement for raising martial arts competitors' performance in events including boxing, judo, karate, taekwondo, and wrestling.²⁵

An ergogenic aid for martial arts, boxing, karate, taekwondo, judo, and wrestling, as well as for muscular endurance exercises. The majority of research on sodium bicarbonate's ergogenic effect has been done on high-intensity exercise programs that last 30 to 12 minutes. Regarding single-dose supplementation regimens, it has been suggested that 0.3 g/kg of sodium bicarbonate is the ideal dosage for an ergogenic effect, even if 0.2 g/kg of the supplement appears to be the minimal dose needed to enhance exercise performance. Higher doses (0.4–0.5 g/kg) in single dose supplementation procedures are said to have no greater benefit than 0.3 g/kg; on the contrary, they may have more adverse effects. In the single-dose supplementation approach, 60 to 180 minutes before to activity or competition is the suggested sodium bicarbonate intake. Protocols involving the multi-day administration of sodium bicarbonate may be useful in enhancing exercise performance. These regimens usually last between three and seven days before exercise testing. Ergogenic effects are obtained from a daily intake of 0.4–0.5 g/kg of sodium bicarbonate. Typically, the daily dosage is broken up into smaller dosages and given throughout the day at various times. The advantage of multi-day procedures is that they lessen the possibility of sodium bicarbonate adverse effects on competition day. Bloating, nausea, vomiting, and abdominal pain are the side effects of sodium bicarbonate supplementation that occur most frequently. Individual differences exist in the frequency and intensity of adverse effects, although most are modest. Using sodium bicarbonate consistently, for example, before every training session, may enhance training adaptations including longer recovery times and higher power output.¹⁵ Combat sports athletes may think about taking supplements containing sodium bicarbonate to help them perform better. Future studies are yet required to examine the effects of supplementing with sodium bicarbonate, especially in combat sports.^{15, 25}

Caffeine (CAF)

The psychoactive chemical caffeine is naturally present in many plants, including coffee, tea, and cocoa. It is consumed in large quantities all around the world. Young adults and those who exercise have been consuming energy drinks, pre-workout supplements, gum, energy gels and chews, and other goods containing caffeine, such as aerosols, at significantly higher rates in the past few years.²⁶ Research on caffeine's effects on health has been ongoing for a long time. Because of its possible impacts on athletic performance, it is especially interesting in the context of sports. Caffeine, which has been included in the category of safe ergogenic aids by various organizations such as the International Olympic Committee (IOC) and the International Society of Sports Nutrition (ISSN) in recent decades, is a very broad area of research among sports supplements.²⁷

In the early 1900s, coaches and athletes surreptitiously created combinations of plant-based stimulants, including caffeine, along with other substances including cocaine, strychnine, ether, heroin, and nitroglycerin, as early ergogenic supplements to give them a competitive edge. The prohibition on the use of medicinal concoctions, especially for endurance athletes, persisted until the 1920s when heroin and cocaine were made available through prescription, and until the late 1960s when the IOC implemented anti-doping initiatives. The 1900s saw the start of the first studies on caffeine. The effects of caffeine on the body and mind have been well studied, particularly in relation to muscle weariness. Studies on various sports began in the 1940s, but the focus of research in the 1970s was on how exercise affects metabolism. Recent research has shown that caffeine improves athletes' physical and mental performance in a variety of sports.²⁸

Although the primary mechanism by which caffeine affects performance has been assumed to be its effects on the central nervous system (CNS), there are alternative theories that explain its ergogenic benefits, such as improved myofibrillar calcium availability, optimized exercise metabolism,

and substrate availability. Many processes, including stimulation, have been proposed. Increased adrenaline (epinephrine)-induced free fatty acid (FFA) oxidation occurs after caffeine use; this may protect glycogen and improve endurance performance.²⁸

Caffeine consumption at low dosages (1-3 mg/kg) has been shown to provide detectable ergogenic benefits without causing substantial physiological reactions (RER, blood lactate, glucose, etc.), suggesting that the reported improvements originate in the CNS.²⁹ Consequently, it has been proposed that it has strong ergogenic support for focus, perceived exertion (RPE), soreness in the muscles, and potentially the skeletal muscle's ability to produce power.³⁰ The ergogenic effect of caffeine may be attributed to its direct effects on muscle. Caffeine most likely helps muscles contract by mobilizing calcium ions (Ca²⁺), which makes it easier for each motor unit to produce force. Taking coffee may help reduce fatigue brought on by the slow reduction in Ca²⁺ release. Similar to this, coffee may partially improve the excitation-contraction coupling necessary for muscular contraction at the periphery by increasing the activity of the sodium/potassium (Na⁺/K⁺) pump.³¹ Although there are several areas of the body where caffeine seems to act, the strongest evidence points to the central nervous system (CNS) as the main target. This is now widely acknowledged as the main mechanism via which caffeine affects both mental and physical function.²⁸ It is believed that caffeine acts on the central nervous system by opposing adenosine receptors, which causes an increase in neurotransmitter release, a slowing down of motor unit firing, and a numbing of pain.^{30, 31} As a neuromodulator and homeostatic regulator in the nervous system, adenosine is engaged in a wide range of pathways and functions. Reduced concentrations of numerous CNS neurotransmitters, such as glutamate, norepinephrine, acetylcholine, dopamine, and serotonin, are the main recognized consequences of adenosine. Similar in chemical structure to adenosine, caffeine binds to adenosine receptors upon ingestion, raising the neurotransmitter's concentration.

For the majority of people, but not all, this has favorable benefits on mood, alertness, focus, and attentiveness.³² Researchers have also described aspects of adenosine A2A receptor activity related to motivation and cognitive functions. Furthermore, variations in 5-HT_{2A} receptor activation may play a role in the ergogenic effects of coffee by influencing dopamine release, which in turn impacts pain, effort, alertness, and motivation.²⁸

Caffeine administration during exercise may also result in a decrease in RPE and a decrease in pain. It has been demonstrated that acute caffeine administration during exercise affects RPE, possibly more than previously believed.²⁸ A research of twenty-one meta-analyses revealed that the administration of caffeine produced ergogenic effects on muscular endurance, strength, anaerobic power, and aerobic endurance.¹⁵ However, there are differences in the efficiency of caffeine as an ergogenic supplement, and it has a 33% negative influence on improving performance. Numerous factors, such as dosage, training status, duration of consumption, time of day, gender, habit, heredity, and type of exercise, may influence the effectiveness of caffeine supplements, according to reports.³³ The impact of caffeine in combat sports is unknown.¹ A systematic review was conducted using a recent meta-analysis.³⁴ When assessing and investigating certain branches in this analysis, a number of other variables were not considered, such as grip strength, dynamic strength-endurance performance, heart rate, and perceived effort rate. As a result, a definitive judgment supported by substantial data could not be drawn. Furthermore, a recent meta-analysis on the effects of coffee in martial arts found that while caffeine consumption had no influence on jump height, it did, in fact, improve workout performance, increasing hand grip strength and duration from 45 seconds to 8 minutes.⁴⁰ Another study looked at how coffee affected taekwondo competitors' reaction times and discovered that it could be a useful tactic.³⁶ Furthermore, a study on taekwondo players revealed that coffee intake raised the kick test's frequency velocity by 4%.³⁵ Caffeine ingestion during

high-intensity intermittent exercise in combat sports has been found to boost lactic acid production, regardless of the dosage and the interval between supplementation and subsequent performance. Because this combat sports workout model truly boosts anaerobic capacity, it has been suggested that caffeine may be employed as an effective pharmaceutical method.³⁵ Caffeine administration (6 mg/kg) was found to have beneficial effects on lower extremity high resistance in a study including 24 participants.³⁷ Caffeine supplementation improved anaerobic performance without affecting lower extremity EMG activity and fatigue, and improved neuromuscular efficiency and reaction time were observed in certain muscles, according to a recent study that examined the effects of caffeine on anaerobic performance, neuromuscular efficiency, and upper and lower extremity fatigue in Olympic-level boxers.³⁸ According to a study comparing the effects of 3 mg, 6 mg, 9 mg, and a placebo on judokas' body weight, 6 and 9 mg/kg CAF enhanced their performance on the SJFT (judo-specific performance test), while 9 mg/kg was said to increase their combat effectiveness. It was discovered that 3 mg/kg CAF had no appreciable beneficial ergogenic effects. Only 9 mg/kg CAF significantly increased SJFT performance in athletes who eat CAF-containing items on a regular basis (consumers), whereas the impact was only shown at 6 mg/kg in non-consumers, or athletes who do not frequently consume CAF-containing products.³⁹ Another study that looked at the effects of 3 mg/kg of caffeine intake on the psycho-physical performance of conditioning activity (CA) in young taekwondo athletes came to the conclusion that it is a strategy that improves performance.³⁵

The way that different sports use caffeine as an ergogenic aid differs. The bulk of research, meanwhile, has been on endurance sports. Research on combat sports based on more specialized variables and training methods would be more instructive.

Effects of Combined Use of Sodium Bicarbonate and Caffeine on Athletic Performance

When taken concurrently, sodium bicarbonate and caffeine may have synergistic benefits since they may improve performance via distinct processes. According to a recent review, one in eight studies on this subject demonstrated synergistic effects when mixing

caffeine and sodium bicarbonate.^{22, 25} Rezaei et al. (2019) observed no discernible impact of taking the two supplements concurrently on performance in another trial including karate players.¹¹ Notwithstanding its limitations, it is reasonable to take into account that the study only involved eight athletes and that it is not possible to compare the results on an individual basis.

CONCLUSION

It is possible to utilize ergogenic aids singly or in combination. When combined, certain ergogenic aids may have even more performance-enhancing effects. It is crucial in this situation that the assessment and advice are tailored to the individual and the sport. Athletes should make decisions based on their age, sport, and the performance metrics they want to raise. Nonetheless, there must be a substantial amount of proof that the supplements taken—whether in combination or apart-improve performance.

It is well-established that sodium bicarbonate can produce synergistic effects on athletic performance when combined with various ergogenic aids. Due to their distinct physiological mechanisms, the concurrent use of sodium bicarbonate and caffeine is hypothesized to offer greater ergogenic benefits compared to either supplement used in isolation. To support this theoretical framework, further research is needed, employing diverse supplementation protocols across different sports disciplines.

REFERENCES

1. Lopez-Gonzalez, L.M, Sanchez-Oliver, A.J, Mata, F, Jodra, P, Antonio, J. and Dominguez, J. (2018). "Acute caffeine supplementation in combat sports: a systematic review". *Journal of International Society Sports Nutrition*, 15 (1), 60. <https://doi.org/10.1186/s12970-018-0267-2>
2. Januszko, P. and Lange, E. (2021). "Nutrition, supplementation and weight reduction in combat sports: a review". *AIMS Public Health*, 8 (3), 485-498. <https://doi.org/10.3934/publichealth.2021038>
3. Da Silva, V, Marins, J.C.B, Franchini, E, Gualano, B. and Artioli, G.G. (2019). "Effects of β -alanine and sodium bicarbonate supplementation on the estimated energy system contribution during high-intensity intermittent exercise". *Amino Acids*, 51 (1), 83–96. <https://doi.org/10.1007/s00726-018-2643-2>
4. Vicente-Salar, N, Fuster-Muñoz, E. and Martínez-Rodríguez, A. (2022). "Nutritional ergogenic aids in combat sports: A systematic review and meta-analysis". *Nutrients*, 14 (13), 2588. <https://doi.org/10.3390/nu14132588>
5. Kerkick, C.M, Wilborn, C.D, Roberts, M.D, Smith-Ryan, A, Kleiner, S.M, Jager, R, Collins, R, Cooke, M, Davis, J.N, Galvan, E, Greenwood, M, Lowery, L.M, Wildman, R, Antonio, J. and Kreider, R.B. (2018). "ISSN exercise & sports nutrition review update: research & recommendations". *Journal of the International Society of Sports Nutrition*, 15 (1), 38. <https://doi.org/10.1186/s12970-018-0242-y>
6. Maughan, R.J, Burke, L.M, Dvorak, J, Larson-Mayer, D.E, Peeling, P, Phillips, S.M, Rawson, E.S, Walsh, N.P, Garthe, I, Geyer, H, Meeusen, R, van Loon, L.J.C, Shireffs, S.M, Spriet, L.L, Stuart, M, Vernec, A, Currell, K, Ali, V.M, Budgett, R.G.M, Ljungqvist, A, Mountjoy, M, Pitsiladis, Y.P, Soligard, T, Erdener, U. and Engebretsen, L. (2018). "IOC consensus statement: dietary supplements and the high- performance athlete". *International Journal of Sport Nutrition Exercise Metabolism*, 28 (2), 104–25. <https://doi.org/10.1136/njsports-2018-099027>
7. Junior, A.H, de Salles, P.V, Saunders, B. and Artioli, G.G. (2015). "Nutritional strategies to modulate intracellular and extracellular buffering capacity during high- intensity exercise". *Sports Medicine*, 45 (Suppl 1), 71-81. <https://doi.org/10.1007/s40279-015-0397-5>
8. Fitts, R.H. (2016). "The role of acidosis in fatigue: pro perspective". *Medicine & Science in Sports & Exercise*, 48 (11), 2335-2338. <https://doi.org/10.1249/MSS.0000000000001043>
9. Lopes-Silva, J.P, da Silva-Santos, J.F, Artioli, G.G, Loturco, I, Abbiss, C. and Franchini, E. (2018). "Sodium bicarbonate ingestion increases glycolytic contribution and improves performance during simulated taekwondo combat". *European Journal of Sport Science*, 18 (3), 431-440. <https://doi.org/10.1080/17461391.2018.1424942>
10. McNaughton, L.R, Gough, L, Deb, S, Bentley, D. and Sparks, S.A. (2016). "Recent developments in the use of sodium bicarbonate as an ergogenic aid". *Current Sports Medicine Reports*, 15 (4), 233-244. <https://doi.org/10.1249/JSR.0000000000000283>
11. Rezaei, S, Akbari, K. and Gahreman, D.E. (2019). "Caffeine and sodium bicarbonate supplementation alone or together improve karate performance". *Journal of the International Society of Sports Nutrition*, 16 (1), 44. <https://doi.org/10.1186/s12970-019-0313-8>
12. Santos, V.G.F, Santos, V.R.F, Felipe, L.J.C, Almeida Jr, J.W, Bertuzzi, R, Kiss M.A.P.D.M. and Lima-Silva, A.E. (2014). "Caffeine reduces reaction time and improves performance in simulated-contest of taekwondo". *Nutrients*, 6 (2), 637-49. <https://doi.org/10.3390/nu6020637>
13. Naderi, A, Earnest, C.P, Lowery, R.P, Wilson, J.M. and Willems, M.E.T. (2016). "Co-ingestion of nutritional ergogenic aids and

- high-intensity exercise performance". *Sports Medicine*, 46 (10), 1407-18. <https://doi.org/10.1007/s40279-016-0525-x>
14. Dennig, H, Talbott, J.H, Edwards, H.T. and Dill, D.B. (1931). "Effect of acidosis and alkalosis upon capacity for work". *The Journal of Clinical Investigation*, 9 (4), 601-13.
15. Grgic, J, Pedisic, Z, Saunders, B, Artioli, G.G, Schoenfeld, B.J, McKenna, M.J, Bishop, D.J, Kreider, R.B, Stout, J.R, Kalman, D.S, Arent, S.M, VanDusseldorp, T.A, Lopez, H.L, Ziegenfuss, T.N, Burke, L.M, Antonio, J. and Campbell, B.I. (2021). "International Society of Sports Nutrition position stand: sodium bicarbonate and exercise performance". *Journal of the International Society of Sports Nutrition*, 18 (1), 61. <https://doi.org/10.1186/s12970-021-00458-w>
16. Siegler, J.C, Marshall, P.W.M. and Bishop, D. (2016). "Mechanistic insights into the efficacy of sodium bicarbonate supplementation to improve athletic performance". *Sports Medicine Open*, 6 (2), 637-49. <https://doi.org/10.3390/nu6020637>
17. Grgic, J, Grgic, I, Pickering, C, Schoenfeld, B.J, Bishop, D.J. and Pedisic, Z. (2020). "Wake up and smell the coffee: Caffeine supplementation and exercise performance-an umbrella review of 21 published meta-analyses". *British Journal of Sports Medicine*, 54 (1), 681-688. <https://doi.org/10.1136/bjsports-2018-100278>
18. Lindinger, M.I. and Cairns, S.P. (2021). "Regulation of muscle potassium: exercise performance, fatigue and health implications". *European Journal of Applied Physiology*, 121 (3), 721-48. <https://doi.org/10.1007/s00421-020-04546-8>
19. Wang, J, Qiu, J, Yi, L, Hou, Z, Benardot, D. and Cao, W. (2019). "Effect of sodium bicarbonate ingestion during 6 weeks of HIIT on anaerobic performance of college students". *Journal of the International Society of Sports Nutrition*, 6 (1), 18. <https://doi.org/10.1186/s12970-019-0285-8>
20. Franchini, E, Artioli, G.G. and Brito, C.J. (2013). "Judo combat: time-motion analysis and physiology". *International Journal of Performance Analysis in Sport*, 13 (3), 624-41. <https://doi.org/10.1080/247448668.2013.11868676>
21. Krstrup, P, Ermidis, G. and Mohr, M. (2015). "Sodium bicarbonate intake improves high-intensity intermittent exercise performance in trained young men". *Journal of the International Society of Sports Nutrition*, 12 (1), 25. <https://doi.org/10.1186/s12970-015-0087-6>
22. Felipe, L.C, Lopes-Silva, J.P, Bertuzzi, R, McGinley, C. and Lima-Silva, A.E. (2016). "Separate and combined effects of caffeine and sodium-bicarbonate intake on judo performance". *International Journal of Sports Physiology and Performance*, 11 (2), 221-6. <https://doi.org/10.1123/ijssp.2015-0020>
23. Durkalec-Michalski, K, Zawieja, E.E, Podgórski, T, Zawieja, B.E, Michalowska, P, Loniewski, I. and Jeszka, J. (2018). "The effect of a new sodium bicarbonate loading regimen on anaerobics capacity and wrestling performance". *Nutrients*, 10 (6), 697. <https://doi.org/10.3390/nu10060697>
24. Durkalec-Michalski K, Zawieja, E.E, Zawieja, B.E, Michalowska, P. and Podgórski, T. (2020). "The gender dependent influence of sodium bicarbonate supplementation on anaerobic power and specific performance in female and male wrestlers". *Scientific Report*, 10 (1), 1878. <https://doi.org/10.1038/s41598-020-57590-x>
25. Grgic, J. (2021). "Effects of combining caffeine and sodium bicarbonate on exercise performance: a review with suggestions for future research". *Journal of Dietary Supplements*, 18 (4), 444-60. <https://doi.org/10.1080/19390211.2020.1783422>
26. Wickham, K.A. and Spriet, L.L. (2018). "Administration of caffeine in alternate forms". *Sports Medicine*, 48 (Suppl 1), 79-91. <https://doi.org/10.1007/s40279-017-0848-2>
27. Higgins, S, Straight, C.R. and Lewis, R.D. (2016). "The effects of preexercise caffeinated coffee ingestion on endurance performance: an evidence-based review". *International Journal of Sport Nutrition Exercise Metabolism*, 26 (3), 221-39. <https://doi.org/10.1123/ijnsnem.2015-0147>
28. Guest, N.S, VanDusseldorp, T.A, Nelson, M.T, Grgic, J, Schoenfeld, B.J, Jenkins, N.D.M, Arent, S.M, Antonio, J, Stout, J.R, Trexler, E.T, Smith-Ryan, A.E, Goldstein, E.R, Kalman, D.S. and Campbell, B.I. (2021). "International society of sports nutrition position stand: caffeine and exercise performance". *Journal of the International Society of Sports Nutrition*, 18 (1), 1. <https://doi.org/10.1186/s12970-020-00383-4>
29. Talanian, J.L. and Spriet, L.L. (2016). "Low and moderate doses of caffeine late in exercise improve performance in trained cyclists". *Apply Physiology Nutrients Metabolism*, 41 (8), 850-5. <https://doi.org/10.1139/apnm-2016-0053>
30. Black, C.D, Waddell, D.E. and Gonglach, A.R. (2015). "Caffeine's ergogenic effects on cycling: neuromuscular and perceptual factors". *Medicine & Science in Sports & Exercise*, 47 (6), 1145-58. <https://doi.org/10.1249/MSS.0000000000000513>
31. Gonglach, A.R, Ade, C.J, Bembien, M.G, Larson, R.D. and Black, C.D. (2016). "Muscle pain as a regulator of cycling intensity: effect of caffeine ingestion". *Medicine & Science in Sports & Exercise*, 48 (2), 287-96. <https://doi.org/10.1249/MSS.0000000000000767>
32. Nehlig, A. (2018). "Interindividual differences in caffeine metabolism and factors driving caffeine consumption". *Pharmacological Reviews*, 70 (2), 384-411. <https://doi.org/10.1124/pr.117.014407>
33. Grgic, J, Trexler, E.T, Lazinica, B. and Pedisic, Z. (2018). "Effects of caffeine intake on muscle strength and power: A systematic review and meta-analysis". *Journal of the International Society of Sports Nutrition*, 15 (11). <https://doi.org/10.1186/s12970-018-0216-0>
34. Da Silva, R.P, de Oliveira, L.F, Saunders, B, de Andrade-Kratz, C, de Salles-Painelli, V. and da Diaz-Lara, J. "Effects of acute caffeine intake on combat sports performance: A systematic review and meta-analysis". *Critical Reviews Food Science and Nutrition*, 27, 1-16. <https://doi.org/10.1080/10408398.2022.2068499>
35. Ouergui, I, Mahdi, N, Delleli, S, Messaoudi, H, Chtourou, H, Sahnoun, Z, Bouassida, A, Bouhlel, E, Nobari, H, Ardigo, L.P. and Franchini, E. (2022). "Acute effects of low dose of caffeine ingestion combined with conditioning activity on psychological and physical performances of male and female taekwondo athletes". *Nutrients*, 14 (3), 571. <https://doi.org/10.3390/nu14030571>
36. Cortez, L, Mackay, K, Contreras, E. and Penailillo, L. (2017). "Acute effect of caffeine ingestion on reaction time and electromyographic activity of the Dollyo Chagi round kick in taekwondo fighters". *RICYDE Revista Internacional de Ciencias Deporte*, 13 (47), 52-62. <https://doi.org/10.5232/ricyde2017.04704>
37. Castillo, D, Domínguez, R, Rodríguez-Fernández, A. and Raya-González, J. (2019). "Effects of caffeine supplementation on power performance in a flywheel device: A randomised, double-blind cross-over study". *Nutrients*, 11 (255). <https://doi.org/10.3390/nu11020255>
38. San- Juan, A.F, López-Samanes, A, Jodra, P, Valenzuela, P.L, Rueda, J, Veiga-Herreros, P, Perez-Lopez, A. and Dominguez, R. (2019). "Caffeine Supplementation Improves Anaerobic Performance and Neuromuscular Efficiency and Fatigue in Olympic-Level Boxers". *Nutrients*, 11 (9), 2120. <https://doi.org/10.3390/nu11092120>
39. Durkalec-Michalski, K, Nowaczyk, P.M, Główska, N. and Grygiel, A. (2019). "Dose-dependent effect of caffeine supplementation on judo-specific performance and training activity: a randomized placebo-controlled crossover trial". *Journal of the International Society of Sports Nutrition*, 16 (1), 38. <https://doi.org/10.1186/s12970-019-0305-8>

40. Christensen, P.M, Shirai, Y, Rirtz, C. and Nordsborg, N.B. (2017). “Caffeine and bicarbonate for speed. A meta-analysis of legal supplements potential for improving intense endurance exercise performance”. 9 (8), 240. <https://doi.org/10.3389/fphys.2017.00240>