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KOSALB International Journal of Human Movements Science, Vol: 4, No: 1, 2025, p 1-12, DOI: 10.70736/2958.8332.kosalb.51 | ISSN: 2958-8332 | Published: 20.06.2025

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Systematic Review

The Impact of Sodium Citrate, Phosphates, and Carnitine on Sports Performance: A Systematic Review

Vanesa Bojku[1ABE] Bujar Begu[2CDE*]

[1]*University for Business and Technology (UBT), University of Food Science and Biotechnology, ORCID: 0009-0001-6173-1371, vanesabojku5@gmail.com, Kosovo.*
[2]*University of Pristina "Hasan Prishtina", Faculty of Physical Education and Sport, ORCID: 0009-0000-8368-3182, bujar.begu@uni-pr.edu, Kosovo.*
**Corresponding author: bujar.begu@uni-pr.edu*

Authors' Contribution: A: Study design, B: Data collection, C: Data analysis, D: Manuscript preparation, E: Discussion and conclusion

ABSTRACT

Study aim(s): The study aims to clarify the impact of sodium citrate, phosphates, and carnitine on sports performance through a systematic review of the literature. These supplements have not been extensively defined or tested in previous experimental studies. Therefore, this review seeks to provide clearer insights into their optimal dosage and timing of use, as existing research primarily focuses on dosage and usage protocols in experimental settings.
Methods: This study follows a systematic review model based on PRISMA standards. It aims to draw new conclusions regarding the Effects of Sodium Citrate, Phosphates, and Carnitine on Sports Performance and their potential impact on athletes' health. The literature search was limited to studies published within the last five years.
Results: The findings indicate that sodium citrate may enhance athletic performance and support skill preservation, although it can cause temporary gastrointestinal discomfort. Phosphate supplementation shows potential benefits for endurance under hypoxic conditions but demonstrates inconsistent effects in trained athletes. Carnitine appears to be most effective for high-intensity performance, with both acute and chronic supplementation contributing to improved power output and overall health benefits.
Conclusions: While supplementation with sodium citrate, phosphate, and carnitine shows potential ergogenic benefits, their effectiveness depends on proper dosage and timing. Sodium citrate (0.5 g/kg BM) may enhance anaerobic performance but requires careful timing (200–240 min pre-exercise) to minimize gastrointestinal discomfort. The impact of sodium phosphate on aerobic performance varies among individuals, with responders particularly benefiting from supplementation, especially under hypoxic conditions. Carnitine supplementation appears most effective for high-intensity activities when taken chronically (2–2.72 g/day for 9–24 weeks) or acutely (3–4 g, 60–90 min pre-exercise).

Keywords: Equivocal Supplements, Sodium Citrate, Phosphates, Carnitine

INTRODUCTION

In the world of sports and fitness, ergogenic aids are substances used to enhance sports performance and offer additional benefits, such as supporting muscle recovery, promoting joint and muscle health to prevent injuries, and aiding in the management of training loads to optimize physical adaptions [1]. These supplements come in various forms such as powders, capsules, sprays, soft gels, liquids, gummies, injections; to accommodate different preferences and absorption rates. Athletes at all levels often use dietary supplements to gain a competitive edge, improve endurance, build muscle, and reduce fatigue [2]. Supplements are often used as meal replacements, particularly by athletes whose busy lifestyles make it challenging to meet their nutritional needs for optimal health, performance, recovery, and injury prevention. Ideally, these nutritional requirements should be fulfilled through whole foods rather than relying on ergogenic aids. However, not all supplements are permitted for use, some are prohibited by WADA and may cause issues for athletes if consumed during competition. Additionally, supplements are not limited to athletes; they are widely used by the general population for various health benefits, such as supporting cognitive function, bone health, joint and muscle health, and preventing nutritional deficiencies. According to WADA, sodium citrate is not listed as a prohibited substance. Athletes may use it as a buffering agent to help neutralize acid in the blood during high-intensity exercise. Phosphate supplementation is also not prohibited by WADA. Similarly, carnitine itself is not banned by WADA. However, according to WADA regulations, intravenous infusions or injections exceeding 100 milliliters per 12-hour period are prohibited, except when legitimately administered during hospital treatments, surgical procedures, or clinical diagnostic investigations [3].

Similar to $NaHCO_3$, sodium citrate acts as a blood buffer by increasing pH of the extracellular environment and enhancing the gradient between the blood and active muscle. This effect occurs through the dissociation of sodium citrate into its constituent ions, which leads to a decrease in $[H^+]$ and an increase in $[HCO_3^-]$ as electrical equilibrium is restored [4]. Early studies investigated sodium citrate doses ranging from 0.1 to 0.5 g/kg BM, consumed 90 min prior to a 60-s maximal sprint test. A dose-response relationship was observed, with ergogenic benefits requiring a minimum ingestion of 0.3 g/kg BM, which increased proportionally with the dose of supplement consumed [5]. Subsequently, a 0.5 g/kg BM dose was reported to produce ∼12% increase in total work completed during exercise tasks lasting 2–4 min [6]. However, higher doses (0.7–0.9 g/kg BM) were associated with increased symptoms of GI distress without further enhancing the degree of alkalosis produced [7]. More recent findings indicate that the peak blood pH occurs 180–240 min after sodium citrate ingestion, suggesting that the dosing protocol should begin at least 3 hr before exercise [7]. Despite a few positive investigations, the overall ergogenic effect of sodium citrate ingestion remains equivocal. A previous meta-analysis highlighting a negligible benefit ($0.0 \pm 1.3\%$ improvement) associated with its use [8]. Given the detrimental side effects associated with both $NaHCO_3$ and citrate, as well as the limited benefits observed with the latter, athletes and their support staff are encouraged to carefully trial these blood buffers during training. This allows for the development of a personalized and well-tolerated protocol before considering their use in a competitive setting.

With regard to phosphate, numerous hypotheses have been proposed to explain the potential benefits of phosphate supplementation on athletic performance [9]. The proposed mechanisms underpinning these benefits include an enhanced rate of ATP and PCr resynthesis [10]; improved buffering capacity to support high rates of anaerobic glycolysis

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KOSALB International Journal of Human Movements Science, Vol: 4, No: 1, 2025, p 1-12, DOI: 10.70736/2958.8332.kosalb.51 | ISSN: 2958-8332 | Published: 20.06.2025
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[10]; improved myocardial contractility, leading to increased cardiac efficiency [11]; and an increased erythrocyte 2,3 diphosphoglycerate (2,3 DPG) concentration, resulting in a reduced hemoglobin-oxygen affinity and greater oxygen unloading to peripheral tissues. Current investigations of phosphate supplementation (sodium, calcium, or potassium phosphate) have focused on the physiological and performance-related outcomes using laboratory protocols, including graded exercise tests to exhaustion, the 30-s Wingate test, 6 × 20 m (~3–4 s) repeated sprint efforts, and TT efforts ranging from 3–60 min. Overall, evidence for performance enhancement from phosphate supplementation is equivocal. In some instances, phosphate has been shown to improve VO2max, anaerobic threshold, and cycling TT performance [10, 11, 12]. However, for the repeated sprints, the magnitude of benefit has been inconsistent and remains unclear [13].

Finally, there is also a substantial body of contrary evidence, based on the same physiological and performance measures; suggesting phosphate supplementation, whether taken in isolation or combined with other buffering agents, has no significant impact on exercise capacity or performance outcomes [14]. Typically, phosphate supplementation is administered over a 3–6-day period, with a total daily dose of ~50 mg/kg of fat-free mass (~3–4 g) consumed either as single or split dose throughout the day. This regimen is often associated with GI distress [14]; however, tolerance appears to improve when phosphate is consumed alongside ~300 ml of a carbohydrate-rich fluid [15]. Nevertheless, the current evidence regarding the efficacy of phosphate supplementation remains inconclusive, particularly given the lack of data supporting its accumulation in the muscle tissue — where many of the proposed mechanism are believed to exert their effects.

Carnitine is a compound found predominantly (95%) in skeletal muscle, where it plays several important roles in substrate utilization. It facilitates the translocation of long-chain fatty acids into the mitochondria for beta-oxidation and acts as a sink for excess acetyl-CoA, thereby assisting the flux of carbohydrate through the citric acid cycle [16]. Increased muscle carnitine stores through L-carnitine supplementation are hypothesized to spare glycogen byenhancing fat oxidation at lower exercise intensities and to promote more efficient carbohydrate oxidation with reduced lactate accumulation at higher intensities. These effects may help delay the onset of fatigue during endurance-based activities. Early research reported a 6% increase in VO2max during graded treadmill running following L-carnitine supplementation (1g every 6 hr for 2 weeks); however, no changes were observed in steady-state VO2 or fuel utilization during submaximal exercise (65% VO2max). Additionally, other studies have shown no effects on VO2max or substrate metabolism when L-carnitine was provided as 2 g/day in split doses over a 2–4-week period. Notably, the lack of performance benefits observed in these studies may be attributed to the fact that muscle carnitine levels do not appear to increase with standard supplement protocols (i.e., up to 4 g/day for 14 days). More recently, Novakova et al. (2016) reported that 12 weeks of L-carnitine supplementation (2 g/day in split doses) resulted in an ~20% increase in plasma carnitine levels among habitual meat eaters, and a ~30% increase in vegetarians [17]. However, this did not alert muscle carnitine levels in the meat-eating group and led to only a modest 13% increase in the vegetarians group, who began the trial with ~10% lower muscle carnitine levels. Importantly, these changes did not translate into improvements in muscle function, energy metabolism, or VO_2 during either submaximal or maximal exercise testing. The limited efficacy of oral L-carnitine supplementation observed in many studies is likely due to its low bioavailability and the failure to significantly increase muscle carnitine stores. However, research by Stephens, Evans, et al. (2007) demonstrated that whole

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body carnitine retention can be increased when the supplement is co-ingested with a substantial carbohydrate source, leveraging insulin-mediated uptake (i.e., 3 g/day consumed with 94 g CHO) over an extended period (i.e., 100 days to increase muscle carnitine by ~10%) [18]. In a follow-up study [19], chronic supplementation consisting of twice-daily intake of 2 g L-carnitine combined with 80 g of carbohydrate for 24 weeks, led to a 21% increase in muscle carnitine content. This was associated with a 55% reduction in muscle glycogen utilization during submaximal cycling (30 min @ 50% VO2max), improved metabolic flux alignment during high-intensity cycling (30 min @ 80% VO2max), and an increase in work output (+11%) during a 30-min "open-intensity" performance trial. This enhanced performance was attributed to a reduced reliance on anaerobic ATP production. Despite the observed performance benefits, the ingestion protocols required to increase carnitine levels are likely impractical for daily basis, and the potential health impacts of such high-dose, long-term supplementation remain unclear. Given the limited research in this area and the considerable effort required to implement such a protocol, further investigation is warranted to clarify the efficacy and safety of prolonged supplement regimes [20].

METHODS

Research design

This study follows a systematic review model based on PRISMA standards. It aims to draw new conclusions regarding the impact of sodium Citrate, phosphates, and carnitine on sports performance and their effects on athletes' health [21]. The search criteria focus on studies published within the last 10 years.

Keywords used in the search process

- Sodium Citrate Effect on Athletic Performance
- Phosphates Effect on Athletic Performance
- Carnitine Effect on Athletic Performance

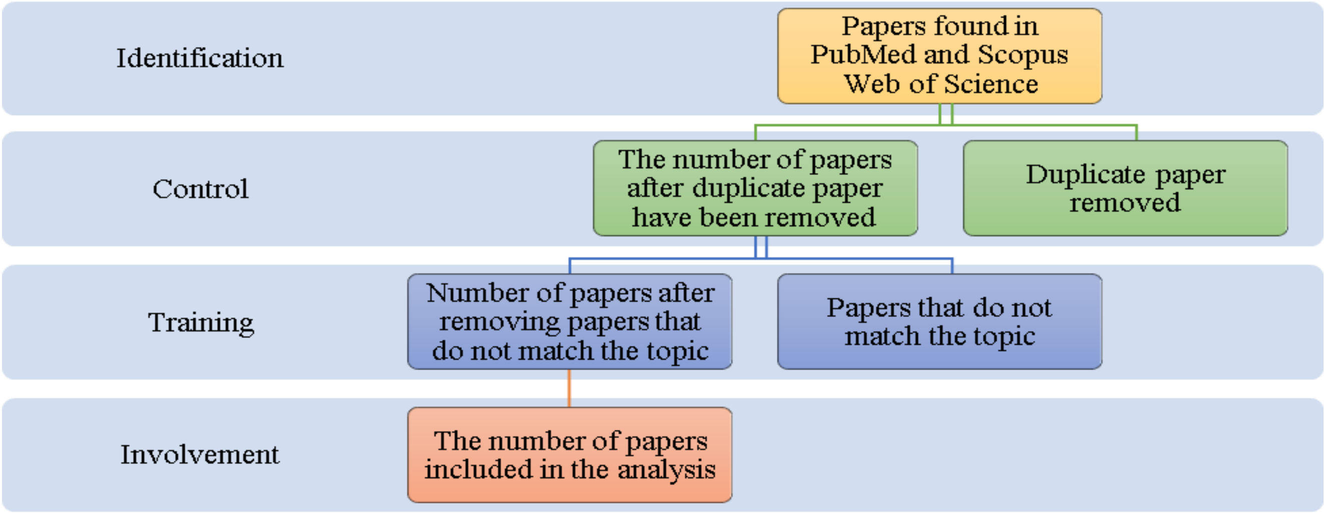

Figure 1. Flowchart of the literature review process

**No exclusion criteria based on quality were applied, as the search was limited to WOS, PubMed, and Scopus*

Table 1. Current studies found using the keyword "sodium citrate effect on athletic performance"

Reduction	PubMed	Web of Science	Scopus	Total
Papers found	3	1	5	9
Papers with conclusions relevant to the topic	3	0	3	3*

The total number of papers is three, as the same studies were identified in both PubMed and Scopus.

Based on Table 1, approximately nine scientific papers were published between 2020 and 2025, three of which have clear conclusions related to the effect of sodium citrate on athletic performance. Most of the published papers are indexed in more than one database, as shown in the table.

Table 2. Current studies found using the keyword "phosphates effect on athletic performance"

Reduction	PubMed	Web of Science	Scopus	Total
Papers found	14	3	25	43
Papers with conclusions relevant to the topic	4	0	2	4*

The total number of papers is for, as the same two studies were identified in both PubMed and Scopus.

Based on Table 2, approximately 43 scientific papers were published between 2020 and 2025, four of which have clear conclusions related to the effect of phosphate son athletic performance. Two of these papers are indexed in more than one database, while the other two are indexed in only one.

Table 3. Current studies found using the keyword "carnitine effect on athletic performance"

Reduction	PubMed	Web of Science	Scopus	Total
Papers found	15	4	14	33
Papers with conclusions relevant to the topic	2	1	1	3*

The total count is three because one paper was found in PubMed; one was found in both PubMed and WoS; and one more was found in Scopus.

Based on Table 3, approximately 33 scientific papers were published between 2020 and 2025, three of which have clear conclusions related to the effect of carnitine on athletic performance. Most of the published papers are indexed in more than one database, as shown in the table, while some are indexed in only one.

RESULTS

Table 4. Conclusions on Sodium Citrate from studies published in Web of Science, PubMed, and Scopus

Title	Conclusion of the paper	Source	Index
Effect of Pre-exercise Sodium Citrate Ingestion on Repeated Sprint Performance in Soccer Players	The study demonstrates that pre-workout of sodium citrate (0.5 $g \cdot kg^{-1}$ BM) 180 minutes before exercise effectively enhances repeated sprint performance in soccer players. The ergogenic effects of sodium citrate were associated with higher blood pH, bicarbonate, and lactate levels compared to the placebo. However, gastrointestinal discomfort was reported shortly after ingestion but resolved within 90 minutes. Therefore, sodium citrate can be a practical ergogenic aid for athletes in field-based sports requiring repeated sprints.	[22]	PubMed, Scopus
Enhancing Performance in Young Athletes: A Systematic Review of Acute Supplementation Effects	This review identified only three supplements ─ beetroot juice, sodium citrate, and carbohydrates ─ with sodium citrate showing potential to support the preservation of skill performance.	[1]	PubMed, Scopus
Use of Buffers in Specific Contexts: Highly Trained Female Athletes, Extreme Environments and Combined Buffering Agents-A Narrative Review	This review examined the effectiveness of buffering agents (sodium bicarbonate, sodium citrate, and beta-alanine) in female athletes. Findings showed that only 19% of studies reported performance benefits, with just 10% involving highly trained athletes. Research gaps included the lack of consideration for the menstrual cycle and the small number of studies replicating real-word performance demands.	[23]	PubMed, Scopus

Based on existing scientific studies on the effect of sodium citrate on athletic performance published in PubMed and Scopus, Aktitiz [22] showed that sodium citrate used as a pre-workout supplement positively impacts athletic performance, although some gastrointestinal issues occurred but resolved within 90 minutes of ingestion. Martinho [1] concluded that sodium citrate supplement appears to support the preservation of skill performance. Lastly, Burke [23] examined the effectiveness of sodium citrate in female athletes, finding that only 19% of studies reported performance benefits, with just 10% involving highly trained athletes.

Table 5. Conclusions on Phosphates from studies published in Web of Science, PubMed, and Scopus

Title	Conclusion of the paper	Source	Index
Effects of Short-Term Phosphate Loading on Aerobic Capacity under Acute Hypoxia in Cyclists: A Randomized, Placebo-Controlled, Crossover Study	SP supplementation is not an ergogenic aid for aerobic capacity in hypoxia. However, some benefits may be expected in certain individuals, particularly athletes with less training-induced central and/or peripheral adaptation.	[29]	PubMed
The Effects of Sodium Phosphate Supplementation on the Cardiorespiratory System and Gross Efficiency during Exercise under Hypoxia in Male Cyclists: A Randomized, Placebo-Controlled, Cross-Over Study	Six days of tri-sodium phosphate (SP) supplementation improved cardiorespiratory efficiency during low- and moderate-intensity exercise under hypoxia by decreasing heart rate increasing stroke volume, and enhancing oxygen pulse (VO2/HR), accompanied by a rise in serum inorganic phosphate levels. However, SP did not significantly affect gross efficiency (GE). These	[24] Maz	PubMed

	findings suggest that SP supplementation may benefit endurance performance in hypoxic conditions.		
Phosphate Loading Does Not Improve 30-km Cycling Time-Trial Performance in Trained Cyclists	Supplementing with high doses of phosphates (i.e., >10 mmol daily for 4 days) showed no ergogenic effects in trained cyclists completing 30-km time trials.	[25]	Scopus, PubMed
Ergogenic Aids to Improve Physical Performance in Female Athletes: A Systematic Review with Meta-Analysis	This systematic review and meta-analysis highlight the limited yet promising evidence regarding the effects of ergogenic aids (EAs) on sports performance in female athletes. Sodium phosphate demonstrated potential benefits for sprints and anaerobic performance.	[26]	Scopus, PubMed

Based on these existing scientific studies on the topic "phosphates' effect on athletic performance" published in PubMed and Scopus, Płoszczyca [24] suggested that SP supplementation may benefit endurance performance in hypoxic conditions. However Max Davis's [25] study concluded that supplementing with high doses daily for 4 days exerted no ergogenic effects on trained cyclists completing 30-km time trials. Lastly, Capel-Escoriza [26] reported potential benefits for sprints and anaerobic performance in female athletes.

Table 6. Conclusions on Carnitine from studies published in Web of Science, PubMed, and Scopus

Title	Conclusion of the paper	Source	Index
Effect of Acute and Chronic Oral l-Carnitine Supplementation on Exercise Performance Based on the Exercise Intensity: A Systematic Review	L-Carnitine (l-C) supplementation, at doses of 3 to 4 g taken 60 to 90 minutes before high-intensity exercise or 2 to 2.72g/day over 9 to 24 weeks, has been shown to improve performance during high intensity exercise. Benefits include reduced perceived exertion, as well as enhanced power and endurance. However, no significant improvement has been observed in moderate-intensity exercise performance, whether with acute or chronic supplementation. Therefore, l-C is more effective for enhancing high-intensity performance than moderate exercise.	[2]	PubMed
l-carnitine: Nutrition, pathology, and health benefits	Carnitine is an essential nutrient that plays a key role in energy production and fatty acid metabolism, but it has higher bioavailability in vegetarians. Deficiencies, due to genetic or heath conditions, can lead to various issues, including muscle weakness and heart problems. Supplementation is effective in treating both primary and secondary deficiencies, improving symptoms such as muscle weakness. It has shown benefits in heart disease, athletic performance, and certain conditions such as dialysis-induced carnitine depletion.	[27]	PubMed,WoS
Randomized Clinical Trial of Combined L-Carnitine Supplement and Exercise on Biochemical Markers	This review highlights the potential benefits of L-Carnitine supplementation combined with exercise in enhancing biochemical markers and improving exercise performance. When L-Carnitine is taken during aerobic or anaerobic	[28]	Scopus

and Exercise Performance: A Systematic Review	exercise at recommended dosages, it can positively enhance overall health and performance.

Based on existing scientific studies on the topic of "carnitine's effect on athletic performance" published in PubMed, Scopus, and Web of Science, [2] concluded that L-Carnitine is more effective in enhancing high-intensity performance than moderate exercise, whether through acute or chronic supplementation. Alhasaniah [27] highlighted the role and impact of carnitine supplementation on overall health and well-being. Ahmad [28] showed that when L-carnitine is taken during aerobic or anaerobic exercise at recommended doses, it can enhance both health and performance.

DISCUSSION

Research on the effect of sodium citrate on athletic performance suggests potential benefits, although side effects and limitations must be considered. Akitiz [22] found that a dose of 0.5 $g \cdot kg^{-1}$ BM taken 180 minutes before exercise improved performance in male soccer players during anaerobic tests, despite mild gastrointestinal discomfort that subsided within 90 minutes. Similarly, Martinho [1] reported that the same dosage, taken 200–240 minutes before high-intensity exercise, enhanced skill performance, particularly under fatigue, although side effects such as bloating and abdominal pain were observed. Burke [23] focused on female athletes and found only 19% of studies reported performance benefits, with just 10% involving highly trained athletes—raising questions about the appropriate dosage and timing for elite performers. The limited data, particularly concerning in female athletes and the lack of menstrual cycle control, underscores the need for more targeted research. Overall, sodium citrate may support athletic performance, but its effectiveness depends on carefully managing dosage, timing, and individual variability. This study also had limitations, including the small number of sodium citrate studies conducted on female and the absence of research controlling for menstrual cycle (MC) phases in these participants.

The effects of phosphate on athletic performance have been widely studied, yet the findings remain inconclusive. While some research suggests potential benefits under specific conditions, others report no significant ergogenic effects. Chalimoniuk [29] found that sodium phosphate (SP) increased blood phosphate levels but did not consistently enhance aerobic performance in hypoxia, with only some individuals ("responders") showing a 3–5% improvement. Similarly, Płoszczyca [24] observed cardiovascular benefits such as lower heart rate and higher stroke volume in trained cyclists using SP in hypoxia, although energy efficiency remained unchanged. However, Davis [25] found no performance benefit in a 30-km cycling trial after phosphate loading, despite phosphate's known role in metabolism. Capel-Escoriza [26] highlighted the limited research on ergogenic aids in women, reporting some performance improvements from SP and caffeine in amateur female athletes. These findings underscore the variable effects of SP, which appear to be influenced by factors such as training status, individual physiology, and gender. Overall, this study emphasizes the significant lack of research on EAs, especially in female athletes. Future studies should explore how these aids interact with the menstrual cycle, long-term training adaptations, and individual variability to better determine their effectiveness and optimal dosing in female populations.

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KOSALB International Journal of Human Movements Science, Vol: 4, No: 1, 2025, p 1-12, DOI: 10.70736/2958.8332.kosalb.51 | ISSN: 2958-8332 | Published: 20.06.2025

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Based on the comprehensive review on carnitine's effects on athletic performance, it was concluded that carnitine supplementation appears to enhance athletic performance, particularly in high-intensity exercise, and may also support cognitive and cardiovascular health. Calleja-González [2] found that chronic supplementation (2–2.72 g/day for 9–24 weeks) improved high-intensity performance (≥80% VO_2 max), reduced perceived exertion, and increased power and endurance. Acute doses of carnitine (3–4 g, taken 60–90 minutes prior to exercise) have also been shown to enhance performance in short-duration, high-intensity tests. However, no significant benefits were observed for moderate-intensity efforts (50–79% VO_2 max). Alhasaniah [27] highlighted carnitine's role in energy metabolism, its greater absorption in vegetarians, and its therapeutic potential in heart disease. Ahmad [28] emphasized L-carnitine's antioxidant, anti-inflammatory, and lipid-lowering properties. These findings suggest that carnitine may support both performance and recovery; however, its effectiveness depends on factors such as dosage, timing, exercise type, and individual variability. Further research is needed to confirm its benefits across diverse athletic populations.

CONCLUSIONS

The current body of research on ergogenic aids such as sodium citrate, phosphate, and carnitine, highlights both their potential benefits and limitations in enhancing athletic performance. While these supplements show promising effects, their effectiveness varies depending on factors such as dosage, timing, individual physiology, and training status. Sodium Citrate (0.5 $g \cdot kg^{-1}$ BM) may enhance anaerobic and high-intensity performance, particularly in sprinting and skill-based sports. However, it can cause gastrointestinal discomfort, and its effectiveness in elite and female athletes remain uncertain. Sodium phosphate supplementation has shown inconsistent results. While some athletes experience improved aerobic performance and cardiovascular efficiency, particularly under hypoxic conditions, many do not respond, suggesting its benefits may be limited to specific physiological profiles. Carnitine appears to be most effective for high-intensity efforts. Chronic supplementation (2-2.72g/day for 9-24 weeks) has been shown to improve power output, endurance, and resistance training performance. Acute doses (3-4g, taken 60-90 minutes before exercise) can boost short-term power, but offer little benefit for moderate-intensity exercise. Bioavailability varies among individuals; vegetarians often absorb carnitine more efficiently.

CONFLICT OF INTERESTS

No potential conflict of interest was reported by the authors.

REFERENCES

1. Gruska N, Sarmento H, Martinho D, Field A, Massart A. Enhancing performance in young athletes: A systematic review of acute supplementation effects. *Nutrients, 16*(24), 4304; 2024, DOI: https://doi.org/10.3390/nu16244304.
2. Mielgo-Ayuso J, Pietrantonio L, Viribay A, Calleja-González J, González-Bernal J, Fernández-Lázaro D. Effect of acute and chronic oral L-carnitine supplementation on exercise performance based on the exercise intensity: A systematic review. *Nutrients, 13*(12), 4359; 2021, DOI: https://doi.org/10.3390/nu13124359.
3. World Anti-Doping Agency. (2023). *2024 Prohibited list*. https://www.wada-ama.org/sites/default/files/2023zzzzzzzzzzzzzzzz

zzazz-09/2024list_en_final_22_september_2023.pdf.
4. Requena B, Zabala M, Padial P, Feriche B. Sodium bicarbonate and sodium citrate: Ergogenic aids? *Journal of Strength and Conditioning Research, 2005; 19*(1), 213–224, DOI: 10.1519/13733.1.
5. McNaughton LR. (1990). Sodium citrate and anaerobic performance: Implications of dosage. *European Journal of Applied Physiology and Occupational Physiology, 1990; 61*(5–6), 392–397, DOI: https://doi.org/10.1007/BF00236058.
6. McNaughton L, Cedaro R. (1992). Sodium citrate ingestion and its effects on maximal anaerobic exercise of different durations. *European Journal of Applied Physiology and Occupational Physiology, 1992; 64*(1), 36–41, DOI: 10.1007/BF00376437.
7. Urwin CS, Dwyer DB, Carr AJ. Induced alkalosis and gastrointestinal symptoms after sodium citrate ingestion: A dose-response investigation. *International Journal of Sport Nutrition and Exercise Metabolism, 2016; 26*(6), 542–548, DOI: https://doi.org/10.1123/ijsnem.2015-0336.
8. Carr AJ, Hopkins WG, Gore CJ. Effects of acute alkalosis and acidosis on performance: A meta-analysis. *Sports Medicine, 2011; 41*(10), 801–814, DOI: https://doi.org/10.2165/11591440-000000000-00000.
9. Buck CL, Wallman KE, Dawson B, Guelfi KJ. Sodium phosphate as an ergogenic aid. *Sports Medicine, 2013; 43*(6), 425–435, DOI: https://doi.org/10.1007/s40279-013-0042-0.
10. Kreider RB. Phosphorous in exercise and sport. In J. A. Driskell & I. Wolinsky (Eds.), *Macroelements, water and electrolytes in sport nutrition* (pp. 29–43). CRC Press, 1999, DOI: https://doi.org/10.1201/9780203748527.
11. Kreider RB, Miller GW, Schenck D, Cortes CW, Miriel V, Somma CT, Hill D. Effects of phosphate loading on metabolic and myocardial responses to maximal and endurance exercise. *International Journal of Sports Nutrition, 1992; 2*(1), 20–47, DOI: https://doi.org/10.1123/ijsn.2.1.20.
12. Folland JP, Stern R, Brickley G. Sodium phosphate loading improves laboratory cycling time-trial performance in trained cyclists. *Journal of Science and Medicine in Sport, 2008; 11*(5), 464–468, DOI: https://doi.org/10.1016/j.jsams.2007.04.004.
13. Kopec BJ, Dawson BT, Buck C, Wallman KE. Effects of sodium phosphate and caffeine ingestion on repeated-sprint ability in male athletes. *Journal of Science and Medicine in Sport, 2016; 19*(3), 272–276, DOI: https://doi.org/10.1016/j.jsams.2015.04.001.
14. West JS, Ayton T, Wallman KE, Guelfi KJ. The effect of 6 days of sodium phosphate supplementation on appetite, energy intake, and aerobic capacity in trained men and women. *International Journal of Sport Nutrition and Exercise Metabolism, 2012; 22*(6), 422–429, DOI: https://doi.org/10.1123/ijsnem.22.6.422.
15. Brewer CP, Dawson B, Wallman KE, Guelfi KJ. Effect of repeated sodium phosphate loading on cycling time-trial performance and VO2peak. *International Journal of Sport Nutrition and Exercise Metabolism,2013; 23*(2), 187–194, DOI: https://doi.org/10.1123/ijsnem.23.2.187.
16. Stephens FB, Constantin-Teodosiu D, Greenhaff PL. New insights concerning the role of carnitine in the regulation of fuel metabolism in skeletal muscle. *Journal of Physiology, 2007;581*(2), 431–444, DOI: https://doi.org/10.1113/jphysiol.2006.125799.
17. Novakova K, Kummer O, Bouitbir J, Stoffel SD, Hoerler-Koerner U, Bodmer M, ... Krähenbühl S. Effect of L-carnitine supplementation on the body carnitine pool, skeletal muscle energy metabolism and physical performance in male vegetarians. *European Journal of Nutrition,*

2016; 55(1), 207–217, DOI: https://doi.org/10.1007/s00394-015-0838-9.
18. Stephens FB, Evans CE, Constantin-Teodosiu D, Greenhaff PL. Carbohydrate ingestion augments L-carnitine retention in humans. *Journal of Applied Physiology, 2007; 102*(3), 1065–1070, DOI: https://doi.org/10.1152/japplphysiol.01011.2006.
19. Wall BT, Stephens FB, Constantin-Teodosiu D, Marimuthu K, Macdonald IA, Greenhaff PL. Chronic oral ingestion of L-carnitine and carbohydrate increases muscle carnitine content and alters muscle fuel metabolism during exercise in humans. *Journal of Physiology, 2011; 589*(4), 963–973, DOI: https://doi.org/10.1113/jphysiol.2010.201343.
20. Peeling P, Binnie MJ, Goods PSR, Sim M, Burke LM. Evidence-based supplements for the enhancement of athletic performance. *International Journal of Sport Nutrition and Exercise Metabolism, 2018; 28*(2), 178–187, DOI: https://doi.org/10.1123/ijsnem.2017-0343.
21. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Moher D. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *International Journal of Surgery, 2021; 88*, 105906, DOI: https://doi.org/10.1016/j.ijsu.2021.105906.
22. Kuru D, Akitiz S, Atakan MM, Köse MG, Turnagöl HH, Koşar ŞN. Effect of pre-exercise sodium citrate ingestion on repeated sprint performance in soccer players. *Journal of Strength and Conditioning Research, 2024; 38*(3), 556–562, DOI: https://doi.org/10.1519/JSC.0000000000004651.
23. Carr AJ, McKay AKA, Burke LM, Smith ES, Urwin CS, Convit L, Jardine WT, Kelly MK, Saunders B. Use of buffers in specific contexts: Highly trained female athletes, extreme environments and combined buffering agents-A narrative review. *Sports Medicine,2023; 53*(Suppl 1), 25–48, DOI: https://doi.org/10.1007/s40279-023-01872-7.
24. Płoszczyca K, Gajda R, Czuba M. The effects of sodium phosphate supplementation on the cardiorespiratory system and gross efficiency during exercise under hypoxia in male cyclists: A randomized, placebo-controlled, cross-over study. *Nutrients, 2021; 13*(10), 3556, DOI: https://doi.org/10.3390/nu13103556.
25. Pope H, Davis M, Delgado-Charro MB, Peacock OJ, Gonzalez J, Betts JA. Phosphate loading does not improve 30-km cycling time-trial performance in trained cyclists. *International Journal of Sport Nutrition and Exercise Metabolism, 2022; 33*(2), 93–101, DOI: https://doi.org/10.1123/ijsnem.2022-0111.
26. López-Torres O, Rodríguez-Longobardo C, Capel-Escoriza R, Fernández-Elías VE. Ergogenic aids to improve physical performance in female athletes: A systematic review with meta-analysis. *Nutrients, 2022; 15*(1), 81, DOI: https://doi.org/10.3390/nu15010081.
27. Alhasaniah AH. L-carnitine: Nutrition, pathology, and health benefits. *Saudi Journal of Biological Sciences, 2023; 30*(2), 103555, DOI: https://doi.org/10.1016/j.sjbs.2022.103555.
28. Samsudin N, Ahmad NS, Ooi FK, Kadir AA, Kassim NK. Randomised clinical trial of combined L-carnitine supplement and exercise on biochemical markers and exercise performance: A systematic review. *Malaysian Journal of Medicine and Health Sciences, 2023; 18*(2), 259–270, DOI: https://doi.org/10.47836/mjmhs.19.2.37.
29. Płoszczyca K, Chalimoniuk M, Przybylska I, Czuba M. (Effects of short-term phosphate loading on aerobic capacity under acute hypoxia in cyclists: A randomized, placebo-controlled, crossover study. *Nutrients, 2022; 14*(2), 236, DOI: https://doi.org/10.3390/nu14020236.

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KOSALB International Journal of Human Movements Science, Vol: 4, No: 1, 2025, p 1-12, DOI: 10.70736/2958.8332.kosalb.51 | ISSN: 2958-8332 | Published: 20.06.2025

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Systematic Review

FOR CITATION

Bojku et al. The Impact of Sodium Citrate, Phosphates, and Carnitine on Sports Performance: A Systematic Review. *KOSALB International Journal of Human Movements Science*, Vol: 4(1), 2025, p 1-12, DOI: *10.70736/2958.8332.kosalb.51*.