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ERGOGENIC EFFECT OF NITRATE AND MALTODEXTRIN SUPPLEMENTATION ON THE POWER OUTPUT IN SOCCER ADOLESCENT ATHLETES: A PILOT STUDY

EFEITO ERGOGÉNICO DA SUPLEMENTAÇÃO COM NITRATOS E MALTODEXTRINA NA POTÊNCIA DE ATLETAS ADOLESCENTES DE FUTEBOL: UM ESTUDO PILOTO

A.O.
ARTIGO ORIGINAL

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ABSTRACT

INTRODUCTION: Evidence suggests that consuming a 6.9% carbohydrate solution during exercise can reduce glycogen depletion compared to a placebo, potentially mitigating fatigue and maintaining muscle power, particularly in high-intensity intermittent activities like soccer. Additionally, nitrate supplementation in soccer players, when ingested acutely or chronically in a range of ~5–16.8 mmol (~300–1041 mg) 2–3 hours before exercise, has also been associated with enhanced exercise performance.

Hypothesis: Carbohydrate and nitrate supplementation improve power output during high-intensity activities in a soccer-specific scenario, in amateur, adolescent athletes.

METHODOLOGY: Randomized, double-blind, placebo-controlled trial. A group of 8 athletes in a male, under 14 years-old (U14), soccer team were recruited to a trial and randomly divided into 4 groups: 1) Placebo for both (Maltodextrin and Beetroot Juice); 2) Maltodextrin Solution and Placebo of Beetroot Juice; 3) Beetroot Juice and Placebo Maltodextrin; 4) Maltodextrin Solution and Beetroot Juice. After supplementation, participants underwent a protocol inducing transient fatigue, followed by the performance of a counter movement jump test.

RESULTS: The ANOVA test did not show statistically significant differences (p>0.05) in average power, maximum power, and maximum height in counter movement jump between the four nutritional intervention groups.

CONCLUSIONS: Our data suggest that nitrate and maltodextrin supplements, used individually or in combination, do not improve power output in a soccer-specific scenario. Given the exploratory nature of this pilot study, including the reduced sample size, absence of follow-up, and lack of crossover design, these findings should be interpreted with caution. Still, they may be valuable to inform future, more robust trials in this field.

KEYWORDS

Adolescents, Beetroot juice, Carbohydrates, Countermovement Jump, Soccer players

RESUMO

INTRODUÇÃO: A evidência científica sugere que o consumo de uma solução de hidratos de carbono a 6,9% durante o exercício pode reduzir a depleção de glicogénio em comparação com um placebo, levando potencialmente ao atenuar da fadiga e mantendo a potência muscular, especialmente em atividades intermitentes de alta intensidade, como o futebol. Adicionalmente, a suplementação com nitratos em jogadores de futebol, quando ingerida de forma aguda ou crónica numa dose entre ~5–16,8 mmol (~300–1041 mg) 2–3 horas antes do exercício, também tem sido associada a melhorias no desempenho físico.

Hipótese: A suplementação com hidratos de carbono e nitratos melhora a produção de potência durante atividades de alta intensidade num cenário específico de futebol, em atletas adolescentes amadores.

METODOLOGIA: Ensaio aleatorizado, duplamente cego, controlado por placebo. Um grupo de 8 atletas de uma equipa de futebol masculina sub-14 (U14) foi recrutado e dividido de forma randomizada em 4 grupos: 1) Placebo de ambos (Maltodextrina e Sumo de Beterraba); 2) Solução de Maltodextrina e Placebo de Sumo de Beterraba; 3) Sumo de Beterraba e Placebo de Maltodextrina; 4) Solução de Maltodextrina e Sumo de Beterraba. Após a suplementação, os participantes realizaram um protocolo para induzir fadiga transitória, seguido da execução do teste de salto com contra-movimento.

RESULTADOS: O teste ANOVA não revelou diferenças estatisticamente significativas (p>0,05) na potência média, potência máxima e altura máxima no salto com contra-movimento entre os quatro grupos de intervenção nutricional.

CONCLUSÕES: Os nossos dados sugerem que a suplementação com nitrato e maltodextrina, utilizados individualmente ou em combinação, não melhora a produção de potência num cenário específico de futebol. Dada a natureza exploratória deste estudo piloto, incluindo o reduzido tamanho da amostra, a ausência de seguimento e o facto de não se ter utilizado um desenho cruzado (*crossover*), estes resultados devem ser interpretados com cautela. Ainda assim, podem ser relevantes para orientar futuros estudos mais robustos nesta área.

PALAVRAS-CHAVE

Adolescentes, Sumo de beterraba, Hidratos de carbono, Salto com contra-movimento, Jogadores de futebol

INTRODUCTION

A significant decrease in muscle glycogen in both type I and II fibers occurs after exercise (1, 2). However, consuming a 6.9% carbohydrate (CHO) solution during exercise reduces glycogen depletion compared to a placebo, potentially mitigating fatigue and preserving muscle power, particularly in high-intensity intermittent sports like soccer (3). Besides its role in glycogen metabolism, elevated blood glucose levels are linked to improved neuromuscular function(4) and reduced central fatigue (5). The ergogenic effect of CHO in high-intensity, short-duration exercise may involve brain pathways related to reward and motivation activated by CHO recognition in the mouth (6). Rapidly absorbed CHO include glucose, fructose, sucrose, and maltodextrin (7). Current guidelines recommend the intake of 30-60g/h of CHO during intermittent exercise with a duration of 60 minutes or more (8).

Recent studies in soccer players show that using a nitrate supplement can be associated with enhanced exercise performance (9). Nitrates act as ergogenic aids when ingested acutely or chronically (~5–16.8 mmol; ~300–1041 mg) 2–3 hours before exercise (10). Their effects include enhanced blood flow, increased muscle oxygenation, reduced blood pressure, improved glucose uptake, and modulation of calcium metabolism and contractile function (11). Most pre-exercise nitrate intake comes from supplements, as consuming adequate amounts through diet alone is impractical (12). Furthermore, athletes with lower fitness levels may benefit more from supplementation (13). The dose-response effect likely depends on dietary nitrate intake, with greater effects seen in individuals with low baseline levels (14).

Although CHO and nitrate supplementation have been widely studied separately (9, 15, 16) research on their combined effects remains scarce, particularly regarding transient fatigue in high-intensity game scenarios (17). Soccer demands repeated sprints and prolonged running with short recoveries, heavily relying on anaerobic metabolism. The need for rapid energy replenishment via anaerobic pathways may contribute to transient fatigue (18). Considering the aforementioned metabolic benefits of nitrate supplementation, particularly the potential to enhance glucose uptake, the researchers hypothesized that the co-ingestion of nitrate and CHO supplements could result in a synergistic ergogenic effect on countermovement jump (CMJ) performance following a transient fatigue-inducing protocol. Investigating the effects of CHO and nitrate supplementation on power output during these high-intensity phases could provide valuable insights into performance optimization.

Sports supplements are generally discouraged in adolescent soccer players, though exceptions may include sports drinks and CHO gels, depending on medical or dietary guidance (19).

Despite this, supplement use is prevalent among young athletes, with reported rates between 22% and 71% (20, 21). Caution is required regarding dosages, interactions, and contamination risks, which could pose health concerns and lead to positive doping tests (20). While training and performance demands are relevant, adolescent athletes' primary focus should be on growth and maturation. However, most sports nutrition recommendations for this population are extrapolated from adult studies (22).

Metabolic differences exist between children and adults, with children displaying lower glycolytic capacity, higher fat oxidation rates, and lower lactate accumulation during intense exercise (20). Adults rely more on type II muscle fibers at submaximal intensities, leading to greater lactate production and CHO oxidation (23). Studies by Eriksson et al. (24, 25) show that muscle glycogen depletion is more pronounced in children. Research suggests that, as in adults, exogenous CHO intake benefits children during prolonged exercise of sufficient intensity (20). Riddell et al. found that intermittent glucose-fructose ingestion during 90 minutes of cycling at 55% VO_2max, followed by a 90% VO_2max exhaustion test, resulted in an average exhaustion time of 202 seconds in fed children *versus* 142 seconds with water alone (26). Timmons et al. (27) reported that glucose contributed 22% of total energy expenditure in children *versus* 15% in adults during 60 minutes of cycling at 70% VO_2max, indicating a greater reliance on exogenous CHO in children (23). Accordingly, adolescent players may benefit from CHO intake (30–60 g/h) during prolonged training or 90-minute matches to delay fatigue and enhance performance (19).

This study aimed to assess the effects of acute maltodextrin and nitrate supplementation on lower-limb average and peak power following partial execution of a soccer game simulation protocol in male adolescent athletes.

Hypothesis

CHO and nitrate supplementation improve power output during high-intensity activities in a soccer-specific scenario, in amateur, adolescent athletes.

METHODOLOGY

Participants

Following the classification proposed by Hulley et al. (28), this study was a randomized, double-blind, placebo-controlled trial. Participants were male athletes from an under-14 (U14) soccer team.

Potential participants and their legal guardians were presented with the study protocol and invited to participate. Ten athletes initially volunteered, but two were excluded due to meeting at least one exclusion criterion:

- Inability to correctly perform the fatigue-inducing test
- Gastrointestinal symptoms from nitrate consumption

Other exclusion criteria included:

- Non-compliance with the prescribed diet (verified via 24-hour dietary recall)
- Consumption of food, caloric beverages, or caffeine within 3 hours pre-trial
- Daily dietary nitrate intake ≥300 mg in the 24 hours pre-trial (estimated via 24-hour dietary recall)
- Regular mouthwash use
- Strenuous physical activity within 24 hours pre-trial
- Urolithiasis or hypertension (>140 mmHg)
- Musculoskeletal injury
- Use of sports supplements within two weeks pre-trial and throughout the study (except for the intervention)

All eligible participants and their legal guardians provided written informed consent. This trial adhered to the principles of the Helsinki Declaration and complied with all confidentiality and data protection regulations. The trial was approved by an institutional review board (CEUAlg PN.° 142 /2023).

Experimental Protocol

Before the trial phase, participants were randomly assigned to four intervention groups (two athletes per group):

- Group 1 – Placebo (PLA) Maltodextrin and PLA Nitrates
- Group 2 – Maltodextrin Solution and PLA Nitrates
- Group 3 – Beetroot Juice and PLA Maltodextrin
- Group 4 – Maltodextrin Solution and Beetroot Juice

The trial consisted of a single session in which participants completed a transient fatigue-inducing protocol followed by a CMJ test.

One week before the trial, all participants underwent a standardized

familiarization session, including training in CMJ execution, a demonstration of the standardized warm-up, and practice of the partial Yo-Yo test (fatigue-inducing protocol).
All experimental procedures were conducted on the same day, between 11:00 AM and 3:00 PM, to minimize circadian rhythm effects on performance, following López-Samanes et al. (29)

Pre-Trial Procedures

On the trial day, participants completed a 24-hour dietary recall administered by a trained interviewer to verify compliance with dietary restrictions, ensuring nitrate intake remained <300 mg. Participants had previously agreed to:

1. Avoid sports supplements for at least two weeks before the study.
2. Refrain from consuming nitrate-rich foods the day before the trial.
3. Avoid mouthwash/rinse to prevent interference with nitrate-to-nitrite conversion by oral bacteria.
4. Abstain from strenuous physical activity 24 hours before testing.
5. Spend the trial morning resting and free from obligations.
6. Arrive at the training session after fasting for three hours.

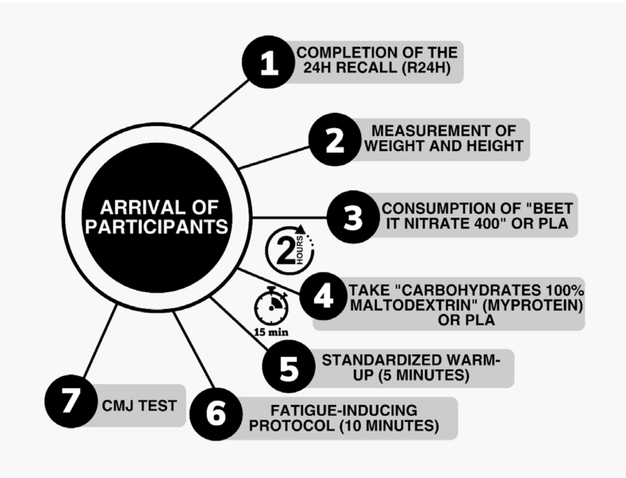
After completing the dietary recall, height was measured to the nearest 0.1 cm using a wall-mounted stadiometer, and body mass was recorded to the nearest 0.1 kg using a calibrated digital scale. Both measurements were performed with participants bare-chested, wearing light clothing and no shoes, following the International Society for the Advancement of Kinanthropometry (ISAK) protocol. Figure 1 provides an overview of the procedural timeline on the trial day.
Regarding supplementation, the placebo (PLA) for beetroot juice was a sugar-free, degassed Fanta grape (The Coca-Cola Company, Atlanta, GA), while the PLA for maltodextrin was mineral water with a steviol glycoside-based sweetener (0% sugar). A physical exercise technician, blinded to group allocation, administered the supplements and conducted the CMJ procedures. To ensure the blinding of both the technician and the participants, supplements were served in opaque cardboard cups with plastic lids, and consumed through straws to prevent visual or olfactory identification of the liquid. Although flavor differences were inherent, none of the participants had previously consumed the 'Beet It Nitrate 400' supplement, thus lacking a reference for comparison. The beverages were provided in identical containers, coded only with a participant-specific number, ensuring that both the administering technician and the participants remained blinded to the intervention groups throughout the CMJ protocols.
Participants consumed the following supplements:

- Beet It Nitrate 400 (Ipswich, Suffolk, UK): 400 mg (6.25 mmol) of nitrates from concentrated beetroot juice with 2% lemon juice.
- 100% Maltodextrin Carbohydrates (MyProtein®, Manchester, UK): a 6.9% maltodextrin solution (50 g powder diluted in 715 mL water).

Following current evidence, a 30-minute interval was maintained between maltodextrin ingestion and the CMJ test (28, 29), while nitrate supplementation occurred 2 hours and 30 minutes prior to CMJ (10). After consuming the nitrate supplement, participants remained seated, watching television, with no physical activity for 2 hours. Exactly at the 2-hour mark, they ingested the maltodextrin solution (or its respective PLA) and waited 15 minutes before initiating a standardized 5-minute warm-up, followed by the partial Yo-Yo Test (fatigue-inducing protocol) lasting 10 minutes.
Figure 2 illustrates the nutritional intervention timeline.
All participants performed a standardized 5-minute warm-up, consisting of a treadmill run at a constant speed of 9 km/h.
The fatigue-inducing protocol used to simulate high-intensity phases of soccer matches was the Yo-Yo Intermittent Recovery Test Level 1, a widely used test for assessing repeated high-intensity exercise capacity. This test consists of shuttle runs over a 20-meter course, with a 10-second walking interval every 40 meters, and a progressive speed increase of 0.5 km/h at set intervals (32). For this study, the highest-intensity segment of the test was used, requiring each participant to cover 1320 m in 10 minutes (including stop times). As the Yo-Yo test was already part of their training routine, all participants were familiarized with the protocol, ensuring efficient execution.
Figure 3 represents the test protocol:
Participants began the first shuttle run at 17 km/h, increasing to 17.5 km/h after the first interval, maintaining this speed for 8 shuttle runs. Speed then increased to 18 km/h for another 8 shuttle runs, followed by 18.5 km/h for 8 more, and finally 19 km/h for the last 8 shuttle runs. To ensure adherence to the protocol, video and audio cues were played during individual test execution (33). Participants received verbal encouragement throughout to maintain the required speed and performance.

Figure 1

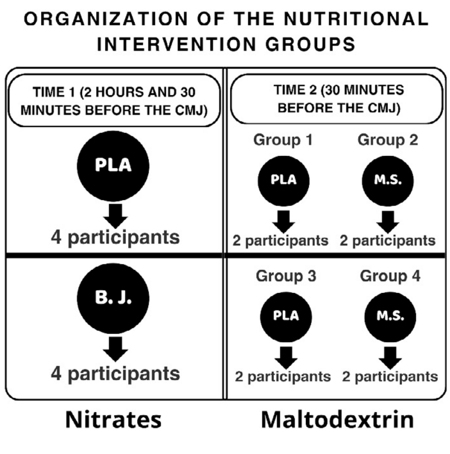
Study Design



CMJ: Countermovement Jump
PLA: Placebo
R24H: 24-hours recall

Figure 2

Organization of the Nutritional Intervention Groups



B.J.:Beetroot Juice
M.S.: Maltodextrin Solution
PLA: Placebo

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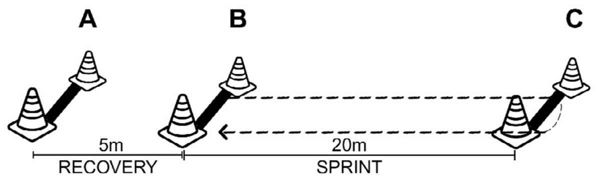
Figure 3

Yo-Yo Test Course



Measurement and data processing

Lower-limb strength was assessed using the CMJ test, which is widely recognized for its accuracy in analyzing soccer performance and detecting fatigue-induced changes (34).

Mechanical power, measured via the CMJ, is a direct indicator of lower-limb muscular power. A contact mat (Chronojump, Barcelona, Catalonia, Spain) with DIN-A4 contact platform and corresponding software was used to measure the mechanical variables of average power (W), maximum power (W), and maximum height (cm).

Participants stood upright on the mat with knees fully extended (180º) and hands fixed on the hips (suprailiac region) to eliminate upper-limb contribution (22). The jump sequence required that participants flexed their legs to an angle of ~90º (eccentric action) and then, at the sound of a whistle, explosively and coordinately extended their legs (concentric action) to reach maximum height. During the training and familiarization processes with the jump, which took place over the week before the controlled trials, participants were also alerted to keep their knees extended throughout the flight phase and informed that the contact with the ground should be made first with the toes.

Each participant performed three CMJs, spaced 1 minute apart. If a participant removed their hands from their hips or moved laterally mid-air, that jump was invalidated. The statistical analysis used the arithmetic mean of the three valid jumps (or two, if one was invalid).

Statistical Analysis

Data were analyzed with the IBM Statistical Package for Social Sciences (IBM Corp., Armonk, NY, USA, version 28.0).

Given the pilot nature of this study and the small sample size, the statistical analysis focused primarily on descriptive statistics and parameter estimation (mean, standard deviation, and sample variance) to explore data distribution and homogeneity within each intervention group.

Adherence to normal distribution was assessed using the Shapiro--Wilk test. Although formal hypothesis testing was conducted through a one-way analysis of variance (ANOVA) to identify potential trends between groups, the results were interpreted with caution due to the limited sample size. As no statistically significant differences were found, post-hoc tests were not applied.

Correlations were studied with Spearman's correlation coefficient. The level of statistical significance was established at 0.05, although emphasis was placed on the descriptive characterization of the variables.

RESULTS

The final sample consisted of eight male athletes (mean age: 13.5 ± 1 years; height: 160.7 ± 7 cm; weight: 52.8 ± 5 kg). Data from the 8 participants show a positive correlation between weight and lower-limb power, but not between weight and maximum height achieved in the CMJ test. The correlation matrix for age, participants' stature and weight, and CMJ test results is shown in Table 1.

The ANOVA test showed that there were no statistically significant differences in average power, maximum power, and maximum height in CMJ between the four nutritional intervention groups. Table 2 shows the results for each group.

Although the results for average power, maximum power, and maximum height of the CMJ do not demonstrate differences associated with the nutritional interventions, the group receiving the combined supplementation of maltodextrin and beetroot juice (MS+BJ) exhibited lower average power (W) compared to all other groups, including the placebo (PLA). The group that took only MS showed higher average jump power (738.58±57.86 W) than the BJ group (675.30±4.86 W) and the PLA group (657.18±167.70 W). Nevertheless, the group that ingested only BJ demonstrated higher average power (W) than the PLA group. The results for the other CMJ variables (maximum power, maximum height) followed the same trend.

Regarding data dispersion, the BJ group exhibited sample variance values of s^2 = 24.01 for average power and s^2 = 5140.89 for power peak. In contrast, the PLA group recorded a variability of s^2 = 28123.29 and s^2 = 513085.69 for the same variables, respectively. Furthermore, the higher average power observed in the MS group was accompanied by a relatively low variance (s^2 = 3352.41). In contrast to the power variables, maximum jump height showed greater dispersion in the BJ group (s^2= 26.01) compared to the PLA group (s^2 = 13.69).

Table 1

Correlation matrix between age, anthropometric variables the participants, and results of the counter movement jump

	SPEARMAN (ρ) CORRELATION COEFFICIENT; *P*-value		
	MEAN POWER	MAXIMUM POWER	MAXIMUM HEIGHT
Age	0.201; 0.632	0.147; 0.728	-0.166; 0.694
Weight	0.856; **0.008**	0.786; **0.021**	0.274; 0.512
Stature	0.271; 0.516	0.342; 0.407	0.496; 0.212

Statistical significance (P<0.05) is boldfaced

Table 2

Descriptive statistics and significance values from the ANOVA test for the jump variables under study, by nutritional intervention group

VARIABLE	MEAN ± STANDARD DEVIATION				ANOVA (*P*-value)
	PLA	BJ	MS	MS+BJ	
Average Power (W)	657.2±167.7	675.3±4.9	738.6±57.9	580.9±67.5	0.502
Power Peak (W)	2241.9±716.3	2422.7±71.7	2673.5±281.2	1913.1±311.0	0.422
Maximum height (cm)	30.1±3.7	36.8±5.1	38.4±4.2	28.6±5.1	0.138

BJ: Beetroot Juice
MS: Maltodextrin Solution
PLA: Placebo

DISCUSSION OF THE RESULTS

The results from this pilot study suggest that combined supplementation of maltodextrin and nitrates (in the form of beetroot juice) does not show an ergogenic effect on the jumping ability and lower limb power in amateur, adolescent soccer athletes. However, these findings should be interpreted with caution due to the study's limitations, including the small sample size, the absence of crossover between interventions, the lack of follow-up (as it was a single time-point study), and its exploratory nature.

Although group differences were not statistically significant, our analysis showed higher power (average and maximum) and higher jump height in the participants supplemented with maltodextrin alone. These results are in accordance with the literature reporting results from muscle biopsies, which suggests that maltodextrin supplementation might be linked to reduced muscle glycogen expenditure observed when individuals consume an CHO solution at a 6.9% concentration during exercise (3). Maltodextrin supplementation could potentially reduce fatigue associated with repeated efforts and insufficient recovery time, thus enhancing muscle power maintenance. Delaying muscle glycogen depletion in the subcellular glycogen compartments may prevent significant concurrent reductions in muscle calcium (35), which has been identified as one of the factors reducing maximum power capacity (36). Additionally, there is evidence supporting the potential ergogenic effect of CHO intake when in high-intensity, short duration exercises, through the activation of brain pathways associated with reward and motivation, in response to CHO recognition in the mouth (6).

The CMJ results were better, although not in a statistically significant way, in the group exclusively supplemented with BJ, when compared with PLA and with MS+BJ. Nitrate supplementation has been associated with improvements in blood flow, blood pressure reduction (vasodilation), and increased glucose uptake in muscle, which could consequently contribute to modulating calcium metabolism and contractile function, primarily at the level of type II muscle fibers (fast glycolytic contraction fibers) (11). Other studies have shown that nitrate supplementation could be linked to a reduction in oxidative phosphorylation in muscle cells, associated with a slower depletion of finite PCr reserves, and consequently, improved tolerance to high-intensity exercise (37).

Dual supplementation (MS+BJ) was associated with poorer results, which may be the results of an insulin increase, following maltodextrin intake (38). It has been suggested that insulin may stimulate anaerobic glycolysis, leading to an accelerated depletion of phosphocreatine (PCr) reserves to meet the increased demand for substrate phosphorylation (37, 39). This shift could impair the ATP-CP system's efficiency, reducing the peak power available for the CMJ. However, as this mechanism remains under discussion and was not biochemically monitored in this study, these findings should be interpreted with caution.

Despite its limitations, this is, to our knowledge, the first randomized, double-blind trial in adolescent soccer athletes comparing nitrate and maltodextrin supplementation. Given its exploratory nature, a formal a priori sample size was not calculated; however, our sample (n = 8) suggests that a definitive future study should target approximately 80 participants to ensure adequate statistical power.

To refine these preliminary findings, future research should implement a crossover design to mitigate inter-individual variability and the variable dose-response relationship of nitrates (40-42). Furthermore, incorporating blood biomarkers (e.g., plasma nitrate/nitrite, glucose, and lactate levels) and controlling for body composition will be essential to verify if observed trends, such as potential insulin-mediated interference in anaerobic glycolysis, are quantitatively significant and whether they interfere with the ATP-CP system. Additionally, while pre-test dietary monitoring strictly controlled nitrate intake, CHO intake was not similarly standardized. These methodological refinements, supported by larger samples and stricter dietary standardization, will provide more robust insights into the synergistic effects of these ergogenic aids. Ultimately, future studies should aim for expanded laboratory resources and multidisciplinary teams to build upon these pilot results.

CONCLUSIONS

The results of this pilot study show that combined supplementation of 400mg nitrates and 6.9% maltodextrin is not associated with an improvement in CMJ ability in 8 adolescent, amateur, soccer athletes. We did not find statistical significant differences in peak power, average power, and maximum height of the CMJ.

The scarcity of studies on the intake of these combined supplements and their impact on fatigue and performance suggests a need for the additional research, which takes into account measurements of additional physiological and biochemical parameters (e.g., insulin, lactate, cortisol, phosphocreatine). More comprehensive research could help clarify the role and effectiveness of combining these specific supplements in sports nutrition and their actual impact on athletic performance under various conditions.

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CONFLICTS OF INTEREST

The authors state that the supplements used in this study were generously provided by the owner of the training center where the research was conducted.

In addition, the owner participated in the collection of operational data, having conducted the countermovement jump (CMJ) procedures and administered the supplements. However, the authors assure that this support did not involve any direct funding and confirm that the procedures were always conducted under blinded conditions, in which the technician was unaware of the allocation of the intervention groups. The technician played no role in the conception or design of the study, the statistical analysis, the interpretation of the data, the drafting of the manuscript, or the final decision to publish the results.

There are no other conflicts of interest to declare.

AUTHORS' CONTRIBUTION

PS, TM: Study conception and design; PS, BP: Data collection / Fieldwork; PS, EP: Data analysis and interpretation; PS, EP: Manuscript drafting;

PS, EP, TM: Critical review of the intellectual content. All authors approved the final version of the manuscript.

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