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Rinse and Recharge: Boosting Anaerobic Power in Adolescent Wrestlers Through Carbohydrate Mouth Rinsing

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Abstract

Background: While carbohydrate ingestion enhances performance, carbohydrate mouth rinsing (CMR) may confer ergogenic benefits via non-metabolic pathways; however, findings remain mixed.

Aim: To examine the acute effects of a 6.4% glucose mouth rinse on anaerobic performance and fatigue in adolescent wrestlers.

Martials and Methods: In a randomized, single-blind crossover design, sixteen trained male wrestlers (16.75 ± 1.4 y; 64.94 ± 8.4 kg; 1.66 ± 0.07 m) completed two trials (CHO and placebo) separated by a 1-week washout. Anaerobic performance (peak, average, and minimum power) and fatigue index were assessed with the Running-based Anaerobic Sprint Test (RAST). During the 10-s recovery of sprints 1, 3, and 5, participants completed 5 s active rest followed by 5 s mouth rinse (25 mL of 6.4% glucose or water).

Results: CHO mouth rinse produced significant improvements in average power ($p = 0.001$, $d = -2.38$), peak power ($p = 0.03$, $d = -0.92$), and minimum power ($p = 0.002$, $d = -1.74$), while no significant change was observed in fatigue index ($p = 0.39$, $d = 0.32$).

Conclusion: CMR boosts anaerobic power but not fatigue resistance, supporting its potential as a practical ergogenic aid for high-intensity, intermittent sports.

Keywords: CMR, Anaerobic, Wrestling, Adolescents, Ergogenic.

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1. Introduction

Optimizing athletic performance has long been a central focus of sports nutrition research [18], particularly strategies that target both physical and neurological factors influencing fatigue. Fatigue can be broadly classified into two types [34]: peripheral fatigue, arising from muscular mechanisms, and central fatigue, involving the central nervous system (CNS). While traditional approaches have emphasized metabolic replenishment, emerging evidence highlights the brain's critical role in modulating exercise performance [56]—especially under conditions of high intensity and prolonged exertion [10, 22, 30, 45].

In combat sports such as wrestling, fatigue is a defining factor in performance [37], particularly in the final stages of a match when energy reserves are depleted. Wrestlers rely heavily on anaerobic capacity [15], and once glycogen stores are compromised, technical execution and decision-making suffer. Although short recovery windows during competition—like halftime or injury timeouts—offer brief respite, they are rarely sufficient for meaningful metabolic recovery. Given that total carbohydrate stores in the human body are limited [5], conserving and strategically utilizing energy becomes essential. Although Ainsworth et al. [1] classified wrestling at 6 METs, actual energy expenditure during intense sessions is likely higher, especially considering the repeated anaerobic bursts and limited recovery. This further underscores the rapid onset of fatigue in this sport.

Interestingly, in high-intensity efforts lasting less than 60 minutes, the performance-enhancing effects of carbohydrate ingestion are often not attributable to metabolic mechanisms alone [24], as blood glucose and muscle glycogen are generally not limiting under such conditions [28]. Instead, emerging evidence suggests that, beyond metabolic replenishment, carbohydrate sensing in the oral cavity can activate brain regions involved in motivation, motor control, and reward processing (e.g., insula and orbitofrontal cortex) [54]. CMR, typically involving a 5–20 second rinse without ingestion, has gained attention as a novel ergogenic aid capable of stimulating sensorimotor areas of the brain [9, 19, 36]. Pioneering research by Carter et al. [12] demonstrated improved endurance performance following carbohydrate rinsing, attributed to central nervous system stimulation rather than energy provision.

Subsequent studies have extended these findings to a range of high-intensity activities. Rinsing with a 6% carbohydrate solution has been shown to enhance outcomes such as counter-movement jump height [16], repeated sprint ability [41], and perceived exertion levels [13]. Notably, improvements are often observed in the final bouts of repeated sprint tests, where fatigue is most pronounced—suggesting a potential role in sustaining performance during the most demanding phases of activity [46].

In addition to its neurological benefits, CMR presents a practical advantage: it avoids gastrointestinal discomfort often associated with carbohydrate ingestion during high-intensity or high-velocity exercise [53], where digestion is impaired [33]. As a result, it offers a non-invasive, rapid, and efficient strategy for performance enhancement, particularly in sports with limited opportunities for mid-session fueling.

Although a growing body of research supports the ergogenic effects of carbohydrate mouth rinsing, findings remain inconsistent across athletic populations. While some trials demonstrate significant benefits [10, 40, 49, 54], others fail to detect meaningful changes [2, 20, 23, 42]. Differences in exercise mode, rinse composition or concentration, and particularly the duration of rinsing may partly explain these conflicting outcomes [25]. Given these methodological nuances, sport- and context-specific studies, like the current trial in adolescent wrestlers, are crucial to better determine when and how CMR is most effective.

To date, the majority of CMR research has focused on endurance athletes, with most studies designed to assess cycling and running performance in exercise protocols lasting longer than 30 minutes [9, 35, 39], with relatively few studies examining anaerobic or intermittent sports such as wrestling. Moreover, research involving adolescent populations is limited [7], despite known age-related differences in metabolism [4], neuromuscular development [3], and central fatigue mechanisms [50]. This study aims to address this gap by evaluating the effects of CMR in adolescent wrestlers—a group currently underrepresented in the literature.

It was hypothesized that carbohydrate mouth rinsing would enhance anaerobic performance variables (power outputs and fatigue index) in adolescent wrestlers compared to placebo.

2. Methods and Materials

2.1. Participation

Sixteen young male wrestlers (mean age: 16.75 ± 1.4 years) from Ilam, Iran voluntarily participated in this study. Participant characteristics, including anthropometric data, are presented in Table 1. Due to the limited availability of trained adolescent wrestlers within the study region, participants were recruited using convenience sampling. All participants were required to meet the following inclusion criteria: (1) male sex; (2) a minimum of six months of continuous wrestling experience, including at least three training sessions per week and active participation in regional or school-level competitions within the past six months; and (3) no history of musculoskeletal injury or cardiovascular/metabolic disorders. Exclusion criteria included inability to complete the testing protocol due to injury or unforeseen circumstances and voluntary withdrawal from the study.

An initial orientation session was conducted to familiarize participants with the study objectives, procedures, and timeline. During this session, demographic and health information was collected via a researcher-designed questionnaire, and participants' training schedules were reviewed and documented. All participants provided written informed consent in accordance with the Declaration of Helsinki. Ethical approval for this study was obtained from the National Ethics Committee for Biomedical Research (Approval ID: IR.ILAM.REC.1403.016).

Table 1. Anthropometric characteristics of participants across study groups

Variables	Groups	
	CHO	Control
Number	8	8
Age (years)	16.5±1.6	16.75±1.48
Height (m)	1.63±0.08	1.70±0.03
Weight (Kg)	60.75±9.93	69.13±3.98
BMI (kg/m^2)	22.72±1.6	23.91±1.11

2.2. Procedure

This study employed a randomized, single-blind, crossover pretest-posttest design. Participants were randomly assigned to one of two groups (n = 8 per group): the experimental group (CHO) used a carbohydrate mouth rinse, while the control group used a placebo rinse (plain water). Randomization was conducted using a simple lottery method to ensure unbiased group allocation. The primary outcomes measured were anaerobic performance variables derived from the RAST, conducted before and after the intervention.

Participants were instructed to avoid intense physical activity for at least 24 hours and abstain from caffeine consumption for at least six hours before each testing session [48]. Both the pre-test and post-test sessions were conducted in the late afternoon to coincide with the athletes' regular training times, thus minimizing the confounding influence of circadian rhythms.

2.3. Instrument

RAST Protocol: The RAST test was used to assess anaerobic power and fatigue index. The test has demonstrated good criterion validity for peak power ($r = 0.70$, $p < 0.001$) and average power ($r = 0.60$, $p = 0.002$) when compared to the laboratory-standard Wingate test in young athletes [55]. Moreover, the RAST exhibits strong reliability, with intraclass correlation coefficients for average power (ICC = 0.88) and peak power (ICC = 0.72) in adolescent populations [11]. Therefore, it is considered a valid and reliable field-based method for estimating anaerobic performance in youth sports contexts.

The test involves six maximal 35-meter sprints, each separated by a 10-second active recovery period. Two researchers administered the test: one gave the starting signal and recorded times using a digital stopwatch, while the other monitored recovery intervals.

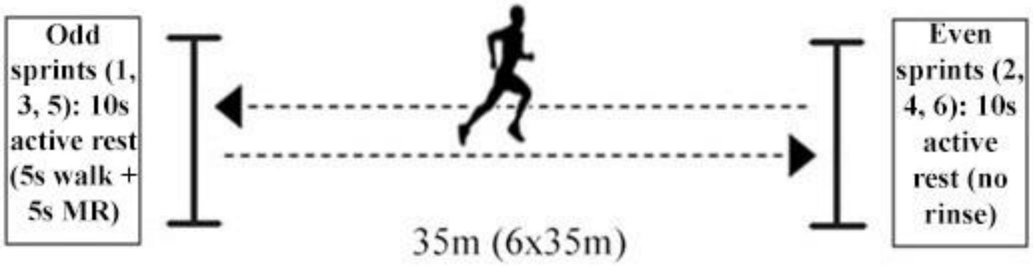

Figure 1. Infographic illustrating the RAST protocol.

Sprint times and body mass (measured using a calibrated Sahand ET model digital scale, accurate to 0.05 kg) were used to calculate the following variables [55]:

Peak Power Output (PPO):

$$PPO = \frac{Body\ Mass\ \times Distance^2}{Time^3}$$

Maximum Power: The highest PPO value recorded across the six sprints.

Minimum Power: The lowest PPO value, typically corresponding to the sprint performed under greatest fatigue.

Average Power: The mean of all six power outputs.

Fatigue Index (FI) was calculated using the relative method:

$$FI = [\frac{(PPO_{max}\ -\ PPO_{\min})}{PPO_{max}}] \times 100$$

This formula expresses the percentage drop from peak to minimum power, and has been widely used in anaerobic performance studies [31, 38].

Mouth Rinse Protocol: During both test sessions, participants performed the RAST test with an additional protocol during the 10-second active recovery phase of sprints 1, 3, and 5. For the first five seconds, participants walked slowly (active rest), and for the final five seconds, they rinsed their mouth with 25 mL of assigned solution (either carbohydrate or placebo), swirled it, and expectorated into a pre-weighed container [24]. The containers were re-weighed after testing to ensure no solution had been swallowed [8, 13]. Both the CHO solution and the placebo (plain distilled water) were colorless and similar in appearance. Informal taste testing confirmed that the 6.4% glucose solution had a very mild or negligible sweetness, making it difficult to distinguish from water. Therefore, no artificial sweeteners or coloring agents were added. This similarity helped preserve blinding for participants and administrators during the trial.

The carbohydrate solution was prepared using food-grade glucose powder (Balmy Life brand) dissolved in distilled water to create a 6.4% solution (64 g per 1000 mL) [13]. Volume and weight measurements were conducted using precision laboratory equipment: a graduated cylinder (±0.001 L) and an electronic scale (±0.01 g).

Both testing sessions were standardized in terms of environment, time of day, warm-up routines, and investigator instructions. A one-week washout period separated the pre- and post-test sessions [9]. Participants were instructed to maintain their typical diet and training routines throughout the study period to minimize variability in muscle glycogen availability [21]. Although detailed food diaries were not collected, verbal compliance checks were performed regularly with both athletes and their coaches. Additionally, all testing sessions were conducted at the same time of day to reduce the impact of acute dietary variation.

2.4. Statistic

All statistical analyses were performed using IBM SPSS Statistics (Version 27.0, IBM Corp., Armonk, NY). Descriptive statistics were computed and reported as mean ± standard deviation (SD). The normality of data distribution for each variable was assessed using the Shapiro–Wilk test. Data were analyzed using paired-samples t-tests to assess pre- to post-test changes within each condition. Effect sizes (Cohen's d) were also calculated to estimate the magnitude of change. The level of statistical significance was set at $p \leq 0.05$.

3. Results

The Shapiro–Wilk test confirmed that all performance variables in both the CHO and control groups followed a normal distribution ($p \geq 0.05$), satisfying the assumptions for parametric testing. An independent samples t-test indicated a marginally non-significant difference in baseline body mass between the CHO (60.75 ± 9.93 kg) and Control (69.13 ± 3.98 kg) groups, df = 14, t = -2.21, p = 0.054, indicating a marginal baseline difference in body mass, which does not appear to significantly confound the interpretation of the main findings.

In the CHO condition, paired samples t-tests revealed significant improvements from pre- to post-test in maximum power (Pre: 298.54 ± 44.07 W; Post: 332.34 ± 77.29 W; p = 0.03, d = -0.92), minimum power (Pre: 195.73 ± 56.37 W; Post: 226.66 ± 49.82 W; p = 0.002, d = -1.74), and average power (Pre: 244.47 ± 50.22 W; Post: 277.49 ± 57.36 W; p = 0.001, d = -2.38). These results suggest that CHO mouth rinsing had a notable effect on enhancing short-term anaerobic performance metrics. However, no significant change was observed in fatigue index (Pre: 34.41 ± 15.16; Post: 30.60 ± 11.43; p = 0.39, d = 0.32), indicating that despite improvements in power output, resistance to fatigue remained largely unchanged.

In contrast, the control group showed no significant pre- to post-test differences in maximum power (Pre: 345.47 ± 65.77 W; Post: 384.3 ± 114.8 W; p = 0.14, d = -0.58), minimum power (Pre: 235.14 ± 44.68 W; Post: 238.16 ± 39.42 W; p = 0.86, d = -0.6), average power (Pre: 284.71 ± 43.35 W; Post: 306.68 ± 56.57 W; p = 0.17, d = -0.54), or fatigue index (Pre: 30.42 ± 14.76; Post: 35.58 ± 12.29; p = 0.07, d = -0.72).

A summary of pre- and post-test performance outcomes for both groups is presented in Table 2. These findings suggest that while CHO mouth rinsing effectively enhances anaerobic power output, its impact on fatigue resistance may be limited.

Table 2. Pre- and post-test comparison of maximum, minimum, and mean anaerobic power and fatigue index in each group

Descriptive statistics Variables		Mean±SD (Pre-Test)	Mean±SD (Post-Test)	Cohen's d	t	p
CHO	Average anaerobic power (W)	244.47±50.22	277.49±57.36	-2.38	-6.75	0.001*
	Maximum anaerobic power (W)	298.54±44.07	332.34±77.29	-0.92	-2.62	0.03*
	Minimum anaerobic power (W)	195.73±56.37	226.66±49.82	-1.74	-4.93	0.002*
	Fatigue Index (%)	34.41±15.16	30.60±11.43	0.32	0.91	0.39
Control	Average anaerobic power (W)	284.71±43.35	306.68±56.57	-0.54	-1.53	0.17
	Maximum anaerobic power (W)	345.47±65.77	384.3±114.8	-0.58	-1.65	0.14
	Minimum anaerobic power (W)	235.14±44.68	238.16±39.42	-0.6	-0.17	0.86
	Fatigue Index (%)	30.42±14.76	35.58±12.29	-0.72	-2.05	0.07

*Significant at the 0.05 level

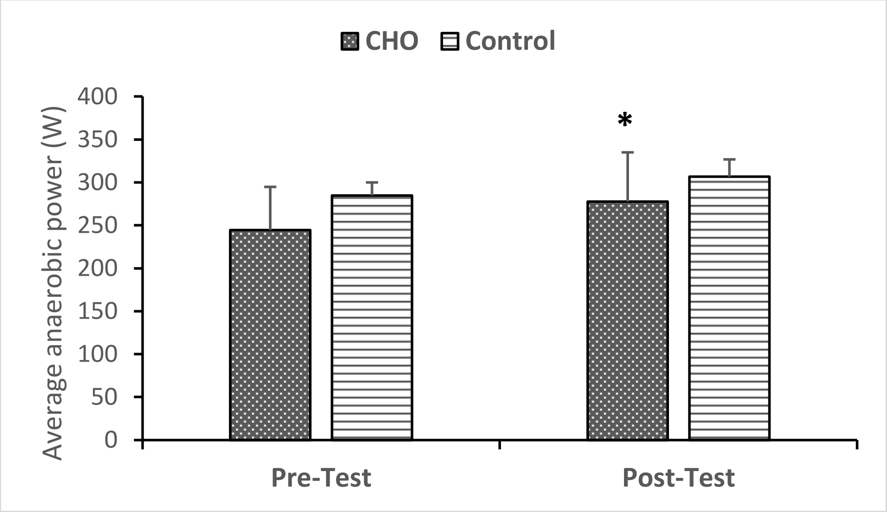

Figure 2. Average anaerobic power values in two groups in pre and post test

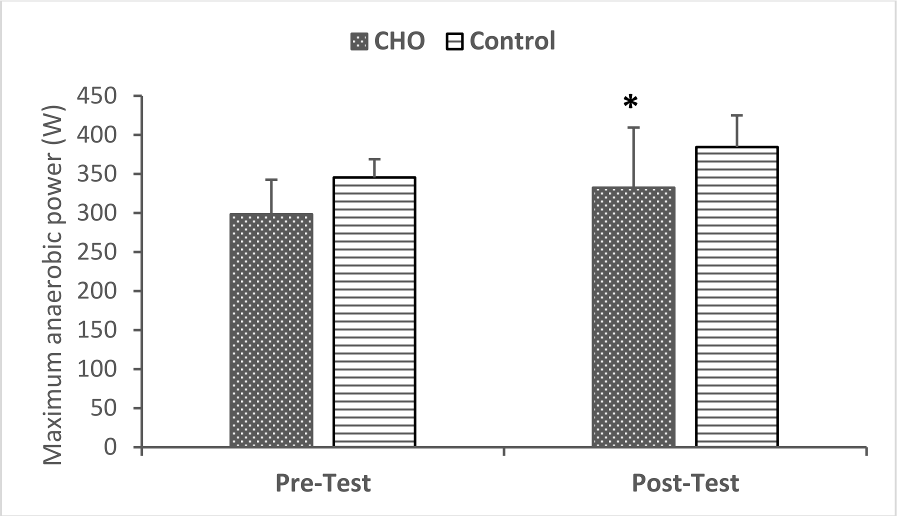

Figure 3. Maximum anaerobic power values in two groups in pre and post test

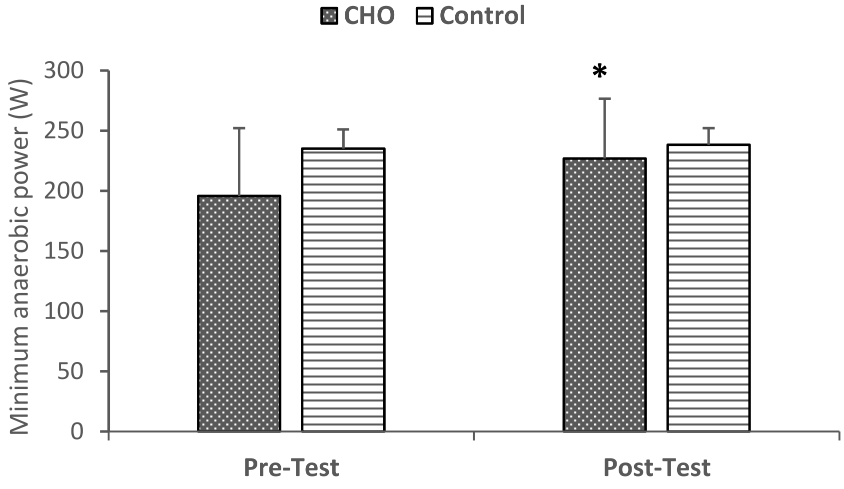

Figure 4. Minimum anaerobic power values in two groups in pre and post test

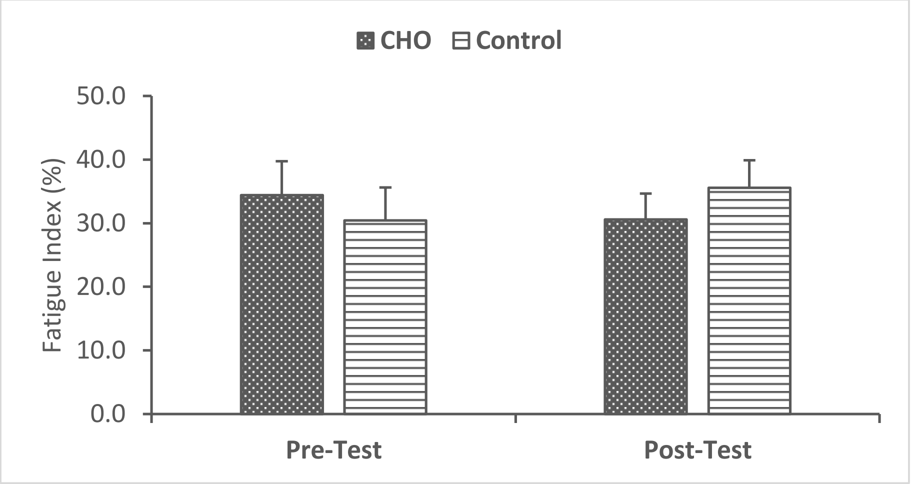

Figure 5. Fatigue Index values in two groups in pre and post test

4. Discussion

This study explored the acute effects of CMR on anaerobic performance and fatigue index in young wrestlers, using RAST to replicate field-based athletic demands. The results demonstrated that rinsing the mouth with a 6.4% glucose solution significantly enhanced performance, as evidenced by improvements in anaerobic power metrics. These findings contribute to the growing body of literature supporting the ergogenic benefits of carbohydrate mouth rinsing, particularly in high-intensity, intermittent sports like wrestling.

A key strength of this study is its field-based design, which enhances ecological validity [17] by better simulating the practical demands of high-intensity, intermittent sports. The RAST protocol mirrors the intermittent, high-intensity nature of combat sports, making it a practical tool for applied performance assessment [55]. Nonetheless, field settings may limit experimental control compared to laboratory conditions, introducing potential sources of variability [17].

Consistent with prior studies, our findings suggest that CMR positively influences anaerobic output. For example, research by Krings et al. [32] demonstrated improved peak power during sprint cycling following a carbohydrate rinse, while Rowlatt et al. [44] observed enhanced accuracy in fencing performance under fatigue. Hsu et al. [26] also reported better performance outcomes in softball players following CMR. Collectively, these studies—and the current one—highlight CMR's potential to benefit short-duration, high-intensity efforts across a range of athletic contexts.

The ergogenic effect of CMR appears to be mediated primarily by central, rather than metabolic, mechanisms [54]. Carbohydrate detection in the oral cavity activates chemoreceptors that communicate with brain regions such as the insular cortex, orbitofrontal cortex, and striatum—areas associated with reward, motivation, and motor control [40]. Functional neuroimaging studies, including those by Chambers et al. [13], have confirmed increased activation in these regions following a carbohydrate rinse, despite no actual ingestion or change in blood glucose. This suggests that the mere presence of carbohydrate in the mouth can enhance motor output [9] via increased central drive and improved psychological states such as motivation and perceived exertion [13].

Further, CMR may be especially beneficial in states of partial energy depletion or fasting. Evidence suggests that taste receptor sensitivity may be heightened when glycogen stores are low, amplifying the brain's response to carbohydrate signals [6]. In the present study, participants refrained from eating for at least two hours before testing, which may have potentiated the performance-enhancing effects of CMR. Supporting this, Ataide-Silva et al. [6] found that carbohydrate mouth rinsing under conditions of limited endogenous carbohydrate availability led to increased neuromuscular activity and power output, as measured via Electromyography (EMG).

Our results also offer practical guidance for implementation. A rinse duration of 5 seconds, repeated three times before the RAST test, was both effective and feasible within the constraints of high-intensity effort. Longer rinsing durations may disrupt breathing patterns during intense exercise [47], making shorter protocols more applicable in real-time sports scenarios. This aligns with other studies [12, 14, 27, 43]. that have standardized 5-second rinses as the most practical compromise between efficacy and athlete comfort.

In the present study no statistically, significant change was observed in the fatigue index, suggesting that while participants were able to generate more power, their resistance to fatigue remained largely unchanged. This finding is consistent with previous studies. For example, Gough et al. [23] reported that neither CHO nor caffeine mouth rinse—administered alone or in combination—had a significant impact on fatigue index during repeated sprint performance. The lack of improvement in our study may be explained by the physiological demands of the RAST protocol, which places considerable stress on both anaerobic and neuromuscular systems. Tomko et al. [52] illustrated this demand through high post-exercise blood lactate levels in a similar protocol. Likewise, Tomazin et al. [51] found that repeated sprints in both running and cycling produced comparable peripheral fatigue, but central fatigue was primarily observed following running. Given the RAST protocol's reliance on anaerobic pathways [29] and its capacity to induce significant peripheral and central fatigue, it is plausible that the central effects of CHO mouth rinse were insufficient to overcome the dominant peripheral fatigue, thereby making any measurable improvements in fatigue resistance.

An important strength of this study is its focus on adolescent wrestlers, a population undergoing dynamic neuromuscular development. Hormonal and maturational factors, such as testosterone levels and biological maturity, have been shown to influence muscle strength and neuromuscular performance in young athletes [3]. In addition, high-intensity exercise in trained adolescents has been reported to induce notable mechanical changes—including increased ground contact time, reduced leg stiffness, and diminished plantar flexor fatigue resistance—which may affect fatigue responses [50]. These developmental characteristics could help explain why the fatigue index remained unchanged in the present study, even though anaerobic power improved, suggesting that maturational factors may mask short-term adaptations in fatigue resistance. These findings highlight the need for further research examining how developmental stage influences the ergogenic effects of CMR.

While some methodological constraints should be considered, they do not diminish the relevance of the findings. The use of convenience sampling and the absence of detailed dietary tracking may have introduced minor variability. Future studies could strengthen dietary control by standardizing pre-test meals to reduce residual variability. Although baseline body mass tended to differ between groups, this difference did not reach statistical significance (p = 0.054). Since body mass may influence anaerobic performance, future studies should better control for this factor during participant selection. Moreover, as this study included only male adolescent wrestlers and focused on acute effects, the generalizability of the findings to female athletes or chronic adaptations remains limited. While the field-based design enhanced ecological validity, it also reduced experimental control compared to laboratory settings.

5. Conclusion

In conclusion, this study demonstrated that carbohydrate mouth rinsing can significantly enhance anaerobic power in young wrestlers, highlighting its potential as a practical ergogenic aid in high-intensity, intermittent sports. However, no improvements were observed in fatigue index, suggesting that while CMR may boost peak and average power, it does not appear to enhance resistance to fatigue. These findings likely reflect central nervous system activation rather than metabolic effects, emphasizing the role of oral sensory input in modulating acute performance. Given its simplicity and non-invasive nature, CMR may represent a valuable short-term strategy for athletes seeking immediate gains during competition or training.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design.

Ethical considerations

The author has completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc [Ethical code]

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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