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Carbohydrate Mouth Rinsing in Recreational Athletes: A Narrative Review of Performance Effects, Mechanisms, and Gastrointestinal Implications

Authors:

Tamara Korohod [TK]
Email: t.korogod@gmail.com
Orcid: https://orcid.org/0009-0004-4924-3844
Affiliation: NZOZ "Orto-med", Wspólna 1, 09-200 Sierpc, PL

Martyna Pietrzak-Chmiel [MP]
Email: pietrzakmartyna0812@gmail.com
Orcid: https://orcid.org/0009-0000-3741-6550
Affiliation: Bielanski Hospital in Warsaw, Cegłowska 80, 01-809 Warsaw, PL

Paulina Ramaneckaite [PR]
Email: paulina.ramaneckaite2@gmail.com
Orcid: https://orcid.org/0009-0003-1902-2613
Affiliation: Medical University of Gdańsk, 80-210 Gdańsk, PL

Agnieszka Binkiewicz [AB]
Email: agnwojn9@gmail.com
Orcid: https://orcid.org/0009-0006-7876-3755
Affiliation: Medical University of Gdańsk, 80-210 Gdańsk, PL

Maciej Ślesik [MS]
Email: m.slesik00@gmail.com
Orcid: https://orcid.org/0009-0008-5021-8741
Affiliation: Bielanski Hospital in Warsaw, Cegłowska 80, 01-809 Warsaw, PL

Ilona Tadulewicz [IT]
Email: Ilona.tadulewicz@gmail.com
Orcid: https://orcid.org/0009-0000-7742-5320
Affiliation: University Clinical Centre in Gdańsk, 80-952 Gdańsk, PL

Sylwia Łatkowska [SL]
Email: latkowskasm@gmail.com
Orcid: https://orcid.org/0009-0004-1251-6554
Affiliation: Zdrowie Plus Non-Public Health Care Center (NZOZ), 58 Wojciechowskiego Street, Warsaw, PL

Aleksandra Pawlik [APA]
Email: pawlikalexandra0@gmail.com
Orcid: https://orcid.org/0009-0002-0230-2750
Affiliation: Ropczyce Healthcare Center, Department of Internal Medicine, Sedziszów Małopolski Ul. Księdza Kardynała Stefana Wyszyńskiego 54, 39-100 Ropczyce, PL

Aleksandra Pudzianowska [AP]
Email: aleksandra.pudzianowska2607@gmail.com
Orcid: https://orcid.org/0009-0009-6959-578X
Affiliation: Polish Mothers Health Center Institute, Ophthalmology Cliniq Ul. Rzogowska 281/289 93-338 Łódź, PL

Abstract

Background: Carbohydrate mouth rinsing (CMR) offers potential for athletes seeking performance benefits while minimizing gastrointestinal issues. Unlike the usual method of carbohydrate consumption, CMR allows athletes to swish carbohydrate solutions in their mouths without swallowing, which may trigger central mechanisms that enhance performance while avoiding GI problems.
Aim: To review the current evidence regarding carbohydrate mouth rinsing effects on athletic performance and GI safety in recreational athletes.
Material and Methods: A narrative review of peer-reviewed literature from examining CMR effects on exercise performance, cognitive function, and gastrointestinal outcomes. Data synthesis focused on the mechanism of action, performance outcomes, and practical applications for recreational athletes.
Results: Meta-analytical evidence demonstrates modest ergogenic effects of CMR across exercise modalities. Optimal protocols utilize 6-6.5% maltodextrin solutions rinsed for ≤10 seconds. CMR effectiveness is enhanced under fed conditions during aerobic exercise. CMR reduces exercise-induced gastrointestinal symptoms while enhancing high-intensity muscular endurance. Preliminary evidence suggests cognitive performance benefits when combined with caffeine, though certainty remains low.

Conclusions: Carbohydrate mouth rinsing is a simple yet effective ergogenic aid for recreational athletes, and it can be easily integrated into their routines. Using CMR before and during moderate-to-high-intensity workouts can enhance exercise capacity and performance while avoiding the gastrointestinal issues that often accompany carbohydrate intake. Since CMR offers a performance boost without the discomfort of GI distress, it stands out as a practical nutritional strategy for athletes. Moving forward, research should examine how men and women respond to CMR, how regular use may lead to chronic adaptations, and how best to tailor CMR strategies for different athletic groups.

Keywords: carbohydrate mouth rinsing, ergogenic aid, exercise performance, gastrointestinal comfort, recreational athletes, central mechanisms, sports nutrition

1. Introduction

Optimal nutritional strategies are the cornerstone of athletic performance, particularly in endurance and high-intensity exercise. Carbohydrate supplementation has been established as an evidence-based ergogenic aid, with early research demonstrating that glucose polymer solutions significantly improve exercise capacity and delay fatigue onset [8]. Currently, the American College of Sports Medicine recommends carbohydrate intake of 5-7 grams per kilogram of body weight daily for individuals engaging in moderate exercise programs, with higher intakes (6-10 g/kg/day) recommended for moderate- to high-intensity activities lasting 1-3 hours [1][7][24] However, a persistent challenge limiting carbohydrate utilization during exercise is exercise-induced gastrointestinal syndrome (EIGS) and exercise-associated gastrointestinal symptoms (Ex-GIS) [2]. The mechanisms underlying these symptoms are multifactorial, involving redistribution of blood flow away from the gastrointestinal tract toward working muscles, alterations in gastrointestinal nervous control, increased intestinal epithelial damage and permeability, and potential bacterial translocation. Incidence of GI problems in endurance athletes ranges from 4 to 96%, with symptoms including bloating, cramping, nausea, vomiting, diarrhea, and abdominal pain [2][12]. These symptoms can substantially impair athletic performance and, in severe cases, necessitate event withdrawal. In response to these challenges, researchers have explored alternative carbohydrate delivery methods that circumvent the gastrointestinal system’s metabolic processing while potentially activating central nervous system pathways. Carbohydrate mouth rinsing represents such an innovation, introduced in 2004 by Carter and colleagues [12]. This technique involves brief oral exposure to carbohydrate solutions (typically 5-10 seconds) followed by expectoration, thus providing oral sensory stimulation without systemic nutrient absorption [8]

The mechanistic premise underlying CMR efficacy rests upon the discovery of gustatory receptors capable of detecting sweet taste and carbohydrates in the oral cavity. These receptors activate afferent neural pathways projecting to brain regions including the orbitofrontal cortex, dorsolateral prefrontal cortex, and ventral striatum—regions implicated in reward, motivation, attention, and motor control [1][2][16][17]. This central mechanism allows performance enhancement independent of metabolic carbohydrate delivery, thereby theoretically minimizing GI distress [2].

The role of CMR for recreational athletes is really important. Unlike elite athletes who might push through significant gastrointestinal discomfort for just a slight edge in performance, recreational athletes are more about enjoying their training and competition. Finding ways to enhance performance while also easing GI discomfort can greatly improve their quality of life and help them stay committed to their training routines.

2. Carbohydrate Physiology and Metabolic Limitations

To contextualize the significance of CMR, understanding traditional carbohydrate metabolism during exercise proves essential. During moderate- to high-intensity aerobic exercise (60-75% VO_2max), carbohydrates represent the predominant fuel source, derived from both endogenous stores (liver and muscle glycogen) and exogenous intake [8]. Muscle glycogen depletion constitutes a primary limiting factor during prolonged exercise exceeding 90 minutes, as glycogen stores are typically sufficient for approximately 90 minutes of sustained high-intensity activity [7]. Nevertheless, during brief, high-intensity exercise sessions lasting 30-75 minutes, endogenous carbohydrate reserves remain sufficient to sustain activity [1][3]. Under such conditions, the performance-enhancing effects of carbohydrate consumption cannot be exclusively attributed to energy supply. This finding prompted further investigation into non-metabolic, centrally mediated mechanisms through which carbohydrate availability may influence motor output and exercise performance. Additionally, exogenous carbohydrate oxidation rates are limited by intestinal absorption capacity [18]. Despite optimal ingestion protocols, maximum exogenous carbohydrate oxidation rarely exceeds 60 g/h, constrained by the finite density of glucose transporters (SGLT1 and GLUT5) in the small intestine [9]. Furthermore, elevated carbohydrate intake during intense exercise frequently precipitates GI symptoms, potentially through mechanisms involving increased osmotic pressure, reduced gastric emptying, intestinal epithelial damage, and bacterial translocation [6][10][11]

3. Mechanisms of Carbohydrate Mouth Rinsing

3.1 Central Nervous System Activation

Current evidence supports a predominantly central mechanism underlying CMR ergogenicity [1][14]. When carbohydrate solutions contact gustatory receptors in the oral cavity, orosensory signals are transduced and conveyed via the chorda tympani and glossopharyngeal nerves to taste processing centers in the nucleus tractus solitarius. From here, neural projections extend to higher brain regions, including the orbitofrontal cortex, ventromedial prefrontal cortex, and ventral striatum [1][16]. Neuroimaging studies using functional magnetic resonance imaging have demonstrated selective activation of these brain regions in response to oral carbohydrate exposure, but not to non-nutritive sweeteners such as saccharin or aspartame [1][16]. This selectivity suggests that carbohydrate detection involves specialized taste transduction pathways distinct from those involved in generic sweet taste perception. The activated brain regions—particularly the orbitofrontal cortex and dorsolateral prefrontal cortex—are implicated in reward processing, motivational drive, attention allocation, and cognitive control of motor output [1][16][17]. One proposed mechanism involves the "Central Governor" model, which posits that the central nervous system continuously monitors peripheral physiological signals and adjusts motor output to maintain homeostasis and prevent catastrophic system failure. Carbohydrate-induced afferent signals may modify the central governor's perception of fatigue and metabolic stress, thereby permitting increased motor output and performance [1][8][19]

3.2 Attentional and Cognitive Mechanisms

Recent neurophysiological investigations have illuminated more granular mechanisms through which CMR influences cognition. Event-related potential (ERP) studies examining electroencephalographic correlates of attention reveal that CMR modulates both bottom-up and top-down attentional processes. Specifically, relative to non-nutritive sweetener controls, CMR decreases the amplitude of the N1pc ERP component (reflecting initial attentional orienting to lateralized stimuli), suggesting CMR dampens automatic, stimulus-driven attention. Conversely, CMR increases the amplitude of the N2pc ERP component (reflecting effortful target selection and attentional control), indicating an enhancement of voluntary, goal-directed attention [16]. These findings suggest that CMR shifts attentional allocation from stimulus-driven to cognitively controlled, task-relevant processes. Such modulation would facilitate sustained focus on exercise-relevant goals while reducing distraction by peripheral stimuli or fatigue-related cues [16]. This mechanism may particularly benefit performance in cognitively demanding sports or during high-intensity efforts requiring sustained voluntary attention.

3.3 Fatigue Mechanisms

CMR appears to influence multiple fatigue-related processes. The reduction in perceived exertion and fatigue index observed following CMR suggests modulation of afferent signals conveying information about metabolic stress, heat accumulation, or neuromuscular fatigue. By dampening subjective fatigue perception without altering the underlying physiological constraint (i.e., carbohydrate availability), CMR may allow athletes to tolerate greater effort before voluntarily terminating exercise.[8][18]

4. Performance Effects: Exercise Modality and Duration

4.1 Cycling Performance

Cycling studies constitute the largest body of CMR research. Meta-analytical reviews examining 1-hour cycling time trials consistently demonstrate small positive effects of CMR on performance [1][3]. In the conventional meta-analytic approach, overall CMR use improved cycling performance compared with placebo, with a standardized mean difference (SMD) of 0.15 (95% confidence interval [CI] 0.04-0.27, $p = 0.01$). More conservative meta-regression modeling employing robust variance estimation revealed similar trends (SMD = 0.17, 95% CI -0.01-0.34, $p = 0.051$) [1]. Performance improvements with CMR in cycling time trials range from approximately 1-6%, depending on duration, intensity, protocol specifics, and nutritional state. Studies demonstrate a 2.9% improvement in cycling time-trial performance following a 5-second rinse with a 6.4% maltodextrin solution [1][8][12][14]. Longer rinsing durations (15 seconds) have produced larger performance effects in some studies, though the optimal duration remains debated. Recent evidence suggests that 10 seconds or less may be preferable in competition settings, potentially because prolonged rinsing disrupts breathing patterns and concentration during high-intensity effort [15]. Power output improvements have been observed in both absolute terms and relative to lactate thresholds. Studies examining mean power output during 1-hour cycling time trials at 65-75% VO_2max report improvements of 5-10 watts with CMR versus placebo, representing approximately 2-3% performance enhancement [12][15][25]

4.2 Running Performance

Running-based studies have yielded more heterogeneous results compared with cycling protocols. This variability partly reflects methodological differences, including laboratory-based treadmill testing versus field-based, self-paced running, diverse exercise durations (30-60 minutes), and variable CMR protocols. Some field-based studies examining self-paced running in naturalistic conditions have failed to detect significant performance benefits of CMR, whereas laboratory-based studies more consistently demonstrate ergogenic effects [8][25]. Time-to-exhaustion testing during high-intensity running (73-80% VO_2max) has shown improvements of 3-11% with CMR versus placebo. A study examining repeated sprint running with 5-second cycling sprints demonstrated significant reductions in fatigue index with CMR, despite no significant improvements in actual sprint performance metrics. The heterogeneity in running outcomes may reflect biomechanical differences between cycling and running.[8][21][25]

4.3 Resistance Exercise and Muscular Endurance

Emerging evidence suggests CMR may enhance lower-body muscular endurance during resistance exercise, particularly when combined with caffeine. In a study examining squat and bench press performance in resistance-trained participants, combined carbohydrate-caffeine mouth rinsing significantly improved squat endurance performance in the first set and overall cognitive performance in both male and female athletes, despite producing no effects on maximal strength (1-repetition maximum) [5][17][20]

The mechanism underlying muscular endurance enhancement likely involves supraspinal mechanisms involving the central nervous system rather than peripheral metabolic factors, consistent with the proposed central mechanism of CMR. Recruitment of higher-order motor control regions may permit greater volitional motor unit activation and maintenance of force output during fatiguing contractions

5. Optimal CMR Protocols

5.1 Carbohydrate Type and Concentration

The predominant carbohydrate utilized in successful CMR studies is maltodextrin, a glucose polymer with an intermediate chain length. Meta-analytical evidence and systematic reviews consistently identify 6-6.5% maltodextrin solutions as optimal, with this concentration demonstrating superior effects compared with lower concentrations (e.g., 4%) or other carbohydrate types [1][3][14]. Pure glucose solutions have yielded somewhat variable results, possibly due to differences in taste perception and orosensory signaling efficacy. Some studies utilizing glucose-maltodextrin mixtures (often in 1:1 ratios) have demonstrated performance benefits, though maltodextrin monotherapy appears most consistently effective [1][3]. The specific structural properties of maltodextrin—particularly its dextrose equivalent (DE) and molecular weight distribution—likely influence taste perception and receptor activation. Shorter-chain maltodextrins (higher DE) may produce stronger sweet taste signals, potentially enhancing central receptor activation [1].

5.2 Rinsing Duration and Frequency

Rinsing duration has emerged as a critical protocol variable. Early research demonstrated that 10-second rinsing was superior to 5-second rinsing in cycling performance studies. However, the dose-response relationship plateaus at 10 seconds; extended durations (≥15 seconds) do not produce additional ergogenic benefits and may interfere with breathing and concentration during high-intensity exercise. Consequently, contemporary recommendations favor rinse durations of 5-10 seconds, with 10 seconds optimal during sustained aerobic efforts and shorter durations (≤5 seconds) preferred immediately before high-intensity resistance or sprint exercise. [1][12][14][15]. The optimal rinsing frequency during prolonged exercise remains incompletely characterized. While some laboratory studies employ single pre-exercise rinsing episodes, landmark efficacy studies (Carter et al., Chambers et al.) have employed repeated carbohydrate mouth rinsing at 5–10 minute intervals during exercise lasting 30–75 minutes, with this repeated-rinse protocol demonstrating more consistent performance benefits. Limited evidence suggests that repeated rinsing during exercise bouts lasting ≥60 minutes may produce sustained ergogenic effects, though optimal rinsing frequencies for very prolonged efforts (>90 minutes) remain understudied.[1][12][14][15]

6. Effects of Nutritional State: Fed versus Fasted

A critical distinction in CMR efficacy concerns the participant's nutritional state during testing. Early foundational studies administered CMR following overnight fasting (8-12 hours), creating a state of heightened metabolic need and potentially enhanced central appetite signaling [1][4]. Subsequent research has increasingly examined CMR effects in postprandial (fed) states, which are more reflective of competitive conditions in which athletes consume pre-event meals [4].

Recent meta-analytical evidence demonstrates that CMR retains ergogenic efficacy under fed conditions, with effect sizes comparable to or only modestly reduced relative to fasted states [4]. A comprehensive three-level meta-analysis examining postprandial CMR effects found a small but significant ergogenic effect (Hedges' $g = 0.18$, 95% CI 0.09-0.28, $p < 0.01$) across 33 exercise studies [4]. Notably, CMR effectiveness appears to be maximized when administered after high-carbohydrate pre-exercise meals, suggesting additive or synergistic interactions between exogenous carbohydrate availability and CMR-induced central signaling.

This fed-state efficacy has substantial practical implications for recreational athletes, as most competitive events follow pre-event nutritional intake [4]. The persistence of CMR benefits despite carbohydrate-replete metabolic states provides further evidence that metabolic fuel availability does not constitute the primary mechanism, supporting central nervous system-mediated models [4].

7. Gastrointestinal Considerations and Symptom Management

7.1 Exercise-Induced Gastrointestinal Syndrome

The gastrointestinal tract represents a critical yet frequently underappreciated system for endurance performance. The high prevalence of GI symptoms in endurance athletes—ranging from 4-96% depending on sport and intensity—reflects the substantial physiological stress imposed by sustained exercise [2][12][13][26]. Primary mechanisms include redistribution of splanchnic blood flow toward working musculature, sympathetic nervous system activation with resulting alterations in GI motility, increased intestinal epithelial permeability and bacterial translocation, and inflammatory cascades.

Traditional carbohydrate supplementation during exercise frequently exacerbates these mechanisms, particularly at high intake rates. GI symptoms commonly reported include upper GI symptoms (nausea, vomiting, regurgitation, heartburn) and lower GI symptoms (abdominal cramping, flatulence, diarrhea) [2][12][13][26].

7.2 CMR and Gastrointestinal Comfort

A principal advantage of CMR relative to traditional carbohydrate ingestion is the virtual elimination of GI distress [1][2][3]. Because CMR involves minimal swallowing and no post-oral nutrient absorption, it bypasses the primary mechanisms generating GI symptoms: gastric distension, osmotic pressure changes, and nutrient malabsorption [1][2][3].

Evidence examining GI outcomes with CMR is limited but consistently demonstrates safety and symptom reduction. Studies directly comparing CMR to traditional carbohydrate ingestion or placebo report no significant GI symptoms with CMR, whereas traditional supplementation produces measurable GI distress [1][3]. This represents a paradigm shift for athletes with pre-existing GI sensitivities or those competing in conditions predisposing to EIGS (heat stress, rapid transit times, altitude) [2][6][12][13].

7.3 Gut Training and Adaptation

Emerging evidence suggests the gastrointestinal system demonstrates remarkable plasticity and adaptability in response to repeated nutritional challenges. The concept of "gut training" involves progressive exposure to specific carbohydrate types and quantities, inducing upregulation of intestinal glucose transporters (SGLT1) and adaptation of gastric accommodation mechanisms [6][22][23].

Studies examining gut training protocols demonstrate that 2-week exposure to high carbohydrate intake during exercise reduces carbohydrate malabsorption by 45-54% and decreases overall GI discomfort by 26-47% [2][6][22]. These adaptations appear nutrient-specific; exposure to a high-carbohydrate diet increases SGLT1 transporter density and activity, but does not similarly influence protein or fat absorption [22][23]. For recreational athletes considering CMR, the potential for combined strategies deserves consideration.

8. Cognitive Function and Performance

Beyond physical performance metrics, emerging evidence suggests CMR influences cognitive function through mechanisms likely involving reward processing and attention modulation. Studies examining cognitive task performance during or immediately following CMR demonstrate improvements in reaction time, accuracy, and executive function [5][20].

Combined carbohydrate-caffeine mouth rinsing produces significant enhancements in cognitive performance assessed using standard cognitive testing batteries. The additive effect of combined rinsing relative to CMR or caffeine rinsing alone suggests synergistic central mechanisms [5][21][27]. Preliminary evidence from two studies suggests that combined carbohydrate-caffeine mouth rinsing may produce synergistic enhancements in cognitive performance; however, additional research with larger samples and neuroimaging approaches is needed to definitively characterize these mechanisms.

This cognitive enhancement may be particularly relevant for recreational athletes participating in sports that require rapid decision-making, tactical complexity, or attentional control. Examples include team, combat, and endurance sports with technical components. The ability to enhance both physical performance and cognitive function through a single, non-invasive intervention represents a meaningful advantage [5][20].

9. Practical Applications for Recreational Athletes

9.1 Implementation During Training and Competition

For recreational athletes, CMR represents a practical, evidence-based strategy for enhancing performance during moderate- to high-intensity exercise lasting 30-75 minutes. Specific recommendations include:

Optimal Protocol: Use 6-6.5% maltodextrin solutions (approximately 10-15 grams in 200-250 mL water), rinsed for 5-10 seconds before or during exercise, with the rinse expelled after rinse completion [1][3][14][15].

Timing: Most efficacy studies employ repeated intra-exercise rinsing at 5-10 min intervals rather than single pre-exercise administration. This approach has demonstrated consistent performance improvements of 2-3% during sustained efforts lasting 30-75 minutes. While single pre-exercise rinsing may be practical in specific contexts (e.g., before resistance exercise sets), systematic evidence indicates that repeated intra-exercise rinsing produces more robust ergogenic effects. The optimal inter-rinse interval remains incompletely characterized, though documented intervals of 5-10 minutes have demonstrated consistent benefits in landmark studies. [1-3][7][12][13][14]

Integration with Training Nutrition: CMR complements rather than replaces periodic carbohydrate ingestion during longer exercise bouts exceeding 75 minutes [1][3][11]. Athletes might employ CMR during high-intensity efforts or when ingestion causes GI distress, alternating with conventional supplementation as tolerated [1][2][3].

Trial and Practice: Like any performance intervention, CMR should be practiced during training to establish comfort with the technique and verify individual responsiveness before competitive deployment.

9.2 Special Populations

Recreational athletes with exercise-induced gastrointestinal symptoms—including those with irritable bowel syndrome, inflammatory bowel disease, or previous negative experiences with carbohydrate supplementation—represent a population for whom CMR offers particular clinical value. [1][26][29] CMR permits equivalent performance optimization (2–3% improvement in 30–75 minute efforts) while eliminating ingestion-related GI complications, as the expectorated solution avoids gastric distension, delayed gastric emptying, osmotic diarrhea, and intestinal fermentation.[1] While CMR's GI-friendly advantage persists across environmental contexts, its performance-enhancement utility is context-dependent: reliable in temperate conditions (17–25°C), eliminated in heat stress (≥30°C) due to thermal and cardiovascular strain overriding central mechanisms, and empirically uncharacterized at altitude (>2000 m) or during rapid intestinal transit scenarios. For athletes in challenging environmental conditions, alternative strategies such as menthol rinsing (3.6–34.4% benefit in heat) or conventional carbohydrate supplementation with gut-training protocols may prove more effective. Direct clinical trials in IBS/IBD athlete populations remain limited, warranting individualized tolerance assessment during training before competition use. [1][2][11][28]

10. Limitations and Future Research Directions (DISCUSSION)

10.1 Current Evidence Gaps

Several important limitations characterize the current CMR literature. *First*, most studies employ healthy, young participants, limiting generalizability to older athletes, those with chronic health conditions, or diverse racial/ethnic populations. *Second*, the majority of studies examine acute, single-dose CMR effects; chronic effects of repeated CMR use remain understudied [1][3][6].

Third, mechanistic investigations employing neural imaging or electrophysiological methods remain limited, constraining our understanding of the precise central mechanisms underlying performance enhancement [3][6][20]. *Fourth*, practical implementation guidelines remain somewhat uncertain regarding optimal rinsing duration, frequency, and timing during varied sporting contexts [1][3].

10.2 Future Research Priorities

Critical future research directions include:

Mechanistic investigations employing functional neuroimaging, transcranial magnetic stimulation, or advanced electrophysiological methods to elucidate the precise central mechanisms underlying CMR-induced performance enhancement [16][20].

Sex- and age-specific analyses examining whether CMR efficacy varies across the lifespan or between biological sexes, with investigation of mechanisms underlying any identified differences [5][21].

Chronic adaptation studies examining whether repeated CMR exposure induces central nervous system adaptations that enhance baseline performance or alter responsiveness to CMR.[1][3]

Sport-specific investigations examining CMR applications in diverse sporting contexts, including team sports, technical sports, and environments with extreme temperature or altitude conditions [1][3][5][6].

Gut health interactions investigating potential interactions between CMR, gut microbiota composition, and gut health markers in both acute and chronic contexts [2][6][22].

Dose-response investigations systematically examining carbohydrate concentration, solution volume, rinsing duration, and rinsing frequency to define precise optimal protocols [1][3][14].

11. Conclusions

Carbohydrate mouth rinsing represents a practical, evidence-based ergogenic aid for recreational athletes seeking performance enhancement during moderate- to high-intensity exercise lasting 30-75 minutes [1][3]. Meta-analytical and systematic review evidence demonstrates small but statistically significant improvements in exercise performance (approximately 2-3%), with effect sizes comparable to or exceeding those of many conventional nutritional interventions [1][3].

The proposed mechanism—central nervous system activation through orosensory stimulation of taste receptors—explains both the performance benefits and the critical advantage relative to traditional carbohydrate supplementation: virtual elimination of gastrointestinal distress [1][2][4]. For athletes plagued by exercise-induced gastrointestinal symptoms, CMR provides an opportunity to optimize performance while maintaining complete GI comfort [1][2][3].

Optimal protocols employ 6-6.5% maltodextrin solutions rinsed for 5-10 seconds at repeated 5-10 min intervals during exercise, or as a single pre-exercise rinse for efforts <60 minutes, with expulsion following the rinse [1][3][14]. Benefits persist under both fasted and fed conditions, suggesting applicability across diverse competitive scenarios in temperate environments. However, CMR efficacy appears substantially diminished under high heat stress conditions (≥30°C), where thermal and cardiovascular strain may override the benefits of central mechanisms;[28] efficacy at altitude and in other extreme environmental conditions remains incompletely characterized. CMR effectiveness appears maximized during aerobic exercise modalities, and preliminary evidence (2 randomized controlled trials) suggests potential to enhance cognitive function through reward pathway activation, though additional research is required through reward pathway activation and attentional modulation [1][4][5][20].

For recreational athletes, CMR should be incorporated into an evidence-based nutritional strategy that considers total carbohydrate availability, hydration status, individual GI tolerance, and sport-specific demands [1][3][11]. While current evidence is encouraging, additional research—particularly employing mechanistic approaches and examining diverse populations—remains necessary to fully optimize CMR protocols and identify subpopulations experiencing maximal benefit [1][3][6][20].

Disclosure

Author Contributions:

Conceptualization: [TK], [MS], [AP]
Methodology: [MP], [SL]
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Check: [MP], [MS], [APA]
Formal analysis: [AB], [SL]
Investigation: [PR], [IT]
Data curation: [MP], [MS]
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