The Bioscan
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
21(2), 407-415, 2026 www.thebioscan.com

Effects of Carbohydrate Mouth Rinsing on Cognition and Motor Skills in Sports Psychology

Dr. Lakshyashree (PT)[1], Dr. Soumya Ranjan Lenka (PT)[2], Dr. Priyanka Kumari Nahak (PT)[3]*, Dr. Palak Gajjar (PT)[4], Dr. Dushyant Bawiskar (PT)[5]

[1]Assistant Professor, Department of Allied Health Sciences, Brainware University, Barasat, Kolkata, West Bengal, India. Email: lakshyasingh1995@gmail.com
[2]Assistant Professor, KIMS School of Physiotherapy, KIIT University, Bhubaneswar, Odisha, India. Email: soumyalenk03srl@gmail.com
[3] Assistant Professor, Department of Health Sciences (Physiotherapy), The Neotia University, Diamond Harbour, South 24 Parganas, Kolkata, West Bengal, India. Email: priyanka298nahak@gmail.com*
[4]Associate Professor, Shridevi College of Physiotherapy, NH-4, Sira Road, Maralenahalli, Tumkur, Karnataka, India. Email: pgajjar1995@gmail.com
[5]Assistant Professor, Department of Sports Physiotherapy, Ravi Nair Physiotherapy College, Datta Meghe Institute of Higher Education and Research (Deemed to be University), Sawangi Meghe, Wardha, Maharashtra, India. Email: dushyant.bawiskar.1996@gmail.com

Corresponding Author: Priyanka Nahak, priyankakumari.nahak@tnu.in

DOI: https://doi.org/10.63001/tbs.2026.v21.i02.pp407-415

KEYWORDS
Carbohydrate mouth rinsing (CMR), Motor performance, Cognitive Performance, Sports Psychology, Central nervous system

Revised on:
02-04-2026
Received on:
29-03-2026
Accepted on:
10-04-2026
Published on:
20-04-2026

Abstract

Background: Carbohydrate mouth rinsing (CMR) has gained attention as a practical strategy to enhance athletic performance without actual carbohydrate ingestion. While its role in endurance performance is well documented, its influence on cognitive functions and motor skills—critical components of sports performance—remains an evolving area of research. **Objective:** This review aims to examine the effects of carbohydrate mouth rinsing on cognitive performance (attention, decision-making, working memory) and motor skills (power, speed, coordination, endurance) within the context of sports psychology. It also explores the underlying neurological and psychological mechanisms influencing these outcomes. **Method:** A comprehensive literature search was conducted across databases including PubMed, Scopus, Web of Science, and SPORTDiscus. Studies included were peer-reviewed, written in English, involved human participants, and primarily used randomized controlled or crossover designs. A total of 322 records were identified, with 22 studies meeting the inclusion criteria after screening and eligibility assessment. Data were synthesized using a narrative approach due to heterogeneity in study designs and outcome measures. **Results:** Evidence suggests that carbohydrate mouth rinsing can positively influence both cognitive and motor performance. Improvements were observed in attention, reaction time, and decision-making, along with enhancements in power output, endurance, and motor coordination. These effects are largely attributed to the activation of oral carbohydrate receptors, which stimulate brain regions associated with reward, motor control, and effort regulation. Additionally, CMR appears to reduce perceived exertion and enhance motivation, contributing to improved performance outcomes. **Conclusion:** Carbohydrate mouth rinsing represents a simple, non-invasive strategy that may enhance athletic performance through central nervous system activation rather than metabolic pathways. Its benefits extend beyond physical performance to include cognitive and psychological domains. However, variability in protocols and study designs highlights the need for further research to standardize application and better understand individual responses. When used appropriately, CMR can serve as a valuable complementary tool in both training and competitive settings.

1.INTRODUCTION

1.1 Background and rationale

Carbohydrate mouth rinsing, a technique involving swishing a carbohydrate solution in the oral cavity for a brief period without ingestion, has emerged as a topic of considerable interest in sports psychology and exercise physiology. The primary focus of research in this area has been on its potential ergogenic effects, particularly in enhancing endurance performance [(1)]. However, the influence of carbohydrate mouth rinsing extends beyond physical performance, potentially impacting cognitive functions and motor skills relevant to athletic performance [(2)]. The rationale behind this technique lies in the activation of specific receptors in the oral cavity that are sensitive to carbohydrates [(1)]. These receptors, when stimulated, are believed to send signals to the brain, influencing motor output and perception of effort [(3)]. This neurological response could potentially enhance alertness, decision-making, and motor control, all of which are critical for optimizing athletic performance, especially in sports requiring complex cognitive processing and precise motor execution. The effectiveness of carbohydrate mouth rinsing is still up for debate. The complex interplay between physiological and psychological mechanisms makes it a fascinating area of study within sports psychology.

1.2 Carbohydrate mouth rinsing: Mechanism and Theory

Carbohydrate mouth rinsing involves swilling a carbohydrate-containing solution in the mouth for a short period, typically 5-10 seconds, without actually ingesting it. This technique has emerged as a practical and accessible method for potentially enhancing athletic performance, particularly in situations where carbohydrate ingestion may be impractical or undesirable. The premise behind carbohydrate mouth rinsing lies in the activation of specific receptors in the oral cavity that are sensitive to the presence of carbohydrates.

These receptors, primarily T1R2/T1R3 heterodimers, trigger a cascade of neural and hormonal responses that can influence brain activity and subsequent motor output [(4)]. Activation of these receptors has been shown to stimulate reward centers in the brain, leading to increased motivation, reduced perception of effort, and improved cognitive function [(5)]. The underlying mechanisms of carbohydrate mouth rinsing are complex and multifaceted, involving both central and peripheral pathways. The stimulation of oral carbohydrate receptors can lead to increased activation of brain regions associated with motor control, attention, and reward processing. This heightened neural activity may contribute to improved motor performance by enhancing muscle recruitment, coordination, and power output. Athletes should consume 1.0– 1.5 g/kg of bodyweight during the first half hour and again every 2 h for 4–6 h after exercise to replace liver and muscle glycogen stores [(6)].

1.3 Cognitive and motor skills demand in sports

Athletes must constantly integrate perception, decision-making, and movement control under a variety of physical and psychological stresses because sports performance is a complex interplay between cognitive processes and motor execution. In dynamic sports contexts, cognitive abilities including working memory, attention, anticipation, and decision-making are crucial for deciphering environmental clues and choosing the right motor responses.

The smooth interaction of the musculoskeletal and central neural systems is essential for highlevel athletic performance. In situations of exhaustion, strain, and competitive stress, athletes must integrate vast amounts of sensory data, including visual, aural, and proprioceptive inputs, while reacting quickly and effectively. Reaction time, movement precision, and decisionmaking can all be negatively impacted by cognitive fatigue, which eventually lowers performance efficiency.

1.4 Purpose of the review

The purpose of this review is to investigate how mouthwash containing carbohydrates affects cognitive and motor function in the setting of sports psychology. This review specifically attempts to investigate the effects of carbohydrate mouthwash on critical cognitive processes like working memory, attention, and decision-making—all of which are critical for peak athletic performance. Furthermore, the review aims to assess how carbohydrate mouthwash affects motor performance outcomes such as power, speed, coordination, and endurance.

Examining the effects of carbohydrate mouthwash on psychological states related to athletic performance, such as motivation, focus, perceived exertion, and mental exhaustion, is another goal of this review. In order to control effort, performance consistency, and competitive behaviour during training and competition, it is essential to comprehend these psychological mechanisms. In order to accomplish these goals, this review summarizes the body of research on carbohydrate mouthwash, with a focus on studies examining its effects on cognition, neuromuscular function, and psychology. This review aims to provide a thorough knowledge of the possible mechanisms behind carbohydrate mouth rinsing and its practical consequences for athletes and practitioners by combining studies from sports physiology, neurology, and sports psychology.

Ultimately, this study seeks to guide future research directions and applied practices in sports psychology and athletic performance optimization, as well as to add to the expanding body of knowledge on nutritional solutions for performance enhancement.

2. THEORETICAL BACKGROUND

2.1 Neurological mechanism of carbohydrate mouth rinsing

Rather than through metabolic or energy routes, central nervous system mechanisms are the main method that carbohydrate mouth rinsing (CMR) works. Mouth rinse is briefly exposing carbohydrate solutions to oral receptors without ingestion, in contrast to carbohydrate consumption, which affects blood glucose levels and muscle glycogen availability. Neural circuits that affect reward, motivation, motor control, and cognitive processing are activated by this interaction (Stellingwerff & Cox, 2014).

2.2 Central nervous system activation and reward pathways

Studies using neuroimaging have shown that rinsing your mouth with carbohydrates activates a number of important brain areas related to motivation, effort management, and motor planning. These consist of the striatum, anterior cingulate cortex, primary motor cortex, and premotor cortex (Chambers et al., 2009; Hartley et al., 2022). When these areas are activated, corticospinal excitability is increased, which promotes better motor output and neuromuscular recruitment.

Decision-making, error detection, and effort perception all depend heavily on the anterior cingulate cortex. When this area is activated, the willingness to maintain effort during exercise may increase and perceived exertion may decrease. In addition, stimulation of reward-related brain regions boosts motivational drive, which strengthens perseverance and task engagement.

Carbohydrate mouth rinsing has been shown to influence motor unit recruitment and neuromuscular efficiency. Enhanced excitability of the motor cortex improves the transmission of neural signals to working muscles, allowing for more efficient force production and coordination (Spampinato & Celnik, 2017). This mechanism is particularly relevant in highintensity or skill-dependent sports where rapid force generation and precise movement control are required.

Furthermore, the cerebellum—responsible for movement coordination, timing, and motor learning—may also be indirectly influenced through sensory feedback and cortical integration. This neural facilitation contributes to improvements in motor accuracy, reaction time, and overall movement efficiency.

2.3 Psychological models of fatigue and performance

Different psychological models collectively emphasize that collectively emphasize that fatigue is not solely a physiological phenomenon but is strongly influenced by cognitive, emotional and motivational factors. Carbohydrate mouth rinsing may interact with these mechanisms by modulating perception of effort, enhancing reward processing, and supporting attentional control. This interaction highlights the importance of integrating psychological frameworks when examining nutritional strategies aimed at optimizing athletic performance.

3. Carbohydrate mouth rinsing and Cognitive Performance

The ingestion of carbohydrates during prolonged exercise has been shown to improve performance [(7)]. The precise mechanisms through which carbohydrate mouth rinsing exerts its effects are still under investigation, but neurophysiological pathways are thought to play a crucial role. It is hypothesized that the activation of carbohydrate receptors in the oral cavity, such as the sweet taste receptors, triggers a cascade of neural signals that ascend to various brain regions involved in motor control and reward [(8)]. These regions may include the motor cortex, which is responsible for planning, control, and execution of voluntary movements, and the striatum, a key component of the basal ganglia involved in motor learning and action selection. The activation of these brain areas may lead to enhanced motor output, improved coordination, and a greater sense of motivation, ultimately contributing to improved athletic performance [(9)]. The effect of carbohydrate mouth rinsing on cognitive functions such as attention, focus, and decision-making is an area of growing interest (9). The potential for carbohydrate mouth rinsing to act as a cognitive enhancer during exercise stems from the close connection between brain regions involved in motor control and those involved in cognitive processing. For instance, the prefrontal cortex, which is responsible for higher-order cognitive functions such as working memory and executive control, has extensive connections with the motor cortex and the basal ganglia [(10)]. Stimulation of the oral carbohydrate receptors may also modulate the activity of the anterior cingulate cortex, which is involved in effort perception and motivation [(11)]. The modulation of brain activity can lead to a reduction in the perception of effort, increased alertness, and improved cognitive processing, all of which can be beneficial in sports settings.

The cognitive benefits of carbohydrate mouth rinsing have garnered increasing attention, particularly in the context of sports psychology. Studies have demonstrated that carbohydrate mouth rinsing can improve cognitive functions such as attention, focus, and decision-making, which are critical for optimal athletic performance. These cognitive enhancements may be attributed to the activation of brain regions involved in cognitive control and reward processing. The ingestion of carbohydrate 3-4 hours before exercise increases liver and muscle glycogen and enhances subsequent endurance exercise performance [(12)].

The potential for carbohydrate mouth rinsing to enhance cognitive function has significant implications for athletes across various disciplines, contributing to quicker reaction times and better strategic decision-making during competition. Raisins, bananas, and honey may be particularly useful CHO foods for consumption during exercise, as they are easily transportable. Honey, with its rich composition of carbohydrates, minerals, and vitamins, has demonstrated potential in enhancing both sports performance and overall health. Honey's unique blend of properties may contribute to improved aerobic exercise performance and offer benefits such as enhanced bone health, immune system support, and antioxidant effects [(13)].

4. Carbohydrate mouth rinsing and Motor skills

Motor skills, which encompass a wide range of movements from simple reflexes to complex coordinated actions, are fundamental to athletic performance. Carbohydrate mouth rinsing may have a facilitatory effect on motor skill execution through the modulation of neural pathways involved in motor control [(14)]. This is very important for athletes that need to maintain high levels of focus. Studies have indicated that carbohydrate mouth rinsing can improve measures of motor performance, such as reaction time, agility, and fine motor control.

4.1 Motor control and coordination

The activation of motor-related brain areas might result in more efficient recruitment of motor units, enhanced neuromuscular coordination, and a heightened sense of body awareness, leading to improved motor skill execution. The cerebellum's role in motor learning and adaptation is also noteworthy in this context [(15)]. The repeated stimulation of oral carbohydrate receptors may promote long-term adaptations in motor control, potentially enhancing the efficiency and accuracy of motor skills over time. It is also important to consider the taskspecific nature of motor skills. In addition to cognitive benefits, carbohydrate mouth rinsing has been shown to positively influence motor performance in athletes.

Studies have reported improvements in endurance capacity, power output, and sprint performance following carbohydrate mouth rinsing. These motor performance enhancements may be mediated by alterations in neuromuscular function, muscle recruitment patterns, and perceived exertion. The activation of oral carbohydrate receptors can influence the excitability of motor neurons, leading to increased muscle activation and force production. Athletes often use nutritional strategies to enhance cognitive function, especially under stressful conditions. Moreover, carbohydrate mouth rinsing may reduce the perception of effort, allowing athletes to sustain higher intensities of exercise for longer durations.

5. Practical Implications for sports psychology and performance

From a sports psychology perspective, the use of carbohydrate mouth rinsing holds significant implications for optimizing athletic performance and enhancing the overall training experience. The psychological effects of carbohydrate mouth rinsing are thought to be a key factor in its ergogenic potential. Athletes' perceptions of effort, motivation, and self-efficacy can significantly influence their performance. The psychological benefits of carbohydrate mouth rinsing may be particularly relevant in situations where athletes face high levels of stress, fatigue, or uncertainty. By providing a readily available source of stimulation, carbohydrate mouth rinsing may help to improve mood, reduce anxiety, and increase confidence, all of which are important for maintaining optimal performance under pressure [(16)]. Furthermore, integrating mindfulness practices with sports nutrition strategies can offer athletes a holistic approach to performance enhancement. It is now generally accepted that carbohydrates are perhaps the most important energy substrate for elite performance [(17)]. Carbohydrate mouth rinsing may influence cognitive and motor performance through several pathways. The taste of carbohydrate solutions can activate reward centers in the brain, leading to increased motivation, focus, and alertness [(20)]. This "sweet taste" effect may enhance an athlete's psychological state, promoting a more positive and confident mindset during competition.

Furthermore, the act of rinsing and spitting may serve as a psychological cue, signaling to the athlete that they are actively taking steps to improve their performance. This sense of control and self-efficacy can further enhance motivation and reduce anxiety, ultimately leading to improved cognitive and motor outcomes. Moreover, encouraging naps and teaching selfcontrol skills can help athletes conserve energy and maintain calmness. The use of specific diets can improve sports performance. Athletes may need self-control to engage in recovery activities, particularly when

they feel tired or stressed. Nutritional interventions that enhance the restoration of endogenous fuel stores and improve muscle damage repair have received a lot of attention.

5.1 Application in training and competitions

Due to its potential to improve cognitive and motor performance without the gastrointestinal burden associated with carbohydrate absorption, the use of carbohydrate mouth rinse (CMR) in training and competitive situations has drawn growing attention. It is a useful tactic for athletes in a variety of sports due to its ease of use, quick action, and low physiological disturbance. Carbohydrate mouth washing can be carefully used throughout training to assist cognitive and physical demands, especially during highly taxing or high-intensity exercises. Training frequently entails prolonged periods of exertion that call for sustained focus, motor coordination, and fatigue-related decision-making. When energy availability is minimal or when sessions are conducted when fasting or glycogen-depleted, using carbohydrate mouth washing during training may also aid athletes maintain training quality. This is especially important for athletes using periodized nutrition plans or heavy exercise loads. By reducing mental fatigue and enhancing perceived energy levels, CMR may support consistent technical execution and reduce performance variability during prolonged or intense training sessions. Additionally, the use of carbohydrate mouth rinsing during practice may serve as a psychological conditioning tool. Athletes may associate the sensory stimulus with improved performance, potentially enhancing confidence and motivation during competition. This learned association may strengthen the placebo or expectancy effects that contribute to performance enhancement.

In competitive environments, where cognitive demands and psychological pressure are heightened, carbohydrate mouth rinsing may offer a valuable ergogenic advantage. Athletes are often required to maintain focus, make rapid decisions, and execute precise motor skills under stress and fatigue. CMR may help sustain attentional resources and reduce perceived effort, thereby supporting performance consistency during critical moments of competition.

Carbohydrate mouth rinsing is particularly useful in sports where ingestion during performance is impractical or undesirable, such as sprint events, team sports, combat sports, and intermittent high-intensity activities. In such scenarios, CMR provides a non-invasive method to stimulate central nervous system activity without causing gastrointestinal discomfort or interrupting performance flow. By activating central brain circuits linked to reward and motor control, CMR may help sustain concentration, lessen perceived effort, and increase motivation during these sessions.

Furthermore, CMR may be strategically applied during breaks in play, halftime intervals, or between sets or rounds. This allows athletes to maintain cognitive readiness and motor efficiency without altering hydration strategies or caloric intake. The psychological reassurance associated with the perception of energy availability may further enhance confidence and competitive resilience.

5.2 Integration with psychological skills training

From a sports psychology perspective, carbohydrate mouth rinsing can be effectively integrated with psychological skills training such as goal setting, imagery, attentional control, and self-talk. When combined with these techniques, CMR may reinforce mental preparedness and facilitate optimal arousal states during both training and competition.

The interaction between nutritional strategies and psychological skills highlights the importance of a holistic approach to performance enhancement. Athletes who develop awareness of how nutritional cues influence perception, motivation, and focus may be better equipped to regulate effort and maintain performance under pressure. For effective application, athletes and practitioners should consider individual variability in response to carbohydrate mouth rinsing. Factors such as training status, sport-specific demands, and personal sensitivity to taste or sweetness may influence effectiveness. It is also essential to ensure that mouth rinsing protocols are practiced during training to avoid unfamiliarity during competition.

Ethical considerations should also be acknowledged, particularly regarding informed use and avoidance of overreliance on ergogenic aids. Carbohydrate mouth rinsing should be viewed as a complementary strategy rather than a substitute for sound nutrition, training, and recovery practices.

In summary, carbohydrate mouth rinsing represents a practical and evidence-supported strategy for enhancing cognitive and motor performance in both training and competition. Its benefits appear to stem from central nervous system activation, improved perception of effort, and enhanced psychological readiness. When integrated thoughtfully into training routines and competitive strategies, carbohydrate mouth rinsing can contribute meaningfully to athletic performance and mental resilience.

5.3 Ethical and placebo considerations

The use of carbohydrate mouth rinsing (CMR) in sports performance raises important ethical and placebo-related considerations that must be addressed to ensure responsible and evidence-based application. While CMR is generally regarded as a safe and non-invasive strategy, its psychological and perceptual effects require careful interpretation, particularly when applied in competitive and training environments. Carbohydrate mouthwash is regarded as a legitimate and acceptable performance

tactic and does not contravene anti-doping laws from an ethical perspective. Ensuring athletes are properly informed about the scientific evidence, advantages, and restrictions of its use, however, is an ethical obligation. In order to prevent misleading athletes and creating irrational expectations, practitioners should refrain from exaggerating performance gains. When using nutritional or psychological therapies, informed consent is crucial. To promote open and moral behaviour, athletes should be informed about the central (neurological) rather than metabolic mechanism of carbohydrate mouthwash. Additionally, since not all athletes gain from the same cognitive or performance advantages, practitioners should take individual variability in response into account.

The placebo effect plays a significant role in sports performance, particularly in interventions that influence perception, motivation, and effort regulation. Carbohydrate mouth rinsing may exert part of its effect through expectancy mechanisms, whereby athletes believe that the intervention will enhance performance, leading to improved outcomes regardless of physiological changes.

Psychological expectancy can influence central nervous system activity, motivation, and perceived exertion. When athletes anticipate performance benefits, neural pathways associated with reward and effort regulation may be activated, resulting in improved task engagement and persistence. This highlights the importance of psychological context in interpreting performance outcomes related to carbohydrate mouth rinsing.

Importantly, placebo effects should not be dismissed as invalid or deceptive. Instead, they represent a meaningful psychobiological response that can positively influence performance when ethically managed. Transparent communication about potential benefits—without exaggeration—allows athletes to benefit from expectancy effects while maintaining autonomy and informed decision-making.

6. Moderating factors influencing effectiveness

6.1 Exercise intensity and duration

Exercise intensity and duration significantly influence the effectiveness of carbohydrate mouth rinsing (CMR). Evidence suggests that CMR is more effective during **moderate- to high-intensity exercise**, where cognitive and neuromuscular demands are elevated. Under such conditions, stimulation of oral carbohydrate receptors may enhance central nervous system

activation, reduce perceived exertion, and support sustained motor output (Stellingwerff & Cox, 2014).

During prolonged exercise, particularly sessions exceeding 60 minutes, mental fatigue often precedes physical exhaustion. Carbohydrate mouth rinsing has been shown to help maintain attentional focus and decision-making capacity by modulating central fatigue mechanisms, even in the absence of carbohydrate ingestion (Jeukendrup, 2004). This effect is especially relevant in endurance and intermittent sports, where cognitive engagement and pacing strategies play a critical role in performance outcomes.

6.2 Nutrition status and carbohydrate availability

Nutritional strategies are of utmost importance for athletes and coaches . To achieve a highperformance level during exercises that rely on the glycolytic pathway, athletes should begin exercising with full glycogen stores and supply carbohydrates throughout the effort [(18)]. Athletes should consume a high-carbohydrate diet to maximize bodily carbohydrate reserves. It is essential to practice race nutritional strategies in training and become accustomed to higher intake volumes or higher carbohydrate intakes.

The investigation into the effects of carbohydrate mouth rinsing on both cognitive and motor performance stems from a rich history of sports nutrition research aimed at optimizing athletic capabilities. Ensuring sufficient carbohydrate availability before, during, and after training has become a cornerstone of sports nutrition for athletic populations. While traditional carbohydrate loading and supplementation strategies have primarily focused on the physiological impact of carbohydrate ingestion on muscle glycogen stores and energy metabolism, the discovery of performance enhancements via simple mouth rinsing has opened new avenues for exploration. The established link between carbohydrate depletion and declines in exercise intensity, coupled with the understanding that strategic carbohydrate supplementation can improve performance by increasing carbohydrate stores, maintaining blood glucose, and facilitating rapid glycogen replenishment [(19)], provides a solid foundation for examining alternative modes of carbohydrate delivery. The practical implications of carbohydrate mouth rinsing are far-reaching, offering athletes a convenient and non-invasive method to potentially enhance both cognitive and motor function during training and competition. Carbohydrates should be balanced with a fluid intake plan, but solid foods and highly concentrated carbohydrate solutions have been shown to reduce fluid absorption. It is important to consider that manipulating pre-exercise skeletal muscle glycogen content could be a strategy to optimize body mass prior to competition, if glycogen depletion does not become limiting for performance.

Strategies have been developed to ensure that carbohydrate stores are well stocked before exercise and restored as soon as possible after exercise. Ingesting 6-12 g carbohydrate per kg is sufficient to restore glycogen reserves, but this is only when the recovery time is at least 24 hours. For rapid recovery from prolonged exercise, it is important to replenish muscle glycogen stores and initiate muscle tissue repair and adaptation [(19)]. In situations where athletes compete multiple times per day, recent studies indicate that they benefit from the swift restoration of their muscle glycogen reserves [(19)]. To optimize glycogen synthesis during the hours after exercise, carbohydrates should be consumed immediately after exercise and at frequent intervals thereafter [(19)].

6.3 Mouth rinse protocol variables (Concentrations, timing, frequency)

A number of protocol-related factors, such as the concentration of the carbohydrate solution, the timing of administration, and the frequency of rinsing, affect how effective carbohydrate mouth rinsing (CMR) is. The degree to which exercise improves cognitive and motor performance is largely dependent on these elements.

Concentration of Carbohydrate Solution

The majority of research on carbohydrate mouthwash has utilized glucose or maltodextrin solutions with carbohydrate contents between 6 and 10%. According to research, oral carbohydrate receptors can be activated at concentrations within this range without generating discomfort or aversion (Jeukendrup, 2004; Stellingwerff & Cox, 2014). Higher concentrations may have a detrimental impact on palatability, which could lower compliance, and they do not always yield larger performance benefits. The main mechanism behind performance improvement seems to be the activation of oral sweet receptors rather than carbohydrate oxidation.

Timing of mouth rinsing

One important factor that determines how effective carbohydrate mouthwash is when to do it. According to studies, rinsing works best when done during times of high physical or cognitive strain, including during intensive workouts or competitive stages that call for prolonged focus and motor control (Jeukendrup, 2014). It has been demonstrated that rinsing for **five to ten seconds** prior to expectorating is sufficient to activate the central nervous system and stimulate oral receptors. When mouth rinsing is done frequently as opposed to only once at the start of exercise, the benefits seem to be more noticeable.

Frequency of mouth rinsing

The frequency of carbohydrate mouth rinsing varies across studies, with protocols typically involving rinsing every **10-15 minutes** during prolonged or intermittent exercise. Repeated exposure may help sustain neural activation and mitigate cognitive fatigue over time. However, excessively frequent rinsing does not appear to provide additional benefits and may cause sensory adaptation or discomfort. Therefore, an individualized approach based on exercise duration, intensity, and athlete tolerance is recommended (Stellingwerff & Cox, 2014).

Optimizing mouth rinse protocols requires balancing effectiveness with practicality. Athletes should practice mouth rinsing strategies during training to determine optimal concentrations, timing, and frequency before applying them in competition. Consistency in protocol execution enhances reliability and maximizes potential cognitive and performance benefits.

Research Questions and Objectives

This paper aims to address the following research questions:

- How does carbohydrate mouth rinsing influence cognitive function in athletes, specifically in terms of attention, decision-making, and working memory?
- What are the effects of carbohydrate mouth rinsing on motor performance outcomes, such as power, speed, and endurance?
- How does carbohydrate mouth rinsing impact an athlete's psychological state, including motivation, focus, and perceived exertion?

To address these questions, this paper will review the existing literature on carbohydrate mouth rinsing and its effects on cognitive and motor performance, with a specific focus on the sports psychology aspects of this intervention.

Additionally, this paper will discuss the potential mechanisms underlying the observed effects, considering both physiological and psychological factors. The act of recovery, which entails the restoration of physiological and psychological resources, is crucial for sustaining athletes' well-being, health, and performance throughout their demanding schedules. Ultimately, the goal of this paper is to provide a comprehensive overview of the role of carbohydrate mouth rinsing in enhancing cognitive and motor performance from a sports psychology perspective, offering practical insights for athletes, coaches, and sports scientists. Many methods exist to enhance recovery, based on the type of practice, time between sessions, and equipment availability.

S.No.	Aspect	Key Points	Key References
1.	General Mechanism	Activates oral receptors signaling to brain; increases motor output and cognitive function	Peake, 2019; Gambassi et al., 2018
2.	Theory 1: Sweet Taste Receptors	Stimulates brain regions for motor control and reward; increases neural drive, power, endurance	Terrados et al., 2019
3.	Theory 2: Prefrontal Cortex Activation	Enhances prefrontal cortex activity; improves decision-making and attention during exercise	Terrados et al., 2019
4.	Cognitive Performance	Improves attention, reaction time, decisionmaking; supports cognitive control and reward processing	Kerksick et al., 2008; Ogoh et al., 2014; Vega & Newhouse, 2014
5.	Motor Performance	Increases muscle power, speed, endurance;	
		enhances neural drive and muscle activation	Cox & Clarke, 2014; Nantel, 1999; Xiang et al., 2020; Yamada et al., 2021
6.	Psychological Factors	Affects motivation, selfconfidence, concentration, anxiety management; impacts mental readiness	Ricci, 2021

Table 1 summarize key theoretical aspects mechanism and applications of carbohydrate mouth rinsing on cognitive and motor performance along with relavant supporting references

In addition to its cognitive benefits, carbohydrate mouth rinsing has been shown to enhance various aspects of motor performance. Research indicates that it can increase muscle power, speed, and endurance, leading to improved athletic performance. The effect of blood flow restricted exercise on cognition are unclear. These motor benefits may be mediated by the effects of carbohydrate mouth rinsing on neural drive to the muscles and muscle activation patterns. Exercise can have direct effects on functional and

cognitive brain structures. Health conditions should be controlled when investigating cognitive performance.

Methodology

The present review employed a comprehensive search strategy across multiple electronic databases, including PubMed, Scopus, Web of Science, and SPORTDiscus, to identify relevant studies investigating the impact of carbohydrate mouth rinsing on cognitive and motor performance in sports-related contexts. Search terms encompassed a combination of keywords related to carbohydrate mouth rinsing (e.g., "carbohydrate mouth rinse," "glucose mouth rinse," "maltodextrin mouth rinse"), cognitive function (e.g., attention, memory, executive function), motor performance (e.g., strength, power, endurance), and sports or exercise. The inclusion criteria mandated that studies be original research articles published in peer-reviewed journals, written in English, and involving human participants. Studies utilizing a randomized controlled trial design or crossover design were prioritized to minimize bias and ensure the reliability of findings. Data extraction was conducted using a standardized protocol to gather pertinent information from each study, including participant characteristics (e.g., age, sex, training status), intervention details (e.g., type and concentration of carbohydrate solution, rinsing duration), cognitive and motor performance measures, and key results. The inclusion of repeated measures designs, randomization, and application of valid measurement techniques are key considerations.

Inclusion and Exclusion Criteria

Studies were included if they met the following criteria: (a) were original research articles published in peer-reviewed journals; (b) were written in English; (c) involved human participants; (d) investigated the effects of carbohydrate mouth rinsing on cognitive or motor performance; and employed a randomized controlled trial design or crossover design. Studies were excluded if they were not original research articles (e.g., reviews, meta-analyses, case studies); were not written in English; did not involve human participants; did not investigate the effects of carbohydrate mouth rinsing on cognitive or motor performance; or did not employ a randomized controlled trial design or crossover design.

A standardized protocol was implemented to extract pertinent data from each included study, encompassing participant demographics (e.g., age, sex, training status), intervention specifics

(e.g., type and concentration of carbohydrate solution, duration of rinsing, timing of intervention), cognitive and motor performance measures (e.g., reaction time, accuracy, power output), and salient findings.

This rigorous approach ensured consistency and accuracy in data collection, facilitating subsequent synthesis and analysis.

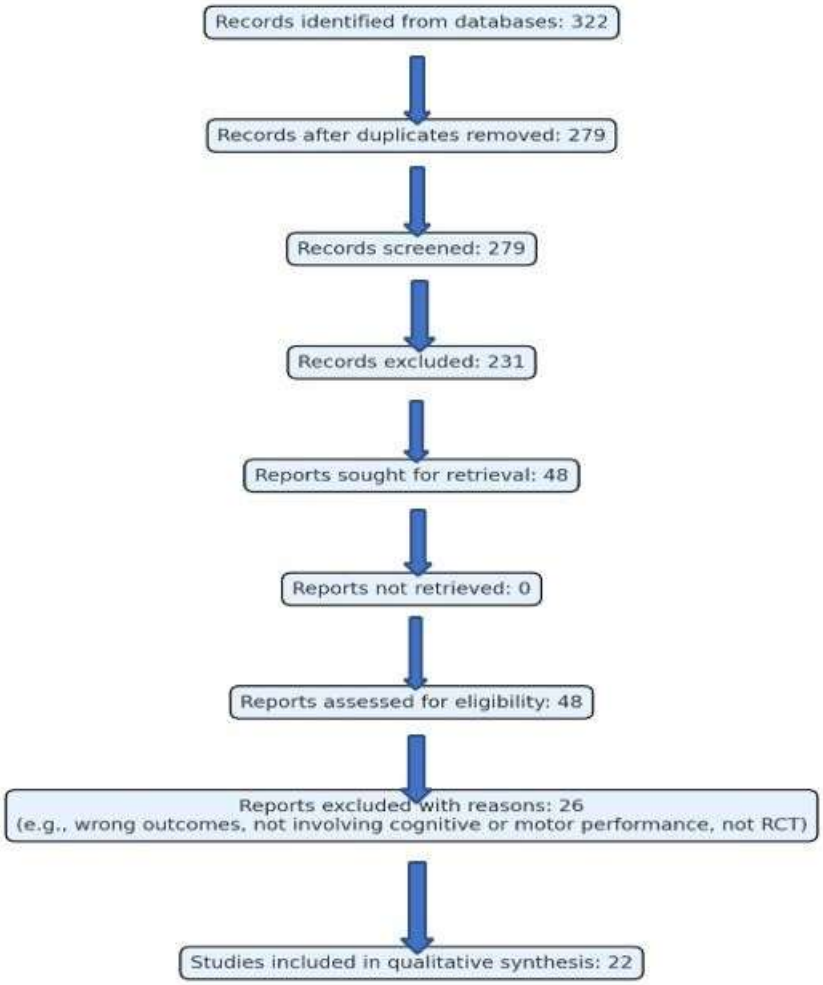

Figure 1 shows that PRISMA flow diagrams for study selection. From 322 identified records, 22 studies were finally included in the qualitative synthesis and eligibility assessment.

Data Synthesis and Analysis

A total of 322 records were identified through database searches (PubMed, Scopus, Web of Science, SPORTDiscus). After removing 43 duplicates, 279 records remained for screening. Following title and abstract screening, 231 records were excluded. Full-text reports were sought for 48 records, all of which were retrieved. After eligibility assessment, 26 reports were excluded for reasons such as wrong outcomes, non-relevant populations, or inappropriate study designs. Finally, 22 studies were included in the qualitative synthesis. These steps are detailed in the PRISMA flow diagram.

Data synthesis was performed using a narrative approach, summarizing the findings of the included studies and identifying common themes and patterns. Meta-analysis was considered if there were sufficient studies with comparable designs and outcome measures. However, due to the heterogeneity of the included studies, a meta-analysis was not feasible.

The risk of bias in the included studies was assessed using the Cochrane Risk of Bias tool for randomized controlled trials. This assessment framework addresses several key dimensions, such as the validity of the randomization method, the implementation of blinding for trial participants and personnel, the blinding status of outcome assessors, the completeness and accuracy of outcome data, the presence of selective reporting of outcomes, and the potential for other biases. The quality of the included studies was assessed using the Mixed Methods Appraisal Tool.

7. RESULT

Study Selection

The search strategy yielded **322** articles, of which **279** remained after removing **43** duplicates. After screening titles and abstracts, **231** records were excluded. A total of **48** full-text reports were assessed for eligibility, and **26** were excluded for reasons such as wrong outcomes, nonrelevant populations, or not using randomized controlled or crossover designs. Finally, **22** studies met the inclusion criteria and were included in this review.

Studies investigated the effects of carbohydrate mouth rinsing on **cognitive performance** (e.g., attention, reaction time, decision-making) (Simmons-Mackie et al., 2016; Ogoh et al., 2014). Other studies examined the effects on **motor performance**, including outcomes like power, endurance, and speed (Cox & Clarke, 2014; Nantel, 1999; Xiang et al., 2020). The included studies varied in terms of participant characteristics (age, sex, training status), intervention protocols (type and concentration of carbohydrate solution, rinsing duration and timing), cognitive and motor performance measures (reaction time, accuracy, power output, endurance), and study designs (randomized controlled trials and crossover designs).

9. DISCUSSION

A primary finding of this review is the indication that carbohydrate mouth rinsing can serve as an ergogenic aid, which is consistent with previous research, with a particular focus on cognitive and motor performance. Specifically, studies have shown improvements in cognitive functions like attention, alertness, and decision-making, and motor skills like reaction time, agility, and power output. Hydration also plays a role in cognitive function, as studies indicate that changes in hydration status throughout the day can affect cognitive performance, which has implications for learning and cognitive tasks. This underscores the significance of maintaining optimal hydration levels for cognitive function, especially in tasks requiring sustained attention and focus.

Carbohydrate mouth rinsing has emerged as a promising ergogenic aid for enhancing both cognitive and motor performance in sports-related contexts. The existing body of evidence suggests that carbohydrate mouth rinsing can improve cognitive functions such as attention, alertness, and decision-making, as well as motor skills such as reaction time, agility, and power output. However, the mechanisms underlying these effects are not fully understood and may involve a combination of central and peripheral factors. While prior research has explored the link between physical activity and cognitive enhancement, the specific role of carbohydrate mouth rinsing adds a nuanced dimension to optimizing athletic performance. It is possible that the activation of sweet taste receptors in the oral cavity triggers a cascade of neural signals that stimulate brain regions involved in cognitive and motor control. The improvements observed in the water group, particularly in thirst and happiness ratings, visual attention, and visual search, highlight the potential benefits of even mild hydration on cognitive function.

Potential Mechanisms: The underlying mechanisms of carbohydrate mouth rinsing are multifaceted, and may involve both central and peripheral factors. Pérez-Castillo et al. in 2023 suggested the hypothesis that the activation of sweet taste receptors in the oral cavity triggers a cascade of neural signals that stimulate brain regions involved in cognitive and motor control.

This "cephalic phase response" may lead to increased arousal, motivation, and motor drive, resulting in improved performance.

The trigeminal nerve, which innervates the oral cavity, relays sensory information to the brainstem and cortex, potentially modulating neural circuits involved in attention, motor planning, and executive function. The role of water in maintaining cognitive health is often understated, despite evidence indicating that dehydration can impair cognitive functions. Even slight dehydration can lead to decreased cognitive performance. Therefore, maintaining adequate hydration is essential for optimizing cognitive abilities. The study by Paradisis et al. in 2017 found no effect of carbohydrate mouth rinse on 60-min running performance in females.

Additionally, carbohydrate mouth rinsing may influence peripheral metabolic processes by providing a readily available source of energy to working muscles.

Future Directions and Limitations of Existing Research

Carbohydrate mouth rinsing offers a practical and convenient strategy for athletes seeking to enhance both cognitive and motor performance. The simplicity and accessibility of this technique make it a valuable tool for athletes across various sports and training contexts. Despite the growing body of evidence supporting the benefits of carbohydrate mouth rinsing, further research is warranted to fully elucidate the underlying mechanisms and optimize its application. Future studies should investigate the effects of different carbohydrate solutions, rinsing durations, and individual factors on cognitive and motor performance outcomes. Although many products claim to improve performance, scientific evidence does not always support these claims. Athletes should consult with medical staff to personalize supplementation strategies based on scientific evidence. Congruence between supplement use and motivation is important for athletes' adherence and effectiveness. Additionally, exploring the potential synergistic effects of carbohydrate mouth rinsing with other ergogenic aids, such as caffeine or creatine, may offer further avenues for performance enhancement. Athletes must eat to stay in good health and avoid dietary practices that might compromise health. Athletes need to eat sufficient amounts of food from all food groups to obtain adequate energy to maintain body weight. By gaining a deeper understanding of the physiological and psychological mechanisms underlying carbohydrate mouth rinsing, sports scientists and practitioners can develop more targeted and effective strategies to optimize athletic performance. It is also important to consider the use of supplements in athletes based on current medical evidence to obtain benefits from them, avoid health and doping risks. Although many products claim to improve performance, scientific evidence does not always support these claims. While the existing body of research provides valuable insights into the effects of carbohydrate mouth rinsing on cognitive and motor performance, it is important to acknowledge certain limitations.

One limitation is the relatively small sample sizes used in some studies, which may limit the generalizability of the findings. Another limitation is the lack of standardization in the protocols used for carbohydrate mouth rinsing, such as the type and

concentration of carbohydrate solution, the duration of rinsing, and the timing of the intervention.

Additionally, more research is needed to fully elucidate the underlying mechanisms responsible for the effects of carbohydrate mouth rinsing on cognitive and motor performance. Further investigation may reduce inconsistencies within previous methodology that may be caused by cognitive performance assessments or dehydration methods. It is important to acknowledge the role of cognitive resilience, which explains the degree to which cognitive functions can withstand the effects of stress [22].The military has a high interest in improving cognitive resilience due to the prevalence of stress tactical athletes face [22]. In fact, a survey conducted by the U.S. Department of Defence found that 87% of military personnel report experiencing at least some stress as a result of their work [22]. Further research is warranted that investigates self-management strategies in athletes, as these may contribute to competition concentration and anxiety resolution.

10. REFERENCES

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