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The Effects of Oral and Mouthwash Carbohydrate Consumption on Glycemic Responses and Endurance Performance in Active boy students

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Abstract: The present study aimed to examine and compare the effects of two forms of carbohydrate intake—mouthwash and oral ingestion—on glycemic responses and endurance performance in active men. Eight physically active boy students aged 16 to 18 years, with at least three years of consistent training experience and a body mass index ranging from 19.5 to 25.5, voluntarily participated in the study. Each participant completed five separate test sessions in a sports physiology laboratory, with at least a three-day interval between each session.

In the first and second sessions, participants used 25 ml of a 6.4% glucose and fructose mouthwash solution, respectively, at five-minute intervals, rinsing for 5–10 seconds each time. In the third session, a placebo mouthwash was used under the same protocol. During the fourth session, participants orally consumed 0.6 g/kg body weight of a 6.4% glucose solution at 15-minute intervals throughout the exercise. In the fifth session, the same protocol was followed using a 6.4% fructose oral solution.

Results indicated that both carbohydrate mouthwash and oral ingestion methods effectively prevented declines in blood glucose during exercise, with no statistically significant difference between the two ($P > 0.05$). However, all carbohydrate protocols showed improved endurance time compared to the placebo ($P < 0.05$), although there was no significant difference between the different carbohydrate protocols in terms of time to exhaustion ($P > 0.05$). A significant difference was observed in the total distance covered across the five protocols ($P < 0.05$), with a notable difference between the glucose and fructose mouthwash groups. No significant differences were found in perceived exertion or heart rate between any of the carbohydrate protocols ($P > 0.05$).

Overall, the findings suggest that both carbohydrate mouthwashes and oral solutions can positively influence blood glucose levels, endurance time, and total distance covered during exercise. However, they appear to have minimal effects on heart rate and perceived exertion.

Keywords: carbohydrate mouthwash, sports endurance, ergogenic aid, glycemic index

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Introduction

In all eras, competitive athletes have always sought to improve their sports performance in various ways. Today, performing various training methods cannot guarantee the success of athletes because in addition to training, many factors can improve athletes' performance. These factors include nutritional carbohydrate solutions in enhancing endurance quality is undeniable.

Also, practical questions such as why carbohydrates are the most efficient fuel, what the optimal consumption schedule is, and what amount and type of carbohydrates should be consumed have been common research topics yielding different answers each time. From a practical point of view, the timing and amount of carbohydrate consumption are very important for carbohydrate ergogenics because excessive consumption at inappropriate times may cause digestive discomfort. Studies show that the peak rate of exogenous carbohydrate oxidation is about 1 g/min (8). The type of carbohydrate is an important factor in the oxidation rate. Research shows that glucose is metabolized more rapidly than fructose and galactose, which are oxidized more slowly when consumed alone, making them poorer energy sources (9).

The oxidation rates of maltose, sucrose, and glucose polymers (maltodextrin) are similar to that of glucose (about 1 g/min). However, the oxidation rates of glucose–fructose or maltodextrin–fructose mixtures are significantly higher than those of monosaccharides alone (10, 11). The commonality among these studies is the presence of fructose in the carbohydrate mixtures consumed by athletes, likely due to the distinct intestinal transport pathways for fructose, which affect the oxidation rate of mixed carbohydrates (9).

Many studies have examined carbohydrate consumption during exercise and its effect on performance; some report performance improvements (12, 13), while others observe no benefit (14, 15). This inconsistency intensified when Carter et al. found that a 1-hour intravenous glucose infusion, despite increasing plasma glucose availability, did not enhance 1-hour performance in athletes (16). They suggested that performance improvements from ingested carbohydrates may depend on non-metabolic factors.

Therefore, Carter et al. conducted the first study on carbohydrate mouthwashes, using a 6% maltodextrin solution for rinsing, which strategies, the use of modern sports equipment and clothing, medical interventions, and mastery of doping science, etc., which directly affect performance; therefore, having basic information about other sciences that affect sports performance is essential for coaches and athletes (1).

Endurance performance is influenced by various physiological factors, including maximum oxygen consumption (VO_2max), cardiac output, lactate threshold (LT), etc. Given the interconnected relationship between training structure and sports performance development tools and their effective role on the quality of final performance, the use of ergogenic aids as a factor improving the quality of performance is always a topic of interest to coaches and researchers. Ergogenics are tools that are mainly classified into five categories: mechanical, psychological, physiological, pharmacological and nutritional, and athletes often use them to increase energy, improve performance and recovery (2).

Carbohydrate is one of the dietary ergogenics that is consumed in various ways, including eating, drinking and intravenous injection, and has an impact on the quality of sports performance, such that carbohydrate consumption during sports activities for 45 minutes or more can increase endurance capacity or performance (3). Carbohydrate improves performance by maintaining blood glucose (4), sparing glycogen consumption (5), increasing glycogen synthesis during sports activities (6) and by affecting the central nervous system (3).

Many studies have been conducted on the ergogenic or acute effect of carbohydrates, and the use of carbohydrate mouthwashes is one of the topics that has been discussed recently. Swirling carbohydrate liquids around the mouth for 5 to 10 seconds and then spitting them out is the definition attributed to carbohydrate mouthwashes (7). A 6% to 6.4% glucose or hydrolyzed maltodextrin solution is the most common ingredient used in mouthwashes. Although it has been proven that mouthwash use leads to improved endurance performance, the role of drinking were instructed to avoid strenuous exercise and carbohydrate intake for four hours prior to each test.

Maximal Aerobic Power Assessment

During the first (familiarization) session, participants performed an incremental exercise test on a calibrated bicycle ergometer under controlled environmental conditions (24–25 °C, 45–50% relative humidity) to determine maximal aerobic power (W_{max}). After a 5-minute warm-up at 100 W, workload increased by 50 W every 2.5 minutes until heart rate reached 160 bpm. Thereafter, workload increments were reduced to 25 W every 2.5 minutes until volitional fatigue. Peak workload achieved was recorded as W_{max}.

Experimental Procedures

Participants reported to the laboratory at their scheduled times and rested quietly for at least 30 minutes to stabilize heart rate and acclimate to the laboratory environment (24–25 °C, 45–50% humidity). Once ready, they completed the designated mouthwash or ingestion protocol, and commenced the endurance test one minute after mouthwash application or solution ingestion.

Carbohydrate Protocols

1. **Protocol 1 (Glucose Mouthwash):** At exercise onset and every 5 minutes thereafter, participants swirled 25 mL of a 6.4% glucose solution in their mouths for 5–10 seconds before expectorating (18).
2. **Protocol 2 (Fructose Mouthwash):** Identical to Protocol 1, substituting a 6.4% fructose solution (18).
3. **Protocol 3 (Placebo Mouthwash):** Identical procedure using a non-caloric placebo solution (18).
4. **Protocol 4 (Glucose Ingestion):** At exercise onset and every 15 minutes,

improved performance by 2.8%. They attributed this enhancement to activation of oral carbohydrate receptors and their effects on brain function and central fatigue mechanisms (17). Given these contradictory findings, the present study compares the effects of oral ingestion versus mouthwash of glucose and fructose solutions on glycemic responses and endurance performance.

Research methodology

This quasi-experimental study evaluated glycemic responses, time to exhaustion, pedaling cadence, heart rate, and perceived exertion as dependent variables. The independent variables were two types of carbohydrate mouthwash (6.4% glucose and 6.4% fructose).

Participants

Active boy students aged 16–18 years (17.1 ± 0.8) who engaged in sports activities at least four times per week were recruited from local sports complexes in Amol via posted notices. Fifteen volunteers initially expressed interest; six were excluded based on their sports history or health screening. All remaining participants received detailed written and verbal explanations of study procedures and provided written informed consent. One participant subsequently withdrew for personal reasons, leaving eight subjects to complete the protocol.

Experimental Design

Participants attended eight sessions in the Exercise Physiology Laboratory at University of Shomal, with at least a three-day recovery interval between sessions. The first session served solely for orientation and familiarization. Sessions two through eight employed a fully randomized, crossover design in which each participant completed: (1) glucose mouthwash, (2) fructose mouthwash, (3) placebo mouthwash, (4) oral glucose solution ingestion, and (5) oral fructose solution ingestion—order counterbalanced across subjects. Participants post-exhaustion. Blood glucose concentrations were determined using a calibrated glucometer, and values were logged for subsequent analysis.

Statistical Analysis

Descriptive statistics (mean ± SD and standard error) characterized the data. Normality of each variable within protocols was assessed via the Shapiro–Wilk test. A one-way ANOVA evaluated differences among the five protocols for glycemic responses and time to exhaustion. Post hoc comparisons employed Bonferroni correction. Statistical analyses were performed in SPSS version 22, with significance set at $P < 0.05$.

Results

Glycemic responses

Changes in the glycemic index at the end of the five protocols were evaluated using a one-way ANOVA, which revealed a significant effect of protocol on post-exercise glycemic index ($P < 0.05$). Overall, all carbohydrate protocols differed significantly from the placebo, and both mouthwash and ingestion improved post-exercise blood glucose. Pairwise comparisons revealed no significant difference between glucose ingestion and fructose mouthwash ($P > 0.05$), while all other comparisons were significant ($P < 0.05$) . Figure 1 illustrates post-exercise blood glucose across sessions.

participants consumed 0.6 $g \cdot kg^{-1}$ body mass of a 6.4% glucose solution by mouth (19).

5. **Protocol 5 (Fructose Ingestion):** Same as Protocol 4, using a 6.4% fructose solution (19).

All carbohydrate solutions were prepared from 100% liquid glucose or fructose (Zar Fructose Company) by dissolving 64 g of sugar per liter of water. Mouthwash aliquots (25 mL) and ingestion volumes (adjusted to body mass) were dispensed into disposable cups. Mouthwash rinse duration was timed with a stopwatch.

Time-to-Exhaustion Test

Following each protocol application, participants began cycling at 40% of their predetermined W_{max}. Every 20 minutes, workload increased by 10% W_{max} until reaching 60% W_{max}; thereafter, participants cycled at constant workload until volitional exhaustion or until cadence dropped to 40 rpm. Throughout the test, participants were instructed to maintain a cadence of 80–100 rpm. Time to exhaustion was recorded as the point of test termination[(20)].

Glycemic Measurements

Capillary blood samples were collected at three time points in each session: pre-exercise, immediately at exhaustion, and five minutes

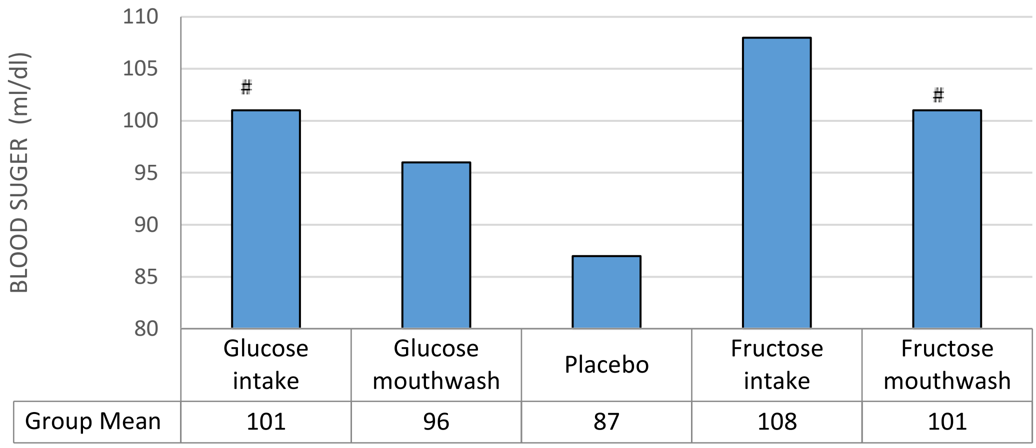

Figure 1- Blood Sugar After Activity

no significant

Time to exhaustion

Changes in time to exhaustion across the five protocols were examined with a one-way ANOVA, which showed no significant effect of carbohydrate method ($P > 0.05$). Bonferroni pairwise comparisons confirmed no differences among the four carbohydrate treatments, although each differed from placebo($P < 0.05$). Figure 2 illustrates time to exhaustion across the protocols.

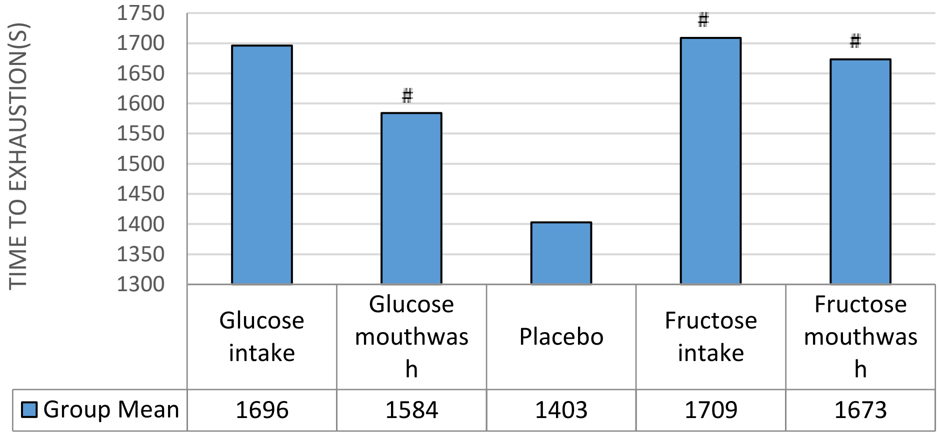

Figure 2- Time to exhaustion

no significant

Distance traveled

Changes in distance covered across the five protocols were analyzed by one-way ANOVA, revealing a significant effect of carbohydrate method ($P < 0.05$). Bonferroni pairwise comparisons showed significant differences among the four carbohydrate treatments. with a notable difference between fructose ingestion and glucose mouthwash ($P < 0.05$). Figure 3 depicts distance covered in each protocol.

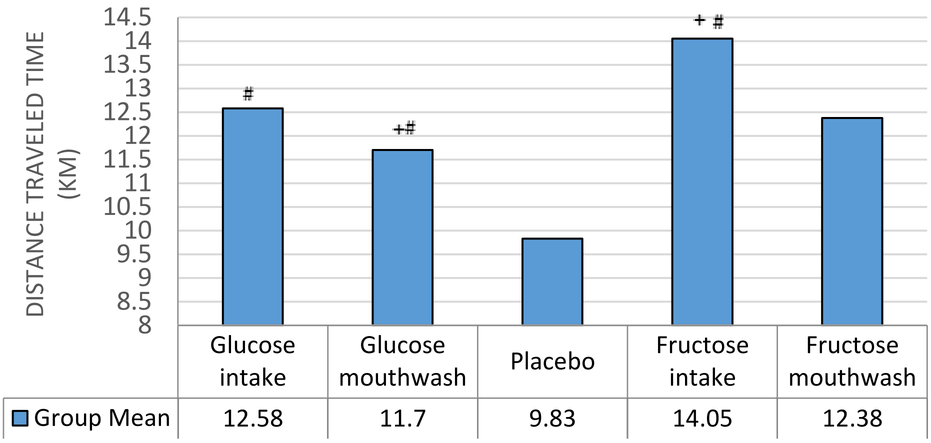

Figure3- Distance traveled

no significant

\+ significant

Rating of perceived exertion (RPE)

Changes in **rating of perceived exertion (RPE)** at the end of the five protocols were assessed using a one-way ANOVA, which found no significant effect of carbohydrate method on RPE ($P > 0.05$). Bonferroni pairwise comparisons showed no differences among the five protocols. indicating that neither ingestion nor mouthwash of carbohydrates affects RPE. Figure 4 illustrates changes in RPE across protocols.

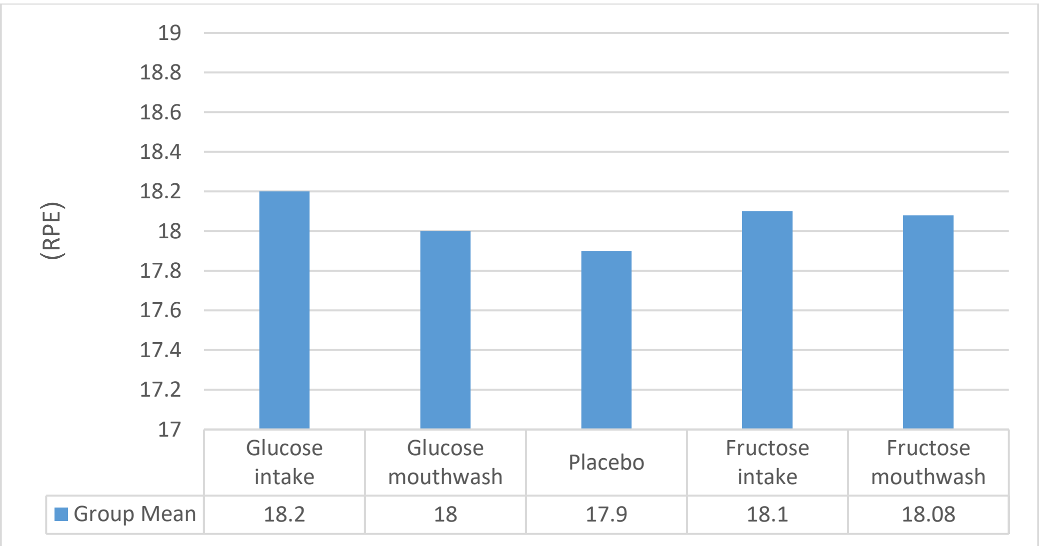

Figure 4- Rating of perceived exertion (RPE)

Heart rate

Changes in heart rate at the end of the five protocols were evaluated with a one-way ANOVA, which revealed no significant effect of carbohydrate method on heart rate (P > 0.05). Bonferroni pairwise comparisons confirmed no differences among the five protocols.indicating that neither ingestion nor mouthwash of carbohydrates significantly affects final heart rate(P > 0.05). Figure 5 illustrates heart rate changes across protocols.

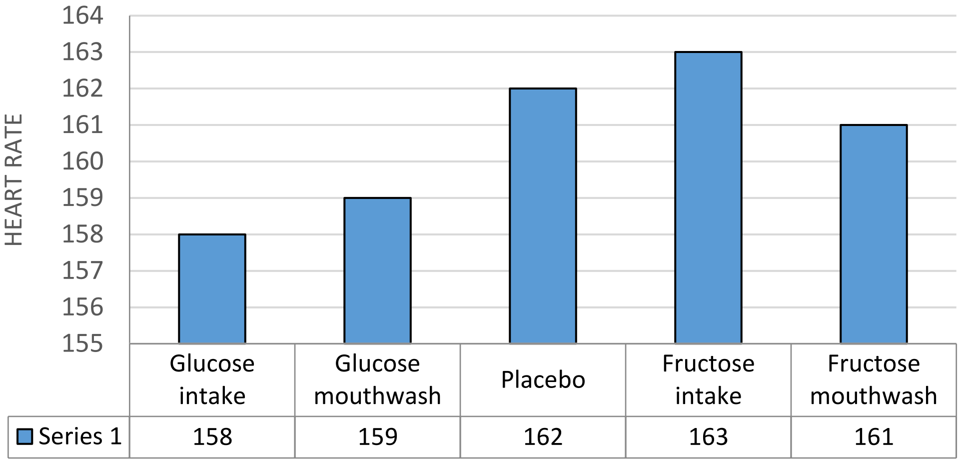

Figure5 - Heart rate

absorption through the oral mucosa, fructose mouthwashes unexpectedly improved performance and blood glucose regulation. This finding aligns with evidence suggesting that fructose absorption during exercise may surpass that of glucose (25). While the exact extent to which fructose delays glycogen depletion or enhances glycogen synthesis remains unclear, the present results suggest a potential advantage for fructose in endurance settings. This notion is consistent with the study by Coyle et al., where cyclists consuming a carbohydrate polymer drink experienced a 20–40% increase in blood glucose levels compared to a control group (26).

In terms of performance outcomes, such as time to exhaustion and distance covered, the study revealed significant improvements associated with both carbohydrate consumption and mouthwash use. This can be

Discussion and Conclusion

The findings of the present study indicate that carbohydrate supplementation, whether through direct consumption or as a mouthwash, exerts notable effects on glycemic regulation and endurance performance. While mouthwashes were shown to influence glycemic indices, their impact was not as pronounced as that of ingested carbohydrate solutions. One of the central mechanisms appears to be related to the modulation of glycogen utilization during exercise. Consuming glucose during physical activity was shown to reduce the reliance on muscle glycogen, a finding consistent with previous research demonstrating that carbohydrate intake can attenuate glycogen depletion during prolonged exercise (23, 24).

In contrast, carbohydrate-based mouthwashes, particularly those containing fructose, demonstrated unique benefits. Despite limited to fatigue without causing gastrointestinal discomfort, further supporting the endurance-enhancing potential of fructose (30).

While Olson (2004) emphasized the efficacy of glucose polymers over fructose for enhancing performance, particularly due to their faster absorption rates (31), the findings of the present study suggest that fructose may in fact be superior under certain exercise conditions. However, results from Denyers et al. (1989), who found slower fructose absorption compared to glucose and sucrose, are inconsistent with our findings, reinforcing the need for further research to elucidate the comparative absorption kinetics and metabolic effects of different carbohydrate types (32).

Conclusion

this study demonstrates that the direct consumption of carbohydrate solutions is more effective than mouthwashes in improving endurance performance. Specifically, fructose ingestion during exercise appears to maintain glycemic stability, reduce reliance on muscle glycogen, and potentially accelerate glycogen resynthesis. These effects collectively contribute to enhanced physical performance and delay in the onset of fatigue. Future studies should explore the underlying metabolic and neurophysiological mechanisms of fructose metabolism in the context of prolonged exercise to confirm and expand upon these promising findings.

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attributed to the prioritized utilization of carbohydrates—primarily glycogen and blood glucose—during moderate to high-intensity exercise (42). These results correspond with prior findings, such as those by Fars et al., who reported improved performance through repeated carbohydrate mouthwash use during submaximal cycling (18), and Rouleau et al., who observed increased endurance with carbohydrate-electrolyte mouthwash without changes in glycemic index (27). Furthermore, the enhancement in performance following fructose ingestion observed in this study is in line with Khanna et al., who demonstrated that carbohydrate-electrolyte intake during training significantly improved endurance time and physiological responses in elite athletes (28).

However, the present findings diverge from Carter et al., who found no significant effect of intravenous carbohydrate infusion on performance time despite significant changes in glycemic indices (16). Our data suggest that improvements in exercise performance are indeed strongly linked to the maintenance of blood glucose levels, underscoring the importance of oral carbohydrate delivery during prolonged physical activity.

Regarding physiological parameters such as heart rate and perceived exertion, no significant differences were observed across conditions. These results suggest that while carbohydrate intake may modulate metabolic substrates, it does not substantially alter cardiovascular responses or perceived fatigue once maximal effort is reached. This is consistent with findings by Grovokan et al. (1989) and Harg-Verz et al. (1985), who reported stable cardiovascular outcomes despite changes in carbohydrate metabolism. Notably, Harg-Verz observed that fructose contributed more effectively than glucose to glycogen resynthesis during recovery and may be preferential for hepatic carbohydrate storage without initiating early muscle glycogenolysis (29). Grovokan et al. found that pre-exercise fructose intake extended time

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