Title: **Effects of Carbohydrate Mouth Rinse on Psychophysiological Responses, Kinematic Variables and Technical Actions during Small-sided Soccer Games**

Running Title: The Effect of Carbohydrate Mouth Rinse on Soccer Small-sided Soccer Games

Erdinc Gorgulu[a], Yusuf Soylu[a], Ersan Arslan[a], Bulent Kilit[a], Neil D. Clarke[b]

[a] Faculty of Sport Sciences, Tokat Gaziosmanpasa University, Tokat 60250, Türkiye

[b] Research Centre for Life and Sport Science (CLaSS), School of Health Sciences, Birmingham City University, Birmingham, UK

ORCID: Erdinc Gorgulu- 0009-0005-2398-3366
Yusuf Soylu- 0000-0003-0609-0601
Ersan Arslan- 0000-0002-2933-6937
Bulent Kilit- 0000-0002-9061-0691
Neil Clarke- 0000-0002-1909-329X

E-mail: gorguluerdinc@gmail.com
yusuf.soylu@gop.edu.tr
ersan.arslan@gop.edu.tr
bulent.kilit@gop.edu.tr
neil.clarke@bcu.ac.uk

Correspondence: Neil Clarke

Research Centre for Life and Sport Science (CLaSS), School of Health Sciences, Birmingham City University, Birmingham B42 2LR, UK

Abstract

This study investigated the effects of carbohydrate mouth rinsing (CHO_{MR}) on various psychophysiological, kinematic, and technical actions during 4-a-side small-sided soccer games (SSGs). In a randomized, crossover, double-blind design, 16 young male soccer players (age: 15 ± 1 years; height: 172.6 ± 7.0 cm; body mass: 57.8 ± 7.9 kg) participated in two 4-a-side SSGs separated by one week following either CHO_{MR} or placebo (PLA). During each SSGs, heart rate (HR_{mean}, %HR, and HR_{max}), rating of perceived exertion (RPE), enjoyment, visual analogue scale (VAS) to perceived mental fatigue, mood states, total distance (TD), high-speed running distance (HSRD), average metabolic power (AMP), high metabolic load distance (HMLD), sprint distance (SD), acceleration (ACC), deceleration (DEC), and technical actions (e.g., passing, tackling, shooting, and interceptions) were assessed. Compared with PLA, CHO_{MR} resulted in significantly higher RPE ($p = 0.025$, $g = 0.86$) and significantly lower VAS scores ($p = 0.010$, $g = -0.71$). In addition, the CHO_{MR} condition showed significantly higher values for interceptions, successful tackles, unsuccessful tackles, unsuccessful shots, and goals ($p < 0.05$, $g = 0.96$-2.02), whereas block values were significantly higher in the PLA condition. There were no statistically significant differences in HR_{mean}, %HR, HR_{max}, enjoyment, TD, HSRD, AMP, HMLD, SD, ACC, DEC, successful passes, unsuccessful passes, successful shots, or mood states between the conditions ($p > 0.05$). The current study findings suggest that CHO_{MR} may enhance selected technical actions and lower VAS scores during 4-a-side SSGs, although it was also associated with higher RPE and did not alter the kinematic responses. In conclusion, CHO_{MR} was associated with higher RPE, lower mental fatigue, and selective improvements in technical actions, with no significant effects on kinematic variables or HR.

Keywords: Game-based training, Carbohydrate mouth rinse, Game performance, Psychophysiological, Performance analysis

Introduction

Soccer is a team sport that imposes physiological demands on players, requiring a combination of intermittent aerobic and anaerobic activities during matches [1]. Soccer players typically cover between 10 and 14 km, with an average game intensity ranging from 80% to 90% of the players' maximum heart rate (HR_{max}) [2]. Consequently, coaches frequently employ high-intensity interval training or game-based training methods integrated with high-intensity activities such as jumps, sprints, and change of direction [3] to familiarize players with internal and external loads [4]. Small-sided soccer games (SSGs) are frequently used because they replicate many of the technical, tactical, and physiological demands of match play [5]. In particular, SSGs can be manipulated through changes in player numbers, game rules, and individual or collective technical-tactical demands to target specific training objectives [3]. Moreover, SSGs require players to perform repeated high-intensity actions, including sprinting and changes of direction, while making rapid decisions under spatial and temporal constraints [6]. Recent evidence [7] suggests that manipulating player numbers in SSGs influences mood responses and technical actions, with the 4-a-side format providing a balanced environment for evaluating technical and tactical performance.

During prolonged high-intensity exercise, such as a soccer match, Mohr et al. [8] highlighted that carbohydrate (CHO) is a key substrate for energy provision to both skeletal muscle and the central nervous system (CNS), helping to attenuate fatigue and declines in physical and technical performance. Furthermore, Cermak and van Loon [9] reported that CHO ingestion and mouth rinsing stimulate regions of the CNS associated with reward and motor control, while CHO ingestion also helps maintain blood glucose concentrations and preserve muscle glycogen during prolonged exercise. As an alternative to CHO ingestion, CHO_{MR} involves rinsing a carbohydrate solution in the mouth for approximately 10 seconds before expectoration and has been proposed as a nutritional strategy to enhance exercise performance [10].

Although CHO ingestion has been shown to enhance cognitive function and skill performance in soccer [11], the ergogenic effects of CHO_{MR} remain less clear. Previous studies have reported mixed findings, with some demonstrating improvements in sprint performance, endurance, and power output [12-15] whereas others have observed no benefits for Yo-Yo test performance or sprinting ability [16,17]. Furthermore, recent evidence indicates that while CHO_{MR} does not influence locomotor performance across varying intensities, it significantly modulates the rating of perceived exertion (RPE) and mental effort during continuous play, as well as enjoyment during intermittent protocols [18]. Despite growing interest in CHO_{MR} as an ergogenic aid, its effects on technical performance and psychophysiological responses during SSGs remain unclear. This is particularly important given that SSGs require players to repeatedly execute technical skills under substantial physical and cognitive demands. Therefore, the aim of this study was to investigate the effects of CHO_{MR} on psychophysiological responses, kinematic variables, and technical actions during 4-a-side SSGs.

Methods

Experimental Approach

The current study used a double-blind, randomized, and counterbalanced crossover design to compare the effects of CHO_{MR} and PLA on psychophysiological responses, kinematic variables, and technical actions during 4-a-side SSGs. The study intervention programs were conducted at the same time of day during separate training sessions in-season to avoid various chronobiological factors. The average temperature was 30°C, with a relative humidity of 35% for the baseline assessments. The second assessment recorded an average temperature of 31 °C with a 35% relative humidity. Before the SSGs sessions, anthropometric characteristics were assessed. The players also completed the Yo-Yo Intermittent Recovery Test level 1 (YYIRTL-1) [19]. The participants included four defenders, four midfielders, and four forwards. All participants had a minimum of four years of structured soccer training. Positional distribution was considered during group balancing alongside coach assessment and Yo-Yo test scores equally distributed players among SSGs teams based on maximal oxygen uptake (VO_{2max}). Of the 16 participants, eight were randomly assigned to begin with the CHOMR condition and eight with the PLA condition, with all players completing both conditions in a counterbalanced order. Prior to the experimental trials, all participants completed a familiarization session consisting of one full 4-a-side SSG bout (4 min) under neutral conditions (no mouth rinse) on the same artificial pitch and at the same time of day as the experimental sessions. This session served to acquaint participants with the SSG format, pitch dimensions, mini-goal setup, and data collection procedures, thereby minimizing any learning effects during the experimental trials. The order of different SSGs (CHO_{MR} or PLA) and solutions (mouth rinse or PLA) was determined by randomization (www.randomizer.org). Each SSGs was separated by at least one week to minimize the potential negative impact of physical and psychological fatigue on game performance. Continuous monitoring and recording of the HR, RPE, enjoyment and mental fatigue (MF), kinematic responses, and technical actions were conducted during all SSGs. Mood responses were assessed before and after each SSGs. UEFA A-licensed strength and conditioning coaches consistently implemented all SSGs sessions on an artificial soccer pitch with verbal coach encouragement.

Participants

A priori sample size calculation was performed using G*Power software (version 3.1.9.7, University of Düsseldorf, Germany). Based on the effect sizes reported in previous CHO_{MR} studies examining exercise performance and psychophysiological responses, a moderate effect size (f = 0.25) was assumed [19].

Using a repeated-measures ANOVA design (within-subject), with an alpha level of 0.05 and a statistical power ($1 - \beta$) of 0.80, the required minimum sample size was calculated to be 14 participants. Therefore, the inclusion of 16 participants in the present study was considered sufficient to detect meaningful differences between conditions, even considering the relatively high variability commonly reported in technical actions during SSGs [20,21]. Sixteen young male soccer players (age: 15 ± 1 years; height: 172.6 ± 7.0 cm; weight: 57.8 ± 7.9 kg) participated in this study (Table 1). The inclusion criteria were as follows: (1) regular training five days a week and playing one competition weekly at the national level; (2) participation in SSGs in previous training experience during soccer practice; (3) involvement of male youth soccer players aged 15–16 years; (4) participation in all data collection during the study; and (5) abstaining from using drugs or stimulating drinks and maintaining good health without injuries or illnesses to avoid health-related bias. Participants were excluded if they: (1) reported any musculoskeletal injury or illness prior to or during the study that could affect performance; (2) consumed caffeine, nutritional supplements, or any stimulant within 24 hours before a test session; (3) were outside the 15–16 age range; (4) failed to replicate the standardized pre-exercise meal before the second trial; or (5) presented a urine colour score ≥4 upon arrival without reaching adequate hydration status after fluid provision. The players and their parents were informed of the study procedures before the intervention. Written informed consent was obtained from the parents or legal guardians, and assent was obtained from the players prior to their participation. The Ethics Committee of ***** ******** University approved the study as ethically appropriate, and all procedures were performed per the Declaration of Helsinki (211840-13.29).

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Measurements

Anthropometric: Tanita BC-418MA is a body composition analyzer used to measure the body composition of athletes. It is designed to provide detailed body composition measurements, including weight, body fat percentage, and muscle mass measurements. The BC-418MA (Tokyo, Japan) uses multiple frequencies (ranging from 1 to 50 kHz) to measure body composition, enabling a more accurate assessment of various body tissues.

External and Internal Load: External and internal load data were collected during the SSG sessions to quantify locomotor and physiological demands. External load was measured using a 10-Hz Global Navigation Satellite System (GNSS) device integrated with a 100-Hz triaxial accelerometer (STATSports Apex, Northern Ireland). GNSS technology enables the tracking of multiple satellite systems (e.g., GPS and GLONASS) and provides precise positional data. The use of GNSS devices is well established in team sports, with previous studies demonstrating acceptable validity and reliability in measuring total distance, speed, and movement patterns [22]. The devices were activated approximately 15 minutes before data collection to ensure optimal satellite signal acquisition. The signal quality ranged between 16 and 21 connected satellites during the sessions. All data were downloaded and processed using the manufacturer's software (Apex version 3.0.02011). The external load variables analyzed included total distance (TD, m), high-speed running distance (HSRD, m), sprint distance (SD, m), average metabolic power (AMP, $W \cdot kg^{-1}$), high metabolic load distance (HMLD, m), number of accelerations (ACC), and number of decelerations (DEC). The total distance (TD) was defined as the TD covered during each SSG bout. High-speed running distance (HSRD) was defined as the distance covered at speeds between 19.8 and 25.2 $km \cdot h^{-1}$, while sprint distance (SD) corresponded to speeds exceeding 25.2 $km \cdot h^{-1}$, in line with commonly used thresholds in the literature [23]. AMP was calculated based on the instantaneous energy cost of running derived from speed and acceleration data, according to the model and further developed by Osgnach et al. [24]. HMLD was defined as the TD covered when the metabolic power exceeded 25.5 $W \cdot kg^{-1}$ and included high-speed running, as well as accelerations and decelerations above ±3 $m \cdot s^{-2}$. ACC and DEC were defined as the number of efforts exceeding +3 $m \cdot s^{-2}$ and below −3 $m \cdot s^{-2}$, respectively, representing high-intensity changes in the velocity. All thresholds were selected based on commonly adopted standards to ensure comparability with previous studies [23]. Internal load was continuously assessed during each SSG session using heart rate monitors (Polar H10, Polar Inc., Kempele, Finland). The analyzed variables included the maximum HR (HR_{max}), mean HR (HR_{mean}), and percentage of maximum HR ($\%HR_{max}$).

Perceived Exertion: The perceived exertion for each SSGs session was calculated using each player's RPE (6-20) [25] during the SSGs. The players were asked, "*How intense was your session?*". This subjective rating is based on the overall feeling of exertion, breathing, HR, muscle fatigue, and other physical sensations experienced during the activity.

Mood: The Brunel Mood of Scale (BRUMS) was developed by Terry et al. [26] to determine mood levels and was adapted into Turkish by Soylu et al. [27] for young and adult athletes. It consists of 24 items and six (6) sub-dimensions (anger, confusion, depression, fatigue, tension, and vitality). The depression subscale of the scale is an indicator of depressive mood, rather than clinical depression. The participants were asked the question "*How do you feel right now?*" before and after the SSGs and were asked to tick a number between 0 and 4 *(0 = not at all, 1 = a little, 2 = moderately, 3 = quite a bit, 4 = extremely)*.

Enjoyment: The exercise enjoyment scale was created by Raedeke [28] from the 8-item short form of the 18-item Physical Activity Enjoyment Scale. The Turkish version was adapted by Soylu et al. [29] for young and adult athletes, respectively. During the SSGs, the players were asked, "*How do you feel while exercising?*". This scale includes eight items and a single subdimension that assesses the level of enjoyment of exercise. The scale uses a 7-point bipolar scale ranging from 1 (strongly disagree) to 7 (strongly agree).

Mental Fatigue: Perceived mental fatigue was assessed using a Visual Analogue Scale (VAS), a validated tool for measuring MF in SSGs [30]. The VAS is a subjective rating scale that assesses an individual's perception or experience of a particular construct such as fatigue. To measure MF using the VAS, individuals are typically presented with a horizontal line or scale, with one end zero (0) representing "*no fatigue*" or "*not tired at all*, " and the other end one hundred (100) representing "*extremely fatigued*" or "*very tired*." The participants were then asked to place a mark on the line indicating their perceived level of MF.

Technical Actions: SSGs were captured using a high-quality Canon HF R806 video camera (Canon, Tokyo, Japan) for the technical analysis of the SSGs. Technical activities were evaluated by an expert and highly qualified match and performance analysis coach for all SSGs using the Metrica Sports Video Analysis software (Amsterdam, The Netherlands). Technical actions were categorized as successful passes (SCP), unsuccessful passes (UNSCP), interceptions (INT), successful tackles (SCTAC), unsuccessful tackles (UNSCTAC), blocks (BLCK), successful shots (SCSH), and unsuccessful shots (UNSCSH). All actions were assessed by two members of the research team who were certified performance analysis coaches. Technical actions were coded using a predefined observational protocol based on previously published notation analysis methods in soccer [30]. Each technical action was operationally defined prior to coding as follows: a successful pass was recorded when ball possession was maintained by the same team following a deliberate distribution; an unsuccessful pass when an attempted distribution resulted in loss of possession through misdirection or interception by the opposition; an interception when a player proactively cut off a pass intended for an opposing player and gained possession; a successful tackle when a legal challenge dispossessed the ball carrier while retaining possession for the defending team; an unsuccessful tackle when the challenge failed to dispossess the opponent or resulted in a foul; a block when a defensive action placed the body in the trajectory of a shot or decisive pass to prevent it reaching its target; a successful shot when the attempt was directed on target regardless of outcome (saved or scored); and an unsuccessful shot when the attempt missed the target entirely or was blocked before reaching the goalmouth. Goals were recorded as a separate category. Prior to the main analysis, both analysts completed a calibration phase requiring ≥80% point-by-point agreement on footage from a pilot session not included in the study data. All match footage was coded independently by each analyst, and any discrepancies were resolved through consensus review of the relevant video clip.

Procedure: To minimize the influence of pre-exercise nutrition on CHO_{MR} responses, participants maintained similar dietary habits before each session. They avoided caffeine and nutritional supplements for 24 hours prior to testing and refrained from strenuous exercise during this period. Players consumed their last standardized meal 2-3 h before the sessions and replicated this meal before the second trial, ensuring comparable nutritional status and reducing the potential confounding effects of recent CHO intake. The SSGs sessions comprised 4-a-side formats of 25 × 32 m (per player 100 m^2) with a mini-goal (1 × 1.6 m). Both SSGs had the same duration and lasted for six four-minute bouts, with two minutes of passive recovery between games. The number of players and bout duration are known to influence technical performance and behavioral responses during SSGs, supporting the rationale for the 4-a-side format with repeated 4-min bouts used in this study [7]. The players were not given tactical instructions or specific rules throughout the games, and numerous balls were placed near the pitch to ensure a continuous game. Psychophysiological responses, such as HR, RPE, VAS, enjoyment, kinematic variables, and technical actions, were recorded during the game. The BRUMS was assessed before and after the two SSGs sessions (Figure 1). The experimental treatment consisted of a 6.4% maltodextrin-based solution (Protein Ocean, Türkiye), whereas the PLA condition utilized distilled water. To ensure the integrity of the double-blind design, both solutions were matched for sensory characteristics (flavour, colour, and viscosity) by incorporating 50 mg of steviol glycosides as a non-caloric sweetener (Fibrelle, Türkiye). During each trial, a 25-ml bolus was administered in pre-weighed, identical opaque cups. The participants were instructed to swirl the solution in their oral cavity for ten seconds before expectoration. This procedure was performed 30 s before the commencement of each bout, allowing sufficient time for the participants to return to their designated positions. All participants and investigators, excluding the individual responsible for solution preparation, were blinded to the treatment order. The indistinguishable nature of the solutions was pre-tested to confirm that investigators and participants could not differentiate between the CHO and PLA treatments. Although Peak Height Velocity (PHV) assessment was not conducted, biological maturation was estimated using the Mirwald maturity offset equation [31] from each participant's age, height, sitting height, and body mass measured during data collection. Estimated maturity offset values ranged from +0.92 to +3.53 years post-PHV (mean: +2.20 ± 0.67 years), indicating all participants were in the post-PHV phase and had passed the period of most rapid growth-related physiological change, reducing the likelihood of maturation as a significant confounding variable in this sample. As an alternative to invasive glycogen quantification requiring muscle biopsy procedures inappropriate for a youth population, participants replicated their habitual dietary intake in the 24 hours before each trial, focusing on carbohydrate-containing meals, and consumed the standardised pre-exercise meal 2–3 hours before each session. Dietary compliance was verified verbally; no exclusions occurred.

*** INSERT FIGURE 1***

Data Analysis

The arithmetic mean and standard deviation were determined to analyze the descriptive information of the research group. The normality of the data was confirmed using the Shapiro-Wilk test ($p > 0.05$ for all variables). A paired t-test was used to determine the differences in psychophysiological responses, kinematic variables, and technical actions between the CHO_{MR} and PLA groups. Additionally, a 95% Confidence Interval (95% CI) was calculated to determine the difference between the mean values of each estimated variable. Inter-observer reliability for the technical action analysis was assessed using intraclass correlation coefficients (ICC) between the two analysts, calculated separately for the CHO_{MR} and PLA conditions. Reliability was interpreted according to the recommended ICC thresholds. Repeated-measures ANOVA was used to assess mood states before and after CHO_{MR} versus PLA. The CV% measured the inter-individual variability in physiological responses, kinematic variables, and technical actions between CHO_{MR} and PLA. Hedges' g effect sizes were calculated for each of the dependent variables. The thresholds for effect size statistics were as follows: < 0.2, trivial; 0.2-0.49 small; 0.5-0.79 moderate; and > 0.8 large [32]. Statistical analyses were performed using SPSS 26.0 (SPSS Inc., Chicago, IL, USA), and the significance level was set at $p \leq 0.05$. Due to the interdependence and multicollinearity of physiological responses, kinematic variables, and technical actions in small-sided soccer games, using an alpha-level adjustment like a Bonferroni correction was methodologically inappropriate. Progressive sports medicine statistics suggest such corrections overly penalize dependent variables, increasing Type II error risk and potentially masking meaningful findings [32]. Thus, to assess practical significance between conditions, emphasis was on calculating and interpreting Hedges'g effect sizes.

Results

Inter-observer reliability for the technical action analysis was assessed separately for the CHO_{MR} and PLA conditions using intraclass correlation coefficients (ICC). The analysis demonstrated good to excellent agreement between the two analysts under both conditions. The ICC values ranged from 0.72 to 0.99 across all variables, with most metrics (e.g., SCP and goals) demonstrating excellent reliability (ICC > 0.90), while more subjective actions, such as UNSCTAC, showed slightly lower but acceptable reliability.

*** INSERT FIGURE 2***

CHO_{MR} induced significantly higher psychophysiological responses (Figure 2) regarding RPE (p = 0.025, g = 0.86 [large effect]) than those induced by the PLA condition. In contrast, perceived MF scores were significantly reduced ($p = 0.010$, $g = -0.71$ [moderate effect]) compared with those in the PLA condition. There were no significant differences in HR_{mean}, %HR, HR_{max}, or enjoyment between the CHO_{MR} and PLA conditions. No significant interactions were found for TD, HSRD, AMP, HMLD, SD, ACC, or DEC ($p \geq 0.05$; Table 2).

*** INSERT TABLE 2***

*** INSERT FIGURE 3***

Figure 3 shows that the repeated-measures ANOVA tested the interactions between time (two assessment periods) and group (CHO_{MR} and PLA). No significant interactions were found for anger ($F = 3.641$; $p = 0.066$; $\eta_p^2 = 0.108$), confusion ($F = 0.734$; $p = 0.398$; $\eta_p^2 = 0.024$), depression ($F = 4.170$; $p = 0.050$; $\eta_p^2 = 0.122$), fatigue ($F = 0.552$; $p = 0.463$; $\eta_p^2 = 0.018$), tension ($F = 0.435$; $p = 0.515$; $\eta_p^2 = 0.014$), vigor ($F = 1.964$; $p = 0.171$; $\eta_p^2 = 0.061$).

*** INSERT TABLE 3***

Table 3 shows the technical actions under the CHO_{MR} and PLA conditions in this study. The CHO_{MR} condition showed significantly higher values for INT, SCTAC, UNSCTAC, UNSCSH, and goals than the PLA condition ($p \leq 0.05$, $g = 0.96$-2.02 [large effects]). A significant difference was also observed for BLCK, with higher values in the PLA condition than in the CHO_{MR} condition ($p \leq 0.05$, $g = 0.96$). No significant differences were observed between the CHO_{MR} and PLA conditions for SCP, UNSCP, or SCSH ($p \geq 0.05$).

Discussion

This study aimed to compare the effects of CHO_{MR} and PLA on the psychophysiological responses, kinematic variables, and technical actions of young male soccer players in 4-a-side SSGs. The current findings demonstrated that the CHO_{MR} condition significantly increased the players' RPE while concurrently decreasing their perceived mental fatigue. While this simultaneous rise in perceived exertion and drop in MF may initially appear contradictory, it aligns well with the psychobiological model of endurance performance. Regarding technical performance, actions such as INT, SCTAC, UNSCTAC, UNSCSH, and goals were significantly higher in the CHO_{MR} condition than in the PLA condition, whereas BLCK values were significantly higher under PLA. The two conditions showed no significant differences in HR_{mean}, %HR, HR_{max}, enjoyment, mood state, or the frequencies of SCSH, SCP, and UNSCP. To the best of our knowledge, this is the first study to evaluate these combined effects during soccer-specific SSGs.

A novel finding of this study was the improvement in selected technical actions following CHO_{MR}. Compared with PLA, players performed more interceptions, tackles, unsuccessful shots, and goals. In contrast, passing actions and successful shots remained unchanged. Given the absence of previous studies examining CHO_{MR} during soccer-specific SSG technical performance, direct comparisons are limited. However, the present findings suggest that CHO_{MR} may have influenced involvement in reactive defensive actions rather than controlled technical execution. Similar observations have been reported in fencing, where CHO_{MR} improved lunge accuracy between bouts [33], whereas no effects have been observed for kicking performance [34] or boxing reaction time [35]. Although theoretical models suggest that oral carbohydrate sensing may stimulate brain regions associated with motivation, reward processing, and attentional regulation [36,37], these explanations should be interpreted cautiously because cognitive function and neural activity were not directly assessed. An alternative explanation is that CHO_{MR} increased player engagement during SSGs, leading to greater participation in defensive actions.

In the present study CHO_{MR} elicited higher RPE despite no differences in HR_{mean}, %HR, HR_{max}, or total distance covered. Similar findings have been reported in repeated sprint [38], cycling [39], and high-intensity exercise protocols [40], while Nehme et al. [17] observed increased RPE following CHO_{MR} during intermittent running in soccer players. In contrast, no significant changes in RPE have been reported during running, jumping [41], repeated sprint exercise [12], or the Loughborough Intermittent Shuttle Test [42]. Collectively, these findings suggest that CHO_{MR} may influence subjective perceptions of effort without necessarily altering cardiovascular strain or locomotor output. Given that RPE is commonly used alongside HR to assess internal load in soccer [43], the present findings may reflect a dissociation between perceptual and physiological responses during SSGs.

No significant differences were observed in kinematic variables between conditions. This finding agrees with previous soccer-specific studies showing no improvement in YYIRTL-1 performance [17] or repeated sprint performance [16] following CHO_{MR}. Similar findings have been reported in older adults during walking exercise [44] and across various endurance and high-intensity exercise protocols [45,46]. Although Rollo et al. [42] reported improvements in intermittent running performance, the overall evidence suggests that CHO_{MR} exerts a greater influence on perceptual responses than on external workload measures. It is possible that the short duration of the SSGs and the spatial constraints of 4-a-side SSGs limited the opportunity for changes in locomotor performance to emerge.

In addition, there were no significant differences were observed in enjoyment or mood state between conditions. This finding is consistent with previous research reporting limited effects of CHO_{MR} on pleasure, enjoyment, and mood responses during exercise [42,45-48]. Furthermore, Miller et al. [49] demonstrated that improvements in executive functioning following glucose ingestion occurred independently of perceived fatigue and affective responses. Collectively, the available evidence suggests that any ergogenic effects of CHO_{MR} are unlikely to be mediated through changes in enjoyment or mood state.

The reduction in perceived mental fatigue following CHO_{MR} is noteworthy given the recognised negative influence of mental fatigue on physical, technical, and cognitive aspects of soccer performance. Previous studies have suggested that CHO_{MR} may attenuate perceptions of fatigue and mitigate some of the detrimental effects of mentally demanding tasks [50,51]. Although the precise mechanisms remain unclear, stimulation of oral carbohydrate receptors may influence reward-related neural pathways associated with motivation and effort regulation [11]. However, mental fatigue is a multifactorial construct influenced by sleep, recovery status, motivation, and individual characteristics [52], and these factors should be considered when interpreting the present findings. The increase in RPE alongside reduced mental fatigue may initially appear contradictory. However, RPE and mental fatigue likely represent distinct perceptual constructs. RPE reflects the conscious perception of effort during exercise, whereas mental fatigue reflects a broader cognitive state. Previous work has suggested that CHO_{MR} may influence central processes related to motivation and effort regulation through oral carbohydrate sensing [42]. Nevertheless, the underlying mechanisms remain speculative because no direct neurophysiological measurements were obtained. Furthermore, the relatively warm environmental conditions (30–31°C; ~35% relative humidity) may have elevated perceptions of effort independent of external workload [53,54]. Therefore, CHO_{MR} may have influenced perceptual responses without producing parallel changes in cardiovascular or locomotor variables.

The strengths of this study include its ecologically valid design, the use of soccer-specific SSGs, and the simultaneous assessment of physiological, perceptual, technical, and kinematic outcomes. However, several limitations should be acknowledged. The primary limitations of the study are the small sample size (n = 16) and the focus on adolescent male players (~15 years old). Since adolescent athletes have distinct biological, physiological, and tactical profiles compared to adults [55], findings cannot be generalized to senior squads, elite professionals, or females. Gender-specific physiological differences and senior soccer's cognitive-tactical demands mean future CHO_{MR} research must target these groups for broader validity. Furthermore, the high coefficient of variation (CV%) for key technical variables (e.g., goals, INT, SCTAC) reflects the variable and chaotic nature of tactical behavior in SSGs. Unlike linear running protocols, technical event frequency fluctuates significantly between bouts due to unpredictable interactions and spatial constraints. This variability is not measurement error, as shown by robust inter-observer reliability (ICC) scores, but reflects the drill's ecological validity. Thus, this variability requires careful interpretation of technical data and emphasizes the need for extended, multi-session familiarization protocols in future designs to stabilize baseline data. The success of the blinding procedure was not formally assessed through a manipulation check, which should be considered when interpreting these findings. Future research should increase or decrease the number of players and game duration for SSGs and conduct extended serial rinsing protocols to evaluate CHO_{MR}'s influence of CHO_{MR} on soccer-specific game-based skills.

Conclusion

The current findings demonstrated that CHO_{MR} conditions significantly increased the players' RPE while concurrently decreasing their perceived MF (assessed via VAS). While this simultaneous rise in exertion and drop in fatigue may initially appear contradictory, it aligns seamlessly with the psychobiological model of endurance performance. The observed dissociation between internal perceptual load and MF suggests that CHO-related oral signalling effectively delays the sensation of mental exhaustion. Consequently, athletes operating with mitigated MF possess a higher tolerance for physical exertion. This empowers them to consciously elevate their central motor drive to sustain high-intensity efforts, particularly during the chaotic, contact-heavy, and pressure-rich environment of SSGs. This neurocognitive mechanism allows players to push their physical boundaries harder, resulting in a higher overall RPE, even if the macroscopic external kinematic output (e.g., TD covered) remains limited due to the spatial constraints of the 4-a-side SSGs.

Author Contributions

Conceptualization was performed by E.G., and Y.S., Methodology by E.G., Y.S., E.A., and B.K. Data analyses by Y.S., and E.A. Writing–original draft preparation-by E.G., Y.S., and N.C. Writing – review and editing-by Y.S., E.A., B.K. and N.C. All the authors approved the final version of the manuscript.

Acknowledgments

We thank all the participants for their selfless participation in the study.

Funding

No external sources of funding were used to conduct or prepare this study.

Consent

Participants provided written informed consent prior to initiating the study procedures.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability Statement

All data and materials are available at https://doi.org/10.5281/zenodo.14249932

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Figure 1. Crossover Study Design

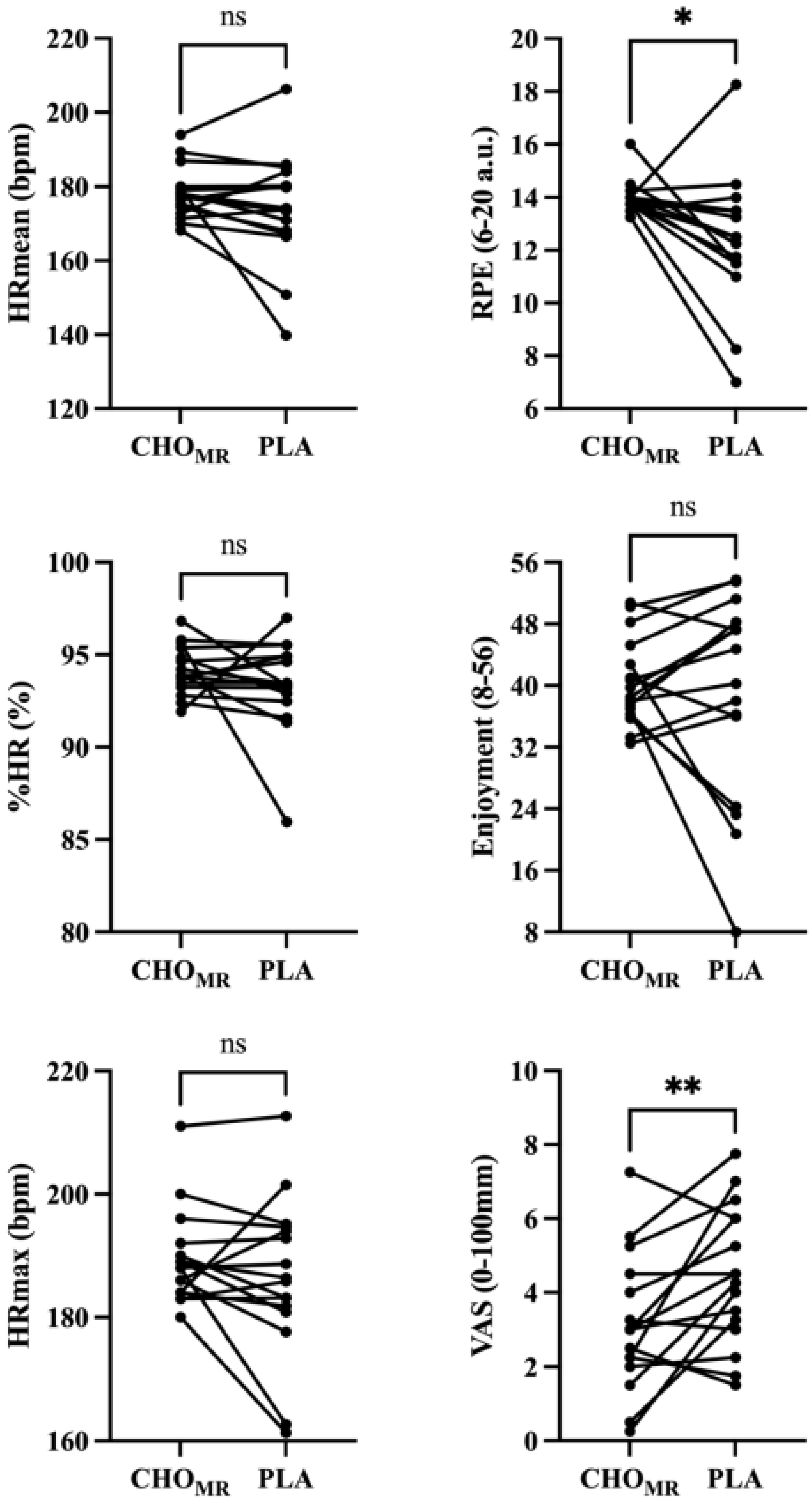

Figure 2. Psychophysiological Responses

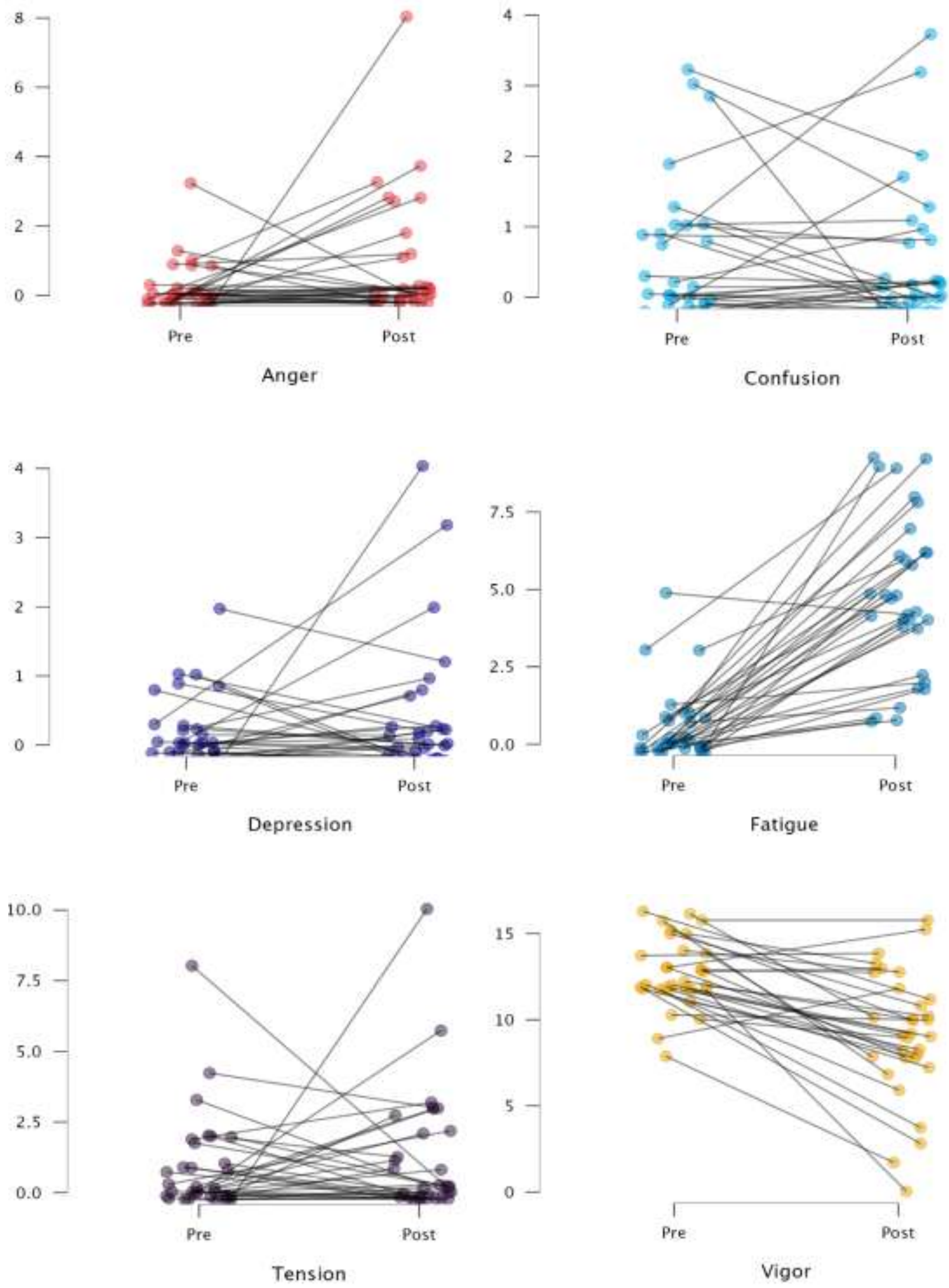

Figure 3. Mood responses on CHO_{MR} and PLA conditions

Table 1. Description variables of soccer players

	Playing Position	Age (years)	Height (cm)	Weight (kg)	Experience (years)	YYIRT-1 Distance (m)	YYIRT-1 VO_{2max} ($ml.min^{-1}.kg^{-1}$)
Player-1	Defender	16	170	55.6	7	1640	50.2
Player-2	Defender	16	181	58.4	7	1720	50.8
Player-3	Defender	15	164	56.6	5	1760	51.2
Player-4	Defender	15	177	66.3	2	2320	55.9
Player-5	Defender	15	176	70.0	4	1120	45.8
Player-6	Defender	16	171	58.2	1	2200	54.9
Player-7	Midfielder	16	176	56.6	3	1120	45.8
Player-8	Midfielder	15	182	65.7	6	1480	48.8
Player-9	Midfielder	16	162	49.3	6	880	43.8
Player-10	Midfielder	15	172	53.1	4	1840	51.9
Player-11	Midfielder	15	171	50.8	2	2200	54.9
Player-12	Midfielder	16	172	44.6	4	1640	50.2
Player-13	Forward	15	172	47.6	2	1960	52.9
Player-14	Forward	15	157	56.2	4	1160	46.1
Player-15	Forward	16	182	65.7	6	1200	46.5
Player-16	Forward	15	176	70.0	6	1920	52.5
Overall (Mean ± SD)		15 ± 1	173 ± 7	57.8 ± 7.9	4 ± 2	1635.00 ± 439.61	50.14 ± 3.70

YYIRT-1: Yo-Yo Intermittent Recovery Test Level 1; VO_{2max}: estimated maximal oxygen consumption from the YYIRT-1.

Table 2: Differences in kinematic responses of players

	CHO_{MR}	CV%	PLA	CV%	Mean Difference (95%CI)	*t*	*p*	*g*
TD (m)	492.19 ± 29.47	5.99	474.96 ± 33.38	7.03	17.23 (-3.99,38.46)	1.731	0.104	0.55
HSRD (m)	26.32 ± 11.44	43.49	26.97 ± 10.35	38.36	-0.66 (-8.12, 6.81)	-.187	0.854	0.06
AMP ($W.kg^{-1}$)	10.91 ± 0.79	7.27	10.67 ± 0.86	8.08	0.23 (-0.28, 0.75)	.972	0.347	0.29
HMLD (m)	128.88 ± 21.82	16.93	121.95 ± 21.75	17.84	6.93 (-7.38, 21.25)	1.032	0.318	0.32
SD (m)	106.04 ± 22.45	21.17	101.01 ± 21.37	21.15	5.03 (-10.44, 20.56)	.693	0.499	0.23
ACC ($n \cdot min^{-1}$)	15.04 ± 2.87	19.06	13.64 ± 2.02	14.83	1.40 (-0.39, 3.18)	1.670	0.116	0.56
DEC ($n \cdot min^{-1}$)	7.77 ± 2.25	28.95	7.59 ± 1.50	19.78	0.18 (-1.02, 1.38)	.315	0.757	0.09

Data are Mean ± SD. CHO_{MR}: Carbohydrate mouth rinsing; PLA: Placebo; CV%: coefficient of

Data are presented as Mean ± SD. CHO_{MR}: Carbohydrate mouth rinsing; PLA: Placebo; CV%: Coefficient of variation; TD: Total distance; HSRD: High-speed running distance; AMP: Average metabolic power; HMLD: High metabolic load distance; SD: Sprint distance; ACC: Accelerations (events per minute); DEC: Decelerations (events per minute); t: Paired t-test value; p: Statistical significance value; g: Hedges' g effect size.

Table 3: Differences in technical actions of players

	CHO_{MR}	CV%	PLA	CV%	Mean Difference (95%CI)	*t*	*p*	*g*
SCP (n)	15.63 ± 6.53	41.80	13.69 ± 3.68	26.91	1.94 (-2.10, 5.98)	1.022	0.323	0.37
UNSCP (n)	4.38 ± 1.86	42.46	4.81 ± 1.42	29.60	-0.44 (-1.05, 0.21)	-1.447	0.168	0.26
INT (n)	3.31 ± 1.25	37.74	1.69 ± 0.70	41.73	1.63 (0.93, 2.32)	4.961	0.001*	1.60
SCTAC (n)	3.50 ± 1.21	34.60	2.06 ± 1.00	48.38	1.44 (0.06, 2.22)	3.941	0.001*	1.30
UNSCTAC (n)	3.50 ± 1.15	32.99	2.06 ± 1.00	48.38	1.44 (0.71, 2.16)	4.213	0.001*	1.34
BLCK (n)	3.31 ± 1.25	37.74	4.63 ± 1.50	32.43	-1.32 (-2.37, -.025)	-2.637	0.019*	0.96
SCSH (n)	2.00 ± 0.73	36.51	1.69 ± 0.79	47.00	0.31 (-0.23, 0.85)	1.232	0.237	0.41
UNSCSH (n)	2.63 ± 1.02	39.04	1.56 ± 0.73	46.56	1.06 (-2.37, -0.25)	4.259	0.001*	1.21
GOALS (n)	2.88 ± 0.62	21.54	1.63 ± 0.62	38.10	1.25 (0.72, 1.78)	5.000	0.001*	2.02

Data are presented as Mean ± SD. CHO_{MR}: Carbohydrate mouth rinsing; PLA: Placebo; CV%: Coefficient of variation; SCP: Successful passes; UNSCP: Unsuccessful passes; INT: Interceptions; SCTAC: Successful tackles; UNSCTAC: Unsuccessful tackles; BLCK: Blocks; SCSH: Successful shots; UNSCSH: Unsuccessful shots; t: Paired t-test value; p: Statistical significance value; g: Hedges' g effect size. * Indicates a significant difference from the PLA condition ($p \leq 0.05$).