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A Syrup–Water Mixture Increases Performance in the Yo-Yo Intermittent Recovery Test after a Soccer-Specific Preload in the Hoff Test: A Double-Blind Crossover Study

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Abstract: Background: The positive effect of carbohydrates from commercial beverages on soccer-specific exercise has been clearly demonstrated. However, no study is available that uses a home-mixed beverage in a test where technical skills were required. Methods: Nine subjects participated voluntarily in this double-blind, randomized, placebo-controlled crossover study. On three testing days, the subjects performed six Hoff tests with a 3-min active break as a preload and then the Yo-Yo Intermittent Running Test Level 1 (Yo-Yo IR1) until exhaustion. On test days 2 and 3, the subjects received either a 69 g carbohydrate-containing drink (syrup–water mixture) or a carbohydrate-free drink (aromatic water). Beverages were given in several doses of 250 mL each: 30 min before and immediately before the exercise and after 18 and 39 min of exercise. The primary target parameters were the running performance in the Hoff test and Yo-Yo IR1, body mass and heart rate. Statistical differences between the variables of both conditions were analyzed using paired samples t-tests. Results: The maximum heart rate in Yo-Yo IR1 showed significant differences (syrup: 191.1 ± 6.2 bpm; placebo: 188.0 ± 6.89 bpm; t(6) = −2.556; $p = 0.043$; $d_z = 0.97$). The running performance in Yo-Yo IR1 under the condition syrup significantly increased by 93.33 ± 84.85 m (0–240 m) on average ($p = 0.011$). Conclusions: The intake of a syrup–water mixture with a total of 69 g carbohydrates leads to an increase in high-intensive running performance after soccer specific loads. Therefore, the intake of carbohydrate solutions is recommended for intermittent loads and should be increasingly considered by coaches and players.

Keywords: athletic performance; physical exertion; dietary supplements

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1. Introduction

Soccer can be characterized as an endurance oriented field sport with an intermittent load structure [1]. The complex requirement profile shows that players cover 10–13 km within a net playing time of 60 min depending on their physical performance level, player position, tactical orientation etc. [2]. A characteristic feature is the frequent change in load intensity. During a typical game about 150–250 anaerobic loads occur [2], 57% of which allow a regeneration time of less than 20 s [3]. The ratio of intensive to extensive phases of the game is between 1:12 and 1:2 [4]. Due to this load structure, blood lactate levels of 2–10 mmol/L or muscle lactate levels around 17 mmol/kg dry weight (d.w.) can occur during the course of a match [2]. The average heart rate is about 85% of the maximum heart rate. Consequently, due to the high level of stress, it is important to maintain maximum performance as long as possible. In addition to various training methods, the liquid intake of carbohydrates seems to be a proven method.

Numerous studies by different research groups show that carbohydrate intake before and/or during exercise can lead to a physical [5,6] and technical performance (e.g., dribbling, passing) improvement [7] when given with a 6–7% carbohydrate solution. In the absence of supplementation, excessive glycogen depletion in the muscles leads to premature fatigue and consequently to a decrease in performance, which is manifested, among other things, by a shorter running distance under high-intensity conditions [8]. Despite a 90% amount of aerobic energy production, the muscle glycogen is a performance determining energy source. The analysis of the glycogen stores before, during, and after the match shows a clear decrease over the course of the match [9]. Therefore, an intake of 30–60 g of exogenous carbohydrates per hour is recommended [10] in order to achieve an increase in blood glucose levels and the oxidation rate of carbohydrates and to avoid excessive emptying of glycogen stores [11]. The intake of exogenous carbohydrates (~1.1 L; 6.9%) during a simulated soccer match reduced the use of muscle glycogen reserves by 22% [12].

Carbohydrate supplementation immediately before, during and after competition is typically realized in form of isotonic drinks [13]. If it is applied at all, these are acquired commercially. Self-mixed syrup–water drinks are rarely used but represent a cost-effective and individually adaptable alternative. Zart and Fröhlich [14] already compared commercial carbohydrate drinks with a syrup–water mixture under intermittent loads, with all groups showing the same running performance and no differences in terms of rates of perceived exertion, heart rate and blood lactate regardless of the drink.

Based on this, the aim of the present study was to test the efficacy of a syrup–water mixture in comparison to an energy-free placebo in a progressive shuttle run test until exhaustion. In times of economic thinking, a cost-effective alternative to commercial beverages. Moreover, the Hoff test, a soccer specific intermittent test that integrates running with a ball, was used as a soccer specific preload [15]. Previous studies have mostly used the Loughborough Intermittent Shuttle Test (LIST) or comparable endurance tests without a ball to simulate a soccer specific load [16]. Only four comparable studies are known which made the subjects play soccer to carry out performance measurements such as time spent running, sprints performed, soccer specific tests with/without a ball [17–19]. All studies could prove a positive effect of drinks with 6–12% carbohydrate content. However, they used commercial drinks (e.g., Gatorade) and no self-mixed beverage.

2. Materials and Methods

2.1. Subjects

A total of 11 male active soccer players participated in this double-blind cross-sectional study. Due to test method compliance, six subjects had to be excluded, because measurement errors occurred twice and another 4 subjects either dropped out due to injuries in the course of data collection or did not show up for all tests (see Table 1). Exclusion criteria were acute injuries, problems of the musculoskeletal system, diabetes mellitus, cardiovascular and lung diseases or intolerance to ingredients of the beverages used. Participation was voluntary and without financial remuneration. The subjects were informed on the study objectives and gave their written consent to participate in the study. The study was planned and performed on the basis of the Declaration of Helsinki [20] and was approved unconditionally by the responsible Ethics Board (2019/25).

Table 1. Description of the sample (n = 9).

	M ± SD	**MIN**	**MAX**
Age [years]	23.3 ± 2.4	20	27
Height [kg]	78.1 ± 11.6	60	95
Weight [cm]	178.1 ± 7.5	169	190

The sample size was derived using the group parameters of the study by Sun et al. [21], who found a significant performance increase of 16% ($p < 0.05$) with 12 subjects. The sample calculation with G*Power 3.1.9.2 resulted in a group size of 10 with an alpha error of 0.05, a beta error of 0.8, and an effect size of 1.0.

2.2. Nutrition and Supplementation

The nutritional behavior of the test persons on the day before the first test was recorded and repeated before each measurement. On the actual test day, the test persons had to appear sober. Only water was allowed as a drink.

The carbohydrate-containing syrup–water mixture consisted of a Yo fruit syrup (taste: elderflower; Eckes-Granini Austria GmbH, St. Florian, Austria) and table water, resulting in a 6.9% carbohydrate solution (Table 2). In addition to water, the carbohydrate-free placebo beverage contained only a natural food flavor (taste: elderflower; Pure Flavour GmbH, Munich, Germany) to achieve the same taste on the placebo condition. Both beverages were filled in brown 250 mL PET bottles (Rigoletto, Packari.com GmbH, Wörgl, Austria) to make the contents as unrecognizable as possible.

Table 2. Drink specification for 100 mL liquid intake.

Properties	Syrup	Placebo
Powder/syrup [g/mL]	9.2	0
Calorific value [kcal]	28	0
Carbohydrates [g]	6.9	0
of which sugar [g]	6.8	0
Lipids [g]	<0.5	0
Protein [g]	<0.5	0
Calcium [mg]	0.01	0

Syrup ingredients: beet sugar; glucose-fructose syrup; water; elderflower extract; citric acid. lemon juice from lemon juice concentrate; caramelized sugar; gum arabic; glycerol ester from root resin. Placebo ingredients: propylene glycol (E1520); water; glycerol triacetate (E1518); natural flavorings and flavor extract.

2.3. Test Procedures

The measurements were carried out on three separate test days at intervals of one week, starting each with a standardized warm-up program (4 min Hoff test). Then, on each of the three test days, a preload was performed with the Hoff test [15], followed by the Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) as a test for exhaustion [22]. The two tests were selected because the Hoff test includes soccer-specific actions (e.g., dribbling) and grants a level of exercise close to a game, and the Yo-Yo IR1 has good reliability and the glycogen stores are depleted similar to a game [15,22].

The exercise protocol consisted of running the Hoff test six times over a 4-min exposure time each. Between each load, there was a 3-min active rest, during which the test subjects dribbled through the Hoff course in a trot. Finally, the subjects ran the Yo-Yo IR1 until exhaustion.

The first test day was used for familiarization with both tests and to record performance on Yo-Yo IR1, which was used for double-blind parallelization of the subjects into the equal-strength sequences syrup–placebo (group A) and placebo–syrup (group B) by rank order.

On the first test day subjects received no supplements. On test days 2 and 3, subjects were given either a syrup–water mixture or flavored water, depending on group affiliation. On all test days, the subjects ran in a fasting state without breakfast in the morning.

Drinks were administered in four doses of 250 mL each throughout the soccer specific preloading (Hoff test), 30 min and immediately before exposure as well as after 18 and 39 min of exposure (“half-time break”) (Figure 1).

The subjects were weighed before and after the intervention to record the loss of fluid over the change in body mass (seca 813; Seca GmbH & Co. KG, Hamburg, Germany). During the intervention, heart rate was continuously recorded for both sport motoric tests (Polar V800; Polar Electro GmbH, Büttelborn, Germany).

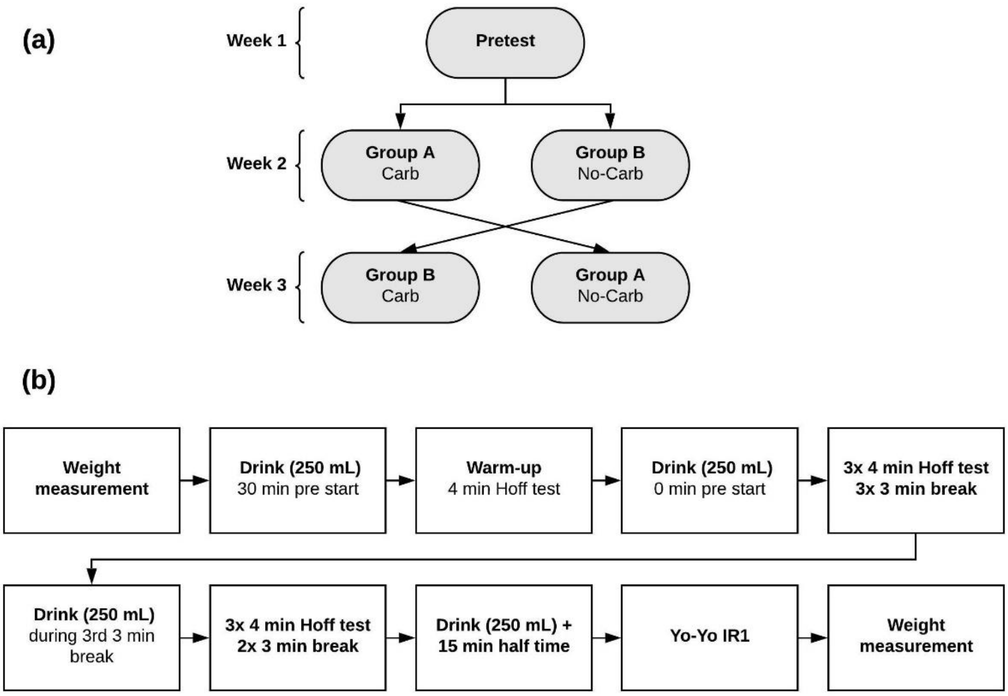

Figure 1. (**a**) research design with the allocation of supplements for both groups and (**b**) time schedule on each research day.

2.4. Statistics

The raw values from the log sheets and polar clocks were entered and edited in Microsoft Excel 2016 before being imported into IBM SPSS Statistics 26. Due to interference with heart rate monitors, not all variables could be included in the analysis for all subjects. The descriptive statistics are presented as minimum, maximum, average values, and standard deviations. Inferential statistics were calculated after verification of the preconditions of standard distribution (Shapiro-Wilk test) and variance homogeneity (Levene test). Differences between syrup and placebo in distances covered during Yo-Yo IR1 and Hoff test, average and maximal heart rate were analyzed using paired samples t-tests. We also calculated Cohen's d_z to analyze effect sizes [23].

3. Results

The fluid intake of one liter in total led to an average change in body mass of −0.10 ± 0.35 kg (placebo) and 0.02 ± 0.49 kg (syrup) in the subjects.

The average (syrup: 161.6 ± 7.0 bpm; placebo: 161.9 ± 6.0 bpm; $t(8) = 0.232$; $p = 0.822$) and maximum (syrup: 185.9 ± 5.8 bpm; placebo: 186.4 ± 7.0 bpm; $t(7) = 0.000$; $p = 1.000$) heart rates under both conditions indicated a comparable physical exertion during the Hoff test. The distance covered by the subjects at the soccer specific load in the Hoff test showed an average difference between both conditions of −1.43 ± 237.38 m (Table 3). The individual running distances of the subjects were between 3850 and 4510 m (placebo) and 3720 and 5000 m (syrup). There was no significant difference between the distances ran in both conditions ($t(6) = -0.016$; $p = 0.988$).

Table 3. Distance covered (m) in the sport motoric tests and the conditions syrup and placebo.

	Placebo [m]	Syrup [m]	*p*-Values
Hoff-Test	4205.71 ± 230.93	4207.14 ± 424.02	0.988
Yo-Yo IR1	826.67 ± 260.77	920.00 ± 256.12	0.011
Hoff + Yo-Yo IR1	4982.86 ± 394.24	5075.71 ± 573.03	0.344

The average (syrup: 176.9 ± 7.0 bpm; placebo: 172.9 ± 8.6 bpm; $t(6) = -1.558$; $p = 0.170$) and maximum (syrup: 191.1 ± 6.2 bpm; placebo: 188.0 ± 6.89 bpm; $t(6) = -2.556$; $p = 0.043$; $d_z = 0.97$) heart rates showed greater differences between conditions in Yo-Yo IR1. The maximum heart rates of the two conditions differed significantly. When comparing the running results of placebo and syrup in the Yo-Yo IR1, it was found that only two subjects were unable to increase their performance by taking the syrup–water mixture. In contrast, seven subjects improved their performance under the syrup condition, resulting in an average improvement in running distance of 93.33 ± 84.85 m (0–240 m) ($t(8) = -3.300$; $p = 0.011$; $d_z = 1.10$) (Figure 2).

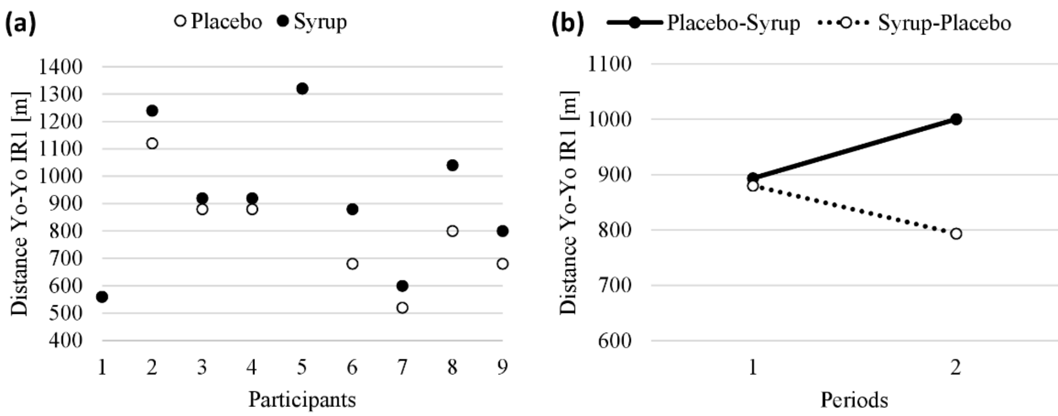

Figure 2. Comparison of (**a**) intra-individual performances in both conditions (subjects 1 and 5 ran the same distance in both conditions) and (**b**) the performances of sequences placebo-syrup and syrup–placebo.

4. Discussion

The aim of the present study was to investigate the effect of a carbohydrate-containing syrup–water mixture in comparison to a carbohydrate-free placebo on the running performance during a soccer-specific load. The results show that a total intake of 69 g of carbohydrates before and during exercise led to an average performance increase of 12.5% in Yo-Yo IR1. The ergogenic effect is thus slightly below the average of 15.1% calculated by Temesi et al. [24] in their meta-analysis.

For this investigation, two sport motoric tests were used. First, the task was to carry out a preload as close as possible to that of the match. For this purpose, the Hoff test was used, a soccer specific field test to estimate the VO_2max [25] as well as a training course to increase aerobic-anaerobic endurance performance [15]. In addition, the Hoff test integrates typical game actions like jumps, change of directions, as well as a variety of ball techniques (e.g., dribbling).

The measured physiological load of the test persons in the Hoff test was for both conditions at almost 85% of their maximum heart rate and therefore in load ranges of typical match situations [26]. The load in the Hoff test, including the active breaks, lasted 39 min and exceeded the net play time of a soccer half, which lasts about 26 min [27]. During this time, the subjects covered a similar distance of about 5 km compared to match analyses [28]. Thus, the initial load in the Hoff test came very close to the temporal and physiological requirement profile of a competition and thus simulated a soccer specific load.

The second sport motoric test was the Yo-Yo IR1, which has a high test-retest reliability [22], and compared the effectiveness of the syrup–water mixture with the placebo on the basis of running performance. At exertion the maximum heart rate of runners in Yo-Yo IR1 is comparable to that of a treadmill step test [22], which is still considered the gold standard for the analysis of endurance performance. The advantage of the increasing load character is a stronger strain on the glycogen stores. According to Krustrup, Mohr, Amstrup, Rysgaard, Johansen, Steensberg, Pedersen, and Bangsbo [22], the glycogen stores are emptied by 23% during a Yo-Yo IR1.

By taking the carbohydrate supplement, the subjects were able to improve their running performance by an average of 93.33 m (approx. +4.5 lanes) compared to the placebo condition. Our results are in accordance with the results of other studies, which also found performance improvements of 24–37% during shuttle runs when carbohydrate-containing beverages were consumed at 6–18% before and during exercise [19,29–31]. One reason for the lower increase in performance (12.5%) in the present study could be the chosen exercise duration. All previously mentioned studies had a preload of 60–75 min at 80–85% HR_{max} or 160–170 bpm. In comparison, our subjects had a preload with similar intensity, but the duration was only half as long. According to Baker, Rollo, Stein and Jeukendrup [1], exogenous carbohydrates have an effect on performance, especially at the end of a game. The study by Muckle [32] showed this clearly by supplementing glucose syrup with mineral salts 30 min before the game. The number of goals scored could be doubled in the second half, especially in the last 15 min of a game.

Studies simulating the load of a soccer ball or actually playing a game also found an 11.8% increase in running distance during anaerobic loads (Rodriguez et al.) and an increase in time spent running (Guerra et al.) for the first half with the intake of a carbohydrate-electrolyte drink. Contrary to the results shown so far is the result of Goedecke et al. [33] for a simulated soccer match. They found no ergogenic effects through the intake of a 7% carbohydrate solution (28 g/h) in the Loughborough Intermittent Shuttle Test (LIST). Potential explanations could be the intake of a breakfast 2 h before the endurance test as well as an insufficient amount of exogenous carbohydrates [33]. Similar findings were demonstrated by Funnell et al. [16], who investigated a 250 mL 12% carbohydrate solution right before and at half-time throughout a modified version of the LIST with sixteen male soccer players in a fed state.

Based on the meta-analysis of Vandenbogaerde and Hopkins [34], in which the effectiveness of carbohydrates on performance in time trials and time-to-exhaustion protocols was determined, an ergogenic effect of up to 6%, but also a reduction in performance of up to 2% could be analyzed. From the results it was concluded that a ~3–10% carbohydrate-plus-protein drink was the best supplement mixture. The benefit was mainly due to the combination of the two carbohydrates glucose (~0.7 g/kg/h) and fructose (~0.2 g/kg/h) and less to the addition of protein (~0.2 g/kg/h). By combining glucose and fructose, the physiological resorption rate can be maximally utilized, since the monosaccharides are absorbed via different pathways [35]. Unfortunately, the ratio of the two carbohydrates in the fruit syrup is not available, so that no statement can be made about the quality of the syrup–water mixture with regard to its resorption capacity. Apart from this fact, the sobriety of the subjects could be another factor to substantiate the results, as the glycogen stores could inevitably not be completely filled at the time of the test start and the reduced reserves were probably compensated for by the intake of the syrup–water mixture. This procedure was considered to be reasonable, as it eliminated potential influencing factors such as caffeine [36] and made it easier to compare the different test points.

The conditions of drink supply and composition before and during the pre-loading were determined according to scientific findings and the practicability throughout competition [36]. As the body mass fluctuated only slightly around the initial value, the intake amount of the drink was considered adequate and therefore a reduction in performance due to dehydration was prevented [37,38]. With about 50 g carbohydrates per hour, the intake in our study was in the range of the recommendation of 30–60 g CHO/h [1] as well as in the optimal range of the intestinal absorption rate, therefore it can be assumed that the supply of exogenous carbohydrates was sufficient and led to an increased blood sugar level as well as to an increased oxidation rate [39]. This may have caused an increased uptake of glucose from the blood plasma into the cells and its use as an energy source, and as a consequence a slower emptying of the glycogen stores [39].

Due to greater energy availability and a positive effect of carbohydrates on the perception of stress [40], increased performance may have been possible in the condition syrup, as indicated by the significant differences in maximum heart rate values (syrup: 92.0%

HR_{max}; placebo: 90.5% HR_{max}). An increase in heart rate after carbohydrate intake with a simultaneous increase in performance was also observed in Davison, McClean, Brown, Madigan, Gamble, Trinick, and Duly [5]. To what extent the emptying of the glycogen stores is the cause of fatigue is not clear but there are connections between glycogen levels and decreasing sprint performance [41]. Saltin [9] pointed out that in a game, the glycogen stores could already be severely depleted at half-time, if the glycogen amount was too low before the match. Since the subjects fasted overnight and had to perform the exercise on an empty stomach, the glycogen stores were probably not optimally filled, so that a critical glycogen level would be conceivable with the condition placebo at half-time, which could have led to a reduced glycolytic rate and a reduction in performance [9].

The interpretation of the findings is limited by the choice and number of subjects. The subjects in this study are male amateur athletes. According to the systematic review by Schmitz et al. [42], the measured performance (873 ± 255 m) does not match the performance of female soccer players at amateur level (920 ± 322 m) and can therefore be classified as low compared to the reference values of male subjects at amateur level (1743 ± 529 m). A transferability of the findings to other performance levels has to be clarified. A further limitation of this study is the sober performance test, which does not correspond to the everyday nutritional behavior before competition. By having breakfast, the test persons could have brought their glycogen stores, which were emptied overnight, to a higher level, at least compared to a sober state. The extent to which the observed performance increases could still be demonstrated when eating a carbohydrate-containing meal will have to be clarified in subsequent studies.

5. Conclusions

The importance of fluid intake before and during soccer is well known. Carbohydrate-containing drinks are in preference to energy-free drinks. The results of the present study show that energy rich drinks with a carbohydrate content of 69g (7%) have a positive influence on energy metabolism and result in a significant increase in performance in male amateur athletes. Syrup as an energy source, with its multiple carbohydrates (glucose; fructose) seems to be an especially favorable and inexpensive alternative to commercial sports drinks. These results could have an impact on the nutritional strategies of trained athletes in game sports, especially amateur soccer players, who predominantly chose sparkling water or mineral water, especially during half time.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the faculty Social Sciences at the University of Kaiserslautern (2019/25).

Informed Consent Statement: All subjects gave their informed consent for inclusion before they participated in the study.

Data Availability Statement: The dataset used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Conflicts of Interest: The authors declare that there are no conflicts of interest or any commercial support.

References

1. Baker, L.B.; Rollo, I.; Stein, K.W.; Jeukendrup, A.E. Acute Effects of Carbohydrate Supplementation on Intermittent Sports Performance. *Nutrients* **2015**, *7*, 5733–5763. [CrossRef] [PubMed]
2. Bangsbo, J. Physiological Demands of Football. *Sport Sci. Exch.* **2014**, *27*, 1–6.
3. O'Donoghue, P.G. Time-motion analysis of work-rate in English FA Premier League soccer. *Int. J. Perform. Anal. Sport* **2002**, *2*, 36–43. [CrossRef]
4. Di Mascio, M.; Bradley, P.S. Evaluation of the most intense high-intensity running period in English FA premier league soccer matches. *J. Strength Cond. Res.* **2013**, *27*, 909–915. [CrossRef]
5. Davison, G.W.; McClean, C.; Brown, J.; Madigan, S.; Gamble, D.; Trinick, T.; Duly, E. The effects of ingesting a carbohydrate-electrolyte beverage 15 minutes prior to high-intensity exercise performance. *Res. Sports Med.* **2008**, *16*, 155–166. [CrossRef] [PubMed]
6. Patterson, S.D.; Gray, S.C. Carbohydrate-Gel Supplementation and Endurance Performance During Intermittent High-Intensity Shuttle Running. *Int. J. Sport Nutr. Exerc. Metab.* **2007**, *17*, 445–455. [CrossRef] [PubMed]
7. Russell, M.; Kingsley, M. The efficacy of acute nutritional interventions on soccer skill performance. *Sports Med.* **2014**, *44*, 957–970. [CrossRef] [PubMed]
8. Bendiksen, M.; Bischoff, R.; Randers, M.B.; Mohr, M.; Rollo, I.; Suetta, C.; Bangsbo, J.; Krustrup, P. The Copenhagen Soccer Test: Physiological response and fatigue development. *Med. Sci Sports Exerc.* **2012**, *44*, 1595–1603. [CrossRef]
9. Saltin, B. Metabolic fundamentals in exercise. *Med. Sci. Sports* **1973**, *5*, 137–146. [CrossRef]
10. Oliveira, C.; Ferreira, D.; Caetano, C.; Granja, D.; Pinto, R.; Mendes, B.; Sousa, M. Nutrition and Supplementation in Soccer. *Sports* **2017**, *5*, 28. [CrossRef] [PubMed]
11. Phillips, S.M.; Sproule, J.; Turner, A.P. Carbohydrate ingestion during team games exercise: Current knowledge and areas for future investigation. *Sports Med.* **2011**, *41*, 559–585. [CrossRef] [PubMed]
12. Nicholas, C.W.; Tsintzas, K.; Boobis, L.; Williams, C. Carbohydrate-electrolyte ingestion during intermittent high-intensity running. *Med. Sci Sports Exerc.* **1999**, *31*, 1280–1286. [CrossRef] [PubMed]
13. Bonetti, D.L.; Hopkins, W.G. Effects of hypotonic and isotonic sports drinks on endurance performance and physiology. *Sportscience* **2010**, *14*, 63–70.
14. Zart, S.; Fröhlich, M. Effects of Commercial Isotonic Sports Drinks during Intermittent Exertion. *Int. J. Kinesiol. Sport Sci.* **2019**, *7*, 8. [CrossRef]
15. Hoff, J.; Wisloff, U.; Engen, L.C.; Kemi, O.J.; Helgerud, J. Soccer specific aerobic endurance training. *Br. J. Sports Med.* **2002**, *36*, 218–221. [CrossRef]
16. Funnell, M.P.; Dykes, N.R.; Owen, E.J.; Mears, S.A.; Rollo, I.; James, L.J. Ecologically Valid Carbohydrate Intake during Soccer-Specific Exercise Does Not Affect Running Performance in a Fed State. *Nutrients* **2017**, *9*, 39. [CrossRef]
17. Guerra, I.; Chaves, R.; Barros, T.; Tirapegui, J. The influence of fluid ingestion on performance of soccer players during a match. *J. Sports Sci. Med.* **2004**, *3*, 198–202.
18. Ostojic, S.M.; Mazic, S. Effects of a carbohydrate-electrolyte drink on specific soccer tests and performance. *J. Sports Sci. Med.* **2002**, *1*, 47–53. [PubMed]
19. Rodriguez-Giustiniani, P.; Rollo, I.; Witard, O.C.; Galloway, S.D. Ingesting a 12% carbohydrate-electrolyte beverage before each half of a soccer match simulation facilitates retention of passing performance and improves high-intensity running capacity in academy players. *Int. J. Sport Nutr. Exerc. Metab.* **2019**, *29*, 397–405. [CrossRef]
20. World Medical Association. World medical association declaration of Helsinki: Ethical principles for medical research involving human subjects. *J. Am. Med. Assoc.* **2013**, *310*, 2191–2194. [CrossRef] [PubMed]
21. Sun, F.-H.; Wong, S.; Chen, S.-H.; Poon, T.-C. Carbohydrate Electrolyte Solutions Enhance Endurance Capacity in Active Females. *Nutrients* **2015**, *7*, 3739. [CrossRef] [PubMed]
22. Krustrup, P.; Mohr, M.; Amstrup, T.; Rysgaard, T.; Johansen, J.; Steensberg, A.; Pedersen, P.K.; Bangsbo, J. The yo-yo intermittent recovery test: Physiological response, reliability, and validity. *Med. Sci. Sports Exerc.* **2003**, *35*, 697–705. [CrossRef]
23. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Lawrence Erlbaum Associates: Mahwah, NJ, USA, 1988.
24. Temesi, J.; Johnson, N.A.; Raymond, J.; Burdon, C.A.; O'Connor, H.T. Carbohydrate ingestion during endurance exercise improves performance in adults. *J. Nutr.* **2011**, *141*, 890–897. [CrossRef] [PubMed]
25. Chamari, K.; Hachana, Y.; Kaouech, F.; Jeddi, R.; Moussa-Chamari, I.; Wisløff, U. Endurance training and testing with the ball in young elite soccer players. *Br. J. Sports Med.* **2005**, *39*, 24–28. [CrossRef] [PubMed]
26. Helgerud, J.; Engen, L.C.; Wisloff, U.; Hoff, J. Aerobic endurance training improves soccer performance. *Med. Sci. Sports Exerc.* **2001**, *33*, 1925–1931. [CrossRef] [PubMed]
27. Castellano, J.; Blanco-Villasenor, A.; Alvarez, D. Contextual variables and time-motion analysis in soccer. *Int. J. Sports Med.* **2011**, *32*, 415–421. [CrossRef]
28. Chmura, P.; Andrzejewski, M.; Konefal, M.; Mroczek, D.; Rokita, A.; Chmura, J. Analysis of Motor Activities of Professional Soccer Players during the 2014 World Cup in Brazil. *J. Hum. Kinet.* **2017**, *56*, 187–195. [CrossRef]
29. Nicholas, C.W.; Williams, C.; Lakomy, H.K.; Phillips, G.; Nowitz, A. Influence of ingesting a carbohydrate-electrolyte solution on endurance capacity during intermittent, high-intensity shuttle running. *J. Sports Sci.* **1995**, *13*, 283–290. [CrossRef]

30. Welsh, R.S.; Davis, J.M.; Burke, J.R.; Williams, H.G. Carbohydrates and physical/mental performance during intermittent exercise to fatigue. *Med. Sci. Sports Exerc.* **2002**, *34*, 723–731.
31. Phillips, S.M.; Turner, A.P.; Gray, S.; Sanderson, M.F.; Sproule, J. Ingesting a 6% carbohydrate-electrolyte solution improves endurance capacity, but not sprint performance, during intermittent, high-intensity shuttle running in adolescent team games players aged 12-14 years. *Eur. J. Appl. Physiol.* **2010**, *109*, 811–821. [CrossRef]
32. Muckle, D.S. Glucose syrup ingestion and team performance in Soccer. *Br. J. Sports Med.* **1973**, *7*, 340–343. [CrossRef]
33. Goedecke, J.; White, N.; Chicktay, W.; Mahomed, H.; Durandt, J.; Lambert, M. The Effect of Carbohydrate Ingestion on Performance during a Simulated Soccer Match. *Nutrients* **2013**, *5*, 5193–5204. [CrossRef] [PubMed]
34. Vandenbogaerde, T.J.; Hopkins, W.G. Effects of acute carbohydrate supplementation on endurance performance: A meta-analysis. *Sports Med.* **2011**, *41*, 773–792. [CrossRef] [PubMed]
35. Jeukendrup, A.; Gleeson, M. *Sport Nutrition*, 3rd ed.; Human Kinetics: Champaign, IL, USA, 2019.
36. Mielgo-Ayuso, J.; Calleja-Gonzalez, J.; Del Coso, J.; Urdampilleta, A.; León-Guereño, P.; Fernández-Lázaro, D. Caffeine Supplementation and Physical Performance, Muscle Damage and Perception of Fatigue in Soccer Players: A Systematic Review. *Nutrients* **2019**, *11*, 440. [CrossRef] [PubMed]
37. Laitano, O.; Runco, J.L.; Baker, L. Hydration science and strategies in football. *Sports Sci. Exch.* **2014**, *27*, 1–7.
38. Campa, F.; Piras, A.; Raffi, M.; Trofè, A.; Perazzolo, M.; Mascherini, G.; Toselli, S. The Effects of Dehydration on Metabolic and Neuromuscular Functionality During Cycling. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1161. [CrossRef] [PubMed]
39. Clarke, N.D.; Drust, B.; Maclaren, D.P.; Reilly, T. Fluid provision and metabolic responses to soccer-specific exercise. *Eur. J. Appl. Physiol.* **2008**, *104*, 1069–1077. [CrossRef]
40. Utter, A.C.; Kang, J.I.E.; Robertson, R.J.; Nieman, D.C.; Chaloupka, E.C.; Suminski, R.R.; Piccinni, C.R. Effect of carbohydrate ingestion on ratings of perceived exertion during a marathon. *Med. Sci. Sports Exerc.* **2002**, *34*. [CrossRef]
41. Krustrup, P.; Mohr, M.; Steensberg, A.; Bencke, J.; Kjaer, M.; Bangsbo, J. Muscle and blood metabolites during a soccer game: Implications for sprint performance. *Med. Sci. Sports Exerc.* **2006**, *38*, 1165–1174. [CrossRef]
42. Schmitz, B.; Pfeifer, C.; Kreitz, K.; Borowski, M.; Faldum, A.; Brand, S.-M. The Yo-Yo Intermittent Tests: A Systematic Review and Structured Compendium of Test Results. *Front. Physiol.* **2018**, *9*, 870. [CrossRef]