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Mineral and sugar concentrations taken during matches and their effect on some physical and functional abilities of football players

Hamed Saleh Mahdi [1]

[1,] University of Baghdad, College of Physical Education and sport sciences

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Abstract

Many athletes believe that it enhances the level of performance during training and competition, in addition to compensating for fluids during exercise when the levels of temperature and humidity in the atmosphere rise during the athlete's intensive training, as it increases the requirements for fluid compensation to avoid the risk of potential thermal disorders. If training continues for more than an hour causing fatigue, athletes are advised to drink carbohydrate drinks that quickly convert to glucose in the blood, while sodium should be included in the fluids consumed during exercise or matches that last more than (1-2 hours). The effect of drinking a drink containing 12% carbohydrates and electrolytes before each half of a simulated football match facilitates the maintenance of passing performance and improves the ability of high-intensity running in football academy players. This study aims to know the effect of mineral and sugar solutions with different mineral concentrations 2%-5% with a carbohydrate percentage of 10% in an amount of 500 ml of water on some physical abilities and functional indicators. The study was conducted on football academy players aged 15-16 years, where the research sample amounted to 20 players and they were divided into two groups for each group (n = 10 experimental 1 took 2% mineral salts and 10% sugar) (n = 10 experimental 2 took 5% mineral salts and 10% sugar)) They were trained three training units per week and the field experiment was conducted on them by holding matches within the academy's football activity while they represented one of the teams. The study concluded that.

Keywords: Mineral supplementation, Sugar intake, Physical performance, Football players.

[1] College of Physical Education and Sports Sciences - University of Baghdad, Hamid.Ali@cope.uobaghdad.edu.iq , 009647702991119

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Introduction

Athletes appreciate the need to consume fluids before, during, and after exercise. Rehydration with energy drinks containing carbohydrates, salts, caffeine, and other ingredients is important, as many athletes believe they enhance performance during training and competition. Additionally, fluid replacement during exercise is important when high temperatures and humidity levels occur during intense training, increasing fluid requirements to avoid the risk of heat exhaustion. It is recommended that athletes consume 5-7 ml of fluid per kilogram of body weight at least four hours before exercise. During exercise lasting more than 40 minutes, athletes should aim to drink enough fluids to replace fluids lost through sweating, ensuring that the fluid deficit during training or competition does not exceed approximately 2% of body mass, averaging 200 ml per 20 minutes of exercise. If training lasts for more than an hour and causes fatigue, athletes are advised to drink carbohydrate drinks that quickly turn into glucose in the blood, while sodium should be included in the fluids consumed during exercise or matches that last more than (1-2 hours). Most energy drinks may contain carbohydrates or caffeine. Ian Rollo & Clyde Williams (2023) study showed the effect of carbohydrate nutrition on the skill performance of football players. Football players are required to perform a variety of specific athletic skills, usually during or immediately after running. These are often fast-paced, and the quality of the skill performance is likely to be influenced by the amount of work done offensively and defensively throughout the game (1,2). Even the most skilled players succumb to the effects of physical and mental fatigue, which can lead to poor skill performance at crucial moments in the game and poor fitness during the game. Tired players find it more difficult to successfully perform basic skills. It is not surprising that teams place a significant emphasis on fitness training (3,4). The importance of team tactics, supported by spatial awareness, should not be overlooked. This is why players resort to high-carbohydrate nutritional supplements before and during matches, believing they help delay the onset of fatigue. This study found some evidence that players who consume carbohydrates can maintain their skills throughout matches while delaying fatigue during play. It may also help with weight maintenance and performance of specific soccer skills. A study by (Paola Rodriguez-Giustinian, Ian Rollo, OliverC.Witard 2018) examined the effect of consuming a drink containing 12% carbohydrates and electrolytes before each half of a simulated football match on maintaining passing performance and improving high-intensity running capacity in academy football players. This study investigated the effect of ingesting a 12% carbohydrate plus electrolyte (CHO-E) solution, providing 60g of carbohydrate, prior to each half of a 90-minute simulated football match protocol on skill performance, sprint speed, and high-intensity running capacity. Eighteen elite academy football players (aged 18 ± 2 years) ingested two doses (250ml) (pre- and mid-training) of a 12% carbohydrate plus electrolyte solution or an electrolyte placebo in a

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randomized, double-blind design. During a simulated indoor football match, dribbling, passing, and sprinting performance were assessed, and blood was drawn for glucose and lactate analysis. High-intensity running capacity was assessed, and results showed that passing accuracy, dribbling, and sprinting speed were maintained throughout the simulated football match. Therefore, ingesting a 12% CHO-E solution prior to each half of a match may help maintain football-specific skill performance and improve high-intensity running capacity. Study (Caroline A. Tarnowski, Ian Rollo, James M. Carter 2022) Fluid balance and carbohydrate intake in elite women's soccer players during training and competition This study examined sweating rate, sweat sodium concentration (Na), carbohydrate and fluid intake in elite female soccer players during training (n = 19) and matches (n = 8). Eight body mass (kg) was measured before and after exercise, and sweating rate and sodium concentration (Na) were calculated, which was determined by absorbent patches on the thigh or back. The percentage of body mass change in elite female players (19 players) during training had a greater loss of body mass after the match (121.12 ± 0.86%) than during training (+0.29 ± 0.34%, p = 0.003), and the sweat rate was similar between training (29 ± 9 mmol·L) and match (35 ± 9 mmol·L). There were no differences in match versus training carbohydrate intake (2.0 ± 2.3 g·h, 0.9 ± 1.5 g·h, respectively, p = 0.219). The average distance covered may have reached approximately 10 km during the match, which indicates their use of the aerobic energy system, as high-intensity effort leads to a significant depletion of glycogen in each muscle fiber, which leads to early fatigue in soccer players, as elite soccer players consume less fluid during matches than during training, and physiological responses were observed. Elevated (heart rate and blood lactate) and early fatigue, sweating rates and fluid balance were monitored during play. Female soccer players played two competitive matches in hot conditions (25°C) and the mean sweating rate was 0.81 L/h, water deficit was 0.9% While studying (Fabrícia. G. Ferreira, Letícia. P, Wallisson. David 2016) The effect of hydration practices on runners during training and competition Emphasizing that the hydration process ensures that the athlete is in an ideal state during exercise, and that insufficient hydration may result in a decrease in the athlete's level, and that the level of knowledge about the hydration method includes several questions categorized in knowing the demographic characteristics, and hydration methods during competition and training. A significant difference was observed in the use of hydration between training and competitions. The data revealed that a large number of runners (41% in competitions and 54.4% in training) as well as a percentage of . Only 35.4% of athletes consumed sports drinks, while 3.88% did not consume fluids at all during training, and 1.5% did not consume fluids at all in competition. While Ozcan Esen, Ian Walshe & Stuart Goodall's 2024 study examined energy, hydration, and sleep status in world-class male archers during competition, eating and sleeping play an important role in performance recovery in elite sport. The present study aimed to evaluate energy intake (EI), hydration status, and sleep parameters in world-class male archers over a four-day

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competition. Daily energy, carbohydrate, and protein intakes ranged between 2,563 and 3,986 kcal, 4 and 7.1 g/kg body mass, and 2.2 and 3.6 g/kg body mass per day, respectively. Energy and carbohydrate intakes were greater on high-volume competition days (i.e., days 1 and 3) than on low-volume days (days 2 and 4) during the tournament. Additionally, urine specific gravity was higher after waking up, compared to pre- and post-competition, and before sleep, while they were hypo-hydrated after waking up with sleep disturbances. The archers appear to be collectively able to partition their food intake according to the daily physical load during the tournament while maintaining adequate hydration and maintaining sleep quality. It can be concluded that these data partially help explain why these archers are so successful. Konstantinos D. Tambalisi's 2022 study indicated that The effect of electrolyte and energy drink consumption on athletic performance The primary objective was to identify the potential effects of electrolyte and energy drink consumption on athletic performance and to provide recommendations for safe consumption. This study also explored the fluid intake athletes need before, during, and after exercise, as well as the importance of hydration using energy drinks containing carbohydrates, salts, caffeine, and other ingredients. Many athletes consider energy drinks to enhance performance and avoid the risk of potential heat exhaustion. Therefore, it is recommended that athletes consume 5–7 ml of fluid per kilogram of body weight at least 4 hours before exercise. For exercise lasting more than 40 minutes, it is suggested to develop hydration strategies that ensure the athlete adequately replaces fluid lost through sweating, with the total fluid deficit during a training or competition session not exceedingly approximately 2% of body mass (at a rate of 200 ml per 20 minutes of exercise). Furthermore, during exercise lasting more than an hour and causing fatigue, athletes are advised to consume a carbohydrate source that is rapidly converted to blood glucose, while sodium should be included in the fluid intake during exercise lasting more than one to two hours. The main energy-generating nutrients in most energy drinks appear to be carbohydrates and/or caffeine. Hence the importance of research into the effect of mineral and sugar concentrations and their consumption as drinks to compensate athletes to maintain some physical abilities and functional indicators for football players. The problem is that although there is research, it is little that has addressed these topics and the effects resulting from the variation in the proportions of mineral and sugar solutions, which reach 10%, while in this study, a percentage of mineral salts will be determined at 2% - 5% and mixed with a percentage of 10% carbohydrates in order to simulate the nature of the football player and his predominant metabolic system for aerobic energy.

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The study aims

1- Knowing the mineral and sugar concentrations as solutions in rehydration.

2-To know the effect of mineral and sugar solutions with a mineral concentration of 2% and a carbohydrate content of 10% in 500 ml of water on some physical abilities and functional indicators.

3- Knowing the effect of mineral and sugar solutions with a mineral ratio of 5% and a carbohydrate ratio of 10% in an amount of 500 ml of water on some physical abilities and functional indicators.

Method and tools:

The researcher used the experimental method by designing two groups, a control and an experimental group. A community of football academies was selected, aged 15-16 years, with an average height of 170.7 ± 4 cm and an average weight of 73.6 ± 5.8 kg. The research sample was 20 players from Uncle Baba Football Academy. They were randomly selected and divided into two groups, each group (n = 10 experimental 1) (n = 10 experimental 2). They trained three training units per week. The field experiment was conducted on them by conducting matches within the academy's football activity, while they represented one of the teams. The sample expressed their willingness and participation after being informed of the study objectives.

Tests

1- Physical ability tests

Sargent test (jumping up) anaerobic phosphagen capacity ,Grip test (measuring hand grip strength)

2- Functional indicators, Body weight, Resting heart rate, Plasma viscosity -Sodium content, Potassium, Magnesium

Laboratory method

3ml of blood is drawn from each player before irrigation with mineral and sugar substances and after the end of the matches. The blood samples are kept in the medical box and then sent to the Elite Laboratory to extract blood indicators.

Experimental design

The research sample was subjected to follow-up tests before and after the matches, where (experimental group 1) was exposed to a mineral and sugar solution with a mineral content of 2% and a carbohydrate content of 10% in an amount of 500 ml of water, while (experimental group 2) was exposed to a mineral and sugar solution with a mineral content of 5% and a carbohydrate content of 10% in an amount of 500 ml of water 20 minutes before the start of the matches and after 45 minutes of the first half of the matches. They

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were allowed to drink only 500 ml of water during the matches, and then continue in the second half. At the end, the post-tests were conducted. The temperatures were monitored at 32-33 degrees Celsius.

Concentration preparation

The solution was prepared in a pharmaceutical laboratory and the contents were

mineral salts and 10% carbohydrate solution (0.5g sodium, 0.3g magnesium, %2 - 0.2g potassium, 5g carbohydrates)

mineral salts and 10% carbohydrate solution (1g sodium, 0.5g magnesium, %5 - 0.5g potassium, 5g carbohydrates)

Statistical methods

SPSS statistical package was used

Results

Table (1) shows the arithmetic means of the functional indicators before and after the match

	Body weight kg		Resting heart rate n/a		Plasma viscosity millipascal/s		Sodium content millimoles/liter		Potassium percentage millimoles/liter		Manganese ratio mg/dL	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Mineral concentration 2% and sugar	62,8	62,1	76,6	79,3	1,42	1,68	139	146	3,9	3,4	1,8	2,2
Mineral concentration 5% and sugar	64,1	63.6	78,1	80,2	1,39	1,64	142	151	3,4	3,2	1,7	2,1

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After processing the data in Table (1) for the arithmetic mean of the functional indicators, mineral and sugar concentrations before and after the match, the researcher relied on the normal ranges for each indicator of mineral concentrations, weight, and resting heart rate to indicate the variables. However, the results showed a weight loss of (0.8 kg) in the first group with a mineral concentration of 2% and sugar concentration of 10%, while the weight loss of (0.5 kg) in the second group with a mineral concentration of 5% and sugar concentration of 10%. The research attributes the weight loss to fluid loss resulting from sweating, and the total fluid deficit during training or competition should not exceed approximately 2% of body mass. Athletes appreciate the need to consume fluids before, during, and after exercise, as well as the importance of hydration sometimes using drinks containing carbohydrates and mineral salts to replace fluids (Leow C, Tan B, Miyashita M, Lee J, 2022). Just as general competition and training strategies must be tailored to each individual athlete and according to their unique needs and preferences, so must training hydration strategies (Tambalis KD, 2022).

The heart rate index in the first group with a mineral concentration of 2% and sugar 10% was within the normal range (75-80), as well as in the second group with a mineral concentration of 5% and sugar 10%. The research attributes that consuming fluids and energy drinks loaded with mineral concentrations helps complete the recovery process and maintain heart function, with the discovery of a lot of training that reaches heart rates of 90% as the maximum heart rate, which shows early fatigue (James, C 0ther 2021). Fatigue during continuous exercise is closely related to the depletion of carbohydrate stores (glycogen) in skeletal muscles and cardiac muscles. In a recent study of fatigue in a football match, a significant decrease in glycogen levels was observed in skeletal and cardiac muscles after playing for 90 minutes (Mohr M, Vigh-Larsen JF, Krustrup P. 2022). The early decline in glycogen stores in muscles, liver, and cardiac muscle, during prolonged exercise, can be prevented by consuming carbohydrates before and during exercise (Mohr M, OTHER 2022)

The results of the plasma viscosity index showed that the first group, with a mineral concentration of 2% and sugar content of 10%, was affected by 0.26 mPa/s, while the second group, with a mineral concentration of 5% and sugar content of 10%, was affected by 0.25, which is close to the first group. The researcher attributes this to the loss of fluids during continuous effort, and that replacing fluids will allow the body to retain fluids through hydration with carbohydrate drinks supplemented with mineral salts, which helps with the metabolic process and energy, enabling the player to complete the match. As a result, the body has heat loss mechanisms, such as increased blood flow in the skin and the onset of sweating, to enable heat loss by evaporation, maintain heat balance, and mitigate further increases in body temperature. All of this leads to an increase in plasma viscosity (Sawka, M.N.; Cheuvront, S.N.; Kenefick, R.W. 2015). Plasma viscosity has an impact on

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the player's functional efficiency as the match progresses and the pace of the match increases, players begin to fail to master both physical skills and abilities (running, sprinting, jumping) (mental concentration, decision-making) faster (Ian Rollok, Clyde Williams 2023). All of this was observed in the concentration ratios, although the results were within normal limits. (Kadhim & Majid, 2023) What appeared in the first group was a 2% mineral concentration and 10% sugar, a difference of +7 mmol/L in sodium, and +0.5 mmol/L in potassium, while magnesium +0.4%. While the concentrations of the second group were 5% in mineral concentration and 10% sugar, a difference of +9 mmol/L in sodium, and +0.2 mmol/L in potassium, while magnesium +0.4%. The research attributes the result of compensation with mineral and energy drinks used in the study to maintaining the loss of these salts and natural proportions in the body. In addition to fluids, (Na+, K, Mg,) are also important factors in the athlete's hydration strategy. They are electrolytes lost in sweating, and have been shown to maintain plasma levels of vasopressin and aldosterone, which promotes total body and extracellular fluid retention (Shirreffs, S.M.; Maughan, R.J. 1998).

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Table (2) shows the difference in means, the error level, the significant differences, and the T value for the ability test between before and after the match

Processors	Anaerobic capacity before the match		Anaerobic capacity after the end of the match		F	F	T value	Say	the difference
	Q	A	Q	A					
Mineral concentration 2% - Sugar 10%	35،6	2,75	31,2	3,7	4,65	-1,7	3,76	0,01	spiritual
Mineral concentration 5% - Sugar 10%	37,4	3,55	35,9	3,45	3,96	-2,2	4,78	0,12	Non-moral

*Significant 0.05 > at a freedom level of 9

The results of anaerobic capacity showed a decrease in the first group, where the difference in vertical jump was significant. The researcher attributed this to the decrease in the amount of mineral salts used in the amount of fluids given, as he proved that fluids containing Na+ work to improve rehydration after effort ((Evans, G.H.; James, L.J.; Shirreffs, S.M.; Maughan, R.J. 2017)), while the second group maintained the level of vertical jump because the rehydration process achieved an improvement in effort and maintained its physical level, as in the hand grip test, the results of which are shown in Table 3.

Table (3) shows the difference in means, the error level, the significant differences, and the T value for the hand grip test between before and after the match.

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Processors	Hand grip test before matches		Hand grip test after matches		F	F	T value	Say	the difference
	Q	A	Q	A					
Mineral concentration 2% - Sugar 10%	23,4	0,87	20,96	1,2	2,66	-1,2	4,33	0,03	spiritual
Mineral concentration 5% - Sugar 10%	24,2	1,67	22,34	1.7	1,98	- 0,87	2,66	0,16	Non-moral

at a freedom level of 9 0.05 > Significant *

Using this nutritional strategy has the role of delaying fatigue and maintaining performance for a longer period than in the absence of this intervention. In addition, carbohydrate intake also facilitates maintaining skill performance when players are tired (Hills SP, Russell M. 2017) .

Nutritional strategies to increase glycogen stores by providing carbohydrates before and during exercise improve endurance and strength performance by delaying the depletion of this essential fuel. The effectiveness of carbohydrate intake does not apply only to running, a common activity pattern in team sports, particularly football (Harper LD, Stevenson EJ, Rollo I, Russell M. 2017).

While adopting nutritional strategies to delay the rapid loss of glycogen stores helps players maintain their work rate during matches, after implementing a carbohydrate-based nutrition strategy, they will be better able to perform the necessary skills in the match. Unfortunately, there are too few studies to provide a definitive answer to this question .

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However, one study reported that when male professional soccer players consumed either a 7% carbohydrate drink or a placebo before (5 ml per kg body mass) and every 15 minutes (2 ml per kg body mass) during a 90-minute on-field soccer match and then completed assessments of four skills: dribbling speed, coordination, accuracy, and power, there was a significant improvement in the retention of dribbling speed and accuracy after carbohydrate ingestion (Ostojic SM, Mazic S. 2002).

Conclusions

Mineral and sugar solutions support the irrigation process and have the effect of .maintaining mineral salt levels in the body

Enhancing the fluids given with mineral salts helps in fluid retention in the body -

Carbohydrates boost energy levels in the muscles and maintain continuous performance levels

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References

Evans, G.H.; James, L.J.; Shirreffs, S.M.; Maughan, R.J. Optimizing the restoration and maintenance of fluid balance after exercise-induced dehydration. J. Appl. Physiol. 2017, 122, 945–951

Harper LD, Stevenson EJ, Rollo I, Russell M. The infuence of a 12% carbohydrate-electrolyte beverage on self-paced soccerspecifc exercise performance. J Sci Med Sport. 2017;12:1123–9

Hills SP, Russell M. Carbohydrates for soccer: a focus on skilled actions and half-time practices. Nutrients. 2017;10(1):22–32..

Ian Rollok. Clyde Williams :Carbohydrate Nutrition and Skill Performance in Soccer , Sports Medicine (2023) 53 (Suppl 1):S7–S14 https://doi.org/10.1007/s40279-023-01876-3

James, C.; Dhawan, A.; Jones, T.; Girard, O. Quantifying Training Demands of a 2-Week In-Season Squash Microcycle. Int. J. Sports Physiol. Perform. 2021, 16, 779–786. [CrossRef] [PubMed]

Kadhim, M. J., & Majid, S. (2023). *Effect of consuming sodium bicarbonate on the numeric value of the accumulation of lactic acid levels in the blood after maximum physical effort between gymnastics and judo players.*

Konstantinos D. Tambalis THE EFFECT OF ELECTROLYTES AND ENERGY DRINKS CONSUMPTION ON ATHLETIC PERFORMANCE – A NARRATIVE REVIEW August 2022 DOI/10.46827:ejfnsm.v3i1.127

Leow C, Tan B, Miyashita M, Lee J, 2022. Cultural differences in hydration practices among physically active individuals: a narrative review. Journal of the International Society of Sports Nutrition 19(1): 150–163. doi 10.1080/15502783.2022.2057196

Mohr M, Ermidis G, Jamustas AZ, Vigh-Larsen J, Poulios A, Draganidis D, Papanikolaou K, Tsimeas P, Batsilas D, Loules G, Batrakoulis A, Sovatzidis A, Nielsen JL, Tzatzakis T, Deli CK, Nybo L, Krustrup P, Fatouros IG. Extended match time exacerbates fatigue and impacts physiological responses in male soccer players. Med Sci Sports Exerc. 2022;55(1):80–92.

Mohr M, Vigh-Larsen JF, Krustrup P. Muscle glycogen in Elite Soccer—a perspective on the implication for performance, fatigue, and recovery. Front Sports Active Living. 2022;4: 876534

Ollie Turner , Nigel Mitchell , Alan Ruddock , Alison Purvis and Mayur K. Ranchordas , Fluid Balance, Sodium Losses and Hydration Practices of Elite Squash Players during Training Nutrients 2023, 15, 1749 .https://doi.org/10.3390/nu15071749

Ostojic SM, Mazic S. Efects of a carbohydrate-electrolyte drink on specific soccer tests

Journal of Physical Education

Volume 37 – Issue (2) – 2025 Open Access

P-ISSN: 2073-6452, E-ISSN: 2707-5729
https://jcope.uobaghdad.edu.iq

and performance. J Sports Sci Med. 2002;1(2):47–53

Ozcan Esen, Ian Walshe & Stuart Goodall, Energy intake, hydration status, and sleep of world-class male archers during competition, , Journal of the International Society of Sports Nutrition, 21:1, 2345358, DOI: 10.1080/15502783.2024.2345358

Sawka, M.N.; Cheuvront, S.N.; Kenefick, R.W. Hypohydration and Human Performance: Impact of Environment and Physiological Mechanisms. Sports Med. 2015, 45, 51–60. [CrossRef]

Shirreffs, S.M.; Maughan, R.J. Volume repletion after exercise-induced volume depletion in humans: Replacement of water and sodium losses. Am. J. Phys. 1998, 43, 868–875.

Tambalis KD, 2022. Special nutritional needs for athletes and exercisers. European Journal of Physiotherapy and Rehabilitation Studies 3(1): 1-22. doi:10.46827/ejprs.v3i1.119.