

Effects of Hydration Strategies on Physical Test Performance in Elite Youth Footballers

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Abstract

Background: Playing football in a hot, humid environment increases the risk of dehydration in youth footballers, which can adversely affect their performance. The aim of this study was to compare the effects of hydration strategies on physical test performance in youth elite football players in Benin. **Methods:** Thirty-two youth footballers (18.7 ± 0.5 years; 172.3 ± 5.3 cm; 63.6 ± 5.5 kg; 55.2 ± 3.3 ml/min/kg; 56 ± 6 bpm), previously hydrated and randomly divided into two groups, underwent tests of countermovement jump, repeated sprint capacity, and Illinois agility before and after a 60-minute training session during which the intervention group (IG), subjected to imposed hydration, consumed 250 ml of bottled still water every 20 minutes, while the control group (CG) drank ad libitum. Urine density of each player before and after exercise was determined with a PEN-Urine 75 S.G clinical refractometer. **Results:** Performance declined less in repeated sprint capacity tests in IG ($p = 0.02$) than in CG ($p = 0.0009$) and in the Illinois agility test between IG ($+0.6\%$) and CG ($+3.1\%$). **Conclusion:** As part of the quest for physical performance, the imposed hydration strategy seems more suited to youth footballers in hot and humid environments.

Keywords

Performance Analysis of Sport, Hydration, Environments, Youth, Football, Male

1. Introduction

Football performance is multifactorial, involving athletic, technical, tactical, mental, and physiological abilities [1]. A player's hydration can affect their performance and state of health [2]. During training and matches, increased body temperature causes players to sweat, which can seriously threaten water balance, physical performance, organ function, and health [3]. Dehydration in excess of 2% of body mass impairs sporting performance, including sprinting and dribbling skills in football [4]. The quest for optimal fluid status should be even more important in youth athletes, who dehydrate easily [5].

During exercise, athletes generally resort to spontaneous, thirst-driven water consumption [6]. The disadvantage of this behavior is that thirst is often delayed, so that athletes who drink according to their thirst never make up for water losses [7], thus compromising their performance [8]. To avoid underperformance due to dehydration, athletes employ several strategies. These fall into two categories: *ad libitum* hydration strategies and imposed hydration strategies. One form of *ad libitum* hydration strategy assumes that water is readily available to the athlete, who can then drink as much as he or she likes without any specific instructions [9]. Imposed hydration strategies, on the other hand, recommend the consumption of a certain volume of water at a given frequency [10].

In Southern Benin, exposure to heat and humidity leads to high levels of dehydration [11]. Most studies on the water status of team sports players report a high proportion of dehydrated players before and during matches [11], inadequate hydration [12], and deterioration in the ability to perform repeated sprints [13]. Two observations can be made in Benin at club training sessions and at Training Camps (TC) in preparation for international competitions. The first is that water is available to players, in large containers or packaged in 1.500 mL bottles, or in 250 mL sachets. The second is that hydration instructions are few and far between, with the result that players generally only drink at half-time or during breaks in training. However, studies report that dehydration remains common among young athletes despite the availability of fluids [3] [14] [15]. These observations raise the question of whether this practice is sufficient to protect youth football players from dehydration, and whether it is not partly responsible for the poor performances of Beninese footballers, characterized by poor results generally recorded in the second half of matches.

Hence, the hypothesis that the imposed hydration strategy is the best adapted to induce a lesser decline in the physical performance of these youth footballers in a hot, humid environment is supported.

2. Methods

2.1. Participants

The study sample consists of 32 youth footballers pre-selected and grouped in National team training camps with a view to selecting 18 players to represent Benin in the qualifiers for the 2018 African Cup of Nations. The 32 youth footballers

who took part in the study were all male, with an average age of 18.7 ± 0.5 years, were preselected for the Benin junior national team, had no certificate of contra-indication to playing sport during the survey period, had participated in all stages of the study and, finally, had freely given their written informed consent. Footballers injured during the intervention or absent from one of the intervention phases were supposed to be excluded from the study sample, but they were not.

The study received prior approval from the Sectoral Scientific Committee for Sciences and Techniques of Physical and Sports Activities of the University Abomey-Calavi and was conducted in accordance with the recommendations of the 1974 Declaration of Helsinki.

2.2. Measures

An individual data sheet was used to obtain information on the players' socio-demographic characteristics and medical history. The players' height and body mass were measured with a wall-mounted body meter 206 (Seca, France) and a BR 9012 bathroom scale (Camry, China), respectively, accurate to 0.1 kg. Body mass index was determined from the ratio of body mass (kg) to height (m) squared. Urine density of each player before and after exercise was determined with a PEN-Urine S.G clinical refractometer (Atago, Japan), calibrated with distilled water before each new urine sample measurement. Radiant temperature and relative humidity were recorded during exercise using a Météo Star multifunction device. Rectal temperature and heart rate (resting and maximum) were measured using 105 MT 401 R automatic thermometers (Cooper, France) and FT4 heart rate monitors (Polar, Finland), respectively. The test started at 2 pm, with an average temperature of 28°C and an average relative humidity of 70%. Running times in the Illinois repeated sprint and agility tests were measured using a photocell system (Brower Timing system, USA). Countermovement jump height was determined using an Opto jump Next device (Microgate, Italy). The total quantity of water consumed by each CG player was determined by considering the number of 1500 mL bottles emptied, to which was added the quantity of water consumed from the last bottle. The latter represented the difference between 1500 mL and the volume remaining, measured with a 500 mL test tube graduated in milliliters. In IG, on the other hand, the quantity of water drunk by each player was equal to the number of sachets emptied during the procedure multiplied by the capacity of one sachet, which was 250 mL.

2.3. Procedures

This interventional study involved 32 pre-selected youth football players, who were brought together at the Stadium Charles de Gaulle in Porto-Novo for a training camp. The final objective was to select 18 players to represent Benin at the African Cup of Nations. The 32 players were randomly divided into two groups: an intervention group with compulsory hydration and a control group with ad libitum hydration.

- Two weeks before the start of the study, the players were briefed on the objective, the procedure, the benefits and the risks, and then freely gave their written informed consent.
- Forty-eight hours before the start of the intervention, the Yo-Yo Intermittent Recovery Test 1 (Yo-Yo IRT1) was performed, followed by a test familiarization session.
- On the day of the intervention, participants underwent field tests before and after a training session. These were the countermovement jump test, the repeated sprint ability test, and the Illinois agility test (AI). The actual intervention took place as shown in **Figure 1**.

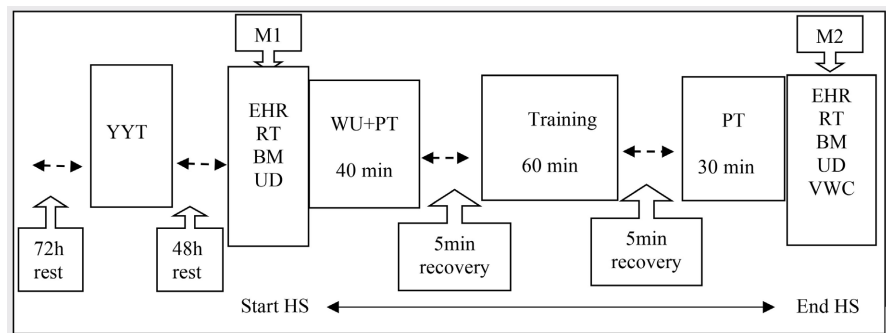


Figure 1. A schematic diagram of the intervention device. YYT: Yo-Yo IRT1; M: Measurement; UD: urine density; RHR: resting heart rate; EHR: exercise heart rate; RT: rectal temperature; BM: body mass; WU: warm-up; PT: physical tests; H: Hour; VWC: volume of water consumed; SH: hydration strategy.

- Two hours and then 20 minutes before the start of exercise, each of the 32 players studied consumed 500 mL and 250 mL of water respectively to make themselves euhydrated [16].
- Ten minutes before the start of exercise, body mass, rectal temperature, resting heart rate, and urine samples were taken (M1).
- During physical effort, IG players systematically consumed 250 mL of water every 20 min [12], while their CG peers drank ad libitum. For this purpose, IG players were provided with 250 mL water sachets, while ad libitum hydration players were each provided with an identified 1500 mL water bottle, which was immediately refilled by an assistant investigator as soon as it was empty. All 32 players were instructed to use the water only for their own consumption, to avoid using it to cool their bodies, and to ensure that no drops fell to the ground.
- At the end of the exercise, body mass, rectal temperature, and urine samples were taken again (M2).

2.4. Studied Variables

2.4.1. Independent Variable

The independent variable was the hydration strategy operationalized in two modalities: imposed hydration and ad libitum hydration.

2.4.2. Dependent Variables

The dependent variables were:

- 1) Water status is operationalized in two modalities, namely euhydration when urine density (UD) is less than or equal to 1.020, and dehydration defined by a UD greater than 1.020 [17];
- 2) the mean volume of water consumed;
- 3) the maximum height of the countermovement jumps among the three tests performed;
- 4) the mean time in the repeated sprints capacity test;
- 5) The running time in the Illinois agility test.

2.4.3. Confounding Variables

Radiant temperature, relative humidity, and exercise intensity were the study's confounding variables.

2.5. Physical Tests

Three tests were carried out: the countermovement jump test [18], the Illinois agility test [19], and the repeated sprints capacity test administered to players before and after a 60-minute training session. The Yo-Yo IRT1 test was performed 48 hours prior to determine their maximal oxygen consumption ($\dot{V}O_2\text{max}$) [20].

2.6. Training Session

The training session lasted 60 minutes and included 15 minutes of technical/tactical work, 20 minutes of overall play, and a 5-minute cool-down. The technical-tactical work consisted of ball handling, two-footed inside passes, pass-and-go, and pass-and-follow. Overall play took place on both halves of the pitch. The 32 players were divided into two groups of 16. Each group played 8 against 8 on one half of the pitch.

2.7. Statistical Analysis

The data collected were processed using Statistica software from StatSoft Inc (Version 7.1). The normality and homogeneity of the distribution of variables were checked using the Kolmogorov-Smirnov and Levene tests, respectively. Descriptive statistics in the form of means (m) $\pm$ standard deviations (s) were calculated. In view of our sample size and the normal distribution of the variables studied, the unpaired Student's *t*-test was used to compare values between measurements and between groups. The significance level for statistical tests was set at $p < 0.05$.

3. Results

This study was conducted with 32 youth football players randomly divided into two groups of equal size: an intervention group (IG) of 16 players subjected to imposed hydration and a control group (CG) of 16 players subjected to ad libitum

hydration as observed in Benin stadiums. Both groups performed the same physical tests under the same conditions. The intervention lasted a total of 140 minutes. The comparative results are shown in **Tables 1-3**.

Table 1. Anthropometric, physiological, and sports history characteristics of the youth football players studied (n = 32).

	ET (n = 32)	IG (n = 16)	CG (n = 16)	P
	m ± s	m ± s	m ± s	
Age (years)	18.7 ± 0.5	18.8 ± 0.3	18.5 ± 0.7	0.23
Height (cm)	172.3 ± 5.3	173.6 ± 5.3	170.9 ± 5.2	0.15
Weight (kg)	63.6 ± 5.5	64.8 ± 5.9	62.3 ± 5.1	0.20
BMI (kg/m ²)	21.4 ± 1.9	21.5 ± 2.1	21.3 ± 1.7	0.77
VO₂max (mL/min/kg)	55.2 ± 3.3	55.1 ± 3.1	55.4 ± 3.6	0.78
VHWT (hours)	11.6 ± 3.1	11.6 ± 3.8	11.5 ± 2.3	0.91
Seniority (years)	3.9 ± 1.2	4.2 ± 1.1	3.6 ± 1.2	0.20
HR (bpm)	56 ± 6	57 ± 4	54 ± 7	0.14

TS: total sample; IG: intervention group subjected to an imposed hydration strategy; CG: control group with an ad libitum hydration strategy; n: number of participants; m: means; s: standard deviations; BM: body mass; BMI: body mass index; $\dot{V}O_2$ max: peak oxygen consumption; VHWT: volume per hour weekly training; Seniority: number of years playing competitive soccer; HR: resting heart rate; bpm: beats per minute.

These were players in the junior category with approximately 3.9 ± 1.2 years of competitive football experience and a weekly training volume of 11.6 ± 3.1 hours, a resting heart rate of 56 ± 3 bpm, and a peak oxygen consumption of 55.2 ± 3.4 mL/min/kg.

The recorded results show that both groups remained euhydrated during exercise, but the GI consumed more water than the CG ($p < 0.0001$). Rectal temperature also rose in both groups ($p < 0.0001$) but much more in the CG ($p = 0.008$).

Table 2. Changes in physiological, anthropometric, and water consumption data during intervention (n = 32).

	IG (n = 16)		CG (n = 16)	
	M1	M2	M1	M2
RT (°C)	36.6 ± 0.3	37.3 ± 0.4***	36.8 ± 0.2	37.7 ± 0.3***
UD	1.005 ± 0.002	1.007 ± 0.004	1.004 ± 0.002	1.009 ± 0.003***
PBML (%)		-0.1 ± 0.4		-0.2 ± 0.6
TVWC (mL)	2000 ± 0.0		1276.1 ± 601.0***	
AVWC (mL)	250 ± 0.0		360.7 ± 144.1**	

Continued

FWC	8 ± 0	3.4 ± 0.8 ^{###}
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The numbers in the boxes represent the means ± standard deviations; IG: intervention group subjected to the hydration strategy; CG: control group subjected to ad libitum hydration strategy; M1: measurements taken before the start of training; M2: measurements taken at the end of training; RT: rectal temperature; UD: urine density; PBML: Percentage Body Mass Loss; TVWC: total volume of water consumed; AVWC: average volume of water consumed at each intake; FWC: frequency of water consumption; n: number of participants; ***: difference between M1 and M2 significant at $p < 0.0001$; #: difference between IG and the CG significant at $p < 0.001$; ###: difference between IG and the CG significant at $p < 0.0001$.

During the procedure, which lasted 2 h 20 min, IG consumed 2000 ± 0.0 mL in eight intakes versus 1276.1 ± 601.0 mL in three intakes for CG ($p < 0.0001$). Mean consumption per intake was 250 ± 0.0 mL for IG and 360.7 ± 144.1 for CG ($p < 0.01$). All participants subjected to both hydration modalities were euhydrated before and immediately after training. Their urine density ranged from 1.004 to 1.009, with a significant difference ($p < 0.001$) in the control group ($p = 0.0002$). Both groups gained weight at the end of the study: 0.1% of their body mass for IG and 0.2% for CG.

Table 3. Changes in physical performance in field tests (n = 32).

	IG (n = 16)		C (n = 16)	
	M1	M2	M1	M2
MHCJ (cm)	41.6 ± 3.7	41.3 ± 2.9*	38.8 ± 2.8	39.8 ± 3.3***
IATRT (s)	15.0 ± 0.5	15.0 ± 0.7	15.2 ± 0.7	15.7 ± 0.8 #
MSRT (s)	5.2 ± 0.1	5.3 ± 0.1*	5.3 ± 0.1	5.5 ± 0.2***

Numbers in boxes represent means ± standard deviations; IG: intervention group subjected to imposed hydration strategy; CG: control group subjected to ad libitum hydration strategy; n: number of participants; M1: measurements taken before the start of training; M2: measurements taken at the end of training; MHCJ: maximum height at countermovement jump; MSRT: mean 40 m sprint running time; IATRT: Illinois agility test running time; *: difference between M1 and M2 significant at $p < 0.05$; ***: difference between M1 and M2 significant at $p < 0.0001$; #: difference between IG and CG significant at $p < 0.05$.

Performance decreased in both groups, but more significantly in the CG than in the IG, in the Illinois agility test and the repeated sprints test ($p = 0.02$).

4. Discussion

The aim of this study was to compare the effects of hydration strategies on physical test performance in youth elite football players in Benin. In relation to the players studied, they all came from training centers where the weekly volume of training may have given them a good level of $\dot{V}O_{2\max}$. This $\dot{V}O_{2\max}$ estimated from the results of the Yo-Yo IRT1 test is comparable to that of the world elite

[21]. It suggests that our study sample has a high endurance capacity, a good ability to repeat sprints, and that they could perform high-intensity actions with or without a ball [21]. The $\dot{V}O_2\text{max}$ of the Beninese youth footballers studied is nevertheless lower than that of their Brazilian counterparts. Their heart rate at rest was within the range of that of top athletes, *i.e.*, below 60 beats per minute. These anthropometric, physiological, and practice history data testify to the fact that these youth players must have benefited from well-structured training at football centers.

With regard to the two hydration strategies, the volume of water drunk and the frequency of consumption during the 2 h 20 min of exercise were greater in the group subjected to imposed hydration than in the group with *ad libitum* hydration. The very structure of the intervention group's hydration plan seems to justify this result. Each player in this group was systematically required to consume 250 mL every 20 min during 140 min of exercise. No such frequency was observed in the control group, which only drank water on three occasions. Although the volume of water drunk at each intake was greater than that of the intervention group ($p < 0.001$), the low frequency of consumption in the control group did not allow them to drink as much as the intervention group. Our results are identical to those recorded in hot climates in youth Israeli athletes who consumed 330 ± 63 versus 237 ± 90 mL during intermittent exercise when subjected to imposed and then *ad libitum* hydration respectively [22].

During exercise, the volume of water consumed with each intake was greater in the *ad libitum* hydration group than in the forced hydration group. This suggests that water consumption in the *ad libitum* hydration group is driven by thirst, as they are accustomed to, whereas their forced hydration peers were required to drink only 250 mL at a time, but every 20 minutes regardless of their condition. During exercise, when athletes drink according to their thirst signals, they consume enough water to quench their thirst [9]. However, this practice, which is in line with their habits, has the disadvantage of not being sufficient to compensate for all the losses suffered by the body [8].

All the football players studied were euhydrated at the end of exercise. The regularity of water consumption by the players subjected to imposed hydration seems to have enabled better replacement of losses. These results are in line with those reported in adolescent athletes after an educational intervention followed by an imposed hydration strategy [23]. Participants in the *ad libitum* hydration group in our study were also euhydrated at the end of exercise. These results, contrary to our expectations, can nevertheless be justified by their pre-exercise euhydrated status, obtained by consuming the 750 mL of water. This status was maintained throughout the effort, thanks to water intakes which, although spaced out, were sufficient. Our results, which confirm the need for all sportsmen and women to start exercise euhydrated and to hydrate during exercise [17], also corroborate those of other studies in which youth players subjected to an individual hydration plan but who had not taken the precaution of making themselves euhydrated before exercise found themselves dehydrated at the end [3].

With regard to performance modification in physical tests, it must first be admitted that a football player's performance is linked to his ability to repeat sprints at an optimal level throughout the match [23]. Similarly, the average time in the repeated sprint test is also a reliable parameter for assessing his performance [13]. In the present study, there was an increase in the mean time for repeated sprints in each group. The players remained euhydrated during exercise even though they lost a small amount of weight, much more so in the *ad libitum* hydration group than in the forced hydration group. The deterioration in performance observed, which was more marked in the *ad libitum* hydration group, can be attributed to fatigue and glycogen depletion [4]. The regularity of consumption and the volume of water drunk at each intake during exercise in the forced-hydration group may have helped limit the loss of body mass and the drop in performance, since both groups of players started the physical tests with the same water status. These results are similar to those obtained in athletes during a series of 10 repeated sprints during which performance deteriorated despite water intake. They are also in line with those recorded during a series of matches in handball players from Benin, who showed deterioration in repeated sprinting ability despite water intake similar to our study [24].

We did not record any cases of dehydrated football players throughout the intervention, which implies that factors other than hydration may have contributed to the observed declines in physical performance. Prolonged physical exercise may have led to hypoglycemia, glycogen depletion, depletion of phosphagen reserves, and electrolyte loss, all of which may have resulted in reduced performance [1]. When physical exertion lasts longer than an hour, it is recommended that energy and electrolytes be provided [9]. It has been well documented that carbohydrate intake improves football performance [1]. The results of this research are in line with those reported in women's football physical testing trials, during which performance declined despite water intake [1]. Rectal temperature increased in both groups. The intensity of the physical effort and the thermal stress must have generated a high demand for thermoregulation, given the radiant temperature conditions, which averaged 33°C and 60% relative humidity. However, the rise in rectal temperature in both groups was less marked in the hydration group. This suggests that the quantity and regularity of water consumption may have contributed to better cooling of the players' bodies in this group, whereas the large volume absorbed at one time in the other group may have caused problems with gastric emptying and hence less effective cooling of the body [25]. These results are in line with those reported in the same hot, humid environment of Benin during a series of handball matches, during which the authors noted a rise in rectal temperature despite high water consumption [26].

5. Conclusion

This study concluded that an imposed hydration strategy limited the increase in rectal temperature, weight loss, and performance decline in the repeated sprint capacity tests and the Illinois Agility Test in youth footballers in a hot and humid

environment. Overall, all the performance declines observed in this study were greater in the ad libitum hydration group than in the imposed hydration group, thus confirming the effectiveness of the imposed hydration strategy in limiting performance declines in youth football players in a hot and humid environment. While waiting for future protocols to integrate themes such as restoring electrolyte losses and carbohydrate intake, coaches and people potentially assigned to nutritional support for teams practicing in hot and humid environments can already adopt this imposed hydration method to prevent athletes from dehydration, which is responsible for performance declines during physical exercise.

Author's Contribution

Design and execution of experiments: Ouédraogo B. Mahougnon K, Data processing: Moussouami S. Sawadogo A., Methodology: Ouédraogo B, Reagents/materials/analysis: Bio Nigan I, Ouédraogo B, Writing/review/editing: Ouédraogo B, Mahougnon K, Sawadogo A. All authors have read and approved the final manuscript.

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Conflicts of Interest

The authors have no conflict of interest.

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