U.PORTO
FACULDADE DE CIÊNCIAS DA NUTRIÇÃO E ALIMENTAÇÃO
UNIVERSIDADE DO PORTO

Impact of fluid restriction and *ad libitum* sports drinks and water intake on skill performance of elite adolescent basketball players

Impacto da restrição hídrica e ingestão *ad libitum* de bebidas desportivas e água na performance de basquetebolistas adolescentes de elite

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Trabalho de Investigação | Porto 2009

Pedro Ramos de Carvalho, 2009

ACKNOWLEDGEMENTS

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Bruno Oliveira

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Hugo Matos

Atletas CNT – Paredes Rota dos Móveis

Coca Cola Company

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ABBREVIATIONS

ACSM – American College of Sports Medicine

ATP – Adenosine Triphosphate

BA – Beverage Acceptability

BW – Body Weight

CSB – 8% Carbohydrate-Electrolyte Sports Beverage

EUH - Euhydration

FT – Free Throw

IHI – Intermittent High-Intensity

NF – No fluid ingestion allowed

RH – Relative Humidity

RPE – Rating of Perceived Exertion

SD – Standard Deviation

SPSS – Statistical Package for Social Sciences

SS – Suicide Sprint

T – Atmospheric Temperature

US – Urine Sample

W – Water

ABSTRACT

Purpose: To determine the effect of fluid restriction and *ad libitum* water and sports drinks consumption on basketball performance, and correlate the athlete´s knowledge about hydration and fluid replacement issues with their behavior in a real situation. **Methods**: Twelve 14 to 15 years' old players underwent, in a cross-over design study, three separate 2-h training sessions in the following conditions: No fluid ingestion allowed (**NF**); *Ad libitum* ingestion of water (**W**); *Ad libitum* ingestion of a commercial 8% carbohydrate-electrolyte sports beverage (**CSB**). After each session subjects performed a set of basketball drills, such as 2-point, 3-point and free-throw shootout, suicide sprints and defensive zigzags. Body weight (at the beginning and at the final of sessions), rating of perceived exertion (**RPE**), urine color and beverage acceptability were determined. Athletes also respond to a survey with questions about their knowledge and behaviors regarding hydration and fluid replacement. **Results**: The percentage of weight lost was significantly higher in NF (2.46 ± 0.87) compared with other two conditions (W: 1.08 ± 0.67, $P < 0.01$; CSB: 0.65 ± 0.62, $P < 0.001$) and in W vs. CSB condition ($P < 0.05$). RPE was higher in NF (16.8 ± 1.96) compared with W (14.2 ± 1.99; $P < 0.01$) and CSB (13.3 ± 2.06; $P < 0.01$) trials. There were no significant differences in basketball performance, urine color and beverage acceptability between conditions. Athletes' knowledge was positively correlated with self-reported behaviors ($r = 0.75$; $P < 0.05$) and fluid intake ($r = 0.76$; $P < 0.05$) during sessions. **Conclusion**: Fluid restriction didn't impaired performance but increase athletes' perceived exertion and body mass lost. The athletes' with more knowledge about hydration issues

had better self-reported behaviors and ingested more fluids during training sessions.

Key Words: Adolescents, Basketball, Fluid Balance, Hydration, Performance, Sport

RESUMO

Objectivos: Determinar o efeito da restrição hídrica e consumo *ad libitum* de água e bebidas desportivas na performance basquetebolística e correlacionar os conhecimentos dos atletas sobre hidratação e reposição hídrica com os seus comportamentos numa situação real. **Métodos**: Doze atletas com idades entre os 14 e 15 anos, experimentaram num desenho cross-over, 3 diferentes condições durante um treino de 2 horas: Proibição de ingestão de fluidos (**NF**); Ingestão *ad libitum* de água (**W**); Ingestão *ad libitum* de bebida desportiva com 8% de Hidratos de Carbono (**CSB**). Em cada treino, os atletas fizeram uma sequência de exercícios destinados a avaliar a performance como séries de 10 lançamentos de 2 pontos, 3 pontos e lances livres, sprints “suicidas” e zigzags defensivos. O peso corporal foi medido no início e no final de cada treino e a percepção de esforço (**RPE**), cor da urina e aceitabilidade da bebida foram também avaliadas. Os atletas preencheram igualmente um questionário sobre hidratação e balanço hídrico. **Resultados**: A percentagem de peso perdido foi significativamente maior na condição NF (2.46 ± 0.87) do que na W (1.08 ± 0.67; $P < 0.01$) e CSB (0.65 ± 0.62; $P < 0.001$). Na condição W, os atletas também perderam uma maior % de peso relativamente à CSB ($P < 0.05$). O RPE foi maior na condição NF (16.8 ± 1.96) em comparação com W (14.2 ± 1.99; $P < 0.01$) e CSB (13.3 ± 2.06; $P < 0.01$). Não se registaram diferenças estatisticamente significativas na performance basquetebolística, cor da urina e aceitabilidade da bebida entre as diferentes condições. Os conhecimentos dos atletas correlacionaram-se positivamente com os comportamentos auto-reportados ($r = 0.75$; $P < 0.05$) e a ingestão de fluidos durante as sessões de treino ($r = 0.76$; $P < 0.05$). **Conclusão**: A restrição de fluídos não teve consequências negativas na performance, no entanto aumentou a percepção do esforço por parte dos atletas e a % de peso perdido. Os atletas com maiores conhecimentos sobre hidratação tiveram igualmente melhores comportamentos auto-reportados e ingeriram mais fluidos durante a prática desportiva.

Palavras Chave: Adolescentes, Balanço Hídrico, Basquetebol, Desporto, Hidratação, Performance

INTRODUCTION

The role of dehydration and fluid replacement in athletic performance has been target of several studies in recent years. It is well described the negative impact of excessive fluid lost in many sports and generally recognized that an excessive body weight loss from water deficit during exercise can compromise performance [(1)].

Water makes up between 50-75% of body weight and affects athletic performance more than any other nutrient because muscle tissue is nearly 75% water and changes in their homeostasis may impair its metabolism [(2-4)]. This issue has a particular interest when applied to young populations since children do not adapt to conditions of high heat and humidity as effectively as adults, and the adaptation of adolescents has been described as somewhere between that of children and adults [(5)]. In fact, children and prepubescent athletes have lower sweating rates than adults due to a lack of sweat production by sweat glands. At first sight this could be an advantage to children because with lower sweat rates they lose less body weight during physical activity. However, they also dissipate less heat through evaporating sweating, so the risks of hyperthermia and heat stress are increased with impact in health and performance. Thus, children and adolescents are a population with special needs for maintaining adequate hydration to prevent heat stress [(6)]. Moreover, some studies [(7-9)] showed that despite unlimited access to fluids, both young and adult athletes weren't able to maintain euhydration during games or practices. This scenario of voluntary dehydration is very frequent because thirst sensation is a late warning of dehydration and athletes only replace one half to two thirds of their fluid needs even with *ad libitum* intake [4]. In this context, sports beverages can be an effective way to increase fluid ingestion due to a higher palatability than water [10] with the additional advantage of providing carbohydrates which may have potential benefits in delaying fatigue in exercise events of ~1 hour or longer [4]. In its position stand [1], the American College of Sports Medicine (**ACSM**) recognized that consumption of beverages containing electrolytes and carbohydrates can help to sustain fluid-electrolyte balance and exercise performance. The carbohydrate amount of the sports drinks generally range between 5-10%, but over 8% the gastric emptying and intestinal water absorption can be compromised [11-13]. These drinks often use sucrose as source of carbohydrates but the use of maltodextrins is increasing since they allow for provision of more carbohydrates without a resultant increase in osmolality [14]. Flavoring drinks seems to be a very effective strategy to increase fluid ingestion, regardless of the flavor used and the energy content of the drink [15, 16]. Sodium content is also a factor that can improve palatability of the drink besides their role in the maintenance of electrolyte balance [14].

Few studies analyzed the impact of dehydration in young athletes' performance in intermittent high-intensity (**IHI**) exercises, such as soccer, basketball, tennis, rugby… These sports are defined by bursts of high-intensity activity intercepted by rest periods and this type of stop-and-go action is associated with heavy sweat losses (1,0 – 1,6 L/h) [1]. In basketball the fluid balance is more easily maintained because it is often played indoors in a moderate climate with several opportunities to drink due to close proximity to fluids and a great number of breaks[8]. Despite these potential advantages relatively to other intermittent high-intensity sports, basketball players often achieve significant reductions of body mass during exercise[8]. Successful performance in these sports involves beyond fatigue resistance, a great cognitive function for decision making and proper execution of complex skills. So, it's probable that ineffective fluid replacement can impair skills performance more than endurance or strength and power performance. The potential impact of dehydration on impairment of vigilance-related attention in male basketball players [17] is a critical issue in a sport with a dynamic environment and stimulus-frequent situations. Cognitive and sensorial skills are a key-point to basketball performance with players performing poorly if they lose concentration or become distracted. In a basketball field this inability can be manifested by costly errors like missed rebounds and shot attempts, turnovers, and defense permissiveness. Thus, the inclusion of carbohydrates in the fluid consumed during exercise may confer and additional advantage in comparison with water [18].

One of the main mechanisms by which dehydration impairs athletic performance is the increase in physiologic strain and perceived effort to complete an exercise task (evidence category A in ACSM Position Stand [1]). There are several studies [9, 19, 20] that report an increase in Ratings of Perceived Exertion (**RPE**) associated with a dehydrated condition which suggests that beyond the physical impairment, dehydration affects the motivation to exercise [21]. The RPE are a 15-point scale developed by Borg [22] and is used to assess perceived exertion of the exercise executed. Current research shows clearly that dehydration and its effects (increased heart rate and core temperature) are associated with higher RPE. Despite all the information available, it's demonstrated that athletes have a lack of knowledge about nutrition and hydration issues [23-25]. Even when they know the general hydration recommendations, they not necessarily put them into practice [26]. We also have to recognize that the quantity of old beliefs involving hydration can be very confusing to athletes' hydration behaviors. In the 60's the athletes were advised to drink only a little quantity of water during exercise and to ignore their thirst and to thus replace a small percentage of lost fluid [(4)]. Body fluid losses of 3-4% were thought to be insignificant to episodes of hyperthermia or impairment of physiological function and performance [(27)] and much of these myths possibly remain until today.

AIMS

The purpose of the present study was to determine the effect fluid restriction, water and sports drinks *ad libitum* consumption on basketball performance and also correlate the athlete´s knowledge about hydration and fluid replacement issues with their behavior in a real situation.

MATERIALS AND METHODS

Subjects:

Twelve male basketball players between 14 and 15 years of age volunteered to participate in this study. Each subject and his parent or guardian were advised of the experimental procedures and associated risks before a verbal assent was given by the child and a written informed consent was given by the parent/guardian. All subjects were healthy, nonobese and highly skilled, and were not taking any medications or nutritional supplements. Although we have not laboratorially demonstrated their high fitness level (e.g., $VO_{2\ max}$), all players belong to National Training Center – Paredes Rota dos Móveis, the equivalent to Portugal national under-15 basketball team.

Study Design:

Each athlete completed 3 different hydration protocols in a cross-over fashion mode design. The 3 conditions were:

1) No fluid ingestion allowed (**NF**);

2) *Ad libitum* ingestion of water (**W**) – 3.8 mg/L Na;

3) *Ad libitum* ingestion of a commercial carbohydrate-electrolyte sports beverage (**CSB**) – 7.2% sugar, 0.8% maltodextrins and 510 mg/L Na. Athletes were able to choose their favorite flavor (Orange Burst, Citrus Charge, and Blood Orange) of this commercial drink (Powerade ®). We assure that the temperature of beverages ranged between 8-12ºC at the beginning of training. Subjects were not blinded to the identity of the 2 fluids as we were interested to investigate how their hydration habits differed between the 2 drinks provided.

The 3 training sessions, designed by the coach, were identical, and occurred in consecutive weeks. In each training athletes were divided in 3 groups (4 subjects in each condition), and crossover in the following sessions. The training sessions had a very similar sequence of drills with a total duration of 1h30. 30, 60 and 90 minutes after the beginning of the training, it was given free access to a beverage for 60 seconds to players. After the training over, 30 additional minutes were taken by athletes to complete a series of drills on order to evaluate technical and physical performance parameters (**Figure 1**). Subjects were encouraged to have identical meals in the days of these training sessions.

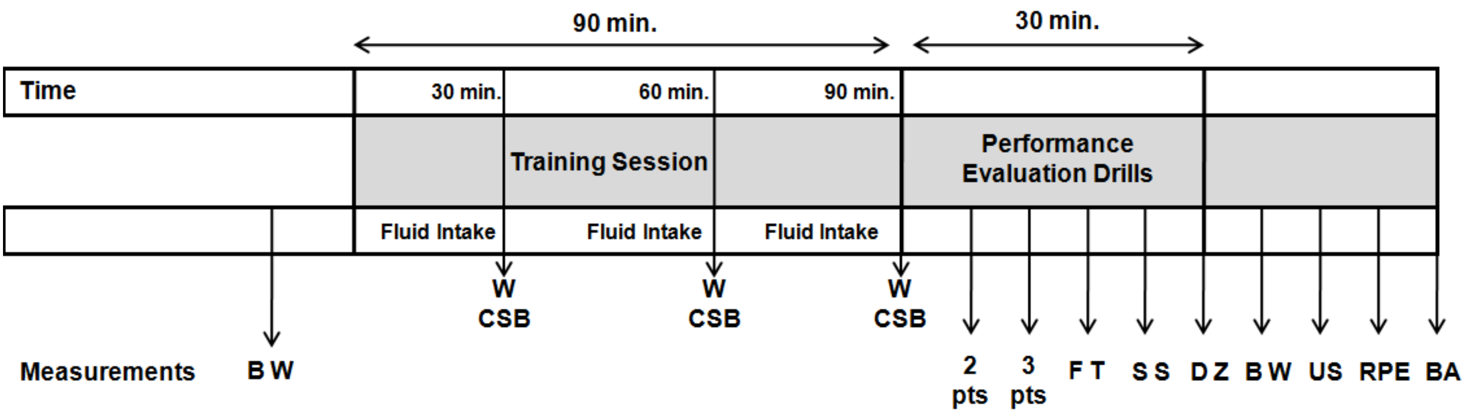

Figure 1. Schematic representation of the trial protocol. BW, Body Weight; W, Water group; CSB, 8% Carbohydrate-Electrolyte group; 2-pts, Around the World 2-point shooting; 3-pts, Around the World 3-point shooting; FT, Free-Throw shooting; SS, Suicide Sprints; DZ, Defensive Zigzag; US, Urine Sample; RPE, Ratings of Perceived Exertion; BA, Beverage Acceptability

<u>Measurements</u>:

Preliminary screening, included anthropometric evaluation and demographic data was obtained. We determine body fat percentage through skinfold thicknesses measurement (biceps, triceps, subscapular, iliac crest, supraspinale, abdominal, front thigh and medial calf) with a Harpenden caliper

(John Bull, United Kingdom with a precision of 0.1mm). We used the Durnin-Rahaman [28] equation to estimate body density and the Weststrate & Deurenberg equation [29] to estimate body fat percentage. The body muscle mass were assessed by Lee [30] equation. The athletes were also weighed (lightly dressed and barefooted) with a Salter Electronic ® scale (with a precision of 100g) and heighted with a stadiometer (with a precision of 0.1 cm).

Before and after training, athletes were weighed wearing only shorts. The fluid intake was assessed by weighing the bottles before and after consumption using an electronic dietary scale SECA 851 ® (with a precision of 2.0 g). Dehydration levels were determined by differences in pre- and post- training weights and expressed as a percentage of pre-training body weight. Sweat rate was calculated by the sum of weight lost and fluid intake during trial (since athletes only urinate in the end of trials). The euhydration (**EUH**) weight was considered as the average of 3 consecutive morning nude body weight measurements after voiding [31]. We also measure (in 15 minutes intervals) the atmospheric temperature and the relative humidity (WS 900 – Geonaute ®) of the court. Urine color was determined by holding each specimen container next to a color scale[32], in a well-lit room.

The performance indices of shooting, defense and sprint were evaluated by the following drills:

1) ***"Around the world" 2-point shooting*** – 2 shots from 5 spots around the restricted area (number made in 10 attempts);

2) ***"Around the world" 3-point shooting*** – 2 shots from 5 spots around 3-point line (number made in 10 attempts);

3) ***Free-Throw Shooting*** – number of converted shots in 10 attempts;

4) ***Suicide Sprints*** – Start at baseline, sprint to free-throw line, sprint back to baseline, sprint to half-court, sprint back to baseline, sprint to opposite free-throw line, sprint back to baseline, sprint to opposite end line, sprint back to baseline (time to completion);

5) ***Defensive zigzag*** – Defensive slides to each corner of restricted area in a zigzag pattern (time to completion).

Each athlete performed 2 trials of suicide sprints and defensive slide, therefore the performance measure was the average of the two scores.

At the end of each training session, athletes were weighed again (after cleaning the sweat with a towel), provided a urine sample to evaluate the color and were asked about their perception of exertion (RPE - Borg Scale [(22)]), and overall acceptability of the beverage on a 9-point hedonic category scale [(33)], ranging from *like extremely* to *dislike extremely*. The coaches also gave their opinion about RPE of the training session.

<u>Survey</u>:

The survey (**Appendix 1**) was distributed to athletes after the 3 basketball protocols ended, to avoid conditioned behaviors caused by the information contained in the questions and the content was approved by coaches. The survey, adapted from Nichols et al [(26)] study, contained two parts, each one with 16 statements regarding the athletes' knowledge and behavior on hydration and fluid replacement. The knowledge section had true/false statements and the behavior section contained yes/no statements. A knowledge score was calculated for each athlete by adding the total number of correctly answered questions in the knowledge section. The minimum score that could be obtained was 0 (0%), and the highest score was 16 (100%). The behavior scores were also calculated using a similar method. The statements on each section of the survey were in the same order but worded differently to address knowledge and behaviors. The authors of the study distributed them, provided the necessary instructions for their completion, and were available to clarify any questions that athletes might have while fulfilling the survey. The athletes took, on average, 10 minutes to complete the questionnaire.

Statistical Analysis:

All statistical analysis was conducted using *Statistical Package for Social Sciences* (**SPSS**) 14.0 for Windows. Group data were expressed as mean ± standard deviation (**SD**). By convention, the level of significance was set at $P<0.05$. A General Linear Model (**GLM**) with Repeated Measures was used to compare data obtained in the 3 hydration protocols for all variables and also to analyze a possible effect of the training week in the results. Where significant main effects were observed, Bonferroni multiple comparisons procedures were used to determine differences between groups. The premises of normality (Kolmogorov-Smirnov Test), sphericity (Mauchly's Test) and homogeneity of variances (Levene's Test) were assured before the utilization of GLM. The Spearman correlation coefficients were determined between the scores of the survey and the training session's data.

RESULTS

Table 1 show the demographic and anthropometric characteristics of the 12 subjects who participated in the study.

TABLE 1. Subjects Characteristics

Athletes (N = 12)	**Means ± SD**	**Range**
Age (years)	14.8 ± 0.45	14 - 15
Weight (kg)	72.9 ± 8.60	93.1 - 61.8
Height (cm)	182 ± 4.55	175 - 189
Body Fat (%)	16.4 ± 3.55	9.2 - 22.1
Muscle Mass (kg)	30.7 ± 2.32	27.3 - 35.7
Playing Experience (years)[a]	7.17 ± 2.12	3 - 10
School Grade	8.83 ± 0.39	8 - 9

[a] Number of years subject reported playing competitive basketball

RPE, Beverage Acceptability and Hydration Variables.

Total fluid intake, percentage of body mass loss, weight at the beginning of training, sweat rate, beverage acceptability, RPE and urine color values are presented in Table 2. The fluid intake of CSB was slightly higher than W, however no statistical differences were observed ($P > 0.05$). As expected, the % body mass loss was significantly higher in NF athletes between W ($P < 0.01$) and CSB ($P < 0.001$). Even in W condition were registered statistical differences compared with CSB ($P < 0.05$). Subjects started the trials euhydrated since no differences were observed ($P > 0.05$) between initial weight and euhydration weight (72.7 ± 8.80) in all conditions. The sweat rate values also had no statistical significance, but the CSB seems to have lower results. The beverage acceptability was great for both fluids, however the CSB tends to be more appreciated by athletes without reaching statistical significance ($P > 0.05$). At the end of training sessions, the perceived exertion was significantly higher in NF condition (NF vs. W, $P < 0.01$; NF vs. CSB, $P < 0.01$). With fluid restriction, the perceived exertion of athletes (16.8 ± 1.96) was also significantly higher ($P < 0.01$) than the values reported by coaches (13.2 ± 0.29). Between W and CSB the RPE values are slightly lower with sports beverage, although did not reached statistical significance ($P > 0.05$). Urine color differences didn't have statistical relevance, however the intake of W and CSB seems to be related to lighter urine colors.

TABLE 2. RPE and Overall Fluid Variables

N = 12	Fluid Intake (L)	Body Mass Lost (%)	Initial Weight (Kg)	Sweat Rate (L/h)	Beverage Acceptability (1-9)	RPE (6-20)	Urine Color (1-6)
NF	-	2.46 ± 0.87 * †	72.6 ± 8.74	0.94 ± 0.40	-	16.8 ± 1.96 * ‡	4.08 ± 1.00
W	1.11 ± 0.47	1.08 ± 0.67 Φ	72.9 ± 9.03	0.96 ± 0.42	7.25 ± 1.49	14.2 ± 1.99	3.58 ± 0.67
CSB	1.14 ± 0.38	0.65 ± 0.62	72.5 ± 9.07	0.82 ± 0.38	7.75 ± 1.55	13.3 ± 2.06	3.83 ± 0.84

Values are mean ± SD. NF, No Fluid ingestion allowed in trials; W, Water drink trial;
CSB, 8% Carbohydrate-Electrolyte drink trial

* $P < 0.01$ vs W

† $P < 0.001$ vs CSB

Φ $P < 0.05$ vs CSB

‡ $P < 0.01$ vs CSB

Performance Variables.

The percentages of 2-point, 3-point and free-throw shooting and time to completion suicide sprints and defensive zigzags are presented in Table 3. In all performance variables, a tendency to worst results in NF condition was observed, however the differences were very small and non-significant. The intake of sports drink had a little and statistically insignificant effect on improvement of defensive skills, 3-point and Free-Throw shooting performance compared to water, and the opposite happens in 2-point shooting performance. We didn't find statistical differences between the 3 conditions in any of the performance variables, even with relatively high values of dehydration (2.46%) of NF condition.

TABLE 3. Performance Variables

N = 12	2-point shooting (%)	3-point shooting (%)	Free-Throw shooting (%)	Suicide sprints (s)	Defensive zigzag (s)
NF	55.0 ± 20.2	36.7 ± 19.7	59.2 ± 22.8	31.1 ± 0.89	8.48 ± 0.48
W	60.8 ± 12.4	37.5 ± 16.0	62.5 ± 20.1	30.9 ± 1.22	8.48 ± 0.49
CSB	60.0 ± 16.5	42.5 ± 16.0	65.8 ± 20.2	30.9 ± 1.39	8.46 ± 0.59

Values are mean ± SD. NF, No Fluid ingestion allowed in trials; W, Water drink trial; CSB, 8% Carbohydrate-Electrolyte drink trial

Overall Results by Training Session

The overall results of 3 training sessions are represented in Table 4. In third trial, sweat rate and fluid intake were significantly higher than the other two sessions. In other variables, the results didn’t change significantly among trials, so the design of study and the training week didn´t affect performance variables and % body mass lost, initial weight, beverage acceptability, RPE and urine color.

The results obtained for sweat rate and fluid intake may reflect the impact of the higher temperatures and higher values of relative humidity recorded in third trial, however to a higher sweat rate corresponded a greater fluid intake, so there were no differences in % weight loss.

TABLE 4. Overall Results by training session

Training Session N = 4	Condition	Sweat Rate (L/h)	Fluid Intake (L)	Body Mass Lost (%)	Initial Weight (Kg)	Beverage Acceptability (1-9)	RPE (6-20)
#1	NF	0.86 ± 0.33	-	2.41 ± 0.79	71.0 ± 3.95	-	17.8 ± 1.50
T = 25.2 ºc	W	1.19 ± 0.34	1.20 ± 0.37	1.41 ± 0.52	81.0 ± 10.7	8.00 ± 1.41	13.8 ± 2.75
RH = 48.3 %	CSB	0.64 ± 0.21	0.98 ± 0.27	0.46 ± 0.82	65.7 ± 3.87	7.75 ± 0.96	13.3 ± 2.36
Mean		0.90 ± 0.36 *	1.09 ± 0.32 *	1.43 ± 1.05	72.6 ± 9.17	7.87 ± 1.13	14.9 ± 2.94
#2	NF	0.87 ± 0.54	-	2.11 ± 1.23	80.4 ± 10.8	-	16.3 ± 2.22
T = 21.9 ºc	W	0.59 ± 0.44	0.67 ± 0.32	0.75 ± 0.87	66.1 ± 3.41	6.25 ± 1.50	14.5 ± 1.29
RH = 50.6 %	CSB	0.62 ± 0.11	0.91 ± 0.16	0.46 ± 0.33	71.2 ± 3.78	8.00 ± 1.41	14.0 ± 0.82
Mean		0.69 ± 0.39 *	0.79 ± 0.27 *	1.11 ± 1.10	72.5 ± 8.76	7.13 ± 1.64	14.9 ± 1.73
#3	NF	1.07 ± 0.40	-	2.87 ± 0.50	66.4 ± 3.65	-	16.3 ± 2.22
T = 26.0 ºc	W	1.11 ± 0.23	1.45 ± 0.39	1.09 ± 0.57	71.5 ± 4.39	7.50 ± 1.29	14.3 ± 2.22
RH = 54.1 %	CSB	1.20 ± 0.43	1.53 ± 0.37	1.04 ± 0.57	80.7 ± 10.9	7.50 ± 2.38	12.8 ± 2.87
Mean		1.13 ± 0.33	1.49 ± 0.35	1.67 ± 1.02	72.9 ± 8.91	7.50 ± 1.77	14.4 ± 2.68

Training Session N = 4	Condition	2-point shooting (%)	3-point shooting (%)	Free-Throw shooting (%)	Suicide sprints (s)	Defensive zigzag (s)	Urine Color (1-6)
#1	NF	40.0 ± 21.6	32.5 ± 22.2	55.0 ± 34.2	31.6 ± 0.64	8.68 ± 0.71	4.25 ± 0.50
T = 25.2 ºc	W	62.5 ± 15.0	45.0 ± 5.78	67.5 ± 22.2	31.0 ± 1.24	8.52 ± 0.18	3.50 ± 0.58
RH = 48.3 %	CSB	52.5 ± 15.0	45.0 ± 5.78	67.5 ± 12.6	31.5 ± 2.29	8.42 ± 0.92	4.00 ± 0.82
Mean		51.7 ± 18.5	40.8 ± 13.8	63.3 ± 23.1	31.4 ± 1.43	8.54 ± 0.63	3.92 ± 0.67
#2	NF	67.5 ± 17.1	42.5 ± 12.6	62.5 ± 22.2	30.5 ± 0.42	8.39 ± 0.15	4.00 ± 1.41
T = 21.9 ºc	W	57.5 ± 12.6	37.5 ± 17.1	57.5 ± 15.0	30.8 ± 1.53	8.55 ± 0.80	3.50 ± 1.00
RH = 50.6 %	CSB	55.0 ± 19.1	37.5 ± 5.00	70.0 ± 21.6	30.7 ± 0.19	8.65 ± 0.47	4.00 ± 1.16
Mean		60.0 ± 15.9	39.2 ± 11.6	63.3 ± 18.7	30.7 ± 0.84	8.53 ± 0.50	3.83 ± 1.12
#3	NF	57.5 ± 15.0	35.0 ± 26.5	60.0 ± 14.1	31.1 ± 1.22	8.36 ± 0.47	4.00 ± 1.16
T = 26.0 ºc	W	62.5 ± 12.6	30.0 ± 21.6	62.5 ± 26.3	31.0 ± 1.26	8.37 ± 0.46	3.75 ± 0.50
RH = 54.1 %	CSB	72.5 ± 9.57	45.0 ± 28.9	60.0 ± 28.3	30.5 ± 1.00	8.30 ± 0.33	3.50 ± 0.58
Mean		64.2 ± 13.1	36.7 ± 24.2	60.8 ± 21.5	30.9 ± 1.09	8.35 ± 0.38	3.75 ± 0.75

Values are mean ± SD. T, Atmospheric Temperature; RH, Relative Humidity

* $P < 0.05$ vs #3

Survey Scores

First of all, we have to mention that all athletes who answered the survey had previous sports nutrition education in the months preceding the study.

Table 5 shows the correlation between knowledge and behavior scores, and the mean of athletes' fluid intake in the 2 conditions (W and CSB). The results evidence a strong correlation between fluids intake and knowledge and behavior scores. This means that athletes with higher knowledge and self-related correct behaviors drink more fluids in field. These 2 correlations had statistical significance ($P < 0.05$). The correlation between knowledge and behavior scores, was also high and has almost reached statistical differences ($P = 0.059$).

TABLE 5. Spearman Correlation Coefficients Between Fluids Intake, Knowledge and Behavior Scores Regarding Hydration and Fluid Replacement

	Knowledge Score	Behavior Score	Fluids Intake
Knowledge Score	1.0	0.56	0.76 *
Behavior Score	0.56	1.0	0.75 *
Fluids Intake	0.76 *	0.75 *	1.0

* $P < 0.05$

In Table 6, we can see that knowledge questions had a higher score than behavior questions (79.7 ± 14.6% vs. 59.4 ± 12.4%), however none athlete achieved a perfect score. The questions with better results were #3, #4 and #5 who had 100% of corrected answers. On the opposite, the question #8 had the worst results either in knowledge (33.3%) or behavior (8.3%). To emphasize that, more than half of players (58.3%) thinks that thirst is the best signal of dehydration, only 8.3% drinks sports beverages in the 2 hours next to exercise, and despite knowing that weigh before and after practice is a good way to evaluate how much body water they loss in exercise (75% of correct answers), only 16.7% actually do it regularly.

TABLE 6. Athletes Response to Knowledge and Behavior Questions Regarding Hydration and Fluid Replacement

	% Correct Answers	
	Knowledge	Behavior
1 - Thirst is the best indicator of dehydration	41.7	50.0
2 - Dehydration decreases athletic performance	91.7	75.0
3 - Athletes should not drink water or fluids during practice	100	100
4 - Coaches should not let players drink fluids during practice	100	100
5 - Coaches should not let players drink fluids during competition	100	100
6 - It is important for fluids to be readily available to athletes during practice	100	91.7
7 - It is important for fluids to be readily available to athletes during competition	100	91.7
8 - Athletes should drink sports drinks within 2 hours after exercise	33.3	8.33
9 - Sports drinks are better than water because they restore glycogen in muscles	100	25.0
10 - An athlete should drink 17-20 fluid ounces of water or sports drink a couple of hours before exercise	91.7	50.0
11 - An athlete should drink 7-10 fluid ounces 10-20 min before competition	58.3	25.0
12 - When exercising more than one hour, an athlete should drink sports drinks rather than water	91.7	8.33
13 - Monitoring color of urine is a way an athlete can judge if he/she is dehydrated	100	75.0
14 - Weighing before and after practice is a good way to determine how much fluid to consume	75.0	16.7
15 - Excessive sweating, thirst, and cramping are signs of dehydration	66.7	58.3
16 - More than 2 alcoholic drinks the day before competition can lead to dehydration	58.3	91.7

DISCUSSION

The main findings of this study were that **1)** fluid restriction during exercise was associated with elevated levels of dehydration and increased perceived exertion but had no impact in basketball performance, and **2)** athletes with higher knowledge about hydration and fluid replacement are more able to prevent excessive levels of dehydration due to higher fluid ingestion.

In the current investigation the athletes in the fluid restriction protocol had levels of dehydration of 2.5% of body weight, a value similar to other studies realized in temperate conditions [34, 35]. Even with free access to fluids, athletes were unable to maintain euhydration (W: -1.08%; CSB: -0.65%). This fact was somewhat expected since *ad libitum* drinking typically leads to an involuntary dehydration, that can be explained because 1.5 L of body water could be lost before thirst is perceived [7, 36]. There were no statistically significant differences in the volume of fluid intake or in the estimated sweat rate between the 2 fluids trials. Therefore, we hypothesized that a combined effect of a non-significant higher fluid intake in CSB with a non-significant larger sweat rate in W could contribute to achieve a significant difference in % of body weight loss observed between both conditions. Despite the levels of dehydration reached, the impact in performance was null. Although some evidence [4] suggests that dehydration by 2% appears to have an insignificant effect on endurance performance in a temperate environment, basketball performance involves other skills besides fatigue resistance. The IHI sports require power, strength and endurance to maintain high level of performance throughout the game [37] and, particularly in basketball, cognitive tasks, such as visual memory, vigilance-related attention, processing information and coordination, are essential. All these skills are recognizably impaired by dehydration, [17, 35] just like postural control. One study [38] noted dizziness in subjects in a dehydrated condition, possibly due to lack of fluid intake and consequent loss of endolymphatic fluid, which decreased inner ear pressure and impaired sensitivity and balance. In our study, we didn't find statistical significant differences between all performance variables analyzed; however, in the NF condition, basketball players underperformed in all shooting exercises and took more time to complete the physical drills. The basal (pre-training) body weight was similar ($P > 0.05$) to the estimated euhydration weight in all conditions, so a probable hyper and hypohydrated state at beginning of training can be discarded. We have also to recognize that although the protocol replicate a regular training session, the performance drills were made separately, so there was some lack of stimulus-frequent situations that characterizes the dynamic environment involving a basketball game. Hereupon, the mild non-significant differences observed in performance variables in NF condition may be explained by dehydration and the physiological mechanisms that it triggers. The energy provision during basketball match-play is assured either by aerobic and anaerobic systems. In fact, a team with superior aerobic fitness would have the advantage of being able to play the game at a faster pace and, recently, it was demonstrated [39] that the aerobic metabolism has a major importance in basketball since more than half of the play time was spent walking. A higher level of anaerobic and strength parameters reduce the risk of injuries and would allow for more powerful rebounds, shooting and shuffling [40]. Thus, it was showed that dehydration of 2.9% body mass decreases the ability to generate upper and lower body anaerobic power [3] and there are many metabolic ways that could explain this impairment. An old theory

[41] postulate that a loss of intracellular potassium hyperpolarizes the muscle cell membrane electrochemical potential and decreases muscle contractibility by inhibiting calcium binding to troponin or by interfering with cross-bridge formation. This mechanism is enhanced after a high-intensity short term exercise because K_{ATP} channels localized in sarcolemma are responsible for potassium loss and tends to open when intramuscular pH declines [42]. Then, the lactate climb after a high-intensity bout and a pH decrease may explain the temporary fatigue associated with accumulation of interstitial potassium [42, 43]. Finally, fluid imbalance may be related to higher glucose oxidation rate mainly due to enhancement of sympathetic nerve activity [44, 45] ,and progressive dehydration over the course of exercise, has a role in fatiguing process by increasing the viscosity of blood, diminishing heat dissipation and increasing heart rate. The metabolites of anaerobic metabolism (lactate and hydrogen ions) would then inhibit muscle contraction and relaxation [46]. Despite all these facts, the majority of published studies indicate that dehydration up to a loss of 7% of body mass can largely be tolerated without a reduction in measured maximal isometric of isotonic muscle contractions [21]. Other authors [47] didn't find any effect of 4.8% dehydration on vertical jump height, peak lower-body power, and peak lower-body force. Recently, Edwards, *et al* [46] gave an explanation for these results reporting that even in circumstances where muscles are forced to contract under ischemic conditions, ATP concentrations do not drop below 60% of resting values, which indicates that muscle ATP concentrations are in some way "defended" in order to prevent the development of skeletal muscle rigour [48, 49] . So, their explanation for fatigue onset is that effort is reduced by a central governor responding to a range

of factors and continually acting to regulate performance by manipulating muscle recruitment in order to ensure that these systems are never maximally utilized.

It's certainly very difficult to know for sure the exact mechanisms by which dehydration affects IHI sports performance. However, studies with a similar design reported that 2% body mass loss impaired skill performance in 12- to 15 years old male basketball players (50), and shooting drills declined progressively as % dehydration increased in older players (20). Thus, the lack of significant losses with dehydration in the performance parameters we measured contradict some published literature. We can speculate that the temperate conditions of the training arena and/or the moderate levels of dehydration achieved by athletes were not enough to impair some of the physiological mechanisms above mentioned.

Even though we assessed RPE at the end of training while the majority of studies did it throughout the exercise, our results are consistent with other investigations (9, 19, 51-53). We found an increased self-rated perceived exertion in the fluid restriction protocol compared with the other conditions. These differences in RPE values may be explained due to a cardiovascular strain imposed by dehydration that is also been shown to coincide with an increase in perceived effort (21). The CSB group was the only that had a perceived exertion below the RPE value (13.7) described for a basketball game (39), and which is closer to the mean score gave by coaches about training severity (13.2). It is well described that carbohydrate intake during exercise, besides the role in the reduction of phosphocreatine degradation (54) (which is a major energy source in high-intensity exercises), can delay mental fatigue and reduce perceived exertion (48). The mechanisms by which this happens have yet to be elucidated, but may be associated with an increase in cerebral glucose uptake [55], a decrease in serum free fatty acids and a consequent decrease in brain tryptophan concentrations and serotonin synthesis [56]. Ammonia production may also play a role in this process due to an overproduction in exercising muscle during heat stress and cerebral uptake of this compound have detrimental effects on cerebral function[57, 58].

We didn´t find a significant difference either in the ad libitum fluid intake and acceptability between the two beverages, though athletes dehydrated less when they ingested CSB. These results were somewhat unexpected since the overall higher acceptability and total fluid ingestion of sports beverages by athletes documented in the literature [48]. The main determinant of fluid intake seems to be the flavor of the drink regardless of the awareness of the energy content of drink [16], and once flavored, different types of flavor have a similar effect [15]. However, other factors may also influence athletes' decision, such as color, odor, temperature and texture of the drink [59]. Indeed, we gave the opportunity for our athletes to choose their favorite flavor from 3 different options. The severity of exercise may also increment the acceptability of sports beverages compared with a rest condition [60]. At a physiological level, sports beverages, besides being a carbohydrate source important to performance, have the advantage to contain electrolytes, like sodium, that are essential for fluid retention in the body [61, 62]. Moreover, water can suppress thirst signal before enough fluid has been consumed to absolutely replace fluid losses [16]. Some investigators in 1990's showed that despite water's favorable osmotic gradient for absorption, a sports beverage may promote fluid absorption better than plain water [63, 64]. The explanation was that without an active solute transport, the intestine cannot transport water effectively, while in the presence of glucose the water transport is enhanced. In fact, more recent studies demonstrate that sports drinks with 6.2% of carbohydrates have a gastric emptying similar to water during intermittent running [65] and lowering the carbohydrate concentration from 6% does not enhance gastric emptying [66]. This information is very useful since IHI exercise delays gastric emptying of fluids compared with equivalent energy expenditure constant exercise or low-intensity walking [67, 68]. In our study, the sports beverage used had 8% carbohydrate content. In theory, it is likely to suppose that this could be an excessive amount, however there is evidence which support that there are no significant differences in physiological responses, relative fluid uptake and exercise performance during competitive running in the heat between a 6% and a 8% carbohydrate sports drink [12] . Actually, the lastest position stand of ACSM advocate 8% as a maximum threshold of carbohydrate content in a sports beverage [1]. The likely delayed fluid uptake with a 8% CBS may not be related with an impaired gastric empty but with an impaired intestinal water absorption. Actually, it is known that intestinal water absorption is lower with a sports beverage with 8% or 9% of carbohydrate than with water and a less concentrated (6%) sports beverage [69].

Urine markers are a practical, easy and inexpensive way to monitoring hydration status [70]. Our study found no differences in urine color between the 3 conditions despite the increased loss of body mass (2.5%) in the NF protocol. This suggests that urine color may not be an accurate method to test short-terms changes in hydration status, as already described in other studies [71]. It's a fact that urine color significantly became darker as the time of exercise protocol increases [20, 50], however in those studies athletes were already dehydrated at the beginning of protocol. As already mentioned, our athletes began the training sessions with body weights very close to the euhydration balance. Therefore, we believe that urine color can be a useful marker of overall hydration status but ineffective to estimate short-term hydration changes during exercise. Perhaps, other urine markers, like specific gravity or osmolality are more reliable than color [72], though some authors still remain skeptics and give no credit to such measurements [73]. The scientific basis for the use of urine color as a hydration assessment method is that when large volumes are excreted the urine is diluted, and solutes are excreted in a large volume which gives the urine a very pale color. On the opposite, when small volumes of urine are excreted, the urine is concentrated, and the solutes excreted in a small volume which gives the urine a dark color. Besides, we have to considerer that there are some dietary factors which can influence urine color, such as like carotene, betacyanins, food colors and even some drugs [73].

One of the most interesting findings of this study was the significant correlation between athlete´s knowledge and self-reported behaviors in hydration issues and their fluid intake in the training sessions. This survey was administered one week after the completion of third trial, so athlete's behaviors during trainings was not influenced by questionnaire information and corresponded to the existing knowledge of each athlete. To the best of our knowledge, only 2 studies evaluated athletes' hydration knowledge and behaviors, but in different conditions than we did [74] and only found very weak correlations [75]. We also found that an increase in knowledge may not be translate into an improved behavior in the same proportion, as we have seen mainly in questions 9, 12 and 14. However, we have to say that correlation between knowledge and behavior score almost reached statistical significance ($P = 0.059$). Our results are in some way related to that of

Nichols *et al* [26] which also reported a weak correlation in the same questions but expressed a global positive correlation between knowledge and behaviors.

LIMITATIONS OF STUDY

The dehydration status was measured trough changes in body mass. Although being practical, easy and inexpensive, this method is not always a reliable measure of changes in hydration status because respiratory water losses can occur during exercise, and mass loss also results from substrate oxidation (however this could also generate water of oxidation which is added to body water pool) [76]. The urine color scale we used [32] makes a clear distinction between 6 different colors of urine, but this scale is not validated.

The performance skills evaluated reflect the physical and technical demands of basketball, but we must considerer that this sport depends largely on mental skills that we didn´t measure. Hence, it's always difficult to extrapolate these results into a basketball game.

One last idiosyncrasy is that athletes of our study do not usually consume sports beverages. So, there may have been a placebo effect regarding some issues in the CSB group, however in practice this will always happens and can be an advantage of sports beverages consumption.

CONCLUSION

In conclusion, even though a positive effect on basketball performance was not seen, ingesting fluids during training decreased the perceived exertion of athletes. Our results also support that the nutritional education of athletes can improve significantly their behaviors contributing to an optimized status of hydration.

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Appendices Index

Appendix 1 | Hydration and Fluid Replacement Survey

Questionário

Responde às seguintes acerca da hidratação em contexto desportivo. As tuas respostas serão confidenciais por isso sê o mais honesto possível!

Nome: ____

Idade: __________ Ano Escolaridade: ___________ Anos Experiência no Basquet: ___________

As questões seguintes destinam-se a avaliar os teus conhecimentos e comportamentos sobre a hidratação. Lê atentamente cada frase e seleciona a melhor resposta.	*Seleciona Verdadeiro (V) ou Falso (F) para cada questão*	
CONHECIMENTOS		
A sede é o melhor indicador de desidratação	**V**	**F**
A desidratação diminui a performance atlética	**V**	**F**
Um atleta não deve beber água ou outros fluidos	**V**	**F**
Os treinadores não devem deixar os jogadores beber líquidos durante os treinos	**V**	**F**
Os treinadores não devem deixar os jogadores beber líquidos durante os jogos	**V**	**F**
É importante disponibilizar bebidas aos atletas durante os treinos	**V**	**F**
É importante disponibilizar bebidas aos atletas durante os jogos	**V**	**F**
Os atletas devem beber bebidas desportivas até 2 horas depois do término do exercício	**V**	**F**
As bebidas desportivas são melhores que a água para restaurar o glicogénio (reservas de açúcar) nos músculos	**V**	**F**
Um atleta deve beber 500-600 ml de líquidos 2 horas antes da competição	**V**	**F**
Um atleta deve beber 200-300 ml de líquidos 10-20 minutos antes da competição	**V**	**F**
Quando o exercício dura mais de uma hora, o atleta deve preferir bebida desportiva a água	**V**	**F**
Monitorizando a cor da urina, o atleta consegue avaliar se está ou não desidratado	**V**	**F**
Uma boa forma de determinar qual a quantidade de fluidos que deve ser ingerida no exercício é pesar-se antes e depois deste	**V**	**F**
Transpiração excessiva, sede e cãimbras são sinais de desidratação	**V**	**F**
Beber mais de 2 bebidas alcoólicas no dia antes da competição pode levar à desidratação	**V**	**F**

COMPORTAMENTOS

Eu uso apenas a sede como indicador de desidratação	**SIM**	**NÃO**
Eu bebo muitos fluidos para a minha performance não diminuir devido à desidratação	**SIM**	**NÃO**
Eu não bebo água ou outros líquidos durante os treinos/jogos	**SIM**	**NÃO**
O meu treinador não me permite beber fluidos durante os treinos	**SIM**	**NÃO**
O meu treinador não me permite beber fluidos durante os jogos	**SIM**	**NÃO**
Disponibilizam-me bebidas durante os treinos	**SIM**	**NÃO**
Disponibilizam-me bebidas durante os jogos	**SIM**	**NÃO**
Eu bebo bebidas desportivas até 2 horas depois do fim do treino/jogo	**SIM**	**NÃO**
Eu bebo bebidas desportivas em vez de água para restaurar o glicogénio (reservas de açúcar) nos músculos	**SIM**	**NÃO**
Eu bebo 500-600 ml de líquidos 2 horas antes da competição	**SIM**	**NÃO**
Eu bebo 200-300 ml de líquidos 10-20 minutos antes da competição	**SIM**	**NÃO**
Eu bebo bebida desportiva em vez de água quando o exercicio dura mais de uma hora	**SIM**	**NÃO**
Eu uso a cor da minha urina, para avaliar se estou ou não desidratado	**SIM**	**NÃO**
Eu peso-me antes e depois do exercicio para saber quanto peso perdi em suor e determinar a quantidade de liquidos que devo consumir	**SIM**	**NÃO**
Eu uso a transpiração excessiva, sede e cãimbras como sinais de alerta de desidratação	**SIM**	**NÃO**
Eu Bebo mais de 2 bebidas alcoólicas no dia antes da competição	**SIM**	**NÃO**