JOMH
Journal of Men's Health

J. Mens. Health **2022**; 18(10): 206
https://doi.org/10.31083/j.jomh1810206

Original Research

Effect of Rehydration with Mineral Water on Cardiorespiratory Fitness Following Exercise-Induced Dehydration in Athletes

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Submitted: 8 April 2022 Revised: 13 May 2022 Accepted: 24 May 2022 Published: 25 October 2022

Abstract

Background: The aim of the present study was to examine the effect of rehydration with mineral water on cardiorespiratory fitness in athletes. **Methods**: Twenty athletes (age 21.7 ± 3 years) underwent a random, crossover design experimental trial. Three visits were arranged, with the first for baseline measurement. The second visit included three phases (pre-dehydration, post-dehydration, and post-rehydration), with either Zamzam (mineral water) or bottled water (control water) used. The third visit was similar to the second visit, but with an exchange of the type of water used. Cardiorespiratory fitness and blood parameters were evaluated. Results were compared between Zamzam water and bottled water, and between the phases for each type of water. **Results**: No significant difference was found between Zamzam and bottled water for the cardiorespiratory fitness markers. However, Zamzam water maintained cardiorespiratory functions including VO_{2peak}, VT1, VT2, and VE_{peak}, even with rehydration equivalent to 100% of the loss in body weight following exercise-induced dehydration (>2% loss in body weight). Rehydration with bottled water was associated with a significant reduction in both the VO_{2peak} and VE_{peak}. **Conclusions**: Rehydration with mineral water such as Zamzam is unlikely to impair cardiorespiratory fitness, even with an intake equal to 100% of the loss in body weight.

Keywords: dehydration; rehydration; cardiorespiratory fitness; athletes

1. Introduction

Exercise can induce sweat loss and decrease total body water, together with the loss of electrolytes [1]. Sweat contains sodium and chloride, as well as small amounts of other electrolytes such as potassium, magnesium and calcium [2]. However, sweat loss during training affects fluid homeostasis and impacts thermoregulation, which may then result in impairment of performance [3,4]. Taekwondo players may lose ≥2% of body weight because of dehydration during training and competition [5]. Loss of 2–3% of body water may result in a decline in performance, especially for cardiorespiratory fitness. For example, Ganio *et al*. [6] found that dehydration significantly reduced the highest level of oxygen consumption that can be achieved during a maximal exercise test (VO_{2peak}) ($p < 0.05$). Cardiorespiratory fitness is a key fitness component for taekwondo players. To date, few studies have investigated the effect of rehydration following exercise-induced dehydration on cardiorespiratory fitness that may reduce subsequent performance, especially in the short-term [7].

Dehydration by losing more than 2% of body weight may impair endurance performances even during relatively short games such as taekwondo [5,8]. The effect of rehydration with different types of fluid intake such as water or sport drinks on performance has been widely investigated among athletes [9–15]. However, few studies have investigated the effect of rehydration with mineral water such as Zamzam water on the hydration status of athletes. To our knowledge, the impact of rehydration with Zamzam water on fitness components such as cardiorespiratory fitness as one of the main fitness components has yet to be investigated. Zamzam water has unique characteristics compared to normal water, including being rich in minerals [12], and being an alkaline fluid (average pH = 8) [15]. Therefore, Zamzam water with its characterestics may help to maintain wholebody fluid homeostasis [16]. For instance, Addition of 40 or 50 mmol/L of sodium chloride to a rehydration drink has been found to decrease urine output, in turn, enhance the effective of rehydration in short term. However, this did not improve performance 4 h after the end of the rehydration period [17]. In addition, Zamzam water is inexpensive compared to bottled water and much cheaper than sport drinks. The effect of rehydration with Zamzam water on cardiorespiratory fitness in taekwondo players has not yet been reported. The aim of the present study was therefore to investigate the effect of rehydration with two types of water (Zamzam and bottled) on cardiorespiratory fitness markers in professional taekwondo players.

2. Materials and Methods

2.1 Participants

Twenty professional taekwondo male players (at least one Dan) aged 18–30 years old were randomly selected from registered players at the Saudi Taekwondo Federation, Riyadh, Saudi Arabia. All participants were informed about the purpose of the study and the procedure. Written consent was obtained from all participants after the familiarization session.

2.2 Design

Participants were randomized and blinded in a crossover study design. The period between trials was 7 to 14 days. Three visits were arranged for each participant in order to examine the effect of rehydration with Zamzam water on cardiorespiratory fitness markers including the VO_{2peak} (the highest level of oxygen consumption that can be achieved during the standard Bruce exercise testing protocol). The first visit was for baseline measurements, while the second and third visits were for the two trials.

2.3 Anthropometric Measurements

Participant height (to the nearest 0.1 cm) was measured using a Deteco Electronic height rod (Model: DHRWM, USA), while body weight (to the nearest 0.1 kg) was measured using a Seca-869 (Germany). Body mass index (BMI) was calculated as body weight in kilograms divided by height in meters squared ($kg \cdot m^{-2}$). Body composition parameters were assessed through the use of a bioelectric impedance analysis scale (Model BC-980, Tanita Corporation, Tokyo, Japan).

2.4 Blood Parameters

Venous blood samples (15 mL) were taken three times by a phlebotomist at pre-dehydration, post-dehydration, and post-rehydration stages during the second and third visits. These were used to assess the complete blood count (CBC), hemoglobin (Hb), and hematocrit (Hct), as well as electrolytes including calcium (Ca), sodium (Na), potassium (K), chloride (Cl), and magnesium (Mg). Blood samples were analyzed in a specialized medical laboratory.

2.5 Cardiorespiratory Fitness

A standard Bruce protocol was used for determining the VO_{2peak} and ventilatory threshold (VT1 and VT2) values [18]. The three following criteria were used to verify attainment of the VO_{2peak}: (1) oxygen uptake plateau with increased workload, (2) respiratory exchange ratio (RER) greater than 1.1, and (3) perceived exertion based on the 6–20 Borg scale greater than 17 [19].

2.6 Procedures

Each participant was instructed to complete three visits to the Cardiovascular and Exercise Physiology Laboratory, Department of Exercise Physiology, Sport Sciences and Physical Activity College, King Saud University in Riyadh, Saudi Arabia. The first visit was for baseline anthropometrics and measurements of body composition and cardiorespiratory fitness. The second and third visits were for the experimental trials conducted one week apart. Participants were instructed not to exercise for 24-hours prior to each visit and to have the same meal (type, amount, and timing) on the day before the visit. In addition, they were instructed to sleep for the same duration (~7–8 hours), with most of it during the night.

2.7 First Visit

All participants visited the laboratory at 9:00 AM. Following signing of the consent form, body composition and anthropometric evaluations were performed. Cardiorespiratory fitness tests were then carried out, including VO_{2peak}, VT1, and VT2, peak breath frequency (BF_{peak}), and peak minute ventilation (VE_{peak}) using the Bruce protocol on treadmill (h/p Cosmos, Saturn® 300/125 r, Germany). Heart rate (HR) at rest, during exercise, and at recovery sessions was assessed using the Polar H7 Bluetooth Heart Rate Sensor & Fitness Tracker (Polar Electro Oy, Kempele, Finland).

2.8 Second Visit

2.8.1 Pre-Dehydration Session

Participants attended at 9:00 AM for the second visit. A 15 mL blood sample was taken from the radial vein. Blood samples were taken on three occasions as follows: before dehydration, after dehydration, and after rehydration sessions. Furthermore, the body composition including body weight and total body water was measured before and after the dehydration session, as well as after rehydration.

2.8.2 Dehydration Session

In the dehydration session, participants were instructed to exercise using a bike ergometer exercise (Lode, Corival cpet., Netherlands). The intensity of exercise was reached gradually, starting at 30 Watts for 5 minutes as a warm-up at a cadence of between 70 and 80 rpm. The exercise intensity was then increased until it reached 60% of the participant's reserved heart rate ($HR_{reserved}$). The exercise was performed in an environmental chamber (a customized 6 m × 6 m × 3 m room from Weiss Technik UK Ltd.) at relatively hot and humid ambient conditions (37 ± 1 °C and 68% ± 2 relative humidity). The dehydration marker was the loss of at least 2% of body weight. To confirm attainment of the effective dehydration level, the plasma volume change was calculated using a previously validated formula [19,20]. The duration of exercise ranged from 45–60 minutes. Body composition including body weight was measured immediately after drying the body. Next, the rehydration session involved sitting in a chair and drinking an amount of bottled water that equaled the loss in body weight

(2–3%).

Participants were instructed to drink an average of 400 mL initially and then about 300 mL every 20 until the target amount of water (equivalent to 100% of body weight loss) was reached. The temperature of the ingested water was 15 ± 1 °C, while the average duration of the rehydration session including recovery time was 80 ± 10 minutes. The laboratory temperature was 21 ± 1 °C, and the relative humidity was 30 ± 2%. Following sufficient recovery, exercise testing was carried out to evaluate the maximum VO_{2peak} using a portable machine (Cortex – METAMAX 3B®) [21]. Incremental exercise testing of the VO_{2peak} using the Bruce protocol was conducted as described above [18], with a clinical doctor supervising all sessions of the study. Table 1 shows the characteristics of Zamzam water and bottled water [12].

Table 1. Physical and chemical parameters of Zamzam water and of bottled water*

Parameters	Zamzam water	Bottled water
PH	7.7	7.4
Bicarbonates (mg/L)	173.5	25.9
Total hardness (mg/L)	309.7	40.9
Calcium (mg/L)	93.75	10.9
Magnesium (mg/L)	18.9	3.39
Sodium (mg/L)	130.5	16.9
Potassium (mg/L)	44.4	1.19
Chloride (mg/L)	164	18.9
Sulphate (mg/L)	124.3	25.9
Nitrate (mg/L)	131.52	2.9
TDS (mg/L)	798	119.9

* One of the most common bottled water brands was selected from the market.

2.9 Third Visit

All procedures during the third visit were similar to those of the second visit, except for the replacement of bottled water with Zamzam water.

2.10 Statistical Analysis

Data analysis was carried out with the SPSS 26.0 package (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test was used for assessing the normality of data distribution. A paired *t*-test was used for comparing pre- and post-tests for parametric data, and the Wilcoxon test for nonparametric data. All data in the text and tables are presented as the Mean ± SD, with p values < 0.05 indicating statistical significance.

3. Results

The physical characteristics and cardiorespiratory fitness markers of participants are presented in Table 2. These values were recorded during the first visit and reveal that participants were well trained and showed only minor variations in most measurements.

Table 2. Physical characteristics and cardiorespiratory fitness markers (n = 20).

Variables	Mean	SD
Age	21.70	3.21
Height (cm)	176.25	5.63
Body mass (Kg)	67.88	8.76
Body mass index (BMI)	21.88	2.90
Body fat (%)	12.69	4.54
Lean mass (%)	82.78	4.01
Total body water (Kg)	42.52	4.20
Total body water (%)	63.14	3.03
Intracellular water (ICW) (Kg)	26.24	3.20
Extracellular water (ECW) (Kg)	16.30	1.29
Extracellular water/total body water (%)	38.45	1.97
Resting heart rate (bpm)	66.50	7.05
Peak heart rate (bpm)	196	8.67
VO_{2peak} (L/min)	3.81	0.41
VO_{2peak} (mL/kg/min)	55.75	4.72
Ventilatory threshold VT1 (% of VO_{2peak})	53.31	11.6
Ventilatory threshold VT2 (% of VO_{2peak})	91.64	14.29
Peak oxygen pulse (mL/beat)	19.53	2.44
VE_{peak} (L/min)	134.62	21.55
Breathing frequency (times/min)	59.37	9.09

The results confirmed that all participants met the minimum criteria of dehydration status, as represented by the negative values for plasma volume change and the loss of 2% or more of body weight (Table 3). No significant differences were observed between Zamzam water and bottled water for most of the measured variables, with the exception of some electrolytes (sodium and potassium) and Hb ($p < 0.05$). In the Zamzam water trial, participants showed significantly lower Hb concentrations in both pre-dehydration and post-rehydration ($p = 0.002$ and $p = 0.006$, respectively). However, all measured values were within the healthy range and indicated that participants were well trained.

For both water types (bottled and Zamzam), most plasma electrolyte concentrations were significantly elevated post-dehydration compared to pre-dehydration ($p < 0.05$). Moreover, most electrolyte values were persistently higher post-rehydration with both water types, except for sodium and chloride that showed a significant decrease compared to the pre-dehydration stage. The magnesium concentration was lower post-dehydration compared to pre-dehydration with Bottled water only. The plasma Hb concentration and Hct ratio were significantly elevated in post-dehydration and post-rehydration stages with both water types compared to the pre-dehydration stage ($p < 0.05$), except for the Hct ratio which was significantly higher in the post-dehydration stage with Zamzam water ($p = 0.001$).

The heart rate was significantly lower post-

Table 3. The effect of rehydration with Zamzam versus Bottled water on different variables. The mean (±SD) is shown (n = 20).

Variables	Phases	Bottled water	Zamzam water	*p*
Body weight (Kg)	Pre (dehydration)	67.30 (±8.72)	67.36 (±8.62)	0.639
	Post (dehydration)	65.82 (±8.48)	65.84 (±8.60)	0.933
	Post (rehydration)	67.40 (±8.70)	67.35 (±8.78)	0.786
Total body water (Kg)	Pre (dehydration)	42.34 (±4.61)	42.34 (±4.43)	0.983
	Post (dehydration)	44.23 (±4.75)	44.29 (±4.77)	0.801
	Post (rehydration)	42.41 (±4.44)	42.81 (±4.32)	0.804
Plasma volume change	Post (dehydration)	–3.23 (±2.34)	–4.47 (±2.16)	0.075
	Post (rehydration)	–1.30 (±2.13)	–1.01 (±2.29)	0.703
Calcium (dL/mg)	Pre (dehydration)	9.62 (±0.21)	9.50 (±0.25)	0.050
	Post (dehydration)	10.29 (±0.38)	10.21 (±0.37)	0.379
	Post (rehydration)	10.03 (±0.31)	9.90 (±0.39)	0.186
Sodium (L/mmol)	Pre (dehydration)	140.45 (±1.00)	139.73 (±1.48)	0.016
	Post (dehydration)	141.75 (±1.13)	141.50 (±1.67)	0.494
	Post (rehydration)	137.73 (±1.28)	137.25 (±1.77)	0.226
Potassium (L/mmol)	Pre (dehydration)	4.21 (±0.31)	4.00 (±0.31)	0.015
	Post (dehydration)	4.21 (±0.24)	4.13 (±0.27)	0.305
	Post (rehydration)	4.53 (±0.47)	4.37 (±0.40)	0.218
Chloride (L/mmol)	Pre (dehydration)	100.56 (±1.59)	100.37 (±2.05	0.527
	Post (dehydration)	101.54 (±1.35)	101.29 (±2.02)	0.535
	Post (rehydration)	97.43 (±1.35)	97.19 (±2.18)	0.628
Magnesium (dL/mg)	Pre (dehydration)	1.96 (±0.13)	1.95 (±0.15)	0.641
	Post (dehydration)	1.89 (±0.15)	1.93 (±0.17)	0.305
	Post (rehydration)	1.94 (±0.13)	1.99 (±0.28)	1.000
Hemoglobin (dL/mg)	Pre (dehydration)	14.91 (±0.61)	14.51 (±0.71)	0.002
	Post (dehydration)	15.60 (±0.71)	15.40 (±0.76)	0.206
	Post (rehydration)	15.18 (±0.64)	14.71 (±0.75)	0.006
Hematocrit (%)	Pre (dehydration)	45.81 (±2.25)	44.89 (±3.38)	0.225
	Post (dehydration)	47.09 (±2.19)	46.90 (±3.34)	0.820
	Post (rehydration)	46.01 (±2.06)	44.92 (±3.34)	0.224
Peak heart rate (bpm)	Pre (dehydration)	195.10 (±8.67)	195.10 (±8.67)	
	Post (rehydration)	195.01 (±7.97)	193.95 (±8.62)	0.160
VO_{2peak} (L/min)	Pre (dehydration)	3.81 (±0.41)	3.81 (±0.41)	
	Post (rehydration)	3.67 (±0.40)	3.66 (±0.48)	0.864
VO_{2peak} (mL/kg/min)	Pre (dehydration)	55.75 (±4.72)	55.75 (±4.72)	
	Post (rehydration)	53.25 (±8.30)	54.70 (±5.13)	0.424
VT1 (% of VO_{2peak})	Pre (dehydration)	53.31 (±11.6)	53.31 (±11.6)	
	Post (rehydration)	50.56 (±8.37)	53.06 (±11.54)	0.320
VT2 (% of VO_{2peak})	Pre (dehydration)	91.64 (±14.29)	91.64 (±14.29)	
	Post (rehydration)	84.71 (±12.57)	90.36 (±16.30)	0.339
Peak oxygen pulse (mL/beat)	Pre (dehydration)	19.53 (±2.44)	19.53 (±2.44)	
	Post (rehydration)	19.42 (±2.52)	19.16 (±2.69)	0.715
VE_{peak} (L/min)	Pre (dehydration)	134.26 (±21.55)	134.26 (±21.55)	
	Post (rehydration)	128.57 (±18.32)	128.06 (±21.42)	0.931
Breathing frequency (times/min)	Pre (dehydration)	59.37 (±9.09)	59.37 (±9.09)	
	Post (rehydration)	57.38 (±7.93)	57.47 (±8.55)	0.968

rehydration with Zamzam water compared to pre-dehydration (p = 0.014). The VO_{2peak} (mL/kg/min) and VE_{peak} were significantly lower post-rehydration with bottled water compared to pre-measurement (p = 0.029 and p = 0.038, respectively), but not with Zamzam water (p = 0.183). There were no significant differences between the water types (Zamzam or bottled) for VT1, VT2, peak oxygen pulse, and BF_{peak}.

4. Discussion

The aim of this study was to investigate the effect of rehydration with two types of water (Zamzam and bottled) on cardiorespiratory fitness markers in professional taekwondo players. In general, the results demonstrate that rehydration with Zamzam water following significant dehydration may help to maintain or even improve cardiorespiratory fitness. Rehydration with fluid following the loss of 2% or more of body weight could help to prevent a decline in sports performance [9,22–25]. Several studies have examined the effect of exercise-induced dehydration on cardiorespiratory fitness [7,26]. Adams [7] concluded that full fluid replacement, even in a blinded manner, could enhance physical performance.

Cardiorespiratory fitness is a key fitness component for taekwondo players. However, few studies have investigated the effect of rehydration following exercise-induced dehydration on cardiorespiratory fitness that may reduce subsequent performance, especially in the short-term [27]. A trial comparing Zamzam water with bottled water found no significant difference in most measured variables, except for plasma Hb concentration. Compared to bottled water, participants rehydrated with Zamzam water showed significantly lower Hb concentrations in both the pre-dehydration and post-rehydration stages (p = 0.002 and p = 0.006, respectively). Nevertheless, this difference in Hb did not significantly affect the VO_{2peak} (post-rehydration), as no significant difference was observed post-rehydration between Zamzam water and bottled water.

The significant increases in HR, $\dot{V}E$ and breathing rate in the control group compared to the rehydrated group indicates that dehydration (2% loss of body weight) is enough to cause a significant decrease in cardiorespiratory function [28]. However, short-term (~80 minutes ± 10) rehydration with a water volume equivalent to 100% of the loss in body weight may help to maintain cardiorespiratory function. Similar results were reported in a previous study [28,29]. Shillington [30] found there were no significant differences in some cardiorespiratory functions such as VE (72.1 ± 8.4 *vs.* 69.4 ± 7.5 $L{\cdot}min^{-1}$; p = 0.5) and VO_{2peak} (2.4 ± 0.1 *vs.* 2.4 ± 0.2 $L{\cdot}min^{-1}$; p = 0.3) between two types of commercial beverages post-rehydration after an exercise test trial of ~90 minutes.

Table 4 presents results of the pre-dehydration, post-dehydration, and post-rehydration trials for Zamzam and bottled water. Hb and Hct values were significantly increased post-dehydration and post-rehydration with both Zamzam and bottled water compared to pre-dehydration values ($p < 0.05$), although Hct was significantly elevated only in the post-dehydration stage with Zamzam water (p = 0.001). Hb and Hct both increased due to the loss of plasma volume [20]. Moreover, the increased Hb and Hct levels can negatively affect blood viscosity. Alterations in these blood parameters were associated with a reduction in performance capacity due to increased viscosity and thus reduced peripheral blood flow and cardiac output [8,31,32].

Dehydration (>2% loss in body weight) may impair endurance performances even during relatively short games such as taekwondo [5,33]. The present study found that short-term rehydration (~80 minutes) with Zamzam water did not impair most of the cardiorespiratory parameters. For example, with Zamzam water the HRpeak decreased significantly only in the post-rehydration stage compared with pre-dehydration (p = 0.014). Notably, both the relative (mL/kg/min) and absolute (L/min) values of the VO_{2peak} were significantly lower post-rehydration compared to pre-dehydration with bottled water (p = 0.002 and p = 0.029, respectively), but not with Zamzam water (p = 0.094 and p = 0.183, respectively). Zamzam water is rich of minerals that may help to maintain whole-body fluid homeostasis[16]. Addition of 40 or 50 mmol/L of sodium chloride to a rehydration drink decreased subsequent urine output, in turn, providing more effective rehydration in short term. However, this did not improve performance 4 h after the end of the rehydration period [17].

Nevertheless, dehydration during exercise in hot conditions impairs performance more than with similar exercise in cooler conditions. This is thought to be due to the greater cardiovascular and thermoregulatory strain associated with heat exposure [33]. In the present study, exercise testing was performed in relatively cool conditions (21 ± 1 °C). This may explain the absence of significant differences between trials for VT1, VT2, peak oxygen pulse, and BF_{peak} with both Zamzam water and bottled water (all $p > 0.05$). The major finding of the present study was that rehydration with mineral water such as Zamzam water may not impair key parameters of cardiorespiratory fitness, including the VO_{2peak}. Thus, the novelty of the present study: (1) Rehydration with mineral water such as Zamzam water maintained cardiorespiratory functions including VO_{2peak}, VT1, VT2, and VE_{peak} in professional Taekwondo plyers, even with rehydration equivalent to 100% of the loss in body weight following exercise-induced dehydration (>2% loss in body weight), (2) this major findings may help professional Taekwondo players in companions that usually last between 50–80 minutes, (3) in terms of health-related perspective, rehydration with mineral water such as Zamzam water is important for players' health as well. The effect of rehydration with mineral water such as Zamzam water for different types of sport requires further investigation under different conditions.

Table 4. Comparison of pre-dehydration, post-dehydration, and post-rehydration trials for Zamzam water and Bottled water. Values shown are the mean (±SD) (n = 20).

Variables	Trial	Pre (dehydration)	Post (dehydration)	Post (rehydration)	*p*
Weight mass (Kg)	Bottled	67.30 (±8.72)	65.82 (±8.48)	67.40 (±8.70)	a & b
	Zamzam	67.36 (±8.62)	65.84 (±8.60)	67.35 (±8.78)	a
Total body water (Kg)	Bottled	42.34 (±4.61)	44.23 (±4.75)	42.41 (±4.44)	a
	Zamzam	42.34 (±4.43)	44.29 (±4.77)	42.81 (±4.32)	a
Plasma volume change	Bottled	–3.23 (±2.34)	-	–1.30 (±2.13)	b
	Zamzam	–4.47 (±2.16)	-	–1.01 (±2.29)	b
Calcium (dL/mg)	Bottled	9.62 (±0.21)	10.29 (±0.38)	10.03 (±0.31)	a & b
	Zamzam	9.50 (±0.25)	10.21 (±0.37)	9.90 (±0.39)	a & b
Sodium (L/mmol)	Bottled	140.45 (±1.00)	141.75 (±1.13)	137.73 (±1.28)	a & b
	Zamzam	139.73 (±1.48)	141.50 (±1.67)	137.25 (±1.77)	a & b
Potassium (L/mmol)	Bottled	4.21 (±0.31)	4.21 (±0.24)	4.53 (±0.47)	b
	Zamzam	4.00 (±0.31)	4.13 (±0.27)	4.37 (±0.40)	a & b
Chloride (L/mmol)	Bottled	100.56 (±1.59)	101.54 (±1.35)	97.43 (±1.35)	a & b
	Zamzam	100.37 (±2.05)	101.29 (±2.02)	97.19 (±2.18)	a & b
Magnesium (dL/mg)	Bottled	1.96 (±0.13)	1.89 (±0.15)	1.94 (±0.13)	a
	Zamzam	1.95 (±0.15)	1.93 (±0.17)	1.99 (±0.28)	-
Hemoglobin (dL/mg)	Bottled	14.91 (±0.61)	15.60 (±0.71)	15.18 (±0.64)	a & b
	Zamzam	14.51 (±0.71)	15.40 (±0.76)	14.71 (±0.75)	a & b
Hematocrit (%)	Bottled	45.81 (±2.25)	47.09 (±2.19)	46.01 (±2.06)	a & b
	Zamzam	44.89 (±3.38)	46.90 (±3.34)	44.92 (±3.34)	a
Peak heart rate (bpm)	Bottled	195.10 (±8.67)	-	195.01 (±7.97)	-
	Zamzam	195.10 (±8.67)	-	193.95 (±8.62)	b
VO_{2peak} (L/min)	Bottled	3.81 (±0.41)	-	3.67 (±0.40)	b
	Zamzam	3.81 (±0.41)	-	3.66 (±0.48)	-
VO_{2peak} (mL/kg/min)	Bottled	55.75 (±4.72)	-	53.25 (±8.30)	b
	Zamzam	55.75 (±4.72)	-	54.70 (±5.13)	-
VT1 (% of VO_{2peak})	Bottled	53.31 (±11.6)	-	50.56 (±8.37)	-
	Zamzam	53.31 (±11.6)	-	53.06 (±11.54)	-
VT2 (% of VO_{2peak})	Bottled	91.64 (±14.29)	-	84.71 (±12.57)	-
	Zamzam	91.64 (±14.29)	-	90.36 (±16.30)	-
Peak oxygen pulse (mL/beat)	Bottled	19.53 (±2.44)	-	19.42 (±2.52)	-
	Zamzam	19.53 (±2.44)	-	19.16 (±2.69)	-
VE_{peak} (L/min)	Bottled	134.26 (±21.55)	-	128.57 (±18.32)	b
	Zamzam	134.26 (±21.55)	-	128.06 (±21.42)	-
Peak breathing frequency (times/min)	Bottled	59.37 (±9.09)	-	57.38 (±7.93)	-
	Zamzam	59.37 (±9.09)	-	57.47 (±8.55)	-

a: Significant difference between Pre (dehydration) and Post (dehydration); b: Significant difference between Pre (dehydration) and Post (rehydration) ($p \leq 0.05$).

The limitations of the present study include the short period of time tracking the effect of rehydration with mineral water (~80 minutes) as the effect of ingested electrolytes may need relatively longer time (6–12 hours). Moreover, the limit number of subjects fit to the study criteria led to use a cross-over design model. Thus, a randomized control trial design may provide more robust findings.

5. Conclusions

In general, rehydration with water is unlikely to influence most of the cardiorespiratory fitness markers. The present study found no significant differences between Zamzam water and bottled water for most variables, including cardiorespiratory fitness markers. However, rehydration with Zamzam water tends to maintain cardiorespiratory fitness markers such as VO_{2peak} as soon as 80 ± 10 minutes after exercise-induced dehydration (>2% loss of body weight). Although rehydration with 150% equivalent of lost body weight is not recommended, rehydration with Zamzam water of 100% of lost body weight did not impair key cardiorespiratory fitness markers. Further studies are warranted to investigate the effect of similarly available liquids to Zamzam water under different conditions and for different sports.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

Not applicable.

Author Contributions

Conceptualization—TA and KA; methodology—TA, KA, AA, GA; software—AIA; validation—YA, GA and AA; formal analysis—TA, AIA; investigation—TA, KA, AIA, GA; resources—KA, YA; data curation—KA, AA, YA; writing - original draft preparation—KA, GA, AA, AIA, YA, TA; writing - review and editing—KA, GA, AA, AIA, YA; visualization—GA; supervision—KA, GA, AA, AIA, YA; project administration—KA; funding acquisition—GA. All authors have read and agreed to the published version of the manuscript.

Ethics Approval and Consent to Participate

Ethical approval was obtained from the Ethics Committee at the Institute Review Board (IRB) King Saud University (No. E-20-4667).

Acknowledgment

The authors would like to thank the Researchers Supporting Project (RSP-2021/263), King Saud University, Riyadh, Saudi Arabia.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

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