Modulatory Role of Pre-exercise Water Ingestion on Metabolic, Cardiovascular and Autonomic Responses to Prolonged Exercise in Young Mildly Active Male Students

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ABSTRACT

Studies have indicated deranged post-exercise physiological responses in hypohydrated subjects. The study investigated the effect of pre-exercise water ingestion on metabolic, autonomic and cardiovascular responses to prolonged exercise in mildly active male Nigerian students. 36 mildly active young males who emerged from random sampling were assigned into exercise groups I, II and III and were administered 0 L, 0.5 L and 1 L of drinking water at 15°C respectively. Responses were evaluated as % change between post- and pre-exercise levels and statistical analysis was conducted using SPSS-23. When compared with group I, baroreflex sensitivity (BRS), pulse rate (PR), systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), mean arterial blood pressure (MAP), rate pressure product (RPP), double product (DoP), Calculated Cardiac Output (CCO) and Peripheral Oxygen Saturation (SP0₂) responses were significantly raised in groups II and III. Alanine transaminase (ALT), aspartate transaminase (AST) and alkaline phosphatase (ALP) responses were significantly lower in group III when compared with group I or group II. Peak PR, DoP and CCO responses occurred in group II while ALT, AST and ALP responses reached the nadir in group III. As far as groups II and III were concerned, hematocrit, hemoglobin and RBC responses did not significantly differ from group I but BRS positively and negatively correlated with DoP (r=0.952, P<0.05) and SPO₂ (r=-0.568, P<0.05) respectively in both groups. In conclusion, the study showed that ingestion of 1 liters of water prior to prolonged exercise modulated neurovascular, cardiovascular and metabolic responses to prolonged exercise in mildly active male students. (Int J Biomed Sci 2022; 18 (2): 24-34)

Keywords: Pre-exercise; Water ingestion; Nigerian Students; Baroreflex Sensitivity; Alkaline Phosphate; Aspartate Transaminase; Alanine Transaminase

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INTRODUCTION

Exercise is widely recognized as any programmed and purposeful physical activities that foster physical, mental and emotional fitness and wellness (1). In a broader sense, physical, mental and emotional fitness and wellness entail improved musculoskeletal (2) and cardiorespiratory fitness, weight control and lean body mass and reduced total body fat (3), improved immune strength, lowered mortality rates (4), reduced rates of coronary heart disease, hypertension, cerebrovascular disease, breast cancer and diabetes mellitus among others (1, 5). World Health Organization (W.H.O.) (6) recommends that adults aged 18–64 years should engage in a minimum of 2 hours 30 minutes of moderate-intensity aerobic physical activity throughout the week or a minimum of 1 hour 15 minutes of weekly vigorous-intensity aerobic physical activity.

Exercise is characterized by increase in metabolic demand. Hence, physiological responses to exercise induced metabolic changes including changes in hemodynamics, enzyme activities, hemopoiesis and autonomic and cardiovascular functions (7). Among the changes in autonomic and cardiovascular functions during exercise are increase in baroreflex sensitivity, increase in heart rate, increase in systolic blood pressure with or without substantive change in diastolic blood pressure and mean arterial blood pressure, increase in stroke volume and cardiac output, increase in myocardial workload and cardiac sympathetic activity evidenced by increase in rate pressure product and double product (3, 8). Others include increase in respiratory rate and respiratory minute volume and increase in capillarization, mitochondrial volume and oxidative enzymes culminating into an increase in V02max and peripheral oxygen saturation (8).

Endurance training is any aerobic workout programs designed to improve cardiovascular fitness and endurance (3). As such, endurance activities are characterized by prolonged training sessions. Among the physiological benefits of the program are increased beat volume, reduced heart rate, reduced blood viscosity, increased mitochondrial volume, increased insulin secretion and proliferation of muscle mass (2, 3). Prolonged physical exercise under extreme calorie deprivation has been reported to result in increased plasma urea and urine osmolarity, reduced brain natriuretic peptide and increased isovolumic relaxation time without significant change in E/A ratio (9). Furthermore, studies have indicated the adverse health consequences associated with prolonged training session. For example, Studies by Davila et al., (9) and Shave et al., (10) reported that strenuous physical activity orchestrated pulmonary hypertension, high brain natriuretic peptide, elevated troponin level, cardiac arrhythmia and reduction in testosterone and transient left and right ventricular systolic and diastolic dysfunction (11).

Prolonged physical activity elevates body temperature triggering increase in sweating, a form of sensible water loss (12). At least a study has established a relationship between dehydration and and changes in the function of Central Nervous System (CNS) (13). In young individuals, acute dehydration has been reported to result in reduced exercise performance (14) and impaired cognitive function and mood (15). Hence, the role of hydration especially in fostering optimal condition for physical activity performance and for earning homeostatic processes cannot be undersized. Many studies have identified the beneficial effects of water consumption on cardiovascular recovery during and after different physical activities including soccer and prolonged cycling and running (16-18).

With respect to exercise-induced physiological responses, one of the critical determinants is the level of training and physical activity status. Studies have revealed that trained athletes exhibited increased capillary density and mitochondrial mass, a relatively low heart rate and a great cardiac output (3, 19). On the other hand, works are replete on the adverse cardiorespiratory profile exhibited by sedentary people (19). One of the risk groups for sedentary behaviour is College or University students. A study done in United Kingdom by Rouse and Biddle, (2010) (20) showed that University students spent 30% of their 24-hour day in sedentary-related activities. Despite scarcity of empirical data, in Nigerian University Health Facilities, the need to excel propel students to libraries and reading rooms even after classroom teaching where they end up spending additional time in non-exercising sitting posture. In this class of students, the effect of pre-exercise water ingestion on metabolic, hematopoietic and autonomic cardiovascular responses to a single bout of prolonged exercise is not clear. The aim of the study was to determine the effect of pre-exercise water ingestion on metabolic, autonomic and cardiovascular responses to prolonged exercise in mildly active students

MATERIALS AND METHODS

Site of the Study

The work was carried out in the Technologically-Enhanced Laboratory Unit of the Department of Physiology, Edo University Iyamho, Etsako West Local Government
Area, in Edo State. The area was chosen based on the fact that no similar study has been done in the area.

Subjects
Thirty-six apparently healthy mildly active young males who are students of the Edo University Iyamh were used for the study. The students were in the first semester of 200 Level. Ethical clearance was obtained from the Department of Physiology, Edo University Iyamho.

Ethical Certification
Before the conduct of the study, approval (294738) was obtained from the Ethics and Research Committee of the above-named institution.

Inclusion Criteria
Fifty mildly active adult male students aged between 16-21 years were accommodated into the groups. Written consent was gotten from each subject and a well-structured questionnaire was administered to rule out those with medical history of respiratory diseases, cardiovascular, kidney, hepatic and metabolic diseases or anatomical deformsities. History of smoking, alcoholism and caffeine and any form of medication was also taken. Medical examination and physical activity status evaluation were also done. Physical examinations were also done and those that were not medically fit were disqualified. After the screening, 36 male subjects were drawn out and were assigned randomly into three groups of twelve subjects each as indicated below:

Group I (Exercise): were exercised on a treadmill at a speed of 8km/hr at 10° inclination until exhaustion.
Group II (Mild hydration + Exercise): were pre-hydrated with 500 milliliters of water and exercised on a treadmill at a speed of 8km/hr at 10° inclination until exhaustion.
Group III (Moderate hydration + Exercise): were pre-hydrated with 1 liters of water and exercised on a treadmill at a speed of 8km/hr at 10° inclination until exhaustion.

All subjects were fully informed about the purpose of the study and the procedure.

Experimental Protocol
The study was done in the Physiology Laboratory at a temperature of 25°C between 8.00 a.m. and 12.00 pm following twelve hours of overnight fasting and water restriction.

The study was done in two consecutive days. In the first day, anthropometrical data such as weight, height, body mass index and chest circumference, body temperature, blood pressure and aerobic fitness status were determined.

On the second day, the participants were subjected to warm up session where they were acquainted with the procedure. All the participants were instructed to micturate before the commencement of the procedure.

Pre-and post-exercise autonomic and cardiovascular indices such as baroreflex sensitivity, heart rate, blood pressure, pulse rate, mean arterial blood pressure, shock index, calculated cardiac output, rate pressure product, and double product were determined. Peripheral oxygen saturation was measured. Blood samples were also collected for the determination of hematocrit, hemoglobin and metabolic indices such as alanine transaminase, alkaline phosphatase and aspartate transaminase.

Blood samples were collected into heparinized bottles from the antecubital veins using sterile needles and syringes. Then, the blood sample was centrifuged to obtain plasma using bucket centrifuge. Hematocrit, hemoglobin concentration and metabolic indices (plasma hepatic enzymes were analyzed).

Drinking water was purchased from a pharmaceutical store. 0.5 L, 0.5 L and 1 L of the water at 15°C were administered to groups I, II and III respectively fifteen minutes prior to the exercise program.

The treadmill was calibrated according to the Bruce Treadmill Protocol (21). Each subject was maintained on a speed of 8km/hr at an inclination of 10° until exhaustion.

Responses were calculated as % change in a parameter between pre- and post-exercise.

Determination of Anthropometrical Indices and Urine Specific Gravity
Weight was measured using weighing scale (Hanson China) to the nearest 0.5 kg. Height was measured using meter rule.

The BMI of each subject was calculated using the formula (Weight in (kg)/square of metric height).

Chest circumference was measured using tape rule.

Using measuring cylinder (100 milliliters capacity), urine specific gravity was measured using urinometer.

Determination of Body Temperature and Physical Activity Status
Body temperature was measured using mercury in glass thermometer.

Physical activity status was determined using International Physical Activity Questionnaire for young and middle-aged adults (15-69 years) Booth, (2000) (22). Scores between 25%-50%, 50-75% and 75-100% were classified...
as mildly active, moderately active and highly active respectively. Scores below 25% are classified as sedentary.

**Determination of Autonomic and Cardiovascular Responses**

**Determination of autonomic responses (Baroreflex sensitivity).** Heart rate response to blood pressure changes was measured using Valsalva method. Subjects were asked to blow against mercury column for 10 seconds while maintaining a pressure of 40 mmHg. During and 50 seconds after the maneuver, cardiovascular parameters were estimated. Baroreflex sensitivity was calculated using R-R interval/ΔBP (ms/mmHg).

**Determination of Blood Pressure and Pulse Rate.** Blood pressure was measured from the arm, an inch above the elbow using mercury sphygmomanometer in a sitting position after 10 minutes of rest. Pulse rate was measured from radial artery using palpation method.

**Determination of Pulse Pressure, Mean Blood Pressure and Calculated Cardiac Output**

Pulse pressure was determined by subtracting diastolic blood pressure from systolic blood pressure.

Mean arterial blood pressure was obtained using; diastolic blood pressure +1/3 of pulse pressure. Calculated cardiac output was obtained by using; 0.002 * Pulse rate* Pulse pressure.

**Determination of Double Product and Rate Pressure Product**

Double Product was calculated as Pulse Rate * Mean Arterial Blood Pressure.

Rate Pressure Product was calculated as (Pulse Rate * Systolic Blood Pressure)/100.

**Determination of Peripheral Oxygen Saturation**

Peripheral oxygen saturation was measured using pulse oximeter.

**Determination of Hematological parameters**

**Hematocrit determination.** Hematocrit determination was based on the application of centrifugal force to recover blood cells from anticoagulated blood in a tube.

**Hemoglobin determination.** Hemoglobin concentration was measured using Sahli’s method. Red blood cell count determination. Using isotonic fluid, hemolyzed blood cells were diluted (× 200), the number of erythrocytes in a measured quantity of blood was determined using the microscope.

**Determination of Metabolic Indices (gluconeogenic enzymes)**

Alanine transaminase, aspartate transaminase and alkaline phosphatase were determined using ELISA kit (Biosystems S. A Barcelona-Spain).

**RESULTS**

**Physical characteristics of the subjects**

Table 1 shows the physical characteristics of subjects in groups I, II and III. No significant difference between groups.

**Effect of pre-exercise water ingestions and prolonged exercise on metabolic indices**

Figure 1a showed the effect of water ingestion and

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Group I (Mean ± SEM)</th>
<th>Group II (Mean ± SEM)</th>
<th>Group III (Mean ± SEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Temperature (Morning) (°C)</td>
<td>35.9 ± 0.433</td>
<td>36.1 ± 0.231</td>
<td>35.8 ± 0.26</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>65.5 ± 4.908</td>
<td>63 ± 0.577</td>
<td>69.5 ± 3.202</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.69 ± 0.006</td>
<td>1.66 ± 0.069</td>
<td>1.69 ± 0.019</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.0 ± 1.875</td>
<td>23.3 ± 2.141</td>
<td>24.2 ± 1.284</td>
</tr>
<tr>
<td>Chest circumference (cm)</td>
<td>86.4 ± 2.934</td>
<td>85.1 ± 0.734</td>
<td>91.4 ± 2.934</td>
</tr>
<tr>
<td>Resting systolic blood pressure (mmHg)</td>
<td>111 ± 5.196</td>
<td>108 ± 1.440</td>
<td>113 ± 1.440</td>
</tr>
<tr>
<td>Resting diastolic blood pressure (mmHg)</td>
<td>78 ± 1.155</td>
<td>78 ± 1.443</td>
<td>78 ± 1.440</td>
</tr>
<tr>
<td>Urine specific gravity</td>
<td>1.03 ± 0.003</td>
<td>1.02 ± 0.006</td>
<td>1.03 ± 0.001</td>
</tr>
<tr>
<td>Physical activity status (%)</td>
<td>35 ± 5.770</td>
<td>36 ± 6.495</td>
<td>38 ± 7.217</td>
</tr>
</tbody>
</table>
prolonged exercise on alkaline phosphatase (ALP). When compared with pre-exercise, ALP was significantly higher after exercise in groups I and II but lower in III. In group II, ALP response was insignificantly (P>0.05) higher than that of group I. In group III, ALP response was significantly (P<0.05) lower than that of group I. In group III, ALP response was also significantly (P<0.05) lower than that of group II. ALP response was lowest in group III.

Figure 1b showed the effect of water ingestion and prolonged exercise on alanine transaminase (ALT). When compared with pre-exercise, ALT was significantly higher after exercise in groups I and II but lower in III. In group II, ALT response was insignificantly (P>0.05) higher than that of group I. In group III, ALT response was significantly (P<0.05) lower than that of group I and II. ALT response was lowest in group III.

Figure 1c showed the effect of water ingestion and prolonged exercise on aspartate transaminase (AST). When compared with pre-exercise, AST was significantly higher after exercise in groups I and II but lower in III. In group II, AST response was insignificantly (P>0.05) higher than that of group I. In group III, AST response was significantly (P<0.05) lower than that of group I and II. AST response was lowest in group III.

Effect of pre-exercise water ingestions and prolonged exercise on hematological indices (packed cell volume and hemoglobin)

Figure 2a showed the effect of water ingestion and prolonged exercise on packed cell volume (PCV). When compared with pre-exercise, PCV was significantly higher after exercise in groups I, II and III.

Figure 2b showed the effect of water ingestion and prolonged exercise on hemoglobin (HB). When compared with pre-exercise, HB was significantly higher after exercise in groups I, II and III.

Figure 2c showed the effect of water ingestion and prolonged exercise on Red Blood Cell (RBC). When compared with pre-exercise, RBC was significantly higher after exercise in groups I, II and III.

Effect of pre-exercise water ingestions and prolonged exercise on autonomic cardiovascular parameters

Table 2 shows the effects of pre-exercise ingestions and prolonged exercise on autonomic and cardiovascular parameters.

When compared with group I, baroreflex sensitivity

![Figure 1](image-url)
Table 2. Effect of pre-exercise water ingestion on autonomic and cardiovascular responses to prolonged exercise

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-exercise (Mean ± SEM)</td>
<td>Post-exercise (Mean ± SEM)</td>
<td>Response (Mean ± SEM)</td>
</tr>
<tr>
<td>Baroreflex sensitivity (ms/mmHg)</td>
<td>9.23 ± 0.103</td>
<td>9.54 ± 0.180b</td>
<td>3.35 ± 0.794</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>129.50 ± 0.474</td>
<td>142.00 ± 2.210b</td>
<td>9.66 ± 1.300</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>71.50 ± 2.370</td>
<td>72 ± 2.214a</td>
<td>0.70 ± 0.248</td>
</tr>
<tr>
<td>Pulse rate (BPMD)</td>
<td>63.00 ± 0.949</td>
<td>94.00 ± 3.162b</td>
<td>49.04 ± 2.781</td>
</tr>
<tr>
<td>Pulse pressure (mmHg)</td>
<td>58.00 ± 1.897</td>
<td>70.00 ± 0.2000b</td>
<td>20.69 ± 3.687</td>
</tr>
<tr>
<td>Mean arterial pressure (mmHg)</td>
<td>90.83 ± 2.245</td>
<td>95.33 ± 2.790b</td>
<td>4.95 ± 0.480</td>
</tr>
<tr>
<td>Rate pressure product</td>
<td>54.52 ± 3.621</td>
<td>133.48 ± 2.416b</td>
<td>144.83 ± 11.990</td>
</tr>
<tr>
<td>Double product</td>
<td>5722.50 ± 23.750</td>
<td>8961.30 ± 99.960b</td>
<td>56.60 ± 2.360</td>
</tr>
<tr>
<td>Calculated cardiac output</td>
<td>7.32 ± 0.3492</td>
<td>17.86 ± 0.1999b</td>
<td>145.57 ± 9.035</td>
</tr>
<tr>
<td>Baroreflex sensitivity (ms/mmHg)</td>
<td>12.46 ± 1.066</td>
<td>25.554 ± 3.050a</td>
<td>102.45 ± 7.654a</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>104.50 ± 0.791</td>
<td>139.50 ± 1.423b</td>
<td>33.49 ± 2.373a</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>64.50 ± 0.474</td>
<td>73.50 ± 0.158b</td>
<td>13.95 ± 0.593a</td>
</tr>
<tr>
<td>Pulse rate (BPMD)</td>
<td>67.50 ± 1.423</td>
<td>133.50 ± 0.791b</td>
<td>98.23 ± 5.31a</td>
</tr>
<tr>
<td>Pulse pressure (mmHg)</td>
<td>40.00 ± 1.265</td>
<td>66.00 ± 1.265b</td>
<td>65.00 ± 8.49a</td>
</tr>
<tr>
<td>Mean arterial pressure (mmHg)</td>
<td>77.83 ± 0.068</td>
<td>95.50 ± 0.749b</td>
<td>22.70 ± 2.854a</td>
</tr>
<tr>
<td>Rate pressure product</td>
<td>70.54 ± 0.954</td>
<td>186.23 ± 0.797a</td>
<td>164.02 ± 2.455a</td>
</tr>
<tr>
<td>Double product</td>
<td>5235.75 ± 114.300</td>
<td>12749.25 ± 2.205b</td>
<td>142.67 ± 5.270a</td>
</tr>
<tr>
<td>Calculated cardiac output</td>
<td>5.39 ± 0.058</td>
<td>17.60 ± 0.233b</td>
<td>22739 ± 7.87a</td>
</tr>
<tr>
<td>Baroreflex sensitivity (ms/mmHg)</td>
<td>17.60 ± 0.293b</td>
<td>32.57 ± 2.000</td>
<td>84.53 ± 8.321a</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>112.50 ± 0.474</td>
<td>151.50 ± 1.739a</td>
<td>34.67 ± 2.114a</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>58.00 ± 0.8</td>
<td>67.00 ± 0.949b</td>
<td>15.52 ± 2.531a</td>
</tr>
<tr>
<td>Pulse rate (BPMD)</td>
<td>70.00 ± 0.633</td>
<td>130.50 ± 0.158b</td>
<td>86.50 ± 1.912a</td>
</tr>
<tr>
<td>Pulse pressure (mmHg)</td>
<td>54.50 ± 0.752</td>
<td>84.50 ± 0.791b</td>
<td>55.05 ± 3.016a</td>
</tr>
<tr>
<td>Mean arterial pressure (mmHg)</td>
<td>76.17 ± 0.691</td>
<td>95.17 ± 1.565b</td>
<td>24.94 ± 2.854a</td>
</tr>
<tr>
<td>Rate pressure product</td>
<td>78.75 ± 0.380</td>
<td>197.71 ± 2.030b</td>
<td>151.10 ± 1.369a</td>
</tr>
<tr>
<td>Double product</td>
<td>5331.67 ± 41.320</td>
<td>12419.25 ± 143.150b</td>
<td>132.93 ± 2.195a</td>
</tr>
<tr>
<td>Calculated cardiac output</td>
<td>7.38 ± 0.1118</td>
<td>22.05 ± 0.1796b</td>
<td>199.16 ± 4.18a</td>
</tr>
</tbody>
</table>

bRepresents significant difference (P<0.05) between pre-exercise and post-exercise. aRepresents significant difference (P<0.05) from Group I (response). cRepresents significant difference (P<0.05) from Group II (response). Response was calculated as % change between post-exercise and pre-exercise.
(BRS), pulse rate (PR), systolic blood pressure (SBP), diastolic blood pressure (DBP), Pulse pressure (PP), Mean arterial blood pressure (MAP), Rate pressure product (RPP), Double product (DP), calculated cardiac output (CCO) and peripheral oxygen saturation (SPO2) responses were significantly raised in groups II and III compared to group I. Peak CCO, PR, DP occurred in group II.

Effect of pre-exercise water ingestions and prolonged exercise on peripheral oxygen saturation (SPO2)

Figure 3 showed the effect of water ingestion and prolonged exercise on SPO2. When compared with pre-exercise, SPO2 was significantly higher after exercise in all the groups.

Relationship between baroreflex sensitivity, double product and SPO2

Figure 4a showed the linear regression between baroreflex sensitivity and double product in mildly active students. A unit increase in double product increases the baroreflex sensitivity by 1 unit.

Figure 4b showed the linear regression between baroreflex sensitivity and SPO2 in mildly active students. A 0.07 unit increase in baroreflex sensitivity resulted in 1 unit decrease in SPO2.

**Figure 2.** a-c, Effect of pre-exercise water ingestion and prolonged exercise on Packed Cell Volume (PCV), hemoglobin (HB) and red blood cell count. Group I-Exercise, Group II- subjects hydrated before exercise with 0.5L of water+ Exercise, Group III subjects hydrated before exercise with 1L of water + Exercise. "a" represents significant difference (P<0.05) between pre- and post-exercise. Response was calculated as % change between post exercise and pre-exercise.

**Figure 3.** Effect of pre-exercise water ingestion and prolonged exercise on SPO2. Group I-Exercise, Group II- subjects hydrated before exercise with 0.5L of water+ Exercise, Group III subjects hydrated before exercise with 1L of water + Exercise. "a" represents significant difference (P<0.05) between pre and post-exercise. Response was calculated as % change between post-exercise and pre-exercise.
DISCUSSION

Many studies that examined the hemodynamic alterations orchestrated by acute water ingestion have reported pressor response, increase in sympathetic nerve discharge, increased plasma norepinephrine and elevated vascular resistance (23), decreased heart rate and double product with attendant reduction in myocardial workload (24). Others also indicated that water ingestion improved orthostatic tolerance in healthy subjects (25), influenced orthostatic challenge-induced blood pressure and heart rate responses in healthy subjects (26) and improved seated blood pressure in subjects with chronic autonomic failure. The present study investigated the effect of pre-exercise water ingestion levels on metabolic and autonomic cardiovascular responses to prolonged exercise in mildly active Nigerian students.

In popular consensus, metabolic indices such as alanine transaminase, aspartate transaminase and alkaline phosphatase are fondly recognized as components of liver function test (27, 28) and their elevations usually depict liver dysfunctions in the absence of muscle injury. Just like the present study, works have reported transient increases in the levels of alanine transaminase, aspartate transaminase and alkaline phosphatase during exertional conditions such as high intensity and prolonged physical activities (29). Marathon, weightlifting and running have been linked to elevated alanine transaminase, aspartate transaminase and alkaline phosphatase (29). Although, the present study was not specifically aimed at investigating whether prolonged exercise perturbs alanine transaminase, aspartate transaminase and alkaline phosphatase, post-exercise levels of these parameters were significantly elevated when compared with pre-exercise levels. In addition to increase in metabolic demand, exercise induced elevation in alanine transaminase, aspartate transaminase and alkaline phosphatase might relate directly with damage of muscle cells or disruption of blood flow by contracting skeletal muscles (29). Ruptured muscle cells release their sarcoplasmic contents into the blood including potassium, phosphate, transaminases and alkaline phosphatase resulting in rise in the plasma level of potassium, calcium, phosphate, transaminases and phosphatases and reduction in the plasma level of calcium (29). Exercise induced elevation in alanine transaminase, aspartate transaminase and alkaline phosphatase might also be due to exertional hyperthermia-induced muscle damage. At least a study has provided evidence in support of extreme body temperature induced muscle damage and the attendant perspiration (26). Physiologically, exercise may not lead to heatstroke. However, hyperthermia occurs during exercise as a result of vigorous muscle contraction eliciting thermoregulatory responses and this may in addition to exercise-related mechanical crush result in muscle cell damage and elevation in alanine transaminase, aspartate transaminase and alkaline phosphatase.

One of the main findings of the present study is the modulatory impact of moderate pre-exercise water ingestion on metabolic responses to prolonged exercise. Specifically, alanine transaminase, aspartate transaminase and alkaline phosphatase reached the lowest level in moderately pre-hydrated exercise group. However, we observed
that mild pre-exercise water ingestions of water exerted a different effect on these parameters. Precisely, pre-exercise ingestion of 500 milliliters of water raised alanine transaminase, aspartate transaminase and alkaline phosphatase. It is noteworthy that a great decline was observed in these parameters when 1000 milliliters of water was ingested prior to exercise. The decrease in alanine transaminase, aspartate transaminase and alkaline phosphatase showed the beneficial role of pre-exercise hydration with 1000 milliliters of water on metabolic demand. It also indicated the protective role of hydration or cooling in exertional hyperthermia-induced muscle damage. In the present study, in addition to hydration, the temperature of the water ingested by the subjects was 15°C. We are aware that the salutary benefit of ingestion of cold water or water below body temperature on physiological function has been documented (24).

Although, red blood cell count, hematocrit and hemoglobin concentration increased post-exercise, our study showed that mild or moderate pre-exercise water ingestion did not influence hemopoietic response evaluated using hematocrit and hemoglobin concentration. Our finding concurred with the report of Hyun-Kyung et al., (38) but they showed that there was also an increase in mean corpuscular hemoglobin and mean corpuscular hemoglobin concentration two weeks after ingestion of 2 L of water. The stimulatory effect of exercise on erythropoiesis has been extensively documented (23). Also, adaptation to endurance exercise has been claimed to involve decrease in hematocrit, red blood cells and hemoglobin concentrations (23, 24). Though physical characteristics of the subjects including their physical fitness status of subjects might affect physiological responses to exercise (3), the essence of the study was not to train the subjects in the direction of endurance but to understand the hemopoietic response pattern to a single bout of prolonged exercise.

On the role of hydration on cardiovascular response, Researchers have reported increase in blood pressure and a decrease in heart rate thirty-five minutes after ingestion of 500 milliliters of water at 15°C in normoactive subjects (18, 25). In our study, we discovered that systolic blood pressure, diastolic blood pressure, pulse rate, pulse pressure and mean arterial pressure increased both in mildly and moderately pre-hydrated exercise groups. However, pulse rate reached the zenith in mildly pre-hydrated exercise groups. The cardiovascular change may be due to modulation of cardiac vagal tone by activation of cold receptors present in the gastrointestinal tract. Rate pressure product and double product are indices of myocardial workload (34). We observed that rate pressure product and double product increased both in mildly and moderately pre-hydrated exercise groups with double product reaching the peak level in mildly pre-hydrated exercise group. Calculated cardiac output increased in mildly and moderately pre-hydrated exercise groups with calculated cardiac output reaching peak in mildly pre-hydrated exercise group. This implied the relative assuaging potency of moderate hydration (1000 milliliters) prior to exercise on myocardial workload.

Just like the present study, many reports have indicated that baroreflex sensitivity increases during exercise (25). Exercise-induced increase in baroreflex sensitivity has for a long time been connected with exercise-induced sympathetic discharge (3, 12). On the effect of hydration, we observed that in mildly and moderately pre-hydrated exercise groups, baroreflex sensitivity increased. It is not impossible that stimulation of gastrointestinal thermoreceptors elicited increased in sympathetic activity with attendance reduction in vascular diameter, increase in peripheral resistance and rise in vascular blood pressure. Constriction of arterial blood vessel might have led to an increase in the firing of baroreceptor with resultant change in heart rate. We also noticed from the result of the regression analysis indicated that double product, an index of myocardial workload strongly predicted baroreflex sensitivity in mildly active male students. In fact, evidence from the present study indicated that a unit increase in double product produced a unit increase in baroreflex sensitivity in mildly active male students.

The increase in peripheral oxygen saturation post-exercise indicated that there was steady increase in oxygen supply in the exercising skeletal muscles (33) and an improved oxygenation and reoxygenation (35). However, neither mild nor moderate water pre-exercise ingestion could cause any significant increase in peripheral oxygen saturation. Evidence from the regression analysis also revealed that the baroreflex sensitivity may predict peripheral oxygen saturation in mildly active male students.

The study summarily illustrated the relative mitigating and beneficial impact of moderate hydration (1000 milliliters) prior to prolonged exercise on neurovascular reflex and indices of metabolic demand and myocardial workload. Consumption of 1000 milliliters of water prior to exercise relatively mitigated indices of metabolic demand and myocardial workload in mildly active males. The findings of the study provided additional evidence on the promising roles of non-pharmacological interventions such as water as far as improvement in health status (36-
and alleviation of physiological consequences of stress and exertional situations are concerned (44).

In conclusion, the results of the present study revealed the relative modulatory influence of moderate pre-exercise water ingestion on neurovascular, cardiovascular and metabolic responses to prolonged exercise in young mildly active students. Consumption of 1000 milliliters prior to prolonged exercise relatively assuaged indices of metabolic demand and myocardial workload in mildly active males.

CONFLICT OF INTEREST

The authors declared there was no conflict of interest.

REFERENCES