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Acute Effects of High-Intensity Competition on Macroelements and Relationship with Corrected QT Interval

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Abstract

The purpose of this study is the find the changes of calcium, sodium, and potassium ions and relationship with Corrected QT (QTc) interval in professional athletes during a short duration of intense exercise. Thirty-two male athletes (age, 26.9±4.7 yrs) competed in 8 minutes high-intensity competition. The competition items included: Running on Skillmill for 400 meters; Three-stage deadlifting, bar pulling up, 30-kilogram kettle bell swinging, and throwing 20 sand-filled balls. The resting electrocardiogram was recorded in a sitting position for one minute. Venous blood samples were obtained before and immediately after the competition and analyzed for Sodium (NA+), Potassium (K), and Calcium (Ca). Plasma volume changes were estimated from hemoglobin and hematocrit readings before and after the competition. The results showed that the serum calcium ($p<0.001$) and sodium ($p<0.001$) levels significantly increased as a result of intense exercise activities while the serum potassium ($p<0.001$) significantly decreased. After adjusting raw data for plasma volume changes serum calcium, sodium, and potassium significantly decreased ($p<0.001$). No significant relationship between QTc and Ca, Na, and K at rest. These results implicated that high-intensity exercise would provoke the change of macroelements and the current data suggest that the Ca, Na, and K don't have a relationship with QTc at rest.

Keywords: Calcium, Potassium, Sodium, Athletes, Sudden cardiac death

INTRODUCTION

The role of ions, especially calcium, sodium, and potassium, for body health has been well established. These electrolytes are of vital importance for athletes due to their metabolic and physiological roles such as muscular contraction, the transmission of nerve impulse, and heartbeat (12). On the other, Sudden Cardiac Death (SCD) in athletes is an infrequent accident, but each time this happens, it is considered a tragedy or dramatic event that attracts the public's attention. It is difficult to find the underlying reason for the death of healthy active young athletes, and this problem is increasing for them (16, 21). Several studies have shown that the main symptoms associated with sudden cardiac death are structural or electrical. One of these signs is long QTc interval in the athlete's electrocardiogram (ECG), which remains unknown for the athletes who have no history of a familial disease (2). The results of studies in healthy volunteers have shown that changes in these three serum ions can cause abnormalities in the ECG, especially in QTc. In this group, it was shown that the serum calcium and potassium have negative significant relationships with QT interval while there is a positive relationship between the serum calcium and the QT interval (8, 10, 22). Malfunction of myocardial channels can lead to an increased sodium penetration or decreased potassium outflow, which subsequently increases the duration of repolarization and prolongs QTc interval (15). Moreover, the role of calcium ions in the cardiac pacemaking and its destructive effects has attracted more attention (7). Equilibrium between calcium, sodium, and potassium contents is required to lead to a normal contraction and relaxation in the heart muscle. Furthermore, it must be noted that low levels of calcium in the bloodstream can cause tetany and muscle disorders (12).

However, no accurate information is available on the relationship between changes of serum ions and QTc interval for professional athletes in the resting and those in the immediately after exercise. Given its crucial role for controlling sudden cardiac deaths during exercise, it is worth being investigated. To this end, this work investigates changes of calcium, sodium, and potassium ions and the relationship with QTc interval in professional athletes during an intense exercise.

Methodology

Participants

Among 540 male athletes who competed in the qualification stage of a high-intensity interval competition (started about two months before the semi-final stage), 32 male athletes reached the semi-final stage and participated in this research. The demographic characteristics and body composition of participants were shown in Table 1. Body height was measured by an ultrasound stadiometer (InBody, South Korea). Body composition was identified through Bio Impedance Analysis (InBody 270, InBody, South Korea). All participants provided written informed consent. The study followed the ethical guidelines of the Declaration of Helsinki and was approved by the Research Ethics Committee of the faculty of sport science Shahid Rajaee Teacher Training University (IR.SRTTU.SSF.2018.103).

Table1. Participants characteristics. Data are presented as mean ±SE (n=32)

Age (years)	26.9±4.7
Height (cm)	177±5
Weight (kg)	80.7±6.4
Body mass index (kg/m^2)	25.6±1.6
Body fat percent (%)	9.9±2.7
Skeletal muscles mass (kg)	42±4

Procedure and competition stages

The participants (n=32) were divided into 16 groups. Each group included two athletes who competed in two separate lanes in the form of a duel. The total duration of the competition was 8 minutes and the winner of each group was determined in two methods; Method I) The first athlete finishing the competition stages in under 8 minutes would be the winner and the opponent was eliminated, Method II) If none of the athletes completed the competition stages in 8 minutes, the athlete who was ahead in the competition stages would be selected as the winner.

The competition was held indoor, and the competition stages included: 1) 400 m running on the skill mill, 2) triple deadlift including the lifting of 110 kg (5 repetitions), 130 kg (3 repetitions), and 150 kg (1 repetition) weights, 3) pull up (30 repetitions), 4) kettlebell swing (30 kg), and 5) throwing 20 sand balls of different weights at a distance of 5 meters behind a 75 cm box; the stages were run by athletes in succession.

ECG Analysis

Prior to the competition, the electrocardiogram belt (custoguard, customed, Germany), which records the Lead II, was placed on the subjects' chest. In addition, the resting electrocardiogram was recorded in a sitting position by custo diagnostic software at a speed of 25 mm/s and amplitude of 0.1 mv/mm for one minute. The QT interval was calculated from the beginning of the QRS complex to the end of wave T. All of the QT intervals were measured from the mean value of 3 consecutive beats. QTc was calculated by Bazett's Formula (QTc = QT interval/$\sqrt{RR}$ interval) (3).

Blood Sampling and Laboratory Methods

Before and immediately after the competition, fourteen ml venous blood samples were obtained from antecubital veins in a sitting position and poured into three separate tubes. Two ml of the first tube anticoagulated with 3 ml of ethylenediaminetetraacetic acid (EDTA) was used to measure CBC by Cell Counter. Before and after the competition, hematocrit and hemoglobin were used to estimate the percentage change in plasma volume by the Dill and Costill equation (5). Eight ml of the second tube blood was used to measure calcium, sodium, and potassium. Sodium and potassium were measured by the Electrolyte Analyzer Cb4, while calcium content was measured by Hitachi 911. Two ml of the third tube anticoagulated with 3 ml heparin was used to measure lactate by Hitachi 911. All blood samples were stored at a temperature between 3°C and 4°C in the competition location and centrifuged (Behdad, Iran) for 10 minutes at a speed of 3000 rpm.

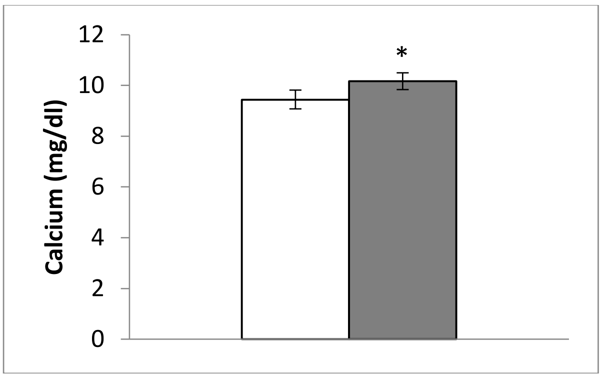
Statistical Analysis

All statistical analyses were performed using IBM Statistical Package for the Social Science software (IBM SPSS statistical. v. 25 for windows). A paired samples t-test was used to examine the difference variables in resting and those in the immediately after competition mean values of all the variables measured. Pearson test was used to examine the relationship of each variable with QTc. The significance level of each statistical analysis was P <0.05.

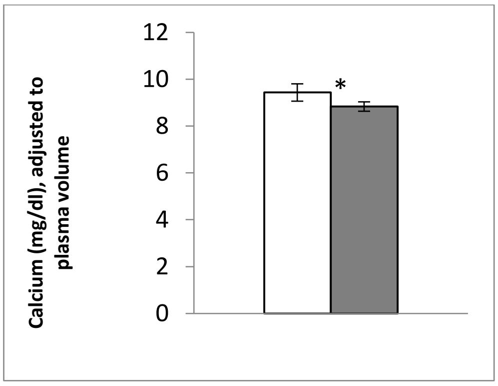
Results

All participants performed the competition and all blood samples were collected. Of the 32 participants, 16 were the winner and qualified for the next stage. Of these 16 winners, three athletes won the competition through the first method in 8 minutes, and the rest through the second method (four in stage 5 and the rest in stage 4).

The competition significantly increased blood lactate levels (Pre exercise it was 3.2 ± 0.7 mmol and immediately after exercise was 21.2 ± 1.6 mmol, P < 0.001). The changes in the plasma volume were calculated to be 12.9%. In comparison with the resting, the serum calcium ($t_{31} = -10.7. P < 0.001$) and sodium levels ($t_{31} = -20.1. P < 0.001$) showed a significant increase (Figs. 1A and 2A) while the serum potassium level significantly decreased after the competition (Fig.3A). By correcting the raw data for the lost volume of plasma, the serum calcium, sodium, and potassium levels ($t_{31} = 5.1. p\ 0.001$ for calcium. $t_{31} = 9.3. p < 0.001\ for\ sodium\ and\ t_{31} = 15.7. p < 0.001\ for\ potassium$) decreased significantly (Figs. 1B, 2B and 3B).



(A)

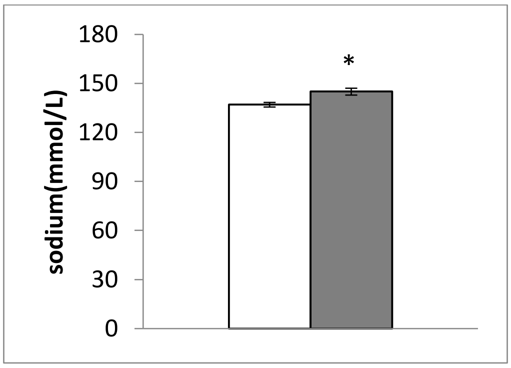


(B)

Figure 1. Mean (±SE) values of serum Calcium pre- (open bar) and the immediately after exercise (solid bar).

Upper and lower graphs represent values before (A) and after (B) adjusting raw data for plasma volume changes, respectively. Significant (P< 0.05) difference between pre- and the immediately after exercise mean values is denoted by *.

The results showed that there was no significant relationship between QTc interval and Ca, Na, and K in rest before and after adjusting raw data for plasma volume changes (Table2). The risk of type 2 error was calculated for pre-exercise Na, K, and Ca relationships with QTc (Table4).



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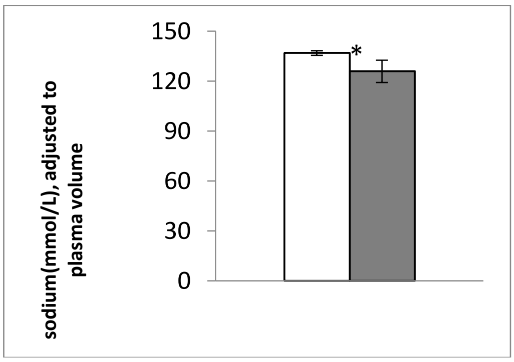
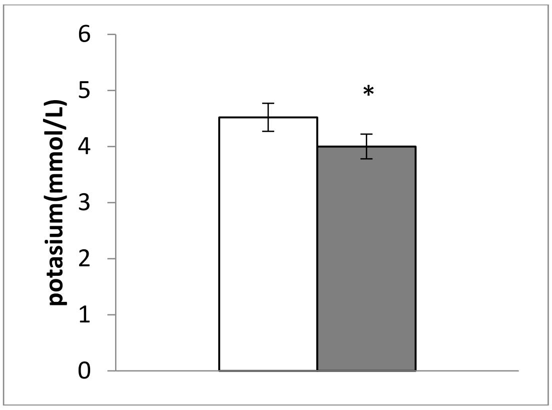


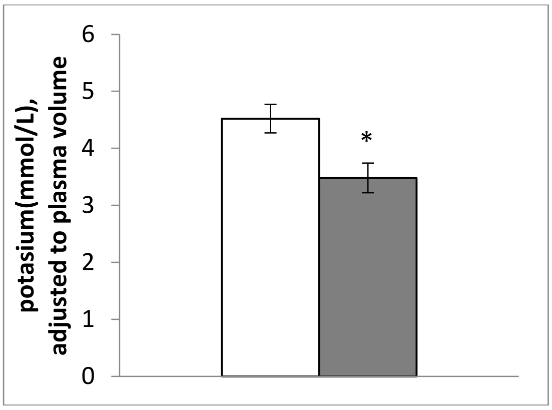
(B)

Figure 2. Mean (±SE) values of serum Sodium pre- (open bar) and the immediately after exercise (solid bar).

Upper and lower graphs represent values before (A) and after (B) adjusting raw data for plasma volume changes, respectively. Significant (P< 0.05) difference between pre- and the immediately after exercise mean values was denoted by *.



(A)



(B)

Figure 3. Mean (±SE) values of serum Potassium pre- (open bar) and the immediately after exercise (solid bar).

Upper and lower graphs represent values before (A) and after (B) adjusting raw data for plasma volume changes, respectively. Significant (P< 0.05) difference between pre- and the immediately after exercise mean values was denoted by *.

Table 2. Correlations between QTc and K, Ca, and Na in rest

QTc	Kpre	Capre	*Napre*
r	-0.31	-0.24	-0.21
P	0.77	0.18	0.23

Table 3. The mean (±SE) values of the ECG parameters (ms)

ECG parameters(ms)	Mean ± SE
QT interval	342 ± 27
R-R interval	727 ± 116
QTc interval	403 ± 30

Table 4. The risk of type 2 error for the Pearson Correlation test.

Ions	K	Na	Ca
Risk of type error 2 (β)	0.09073	0.29599	0.21916

DISCUSSION

In the present study, the results showed that the serum calcium and sodium levels significantly increased as a result of intense exercise activities while the serum potassium significantly decreased. Meanwhile, after adjusting raw data for plasma volume changes serum calcium, sodium, and potassium significantly decreased. No significant relationship between QTc interval and Ca, Na, and K in rest. To our knowledge, this first study determinates the relationship between Na, K, and Ca with QTc in professional athletes.

Reports have shown that the effect of exercise on serum calcium levels is contradictory. Some results showed that the serum calcium level decreases, while others did not show any change or even some showed an increase in the serum calcium level (11). The increase in serum calcium level found in this study may be due to the parathyroid hormone (PTH), which increases the serum calcium level through secretion by bone and the absorption in the intestine and kidney tubules (12). However, the increase in the calcium level might be correlated with the changes in plasma volume (1). As it was seen in the results, the serum calcium level decreased after the correction of raw data for the plasma volume change was made. Additionally, it has been shown in some papers that increased levels of PTH do not play a role in increasing calcium levels during exercise. Moreover, two other physiological events can occur in high-intensity exercises to reduce serum calcium level: increased sweating and hematocrit. Given that it is not possible to quantify the sweat loss, it can be suggested that calcium loss is somewhat related to the decrease in plasma volume, and it can be shown that changes in plasma volume are associated with the loss of calcium in sweat. As shown by the measurement of hematocrit, a possible explanation might be that the plasma volume has returned to the baseline value at this time, while the calcium loss in sweat has not yet been compensated (11). Another possibility is that the calcium loss from sweating was greater than its release from bone cells (23). However, it must be noted that the hypothesis of sweat calcium reduction should be empirically verified (1). In addition, it is possible that in response to high-intensity exercises, more calcium ion enters the muscles and the neural tissue in order to help neural signals (23). On the whole, considering the results shown in this study, it can be concluded that one cannot accurately estimate the serum calcium level since the difference of the estimated calcium concentration with the plasma volume changes obtained by the Dill and Costill equation can be due to the measurement error of Hematocrit, hemoglobin and calcium level. In any case, in short-term exercises, the correlation between calcium and plasma volume reduction is closer (1).

It has been shown that in high-intensity exercises, sodium levels have increased significantly, and it is possible to increase the activity of $Na^{+} - K^{+} - ATPase$. This enzyme additionally catalyzes the intercellular ATP hydrolysis to release more energy and, hence, maintains the extracellular sodium concentration (23). However, having corrected the data for the plasma volume changes, the serum sodium decreased significantly. The competition may lead to dehydration due to severe loss of water and sodium (12). The loss of sodium can result in a loss of plasma volume, releasing antidiuretic hormone (ADH). This causes kidneys to re-absorb water, to dilute the blood sodium, and to increases the chance of hyponatremia (4). Moreover, the cause of sodium changes has not been well-established in the literature (6, 12, 23). There is a non-significant negative relationship between QTc interval and serum sodium, which is similar to the research results that showed a non-significant negative relationship between the serum sodium and QRS duration in athletes (4).

The serum potassium showed a significant decrease immediately after the exercise, and this behavior was also seen before and after the raw data correction for the plasma volume changes. Some studies have demonstrated that this decrease can be attributed to an enhancement in the sodium uptake by skeletal muscle cells for using in Na+-K+ pump (6). Nonetheless, it must be noted the results of the present study is in contrary to many other studies that have shown serum potassium level increases in the post-exercise state (4, 12). In a research, it was shown that the serum potassium level is linearly correlated to the exercise intensity (17). Since humans' skeletal muscles contain the largest single pool of potassium, the increase in the potassium level can be ascribed to the secretions by the muscle cells (6, 12). The reason why the potassium level decreases immediately after the exercise is not completely clear; however, it seems that it is partly due to the uptake of the secreted potassium ion and partly due to the response induced against the parasympathetic system to optimize the cardiovascular system during the relaxation (12). In the present research, it was shown that the QTc interval has a positive non-significant relationship with the potassium level in the pre-competition while having a negative non-significant relationship with the potassium level in the immediately after competition. Begum and Rahman have reported that the QRS duration has a positive non-significant relationship with the serum potassium level (4).

Body mass, body fat and muscle mass are associated with sodium, potassium and calcium levels. Oh et.al reported that higher sodium excretion is associated with higher risk for obesity and it is related to abdominal obesity (20). Yi and Kansagra reported that higher sodium intake is related to higher body mass index (24). Murakami et.al indicated that higher potassium intake is associated with lower risk of obesity (19). Kamycheva et.al showed that calcium intake has opposing effect on body weight (14). A previous study reported that higher sodium excretion, reflecting higher sodium intake, is associated with decreased muscle mass. High sodium intake may result in potassium excretion, which is related to lower muscle mass (9, 13). Due to the high muscle mass of the participants and their low body fat, this can affect changes in sodium, potassium and calcium levels.

CONCLUSION

The results of the present study suggest that the changes in the calcium and sodium levels showed a significant increase immediately after the competition; however, after the correction for the plasma volume changes, a significant decrease was seen. The serum potassium showed a significant decrease immediately after the competition, and this behavior was also seen before and after the correction for the plasma volume changes. The response to the high-intensity sports and the mechanism governing these changes can be multicausal. It is recognized that there are limitations to the results of the present study. For example, the subjects' nutrition programs, dietary supplements, exercise supplements, and drugs had not been controlled. The intake of sodium, potassium, and calcium can affect their serum changes (11, 18). Since the subjects of this study had participated in a single competition, the researcher was not able to control this restriction. Accordingly, more studies under controlled conditions are needed to investigate the precise relationship between QTc interval and serum ions.

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CONFLICT OF INTEREST

The authors and funding agents declare that they have no conflict of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

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