Haematological and Plasma Electrolyte Changes After Long Distance Running in High Heat and Humidity

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ABSTRACT

Aim of Study: To investigate the acute effects of an 18 km run on the haematological and plasma electrolyte parameters, in recreational runners under conditions of high temperatures and humidity.

Method: Haematological and electrolyte parameters changes were measured in 21 acclimatised recreational runners before and after an 18 km run in environmental temperatures and relative humidity of 27.1 ± 0.3°C and 85.0 ± 1.7% respectively, which was measured using the wet bulb globe monitor.

Results: There was a loss of weight which averaged 2.5 ± 0.2% ($p < 0.001$) of initial body weight. Rectal temperature increased by an average of 2.7 ± 0.2°C (an increase of 7.2 ± 0.7%; $p < 0.001$). Immediately after the race, there was a significant ($p < 0.01$) increase in haemoglobin, haemotocrit and plasma osmolality. Mean plasma volume decreased by 4.1 ± 1.1%. Plasma sodium and potassium significantly ($p < 0.01$) increased by 4.5 ± 0.5% and 20.3 ± 3.5% respectively, while magnesium significantly ($p < 0.01$) decreased by 9.0 ± 1.8%. Peripheral blood profile showed significant increases in the post-race white blood cell counts ($p < 0.001$) and platelets ($p < 0.01$).

Conclusion: The acute changes in haematological variables and plasma electrolytes reported in this study at relatively high ambient temperature and humidity were found to be similar to that seen after long-distance running under cooler climatic conditions. However, it is recommended that long-distance runners should be hyperhydrated just before the race and also be encouraged to consume 150 mL to 300 mL every 15 minutes while running to prevent the effects of dehydration.

Keywords: long-distance running, biochemical changes, haematological changes, peripheral blood profile, rectal temperatures

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INTRODUCTION

A number of physiological, haematological and biochemical changes associated with long-distance running have been described[1-6]. Despite the accumulation of an extensive literature on the human body's response to severe stress in the form of prolonged running, in cooler climatic conditions, little has been reported on the acute effects after a long distance run in warmer, high humidity climatic conditions.

This study looked at the acute effects of running 18 km on haematological and plasma electrolyte parameters, in runners with widely varying athletic ability, in conditions of high temperatures and humidity.

METHODS

Subjects

Twenty-one healthy volunteers (18 males, 3 females), who were preparing for a half-marathon race, participated in this 18 km time-trial race. They were of varying athletic ability, ranging from casual joggers to serious long-distance competitive runners; all had, however, undergone some degree of training. Anthropometric parameters of the subjects are shown in Table I.

Blood samples

Venous blood samples (15 mL) were obtained from the cubital vein of each subject within 60 minutes prior to the start of the race and again within 5 minutes of completing the race. All blood samples were taken with the subjects in a seated position. The blood samples taken were divided into 3 parts: 1 mL was anticoagulated with NaEDTA for peripheral blood profile, 1 mL was preserved wth sodium-fluoride for glucose and lactate assay and the balance was anti-coagulated with lithium heparin prior to electrolyte analysis. All pre- and post-run samples were kept in a cool box (4°C) until after the run when they were centrifuged and analysed on the same day.

Table I – Anthropometric data and race time of the 21 subjects studied (mean ± SEM and range)

Age (years)	34.3 ± 1.7	(19 – 52)
Height (cm)	166.4 ± 1.4	(154.5 – 178.5)
Body mass (kg)	66.1 ± 1.7	(49.6 – 81.6)
Body fat (%)	16.8 ± 1.1	(8.3 – 27.5)
Race time (min)	108.6 ± 4.8	(58 – 153)

Body mass recorded is the pre-race value

Haemoglobin was determined by the met-Hb technique and PCV by the standard microcapillary centrifuge method. Plasma volume change was calculated using Hb and PCV values according to the formula of Dill and Costill[7].

Plasma sodium and potassium were determined by ion-selective electrodes (AVL-9848 Electrode Analyzer, Graz, Austria). Plasma chloride was determined by a chloride meter (Jenway PCLM3, Essex, England). Plasma magnesium was measured by photometric methods (Bio-Merieux, Marcy-l'Etolie, France). Plasma glucose was determined spectrophotometrically using Cobas-Bio and plasma lactate was determined on a lactate analyser (YSI, Model 2300 Stat, Yellow Spring, USA). Plasma osmolality was measured by the freeze-point method (Stat OM-6010, Kyoto, Japan). Haematological analysis consisting of an 8 parameter profile was performed using a haematological counter (Autolyzer Contraves Digicell 800, Zurich, Switzerland).

Rectal temperature

All rectal temperature measurements were made using mercury-in-glass clinical thermometer which had previously been calibrated. All measurements were made by one of the investigators who inserted the thermometer to a constant depth of 7 cm beyond the anal margin and recorded the temperature after 2 min. Effort was also made to ensure that there was minimal delay in taking the rectal temperature of each subject after completion of the race.

The 18 km time trial was run on a relatively flat road circuit. The mean wet bulb globe environmental conditions during the race were 27.1°C ± 0.3°C (range 26.0°C to 28.5°C) with relative humidity of 85.0 ± 1.7% (range 78% to 92%). The wet bulb globe temperature was used because it is the most widely used heat stress index[8].

Statistical analysis

The significance of the difference between the analysed values before and after the exercise was tested with Student's t-test for paired samples. All results are presented as mean ± SEM.

Table II – Blood and plasma parameters before and after the 18 km run (mean ± SEM and range)

	Pre-race		Post-race	
	mean ± SEM	Range	mean ± SEM	Range
Packed cell volume (%)	47.6 ± 0.6	41.5 – 55.0	48.7 ± 0.8**	41.0 – 57.5
Haemoglobin ($g.dl^{-1}$)	15.4 ± 0.3	12.9 – 19.2	16.6 ± 0.4**	13.4 – 19.4
Osmolality ($mosmol.kg^{-1}$)	281.8 ± 1.8	267 – 297	291.9 ± 1.7***	281 – 305
Sodium ($mmol.l^{-1}$)	145.1 ± 0.7	140.3 – 150.2	151.6 ± 0.8***	146.4 – 162.9
Potassium ($mmol.l^{-1}$)	4.3 ± 0.1	3.7 – 5.4	5.1 ± 0.1***	4.2 – 5.8
Chloride ($mmol.l^{-1}$)	96.9 ± 0.9	90.0 – 107	99.4 ± 1.1	94 – 115
Magnesium ($mmol.l^{-1}$)	0.9 ± 0.1	0.7 – 1.2	0.8 ± 0.1***	0.7 – 1.0
Plasma glucose ($mmol.l^{-1}$)	5.3 ± 0.2	3.9 – 7.8	5.2 ± 0.2	4.1 – 7.2
Plasma lactate ($mmol.l^{-1}$)	2.7 ± 0.3	1.0 – 5.9	4.9 ± 0.3***	2.8 – 7.7

Asterisks indicate significant post-race increase (** = $p < 0.01$; *** = $p < 0.001$)

RESULTS

The mean body mass decreased from 66.1 ± 1.7 kg to 64.5 ± 1.7 kg after the run ($p < 0.001$). This amounted to body mass loss of 1.6 ± 0.1 kg or 2.5 ± 0.2% of body mass. The mean post-race rectal temperature of the runners increased to 39.6°C ± 0.2°C, compared with a pre-exercise value of 36.9°C ± 0.1°C ($p < 0.001$).

The increase in PCV and Hb concentrations observed (Table II) were in line with the moderate level of dehydration indicated by loss of body mass. Based upon PCV and Hb values before and after the race, the plasma volume decrease was calculated to be 4.1 ± 1.1%. There was a significant ($p < 0.001$) increase in plasma osmolality (Table II). The concentration of plasma sodium and potassium increased significantly ($p < 0.001$) by 4.5 ± 0.5% and 20.3 ± 3.5% respectively, while plasma chloride remained unchanged (Table II). Plasma magnesium decreased significantly ($p < 0.001$) by 9.0 ± 1.8% (Table III).

Plasma glucose was not significantly altered after the race compared with resting pre-race values. Plasma lactate increased significantly ($p < 0.001$) by 77.9% (Table III).

The only significant changes in the peripheral blood profile following the 18 km run were white bloodcells (WBC) and platelets which increased significantly by 53.4 ± 10.4% ($p < 0.001$) and 15.3 ± 5.2% ($p < 0.01$) respectively (Table III). No significant changes in post-race peripheral blood profile were noted for red blood cells (RBC), mean corpulsar volume (MCV), MCH and MCHC (Table III).

DISCUSSION

This study describes the acute effects of an 18 km run on haematological and plasma electrolyte parameters under high ambient temperature and humidity. The decrease in body mass of 2.4% coupled with significant ($p < 0.001$) increases in PCV and Hb obtained were ascribed to the dehydrated state of the runners. Similar findings have been reported for 67 km foot-race and marathon competitions under cooler climatic conditions[3,9].

Significant increases in PCV and Hb concentration are in line with the moderate level of dehydration. This reduction in plasma volume of 4.6% based on haemotocrit and haemoglobin concentration may be due to total fluid loss as body weight decreased significantly during the run and to fluid shifts from intravascular space[10]. The changes in plasma volume are similar to those reported in other long-distance runners under cooler climatic conditions[4,9].

Significant ($p < 0.001$) increases in plasma sodium and potassium after the run were also found to be in agreement with that reported for other long-distance running studies[3,5]. The rise in plasma sodium may be due to volume contraction which occurs with exercise or due to outward shift of hypotonic fluid from extracellular to intracellular compartments[5,11]

Table III – Peripheral blood indices before and after the 18 km run (mean ± SEM and range)

	Pre-race		Post-race	
	mean ± SEM	Range	mean ± SEM	Range
RBC ($10^{12}.l^{-1}$)	5.06 ± 0.17	4.11 – 7.73	5.27 ± 0.11	4.11 – 5.92
MCV (fl)	89.77 ± 0.87	81.11 – 101.35	88.64 ± 0.78	80.68 – 95.79
MCH (pg)	30.92 ± 0.39	27.21 – 34.11	31.43 ± 0.38	27.80 – 33.77
MCHC ($g.dl^{-1}$)	34.49 ± 0.48	30.07 – 38.24	35.47 ± 0.37	31.46 – 37.58
Platelets ($10^{9}.l^{-1}$)	277.90 ± 11.62	205 – 423	314.29 ± 12.71**	243 – 445
WBC ($10^{9}.l^{-1}$)	7.97 ± 0.35	5.20 – 12.90	12.22 ± 1.00***	4.80 – 23.90

Asterisks indicate significant post-race increase (** = $p < 0.01$; *** = $p < 0.001$)

or due to haemoconcentration and loss of hypotonic sweat. This is in contrast to the study of Rehrer et al[3], who found the concentration of sodium remained unchanged after ultra-endurance running.

The rise in plasma potassium in this study is also similar to that reported for marathon or ultra-endurance race[1,3,5]. The rise in plasma potassium may be due to the efflux from intracellular stores as a result of increased cellular turnover[4] or a change in muscle cell membrane permeability[12]. Potassium may also diffuse into extracellular fluid when glycogen is depleted[13] or due to skeletal muscle, liver or red blood cell damage[14]. This rise in both potassium and sodium may also be due, to a large extent, to the loss of sweat with much lower electrolyte content than in plasma, plus inadequate water replacement as evidenced by 2.4% decrease in body weight of our subjects.

There was no significant change in either plasma calcium and chloride which have similarly been reported by others[3,5]. This is in contrast to the reported increase in plasma chloride and calcium levels observed by Riley et al[4] after a marathon. The failure to demonstrate any increase after the 18 km run might be due to loss of these ions in sweating which is quite marked during such a run. The amount of calcium and chloride lost in sweat increases as the rate of sweating increases with no compensatory reduction in urinary calcium[15].

The 9.7% decrease in plasma magnesium concentration after the 18 km run is similar to that seen after a marathon in the study of Lijnen et al[16]. However, decreases of 19 to 21% in magnesium levels after a 42 km and ski marathons have been reported[1,5,17,19]. It is suggested that the decrease in magnesium may represent a loss from body through sweating or due to an intracellular shift of magnesium. The intracellular shift of the electrolyte may be related to the fact that magnesium is an integral part of many important enzyme systems and that cells with a high metabolic activity have a relatively higher concentration than cells with a lower activity[19].

No significant changes were observed in plasma glucose indicating that none of the runners experienced hypoglycemia after the 18 km run.

The acute changes seen in white cell count and platelet number following this 18 km run are a well recognised phenomenon that have been reported to follow short-term and endurance form of exercise[10]. This increase in platelet may have resulted from increased release from the bone marrow, from megakaryocytes in the lungs or demargination, ie. altered flow pattern which results in cells previously at the periphery of the blood stream being brought into the axial flow as a result of increased flow rate[10].

The rectal temperatures recorded in this study at ambient temperature of about 28°C indicated that none of the runners experienced hypothermia but hyperthemia, which is similarly reported by Pugh et al[20] after a marathon race. However, hypothermia has been reported after marathon running in races at low ambient temperatures[21].

In conclusion, the acute changes in haematological variables and plasma electrolytes reported in this study at relatively high ambient temperature and humidity are similar to that seen after a long-distance running under cooler climatic conditions. However, it is recommended that long-distance runners should be hyperhydrated just before the race and also be encouraged to consume 150 mL to 300 mL every 15 minutes while running[22]. This should apply irrespective of the prevailing weather conditions. However, excessive consumption of pure water or dilute fluid (ie. up to 10 litres per 4 hours) during prolonged endurance events may lead to a harmful dilutonal hyponatremia[23] which may involve disorientation, confusion, and seizure or coma[8].

ACKNOWLEDGEMENT

The authors thank the subjects for their co-operation and SportsMan Club, Kota Bharu for the support and assistance. The technical assistance of BS Ang, AL Low and MS Ismail is gratefully acknowledged.

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