Original Article

Acclimated young and adult athletes present a psychophysiological response and exercise tolerance that is similar under cool environmental conditions and under impeded dehydration during long distance running

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Abstract:

The dehydration (body mass loss) induced by exercise may lead to a decrease in sports performance, and this effect may be greater in young people than in adults. The purpose of this study was to analyze the psychophysiological responses of young and adult athletes during long-distance running. We investigated the degree of dehydration, heart rate behavior and perceived exertion. Five adults (22.4 ± 1.1 years) and six young (13.3 ± 1.2 years) males performed running exercise until they were exhausted at an intensity of 75% of the maximal heart rate. The test was carried out in cool environmental conditions with ingestion of water ad libitum. We did not find significant differences in the exercise time or total traveled distance for the adults (133.74 ± 11.1 min, 22800 ± 3187.5 m) compared with the young males (129.99 ± 55.9 min, 20266.7 ± 10013 , 3 m.). The degree of dehydration, body mass loss, and perceived exertion were greater in the adults, but there was no significant difference between the groups. The younger athletes had a higher average heart rate during running. Therefore, this study demonstrates that young and adult athletes that are acclimated present a degree of dehydration, heart rate behavior and perceived exertion that is similar in cool environmental conditions, and dehydration was prevented. Our findings emphasize that trained adults and young have similar psychophysiological responses, breaking the paradigm of training and dehydration in children and adolescents and their differences compared to adults.

Key words: degree of dehydration, heart rate, perceived exertion, endurance, body mass loss, thermoregulation.

Introduction

The increased use of energy substrates during running exercise results in increased muscular power and heat production (Gonzalez-alonso, 2012). Under these conditions, the metabolic enhance of heat production may exceed the maximum heat dissipation capacity (Kenefi, Cheuvront, & Sawka, 2007), which results in an increase in body temperature. In these conditions, lower elevations in body temperature during exercise may increase athletes performance levels (Bogerd, Perret, Bogerd, Rossi, & Daanen, 2010; Stannard, Brandenburg, Pitney, & Lukaszuk, 2011).

Thermoregulatory responses differ between adult and child athletes (Rowland, 2011). Children are more dependent on the peripheral blood flow and its changes can compromise their ability to dissipate heat more than in adults, resulting in a higher increase of the core temperature for a given fluid loss percentage (Falk & Dotan, 2011). Children seem to have a greater need to conserve fluids, resulting in a lower sweating rate given their distinct relationship between surface and body mass. This lower rate of sweating in children also results from the immaturity of the sweat gland, which the smaller the gland, the smaller is the secretory portion (Rowland, 2008; Inoue, Kuwahara, & Araki, 2004).

During running exercise, a significant dehydration increases the central body temperature and heart rate (HR), decreases ejection volume and, if performed in extreme environmental conditions such as high temperatures, these effects can be maximized (Fehling et al., 2015) decreasing the performance (Sawka, Cheuvront, & Kenefick, 2015). Therefore, an adequate water intake is essential to attenuate these psychophysiological effects in young athletes (Cheuvront, Kenefick, Montain, & Sawka, 2010; Nery, Guttierrez, & Dias, 2014).

A psychophysiological integrator is a measure of the perceived exertion (RPE) (Eston, 2012). The RPE is defined as the integration of peripheral signals (muscles and joints) and central (ventilation) signals, which are interpreted by the sensory cortex, producing the general or local perception of the commitment to perform a

certain task (Borg, 1982). Differences in the RPE estimate regarding the age may be due to the variations in work capacity (Borg, 2000).

Currently there is a gap in the literature on the influence of maturation on exercise tolerance, thermoregulation, cardiovascular and psychological responses, and on injuries caused by dehydration in different age groups during the runner practice. Easy access and low cost make this practice the most popular of track and field. Moreover, the number of children and adults participating are increasing in the last decades (Federação Paulista de Atletismo, 2015).

Many studies reported the risks and recommendations for water replacement applied to physically active adults, but there is still little information about the dehydration harmful effects and necessary replacement for physically active children (Juswiak, Paschoal, & Lopez, 2000). Thus, the study analyzed the responses of the physiological and psychological variables of young and adult athletes in a long-term endurance exercise, investigating the degree of dehydration (DD), heart rate behavior and RPE.

Material & methods

Participants

11 males, 6 young between 12-15 years of age and 5 adults aged between 21 to 24 years, naturally acclimatized to environmental conditions (table I) volunteered to participate in the current study. The men were athletes of the same race team with regular training of at least 5 days per week. The young are members of a regional track and field center with regular training of 4-6 days per week. The men and the responsible people for the young were informed about the research purpose and procedures and gave their written informed consent to participation of the study. This study was performed according to the ethical parameters following the guidelines of the World Medical Association (2000) Declaration of Helsinki.

Table 1. General characteristics of group's volunteers: adults and young.

	Adults (n=5)	Young (n=6)
Age (years)	22.4 ± 1.14	13.3 ± 1.21
Body mass (kg)	72.42 ± 10.06	48.3 ± 13.13
Height (m)	1.77 ± 0.04	1.66 ± 0.15
BMI (kg.m ⁻²)	23.11 ± 2.66	17.27 ± 2.37
Body fat (%)	13.13 ± 2.94	10.12 ± 1.41

Note: Values are presented as means ± standard deviations.

Familiarization and Test Protocol

The collections were divided into two visits. The first one was performed to familiarize the individuals with the tests center, with the research evaluators and with the equipment used to data collection. The body fat percentage was also measured by skinfold (Sanny® adipometer, Brazil) according to the protocol of Jackson and Pollock (1978) for adults and Slaughter et al. (1988) for young people. It was calculated the percentage of 75% the maximum heart rate (HR max) by age (Tanaka, 2001) and the RPE (Borg, 1982) scale modified by Foster et al. (2001) was presented. All athletes were familiar with RPE.

The second visit was to perform the test in an official athletics track with a clay floor. Approximately 15 minutes before the running beginning, the food information was collected, and the hydration state by urine color (Ucor) (Armstrong et al., 1994), the resting HR (Polar Heart Monitor RS 810i, Polar Electro®, Finland), the skin temperature and body mass (BM) (Britânia® portable scale, Brazil) with the bladder previously emptied were assessed. Participants were asked not to ingest any dietary supplement that could enhance their performance and water intake was allowed *ad libitum*. During the running the HR, RPE and time were collected at each lap. Individuals performed endurance exercise at or above 75% their HRmax. They could not let the HR reach lower levels than it was proposed. At the moment in which the athlete gave up to continue, the skin temperature was collected and HR recovery was monitored within the first 5 minutes after the test. After, the urine was collected for dehydration analysis, and the BM was measured again following the same protocol to evaluate the DD. The ingested water volume was quantified and it was reported the reason for the athlete's withdrawal. The equation for estimating DD was $DD = [(Pi - Pf) / Pi] \times 100$, where (DD = Degree of Dehydration, Pi = Initial Weight, Pf = Final Weight). The HR and RPE behavior between the groups were analyzed using the percentage total number of laps. As the test was until the voluntary withdrawal, the number of laps was different among the athletes. Thus, a simple three rule was used to measure the laps in percentage.

The HR mean of the first five (HR mean 5 initial) and five last (HR mean 5 final) laps were calculated for the heart rate delta (HRD) according to the equation: $HRD = \text{Initial HR} - \text{Final HR}$. It was also used to verify if there were differences in the initial and final HR of young and adults.

The average time of the individual lap of the first five laps (time / initial lap) and the last five (time / final lap) laps were performed in order to verify if there were changes in the exercise intensity from beginning to end. Environmental conditions (21° C ± 1.9° C, humidity 52.7% ± 10.3%) were monitored during the entire

running using a thermal stress monitor (Equitherm® digital thermohygrometer) positioned one meter above the floor level and next to the athletics track.

Statistical analysis

Data were analyzed statistically using the SPSS® program (Version 20.0) and they were presented in means $\pm$ standard deviation. The distribution was checked via Shapiro Wilk test. To compare the exercise time, the total distance, the body mass loss, the DD, the water intake relative to body mass, the skin temperature delta, the HR mean, the HR recovery, the HR final peak and the HR rest between the groups, the t-test for independent samples was used.

For initial and final HR and the time / lap analysis of young and adults, the t-dependent test was used if the variables followed a normal distribution. For the RPE mean, the total water intake and the water intake relative to time, the HR, heart rate delta and HR 75% reserve, the Mann - Whitney test was use if the sample did not follow a normal distribution. The bivariate correlation of Kendall's was use for non-normal distribution to asseess the correlation between the data of RPE and HR mean. A significance value was assumed with a $p \leq 0.05$.

Results

It was noted a tendency of greater exercise time, total distance, weight loss and DD, and smaller water intake and delta skin temperature in adults. However, the differences between the groups were not significant (table II). Moreover, nobody demonstrated evidence of heat stress during the test. The main reasons alleged by the groups to stop the exercise were the feet discomfort, heavy legs and run monotony on the track. RPE mean was greater in adults but non-significant between groups (5 ± 0.44 scores; 4 ± 1.26 scores).

Table 2. Comparison between young and adults on the exercise time, the total distance, the H₂O intake, the weight loss, the dehydration degree and the skin temperature delta.

	Adults	Young
Exercise time (min)	133.74 $\pm$ 11.1	129.99 $\pm$ 55.9
Total distance (m)	22800 $\pm$ 3187.5	20266.7 $\pm$ 10013.3
H2O intake (ml)	820 $\pm$ 274.1	878.3 $\pm$ 603.1
H2O intake relative to body mass (ml/kg)	11.07 $\pm$ 2.99	20.44 $\pm$ 17.09
H2O intake relative to time (ml/kg/min)	0.09 $\pm$ 0.02	0.14 $\pm$ 0.06
Body mass loss (Kg)	2.12 $\pm$ 0.89	1.22 $\pm$ 0.63
Degree of dehydration (%)	2.88 $\pm$ 1	2.45 $\pm$ 1
Skin temperature delta (°C)	0.1 $\pm$ 1.1	0.2 $\pm$ 0.8

Note: * Significant difference ($p \leq 0.05$)

According to the urine coloring (Ucor), all studied subjects corresponded to the "normohydrate" state at the test beginning. However, the post-test results demonstrated a "minimally dehydrated" situation for young people (Ucor Pre Test: 2 ± 0.6 ; Ucor Post test: 4 ± 1.2) and "significantly dehydrated" for adults (Ucor Pre Test: 2 ± 0.4 ; Ucor Post test: 5 ± 1.5).

The initials laps of both groups were completed in less time than the final laps. The initial HR showed no difference with the final HR to pre and post between the groups (table III).

Table 3. Initial and final time / lap analysis and HR 5 mean: Average of the first and last five laps.

	Time/Lap (sec)		HR Mean 5 (bpm)	
	Initial	Final	Initial	Final
Adults	122 $\pm$ 18	149 $\pm$ 17* **	159 $\pm$ 11	160 $\pm$ 10
Young	146 $\pm$ 19	180 $\pm$ 22*	170 $\pm$ 8	170 $\pm$ 5

Note: * Initial and final significant difference ($p \leq 0.05$). ** Significant difference between the groups ($p \leq 0.05$).

The HR mean the HR reserve and HR 75% reserve were higher in the young (table IV).

Table 4. Comparison between young and adults groups on the HR mean, the HR recovery, the HR final peak, the heart rate delta, the HR rest, the HR and HR 75% reserve.

	Adults	Young
HR Mean (bpm)	159 $\pm$ 6*	170 $\pm$ 3
Recovery HR (%)	75.35 $\pm$ 15.1	65.18 $\pm$ 17.22
HR final peak (bpm)	164 $\pm$ 10	171 $\pm$ 6
Heart rate delta (bpm)	2 $\pm$ 11	-1 $\pm$ 11
Rest HR (bpm)	67 $\pm$ 7	77 $\pm$ 15
Reserve HR (bpm)	198 $\pm$ 1*	207 $\pm$ 1
Reserve HR 75% (bpm)	165 $\pm$ 2*	173 $\pm$ 4

Note: *Significant difference ($p \leq 0.05$)

The HR and RPE behavior during exercise are present in figure I and figure II.

Fig. 1 Heart rate behavior between the groups (N = 5 adults; 6 young). HR= heart rate.

Fig.2. Behavior of perceived exertion during the laps between the groups (N = 5 adults; 6 young). RPE= perceived exertion.

A significant correlation was found between RPE and HR of the adults (0.378) and non-significant correlation was noted for young (0.282). There was a correlation between RPE and HR every 20% the total number of completed laps. None of the young laps obtained a significant correlation, whereas in the adults it was verified an association of 40% and 60%.

Discussion

There were no reports of studies comparing young and adult runners in performance of aerobic resistance until exhaustion, obtaining both physiological and psychological responses. The effects of biological maturation on thermoregulation, exercise responses in hot environmental conditions with laboratory tests have been well documented. However, the purpose of this study was to reports a comparison between young and adults in cool environmental conditions.

The results showed that young athletes dehydrated less than adults according to Ucor, with minimum dehydration values, but no difference in the DD. Children and young produce smaller, less-spaced drops of sweat, while adults are larger, more spaced, and drains through the skin (Inbar, Morris, Epstein, & Gass, 2004). It may be associated with the higher average water intake relative to body mass in the young, reducing the

possibility of a higher dehydration than the adults. However, it is possible that children produce smaller and less spaced drops of sweat, whereas in adults they are larger and more spaced out of the skin (Inbar et al., 2004).

The present study found the same intake water *ad libitum* between groups. Previous studies have reported that children and young people are not more likely to reduce voluntary fluid intake (Phillips, Sykes, & Gibson, 2014; Wilk, Timmons, & Bar-or, 2010), during the exercise. However, these responses may differ according to the sporting modality (Rivera-brown & De Félix-dávila, 2012) due to the frequent restriction of fluids during training. In relation to adults, voluntary drinking volumes in young in respect to their body size are comparable. Young athletes are more conscious of the ingesting water during exercise than non-athletes, and this should be considered. Therefore, the thirst may be an efficient mechanism for protection against significant dehydration (Lopez et al., 2016). The results of Ucor demonstrate that the thirst is an efficient mechanism for protection of young athletes, contributing to thermal regulation. Skin temperature was recorded and it did not show significant increase for both groups. This may be associated to a similar peripheral blood flow between the groups (Inbar et al., 2004).

The heart rate behavior during the exercise in the present study had higher values in the young. This greater activity in the cardiac rhythm observed for the same job demand can be explained morphologically by a compensatory mechanism due to the lower volume of heart and blood volume. This, consequently, leads the child to a lower volume of systolic ejection (Vinet, Nottin, Lecoq, & Obert, 2002). The rest HR of men was smaller than in young, but with no significant difference between them. Anxiety to perform the test may have interfered in the rest HR.

Heart rate delta demonstrated a small increase in HR of adults during the exercise. One of the main reasons is the increase in blood viscosity due to the dehydration, which leads to an increase in heart rate per minute (Fehling et al., 2015). The HR mean 5 initial and HR mean 5 final of both groups did not show differences, but once the exercise was performed in the field and without a speed monitoring, the time/lap was calculated and demonstrated that adults and young people increased the realization time of the laps at the end of the exercise. Thus, HR values could be higher, once the exercise intensity has a cause and effect relationship with HR (Cambri, Foza, Nakamura, & De-oliveira, 2008).

The RPE is related to psychological factors and it is directly related to exercise intensity. As expected, the RPE reached its maximum values at the end of the exercise at the exhaustion moment. During a long distance running, there is a decrease in energy reserves, an increase in body temperature and a imbalance of internal fluid, which difficult the exercise continuation by the athlete (Ament & Verkerke, 2009; O'Leary, Morris, Collett, & Howells, 2016). In this present study, there was no difference between groups regarding the RPE.

Dissociation between RPE and HR was observed in the young. Knowing that they would run until the voluntary exhaustion, the young people would remain in the exercise until the potential level of motivation was attained or interpreted as possible to realize even without physiological failures (Marcora, Staiano, & Manning, 2009).

Rowland et al. (2008) studying the exercise tolerance and thermoregulatory responses during cycling in boys and men, demonstrated that cardiovascular responses, thermoregulation and tolerance in exercise in cool environmental conditions as well as in hot environmental were similar. In the present study, the running performance was similar between young and adults athletes. Therefore, it is likely that in these ambient, temperature and relative air humidity conditions, both young and adult athletes respond in a similar manner in exercise.

The main limitation of the present study was the sample size. For convenience of applicability, the sample "n" can not be increased. Thus, we suggest a reproduction of this study with a larger "n" sample for both groups, also applying the heart rate variability for comparison with the dehydration process and with a greater control of this physiological response comparing these groups.

Conclusion

Acclimated young and adult athletes presented a DD, heart rate behavior, RPE and exercise tolerance similar in cool environmental conditions in a impeded dehydration situation. If athletes are well targeted, an intake of water *ad libitum* during a long time exercise can be a strategy to avoid significant dehydration.

In summary, young and adults athletes presented similar physiological and psychological responses in cool environmental conditions. The performance during the running was similar among them, but the adults water intake was insufficient regarding their weight loss percentage resulting in a greater dehydration compared to the young group. The findings of this study showed that young athletes tend to drink water *ad libitum* to avoid significant dehydration. The hypothesis of this is that young athletes are more conscious of the ingesting water during exercise than non-athletes. Future studies should be done to investigate long-term exercise regarding the weight loss and performance, voluntary or scheduled fluid intake, analyzing possible differences in these variables, searching for new strategies, and elucidating the psychophysiological responses of young athletes.

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