Rev Bras Cineantropom Hum

original article

DOI: http://dx.doi.org/10.5007/1980-0037.2016v18n2p143

Thermoregulation of competitive artistic gymnastic athletes and non-athlete girls exercising in the heat

Termorregulação em atletas de ginástica artística e meninas não-atletas durante exercício no calor

Gabriela Tomedi Leites[1]
Paulo Lague Sehl[1]
Giovani dos Santos Cunha[1]
Adriano Detoni Filho[1]
Flavia Meyer[1]

Abstract – It's unclear whether the combination of intense, chronic training and heat exposure during prepubescence improves thermoregulatory responses to exercise in artistic gymnastics athletes. The objective of this study was to compare thermoregulatory and perceptual responses between artistic gymnastics athletes and non-athlete girls while exercising both in heat and thermoneutral conditions. Seven athletes (8.7 ± 1.3 yrs) and 7 non-athletes (9.4 ± 1.5 yrs) cycled for 30 min at load (W) of ~55% VO2peak, on two separate occasions in a randomized order: heat (35°C, 40% relative humidity) and thermoneutral conditions (24°C, 50% relative humidity). Rectal temperature, heart rate, rate of perceived exertion, thermal sensation, thermal comfort and irritability were measured throughout the exercise. Initial rectal temperature was similar between athletes and non-athletes in both heat (37.2 ± 0.4 vs. 37.4 ± 0.2°C, respectively) and thermoneutral conditions (37.3 ± 0.2 vs. 37.3 ± 0.3°C). Final rectal temperature was similar between groups (38.0 ± 0.2 vs. 38.2 ± 0.2°C in heat and 37.8 ± 0.2 vs. 37.9 ± 0.2°C in thermoneutral conditions). Initial heart rate was lower in athletes in the heat (76 ± 7 vs. 91 ± 11 bpm, P = 0.01); however, throughout cycling, it became similar between groups. Athletes reported similar perceptual responses compared to non-athletes, with the exception of higher thermal comfort in the 10th minute of exercise in thermoneutral conditions (P = 0.003). It was concluded that athletes were similar to non-athletes with respect to thermoregulatory and perceptual responses during 30 min of cycling at similar relative intensities.

Key words: Children; Exercise; Heat; Thermoregulation.

Resumo – *Não está claro se a combinação de treinamento crônico intenso e a exposição ao calor durante a pré-adolescência melhoram as respostas termorregulatórias ao exercício em atletas de ginástica artística (GA). Objetivou-se comparar as respostas termorregulatórias e perceptivas entre atletas de GA e não-atletas durante uma sessão de exercício nas condições de calor (CC) e termoneutra (CT). Sete atletas (8,7 ± 1,3 anos) e 7 não-atletas (9,4 ± 1,5 anos) pedalaram por 30 minutos com carga (W) referente ~55% VO2pico, em CC (35°C e 40% umidade relativa) e CT (24°C e 50% umidade relativa). A temperatura retal (Tre), frequência cardíaca (FC), taxa de percepção de esforço, sensação e conforto térmico e irritabilidade foram medidas durante o exercício. Tre inicial foi similar entre atletas e não-atletas em CC (37,2 ± 0,4 vs. 37,4 ± 0.2°C, respectivamente) e CT (37,3 ± 0,2 vs. 37,3 ± 0.3°C). Tre final foi similar entre os grupos (38,0 ± 0,2 vs. 38,2 ± 0.2°C na CC; e 37,8 ± 0,2 vs. 37,9 ± 0.2°C na CT). FC inicial foi menor nas atletas na CC (76 ± 7 vs. 91 ± 11 bpm, P = 0,01). No entanto, ao longo das pedaladas, foi similar em ambos os grupos. As respostas perceptivas foram similares entre os grupos, com exceção ao maior conforto térmico das atletas aos 10 minutos de pedalada (P= 0,003). As atletas de GA apresentaram respostas termorregulatórias similares as não-atletas durante 30 minutos de pedalada em similar intensidade relativa nas CC e CT.*

Palavras-chave: *Crianças; Calor; Exercício; Termorregulação.*

1 Federal University of Rio Grande do Sul. Graduate Program in Human Movement Sciences. School of Physical Education. Porto Alegre, RS. Brazil.

Received: 24 October 2015
Accepted: 24 November 2015

INTRODUCTION

Girls participating in artistic gymnastics (AG) usually start focusing on competitive training at very early ages (5-7 years old) and prior to puberty[1]. Such training involves intense efforts and a combination of aerobics, flexibility and strength exercises each session that may last ~ 3 to 4 h, 5 to 6 days per week[1]. In addition, AG training may be held in a warm environment, which would add an additional challenge to the training regimen. Such chronic exposure to heat may result in thermoregulatory adaptations, which may prevent excessive and potentially dangerous rise in body temperature during exercise due to efficient heat dissipatory mechanisms, such as improved efficiency of evaporative heat loss as a result of alterations in the sweating response, greater plasma volume and stability of cardiovascular function. However, it is unclear whether such intense and chronic training, as well as the heat adaptation during prepubescence, improves thermoregulatory responses to exercise as observed in adults[2,3]. There is no information about thermoregulatory responses during exercise in the heat in young AG athletes. Most of the information involving thermoregulatory responses in athletes and non-athletes are from studies performed in the adult population.

Exercise training in adults improves thermoregulatory effectiveness, which may improve exercise tolerance and perceptual responses[2-5]. Exercise training improves thermal tolerance, which may partially result from improved evaporative cooling[4,5]. Also, aerobic training may increase the slope of body core temperature-sweat rate[6] and reduce sweating threshold[7]. The thermoregulatory responses in athletes are thought to be comparable to those produced by heat adaptation. Heat adaptation may be affected by years of training, as a response to repeated stress application. In prepubescence, the effect of physical adaptations on thermoregulatory responses is still inconsistent[8], which may be due to insufficient years of training to achieve such adaptations. The limited studies that have investigated thermoregulatory responses of exercising children have focused on hydration aspects[8-10] and groups of non-athletes[11].

The impact of exercise in the heat on thermoregulatory and perceptual responses between AG athletes and non-athletes is still unclear. The purpose of this study was to compare the thermoregulatory and perceptual responses between two groups of prepubescent girls (AG athletes and non-athletes) cycling at similar relative intensities in both heat (HC) and thermoneutral (TC) conditions.

METHODOLOGICAL PROCEDURES

Participants

Fourteen prepubescent girls (7 AG athletes and 7 non-athletes — but physically active) participated in this study. Girls in the group of athletes trained AG for at least 5 days per week, > 3 h per day, during the last year and also participated in competitions. Non-athlete girls were physically active (level ≥ 3), according to the Physical Activity Questionnaire for Older Children (PAQ-C)[12]. Girls did not present any chronic disease and were not taking any medication at the time of participation. The study approval was obtained from the Federal University of Rio Grande do Sul Research Ethics Board (Protocol # 19624). All procedures respected the Declaration of Helsinki (1975) principles and all participants and respective guardians were fully informed about potential risks and freely signed the informed consent and assent forms.

Procedures

This study consisted of a preliminary session and two experimental sessions (separated by 4-7 days). Experimental sessions were performed between January and April, where temperatures ranged from 28 to 42°C and relative humidity from 40 to 95% (Southern Brazil). Data were obtained from the National Meteorological Institute. Participants were similarly acclimatized to heat.

Preliminary session

Stage 1 of biological maturation (prepubertal) was confirmed through observation of breast and the pubic hair development[13]. Height (stadiometer, Urano PS 180) and body mass (G-TECH scale, model BALGLA3C, GTech Technology Ltd, Zhuhai, Guangdong, China) were assessed wearing minimal clothing (shorts and tops with child barefoot). Body surface area (BSA) was determined according to the equation of Dubois & Dubois[14]. Fat mass and total body mass were measured via dual-energy X-ray absorptiometry (DXA) (GE-LUNAR Prodigy, GE medical systems, Madison, WI).

The progressive exercise test to determine VO_{2peak} was conducted on a cycle ergometer (Ergo Fit 167, five-watt resolution; ERGO-FIT, Pirmasens, Germany) using the McMaster protocol[15]. The test began at 25 W and increased in 25 W increments every 2 min while maintaining cadence between 60 and 80 rpm. All girls were verbally encouraged to give their best performance. An open-circuit indirect calorimeter was used (Medgraphics O_2 and CO_2 Analyzer CPX/D [breath-by-breath]; Medical Graphics Corporation, St Paul, Minnesota), and peak was considered to be the highest VO_2 value. The test ended when two of the five following criteria were reached: 1) participant's request to interrupt the test, 2) inability to maintain cycling cadence above 60 rpm, 3) HR (Polar S610; Polar Electro Oy, Kempele, Finland) > 200 bpm, 4) rate of perceptual exertion (RPE) > 19, and 5) respiratory exchange rate (RER) > 1.0. VO_{2peak} was also corrected for the total muscle mass to avoid a confounder effect of fat mass and total body mass.

Experimental design

Participants were asked to avoid strenuous physical activity 24 h prior to experimental sessions and to maintain their eating habits during interval between sessions. The experimental protocol was identical for both sessions except for environmental conditions (HC or TC) for which the order was randomized by lottery during the preliminary session. All experimental trials were scheduled in the morning to eliminate systematic differences between groups due to circadian variation, and participants ate a standardized breakfast that consisted of two portions of white bread (40 g), one portion of jelly (15 g), 200 mL of fruit juice and 200 mL of chocolate milk.

On arrival, each participant provided a urine sample, which was immediately analyzed for urine specific gravity (USG, cut-off value < 1.020) (Atago refractometer, URC-Ne, Japan; ATAGO CO Ltd, Tokyo, Japan) and color[16], using an 8-point scale that ranges from very pale yellow (1) to brownish green (8), to ensure that initial hydration status was similar between groups. Body mass was measured with participants dressed in shorts, top and barefoot. Each participant was equipped with a HR monitor and T_{re} was measured using a flexible thermometer (RET-1, 0.1°C resolution; Physitemp Instruments, Inc, Clifton, New Jersey) with a disposable cover, which was inserted 10 cm beyond the anal sphincter.

Participants received standardized instructions on how to answer the following three perceptual scales: thermal sensation[17], thermal comfort[17] and irritability. Thermal sensation was categorized on a 9-point scale, ranging from (1) "very cold" to (9) "very hot". Thermal comfort was assesses on a 6-point scale ranging from (1) "very comfortable" to (6) "very uncomfortable", and irritability was assesses on a 5-point scale ranging from (1) "nothing" to (5) "very strong".

Participants exercised while exposed to environmental conditions inside a climate chamber (Modular Construction Walk-In Temperature and Humidity Test Chamber; Russells Technical Products, Holland, Michigan). Environmental conditions were similar between AG athletes and non-athlete girls for HC (35.2 ± 0.9°C and 38.4 ± 3.9 % relative humidity) and TC (24.0 ± 1.1°C and 50 ± 8.4 % relative humidity).

Upon entering the climate chamber, participants rested for five minutes, while initial T_{re}, HR, RPE, thermal sensation, thermal comfort, and irritability measurements were recorded. The exercise protocol consisted of pedaling on a cycle ergometer (Ergo Fit; Toledo, Spain) for 30 min with load (W) corresponding to 55% of the $VO_{2peak,}$ and cadence between 60 and 80 rpm. At the 15^{th} min of cycling of submaximal sessions (HC and TC), VO_2 was measured for three minutes to check the target intensity. T_{re}, HR, and RPE were recorded every five min, and thermal sensation, thermal comfort, and irritability were measured at 0, 10, 20, and 30 min. Exercise was stopped early if T_{re} achieved values > 39°C or, two events of the following 4 criteria simultaneously occurred: HR 200 bpm, RPE > 19, heat exhaustion (nausea, disorientation, headache, and dizziness), and inability to maintain cycling frequency between 60 and 80 rpm[18].

During cycling, water (~15 °C) was available for consumption *ad libitum*, and the following instruction was given: "Water will remain available within your reach; you can drink whenever you wish". The bottle was weighed (Ohaus Compact Scale, CS2000; Ohaus Compact scale, Parsippany, New Jersey) before and after cycling to calculate water volume intake. Following the completion of exercise, girls urinated and dried their bodies, and their body mass was measured to calculate sweat volume (Δ body mass before and after cycling, corrected by the volume of water intake and urine volume).

Statistical Analyses

To verify data normality and homogeneity of variance, the Shapiro-Wilk test and the Levene test were used, respectively. For independent samples, the t-test was used for intergroup comparisons. Condition-specific 2-way ANOVAs were used to compare groups over time. When group × time interaction was found, post-hoc analyses were performed using Bonferroni test. All data are expressed as mean and standard deviation (SD). Statistical significance was set at ≤ 0.05, and all analyses were performed using the statistical SPSS software version 18.0 (SPSS Inc, Chicago, Illinois).

RESULTS

Table 1 shows that most of the physical characteristics of AG group were similar to that of non-athlete group, with the exception that they showed lower body fat (kg) (P = 0.04) and % body fat (P = 0.01). BSA (m^2 and $m^2 \cdot kg^{-1}$) and aerobic fitness ($mL \cdot min^{-1}$, $mL \cdot kg^{-1} \cdot min^{-1}$, and $mL \cdot kg^{-1 MuscleMass} \cdot min^{-1}$) were similar between groups.

Table 1. Physical and Physiological Characteristics of Participants by Group.

Characteristics	AG Athletes (n= 7)	Non-athletes (n=7)
Age (yrs)	8.7 ± 1.3	9.4 ± 1.4
Body mass (kg)	24.5 ± 4.3	26.5 ± 5.1
Height (cm)	129.5 ± 0.06	132.5 ± 0.09
Fat mass (kg)	3.2 ± 1.5	5.2 ± 1.8*
% body fat	13.3 ± 4.3	20.3 ± 3.7*
Muscle Mass (kg)	20.2 ± 3.0	20.1 ± 3.1
Body surface area (BSA) (m^2)	0.98 ± 0.11	1.02 ± 0.13
BSA/body mass ($m^2 \cdot kg^{-1}$)	0.038 ± 0.003	0.036 ± 0.002
Aerobic fitness		
VO_{2peak} ($mL \cdot min^{-1}$)	1157 ± 254	1298 ± 470
VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$)	47.5 ± 7.5	46.8 ± 10.1
VO_{2peak} ($mL \cdot kg^{-1MuscleMass} \cdot min^{-1}$)	57.7 ± 9.4	63.18 ± 13.7
Heart $Rate_{max}$ (bpm)	183 ± 12	189 ± 13
$Workload_{max}$ (watts)	89.2 ± 13.3	85.7 ± 19.6
RER_{max}	1.14 ± 0.10	1.08 ± 0.04

Values are expressed as the mean ± SD. * P < 0.05.

Urine color and USG were similar between groups prior to exercise both in HC (2.6 ± 1.3 and 1.018 ± 0.007 in athletes vs. 3.4 ± 1.8 and 1.014

± 0.007 in non-athletes) and TC (2.4 ± 1.3 and 1.018 ± 0.007 in athletes vs. 3.2 ± 0.8 and 1.016 ± 0.008 in non-athletes). At the end of the exercise session, urine color and USG remained similar between groups at ambient conditions, and continued to indicate mild hypohydration.

AG athletes and non-athletes cycled at similar relative intensities (% VO_{2peak}) and absolute workloads (W) in both environmental conditions (54.6 ± 2.1 % VO_{2peak} and 35.0 ± 3.5 W vs. 54.4 ± 3.7 % VO_{2peak} and 37.5 ± 12.5 W, respectively in HC; and 54.3 ± 2.8 % and 33.7 ± 2.5 W vs. 54.9 ± 3.5 % and 36.6 ± 10.0 W in TC).

Figure 1 shows T_{re} and HR in both groups and environmental conditions. Initial T_{re} was similar between AG athletes and non-athletes in both HC (37.2 ± 0.4 vs. 37.4 ± 0.2 °C) and TC (37.3 ± 0.2 vs. 37.3 ± 0.3 °C) conditions. The magnitude of T_{re} increase was also similar between groups in both HC (0.8 ± 0.3 vs. 0.8 ± 0.1 °C) and TC (0.5 ± 0.2 vs. 0.7 ± 0.2 °C) conditions. No group × time interaction was found for T_{re} in HC ($F(6,6) = 0.23$; $P = 0.95$; Power = 0.77) or in TC ($F(6,6) = 2.97$ $P = 0.10$, Power = 0.50). Final T_{re} was similar between AG athletes and non-athletes (38.0 ± 0.2 vs. 38.2 ± 0.2°C in HC; and 37.8 ± 0.2 vs. 37.9 ± 0.2°C in TC). During exercise in HC, group × time interaction was observed with HR ($F(6,7) = 3.99$, $P = 0.046$; Power = 0.69), and initial HR was lower in AG athletes compared to non-athletes (76 ± 7 vs. 91 ± 11 bpm, $P = 0.01$). During exercise in TC, HR was similar between groups at each moment, with no group × time interaction ($F(6,7) = 2.02$, $P = 0.19$; Power = 0.39).

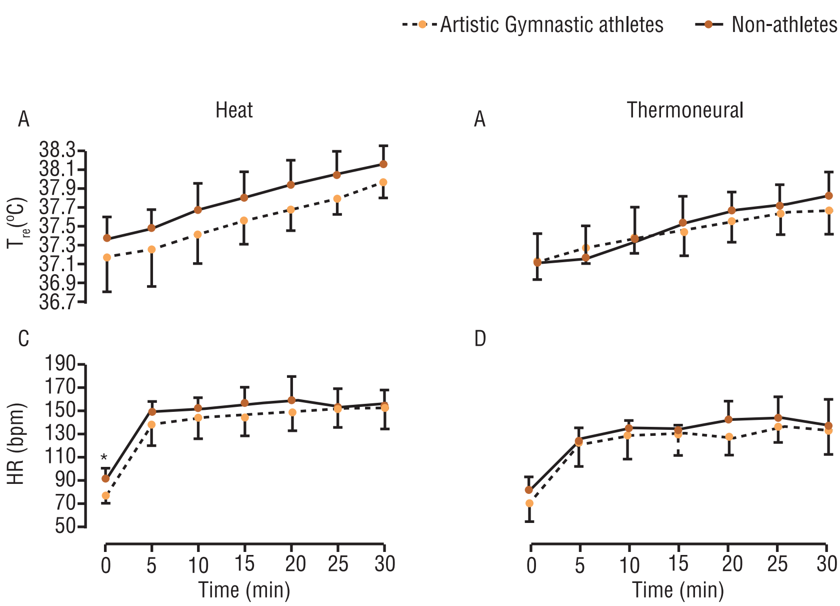

Figure 1. T_{re} during cycling in HC (A) and TC (B) conditions. HR during cycling in HC (C) and TC (D). Results are presented as mean ± SD.

Absolute sweat volume throughout the session (30 min) did not differ between AG athletes and non-athletes in HC (146 ± 118 vs. 195 ± 134 mL) and TC (215 ± 173 vs. 177 ± 210 mL), even when corrected for BSA ($mL·m^{-2}$) in both HC (144 ± 107 vs. 190 ± 134) and TC (234 ± 210 vs. 166 ± 182). Water intake was also similar between AG athletes and non-athletes (64 ± 87 vs. 117 ± 61 mL in HC, and 109 ± 54 vs. 47 ± 44 mL in TC), resulting in similar hypohydration levels (< 1%).

Figure 2 shows RPE, thermal sensation, thermal comfort and irritability during exercise. There were no group × time interactions in both HC and TC in relation to RPE (F(5,7) = 0.9; P = 0.6; Power = 0.2, and F(5-8) = 0.6; P = 0.7; Power = 0.1, respectively), thermal sensation (F(3,10) = 0.3; P = 0.9; Power = 0.09, and F(3-10) = 2.4; P = 0.1; Power = 0.5, respectively), irritability (F(3,10)=1.905; P = 0.19; Power = 0.4, and F(2-11) = 0.1; P = 0.9; Power = 0.7, respectively) and thermal comfort (F(3,10) = 1.6; P = 0.2; Power = 0.3, and F (2-11) = 0.3; P = 0.8; Power 0.1, respectively). After 10 min of exercise in TC, AG athletes showed greater thermal comfort than non-athletes (P = 0.03).

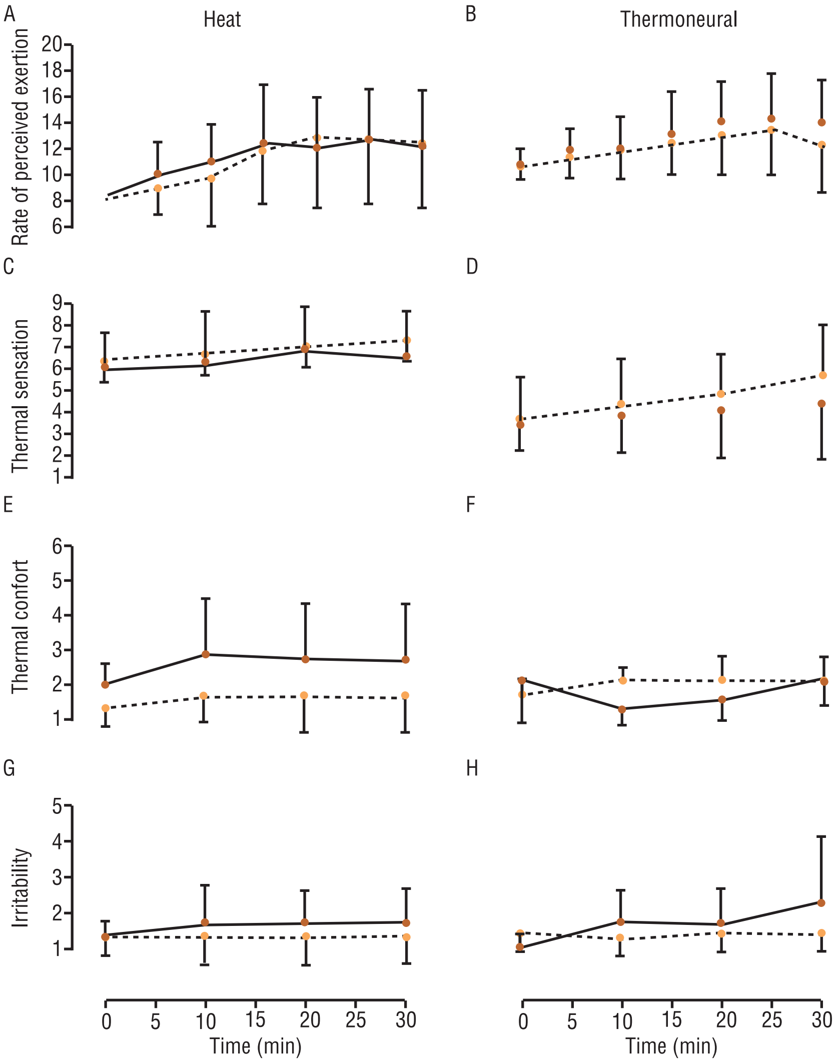

Figure 2. Rate of perceptual exertion in heat (HC) (A) and thermoneutral (TC) conditions (B); Thermal sensation in HC (C) and TC (D). Thermal comfort in HC (E) and TC (F). Irritability in HC (G) and TC (H). Results are presented as mean ± SD. *P < 0.05.

DISCUSSION

The present study showed that, compared to non-athletes, when female AG prepubescent athletes cycled both in HC and TC, they showed similar: 1) initial T_{re} and T_{re} and HR responses while exercising; 2) sweat volume; and 3) RPE, thermal sensation, thermal comfort and irritability. The present study suggested that AG training of at least one year did not affect thermoregulatory and perceptual responses in prepubescent AG athletes compared to their non-athlete peers, with similar acclimatization levels and VO_{2peak}.

T_{re} increase was similar among prepubescent girls in both environmental conditions. Some studies[19,20] have shown that trained adult men and women have lower increases in core temperature and skin temperature compared to untrained individuals while exercising (60-120 min) in the heat (30 – 45°C). Perhaps, the similar T_{re} responses between groups in the present study is due to the relatively shorter duration (30 min) and lower intensity (55% VO_{2peak}) of the exercise protocol compared to the usual high intensity and intermittent nature of AG training sessions. However, an important point in our study is that, in addition to similarities in their previous heat exposure, non-athletics were physically active and had aerobic fitness similar to AG athletes, as indicated by their VO_{2peak}. It is therefore possible that differences in the magnitude of thermoregulatory responses are accentuated when young athletes are compared with sedentary individuals rather than physically active individuals. In male adults, a study [21] showed that the magnitude of VO_{2peak} may not be the main factor to explain thermoregulatory responses when exercise elicits similar metabolic heat production per body mass unit. In the present study, absolute VO_{2peak}, RER and workload were similar between groups, which also resulted in similar metabolic heat production (in W and $W \cdot kg^{-1}$). It is possible that fitness improvement induced by AG training in prepubescent girls is not reflected by a single graded exercise test. Therefore, this supposed similar fitness capacity between groups could be a limitation of the present study. Further studies are needed to compare athletic and non-athletic children with different physical and fitness capacity exercising in the heat.

To compare our results with those obtained with children, it is important to consider how the protocol challenged the thermoregulatory system (i.e. method selected to induce heat exchange). For example in boys, lower T_{re} increment was observed in trained vs. untrained prepubescents; however, they were resting in a seated posture in the heat (30°C and 70% relative humidity) with their legs immersed in hot water (43°C)[22]. This single heat exposure protocol should be observed, as this study[22] used passive and not active (exercise) protocol to compare groups. The choice of this protocol changes the relative contribution of heat gain and loss, and also isolates the physical conditioning effect on thermoregulatory responses. When exercising, heat gain occurs primarily from metabolic heat production while heat is lost via evaporative cooling, conduction and radiation. Therefore, when passive heat is used to compare thermoregulatory responses, radiation, conduction and convection are the main routes of heat gain, and losses are mostly dependent on evaporative cooling.

Physical training, even when regularly practiced in cool environments, may indirectly improve heat tolerance to exercise as endurance adult athletes with higher Vo_{2max} have some thermoregulatory advantages compared to non-athletes[4]. Physical training appears to have a great impact on heat adaptation in adults[4], although the influence of individual $VO_{2max,}$ as an isolated factor affecting thermoregulatory responses, is controversial[21]. Body composition is another feature that usually differs between athletes and non-athletes. The impact of this difference in thermoregulatory responses during exercise is also controversial. A study[21] suggested that body size (mass, composition and BSA) has no great impact on core temperature increase during exercise in the heat when exercise is prescribed to elicit similar metabolic heat production per body mass unit. Other studies suggested that subjects with greater % body fat have higher capacity to store heat and greater increase in core temperature[23,24]. On the other hand, obese and non-obese pubescent boys showed no difference in thermoregulatory responses during exercise in the heat[11]. In prepubescent girls, the lean group presented greater increase in body core temperature compared to the obese group when cycling in the heat; but not at thermoneutral conditions[25]. The extent at which adiposity affects thermoregulatory responses during exercise in the heat is still unclear. In our study, despite the similar body mass between groups, body fat was ~34.5% lower in AG athletes (13.3 vs. 22% in AG athletes and non-athletes, respectively), which is a characteristic in this sport modality[26]. In our study, differences in % body fat did not affect thermoregulation effectiveness of prepubescent girls; however both groups were lean.

Similar sweating responses were observed in AG athletes and non-athletes during both HC and TC. Water loss through sweating is largely dependent on exercise pattern such as intensity and duration. In adults, as aerobic fitness increases, thermoregulatory function and heat tolerance improve which, among other adaptations, may be also due to the earlier onset of sweating and greater sweating rates[27]. Therefore, it is possible that the training lifetime of female AG prepubescent athletes is still insufficient to affect sweating responses. In early-pubertal boys (aged 8-10 years), physiological adaptations due to heat acclimatization may be achieved either by exercise in heat (43°C) or by further training (~65% of VO_{2max}) even if the climate is neutral (24°C)[28]. Children's lower sweat rate and the greater population density of their active glands suggest that the sweat production per gland is lower than in adults, mainly in prepubescent years[15]. Children may be less dependent on evaporation and present greater reliance on heat dissipation via convection, conduction and radiation. In adults, the effects of sports training on sweating responses were observed in runners compared to sedentary males during 30 min of cycling in the heat (35°C) at similar relative intensity (60% VO_{2max}). Runners showed higher sweat rate than sedentary males[29]. A study[30] showed the effect of age and training on thermoregulatory responses in three different groups: young cyclists (aged 19-35 years) at moderate or high training levels and older cyclists (51-63 years). Participants cycled for 60 min at 70% of their VO_{2max} in HC (35°C and 40% relative humidity) and TC (20°C and 40% relative humidity) conditions. Lower sweating rates and sweat loss by evaporation were observed in both young cyclists at moderate physical training levels and older cyclists compared with the group of young and highly trained individuals. Different from trained adults that have increased sweating rate and lower sweat threshold, the effect of training on thermoregulatory responses in prepubescent girls seems to be lower[15].

There is limited information on perceptual responses of prepubescent girls while exercising in the heat. In the present study, RPE, thermal sensation, thermal comfort and irritability were similar between groups of AG athletes and non-athletes. Only after 10 min of exercise in TC, AG athletes showed greater thermal comfort compared to non-athletes. A study[11] showed that during exercise in the heat, the thermal sensation increased in both lean and obese boys; however, in general, it was higher in the obese group.

CONCLUSION

It was concluded that female athletes were similar to non-athletes with respect to thermoregulatory and perceptual responses, perceptual exertion, thermal sensation, thermal comfort and irritability to a single bout of aerobic exercise at similar relative intensity in either HC or TC. Different from trained adults that have increased sweating rate and lower sweat threshold, the effect of training on thermoregulatory responses in prepubescent AG athletes compared to non-athlete but physically active girls seems to be lower. It is possible that differences would be observed when comparing athletes and sedentary prepubescent girls. The cross-sectional design of the present study is a limitation, as well as the small sample size. A practical application is to consider the impact of hyperthermia related to chronic and prolonged exercise training and thermoregulatory adaptation in young athletes.

Acknowledgments

We wish to thank the participants for their time and effort.

REFERENCES

1. Malina RM, Baxter-Jones AD, Armstrong N, Beunen GP, Caine D, Daly RM, et al. Role of intensive training in the growth and maturation of artistic gymnasts. Sports Med 2013;43(9):783-802.
2. Mora-Rodriguez R, Hamouti N, Del Coso J, Ortega JF. Fluid ingestion is more effective in preventing hyperthermia in aerobically trained than untrained individuals during exercise in the heat. Appl Physiol Nutr Metab 2013;38(1):73-80.

3. Kobayashi Y, Ando Y, Okuda N, Takaba S, Ohara K. Effects of endurance training on thermoregulation in females. Med Sci Sports Exerc 1980;12(5):361-4.
4. Pandolf KB. Effects of physical training and cardiorespiratory physical fitness on exercise-heat tolerance: recent observations. Med Sci Sports 1979;11(1):60-5.
5. Shibasaki M, Wilson TE, Crandall CG. Neural control and mechanisms of eccrine sweating during heat stress and exercise. J Appl Physiol 2006;100(5):1692-701.
6. Yanagimoto S, Aoki K, Horikawa N, Shibasaki M, Inoue Y, Nishiyasu T, et al. Sweating response in physically trained men to sustained handgrip exercise in mildly hyperthermic conditions. Acta Physiol Scand 2002;174(1):31-9.
7. Roberts MF, Wenger CB, Stolwijk JA, Nadel ER. Skin blood flow and sweating changes following exercise training and heat acclimation. J Appl Physiol Respir Environ Exerc Physiol 1977;43(1):133-7.
8. Rivera-Brown AM, De Félix-Dávila RA. Hydration status in adolescent judo athletes before and after training in the heat. Int J Sports Physiol Perform 2012;7(1):39-46.
9. Kavouras SA, Arnaoutis G, Makrillos M, Garagouni C, Nikolaou E, Chira O, et al. Educational intervention on water intake improves hydration status and enhances exercise performance in athletic youth. Scand J Med Sci Sports 2012;22(5):684-9.
10. Wilk B, Timmons BW, Bar-Or O. Voluntary fluid intake, hydration status, and aerobic performance of adolescent athletes in the heat. Appl Physiol Nutr Metab 2010;35(6):834-41.
11. Sehl PL, Leites GT, Martins JB, Meyer F. Responses of obese and non-obese boys cycling in the heat. Int J Sports Med 2012;33(6):497-501.
12. Crocker PR, Bailey DA, Faulkner RA, Kowalski KC, McGrath R. Measuring general levels of physical activity: preliminary evidence for the Physical Activity Questionnaire for Older Children. Med Sci Sports Exerc 1997;29(10):1344-9.
13. Tanner J. Growth at adolescence. Oxford: Blacwell Science; 1962.
14. Dubois D, Dubois E. Clinical calorimetry: a formula to estimate the approximate surface area if height and weight be known. Arch Int Med 1916;17:863-71.
15. Bar-Or O, Rowland TW. Pediatric Exercise Medicine: From Physiologic Principles to Health Care Application. Champaign: Human Kinetics; 2004.
16. Armstrong LE, Maresh CM, Castellani JW, Bergeron MF, Kenefick RW, LaGasse KE, et al. Urinary indices of hydration status. Int J Sport Nutr 1994;4(3):265-79.
17. Arens EA, Zhang H, Huizenga C. Partial- and whole-body thermal sensation and comfort. Part I: uniform environmental conditions. J Therm Biol 2006;31:53-9.
18. Meyer F, Bar-Or O, MacDougall D, Heigenhauser GJ. Drink composition and the electrolyte balance of children exercising in the heat. Med Sci Sports Exerc 1995;27(6):882-7.
19. Nadel ER, Pandolf KB, Roberts MF, Stolwijk JA. Mechanisms of thermal acclimation to exercise and heat. J Appl Physiol 1974;37(4):515-20.
20. Cohen JS, Gisolfi CV. Effects of interval training on work-heat tolerance of young women. Med Sci Sports Exerc 1982;14(1):46-52.
21. Jay O, Bain AR, Deren TM, Sacheli M, Cramer MN. Large differences in peak oxygen uptake do not independently alter changes in core temperature and sweating during exercise. Am J Physiol Regul Integr Comp Physiol 2011;301(3):832-41.
22. Matsushita K, Araki T. The effect of physical training on thermoregulatory response of pre-adolescent boys to heat and cold. J Phys Fit Sports Med Jap 1980;29(2):69-74.
23. Godek SF, Bartolozzi AR, Burkholder R, Sugarman E, Dorshimer G. Core temperature and percentage of dehydration in professional football linemen and backs during preseason practices. J Athl Train 2006;41(1):8-14.
24. McLellan TM. The importance of aerobic fitness in determining tolerance to uncompensable heat stress. Comp Biochem Physiol A Mol Integr Physiol 2001;128(4):691-700.
25. Leites GT, Sehl PL, Cunha Gdos S, Detoni Filho A, Meyer F. Responses of obese and lean girls exercising under heat and thermoneutral conditions. J Pediatr 2013;162(5):1054-60.

26. Zanker CL, Gannon L, Cooke CB, Gee KL, Oldroyd B, Truscott JG. Differences in bone density, body composition, physical activity, and diet between child gymnasts and untrained children 7-8 years of age. J Bone Miner Res 2003;18(6):1043-50.
27. Drinkwater BL. Women and exercise: physiological aspects. Exerc Sport Sci Rev 1984;12:21-51.
28. Inbar O, Bar-Or O, Dotan R, Gutin B. Conditioning versus exercise in heat as methods for acclimatizing 8- to 10-yr-old boys to dry heat. J Appl Physiol Respir Environ Exerc Physiol 1981;50(2):406-11.
29. Henkin SD, Sehl PL, Meyer F. Sweat rate and electrolyte concentration in swimmers, runners, and nonathletes. Int J Sports Physiol Perform 2010;5(3):359-66.
30. Best S, Caillaud C, Thompson M. The effect of ageing and fitness on thermoregulatory response to high-intensity exercise. Scand J Med Sci Sports 2012;22(4):29-37.

CORRESPONDING AUTHOR

Gabriela Tomedi Leites
School of Physical Education,
Federal University of Rio Grande do Sul.
Felizardo Street, 750 - Jd. Botânico.
90690-200 - Porto Alegre – RS, Brazil.
E-mail: gabitomedi@yahoo.com.br
leitesgt@mcmaster.ca