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ORIGINAL ARTICLE

Thermoregulatory and perceptual responses of lean and obese fit and unfit girls exercising in the heat☆

Carolina de Ávila Rodrigues, Gabriela Tomedi Leites*, Flavia Meyer

Universidade Federal do Rio Grande do Sul (UFRGS), Escola de Educação Física, Fisioterapia e Dança, Porto Alegre, RS, Brazil

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Abstract

Objective: To verify the thermoregulatory and perceptual responses of obese and lean girls, either fit or unfit, exercising in the heat at a similar rate of metabolic heat production per unit body mass.

Methods: A total of 34 pubescent girls were allocated in four groups: 12 obese fit, 9 obese unfit, 5 lean fit, and 8 lean unfit. The obese groups (13.2 ± 1.4 years, 40.5% ± 5.8% fat by DXA) differed in their aerobic fitness ($\dot{V}O_{2peak}$ 76.0 ± 8.1 vs. 56.6 ± 5.8 mL.kg muscle mass^{-1}.min^{-1}), as well as the lean groups (13.1 ± 1.6 years, 24.0% ± 4.8% fat) ($\dot{V}O_{2peak}$ 74.5 ± 2.9 vs. 56.2 ± 5.0 mL.kg muscle mass^{-1} min^{-1}). Girls cycled two bouts of 25 min with a 10 min rest in between, at ~5.4 W.kg^{-1} in the heat (36 °C and 40% relative humidity) and they were kept euhydrated. Rectal and skin temperatures and heart rate were measured every 5 min. Perceptual responses were evaluated throughout the exercise.

Results: Initial rectal temperature was higher in the obese subjects compared to the lean subjects (37.5 ± 0.3 and 37.2 ± 0.3 °C). No difference was observed among the girls whom were obese (eight fit or unfit) and lean (also fit or unfit) throughout the exercise in rectal temperature (37.6 ± 0.2, 37.5 ± 0.3, 37.5 ± 0.3, 37.4 ± 0.3 °C, respectively), skin temperature (34.8 ± 0.8, 35.1 ± 1.0, 34.4 ± 0.9, 35.2 ± 0.9 °C), and heart rate (128 ± 18; 118 ± 12, 130 ± 16, 119 ± 16 beats min^{-1}). No differences were observed in perceptual responses among groups.

Conclusion: Regardless of the adiposity or aerobic fitness, pubescent girls had similar thermoregulatory and perceptual responses while cycling in the heat at similar metabolic heat production.

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* Corresponding author.
E-mail: gabitomedi@yahoo.com.br (G.T. Leites).

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PALAVRAS-CHAVE
Exercício;
Púbere;
Termorregulação;
Obesidade

Respostas termorregulatórias e perceptivas de meninas magras e obesas com alta e baixa aptidão aeróbica exercitando-se no calor

Resumo
Objetivo: Verificar as respostas termorregulatórias e perceptivas de meninas obesas e magras, com alta e baixa aptidão aeróbica, exercitando-se no calor com produção metabólica de calor similar por massa corporal.
Métodos: Um total de 34 meninas púberes foram alocadas em quatro grupos: 12 obesas com alta aptidão aeróbica, 9 obesas com baixa aptidão aeróbica, 5 magras com alta aptidão aeróbica e 8 magras com baixa aptidão aeróbica. Os grupos obesos (13,2 ± 1,4 anos, 40,5% ± 5,8% de gordura por DXA) diferiram em sua aptidão aeróbica ($\dot{V}O_{2peak}$ 76,0 ± 8,1 vs. 56,6 ± 5,8 mL.kg de massa muscular^{-1}.min^{-1}), bem como os grupos magros (13,1 ± 1,6 anos, 24,0% ± 4,8% de gordura) ($\dot{V}O_{2peak}$ 74,5 ± 2,9 vs. 56,2 ± 5,0 mL.kg de massa muscular^{-1}min^{-1}). As meninas pedalaram duas sessões de 25 minutos com descanso de 10 minutos entre as sessões, a ~5,4 W.kg^{-1} no calor (36 °C e 40% de umidade relativa) e foram mantidas hidratadas. As temperaturas retal e cutânea e a frequência cardíaca foram medidas a cada 5 minutos. As respostas perceptivas foram avaliadas durante o exercício.
Resultados: A temperatura retal inicial foi maior nas meninas obesas em comparação com as magras (37,5 ± 0,3 e 37,2 ± 0,3 °C). Não houve diferença entre as meninas obesas (com alta aptidão aeróbica ou não) e magras (também com alta aptidão aeróbica ou não) durante todo o exercício em relação à temperatura retal (37,6 ± 0,2; 37,5 ± 0,3; 37,5 ± 0,3; 37,4 ± 0,3 °C; respectivamente), temperatura da pele (34,8 ± 0,8; 35,1 ± 1,0; 34,4 ± 0,9; 35,2 ± 0,9 °C), e frequência cardíaca (128 ± 18; 118 ± 12, 130 ± 16, 119 ± 16 batimentos.min^{-1}). Não foram observadas diferenças nas respostas perceptivas entre os grupos.
Conclusão: Independentemente da adiposidade ou do condicionamento aeróbico, as meninas púberes tiveram respostas termorregulatórias e perceptivas semelhantes, enquanto pedalavam no calor com uma produção metabólica de calor similar.

Introduction

Few studies have shown thermoregulatory[1] and perceptual[2] disadvantages of obese compared to lean children during exercise in the heat, although obesity has been pointed as a risk factor for exertional heat illnesses.[3] Physical inactivity and poor aerobic fitness – generally associated with obesity – may also impair thermoregulatory responses, representing an aggravating condition when prescribing exercise in warm conditions.[4]

Depending on girls' aerobic fitness, there may be thermoregulatory and perceptual differences within those who are lean and obese.[5] Aerobic exercise is often recommended for weight management, but adherence may be impaired if girls experience discomfort. In addition to health and safety considerations, the recommended exercise should be enjoyable.[6] Currently, no evidence exists about the impact of fitness associated with adiposity on physiological and perceptual responses during moderate prolonged exercise in the heat.

Furthermore, no confirmation exists that obese teens respond with greater increase in core temperature compared to their lean peers during exercise in the heat.[5] Conflictingly, Leites et al.[6] showed that girls who are obese had a smaller increase in rectal temperature (T_{re}) during exercise in hot conditions compared to the lean ones; however, in boys[2] the responses were similar.

Core temperature can be different between males and females, which could be due to hormones, as estrogen plays a role in thermoregulation and sweating responses.[7] Another explanation for conflicting results may be related to the traditional method of setting the exercise intensity protocol load by a certain % of the individual's peak oxygen consumption ($\dot{V}O_{2peak}$). As suggested,[8,9] such an approach may induce greater metabolic heat production ($\dot{H}_p$) in the lean compared to the obese girls, explaining their greater T_{re} increase.

Previous studies compared heterogeneous body mass groups using a given % $\dot{V}O_{2peak}$[2,6] or an absolute walking speed,[10] which could result in different $\dot{H}_p$ per body unit. A study[11] that compared two groups of adults matched by body mass and body surface area (BSA), with distinct $\dot{V}O_{2peak}$ (~60 vs. 40.3 mL.kg^{-1}.min^{-1}) and % body fat (~12% vs. 22%), showed that exercise at a given absolute $\dot{H}_p$, but not necessarily at a similar % $\dot{V}O_{2peak}$, resulted in a similar core temperature increase. Setting the exercise intensity by $\dot{H}_p$ per body unit[12,13] has been considered a better method to compare groups of heterogeneous body size.[8,14] In youths, there are no studies that have aimed to examine thermoregulatory responses to exercise that considered both aerobic fitness and adiposity.

Perceptual responses may also interfere with exercise tolerance and program adherence under heat conditions. Among active prepubescent girls, thermal comfort was similar between the lean and obese groups; however, the lean girls reported greater irritability during 30 min of cycling in the heat.[6] Obese pubertal boys who were active reported a higher heat sensation compared to their active lean peers while cycling for 30 min at similar % $\dot{V}O_{2peak}$ in the heat.[3] Boys whom are obese (9–12 years old) showed greater perceived effort (2–3 points on Borg scale) compared to the lean boys at similar absolute exercise intensity in the heat.[13] None of the above mentioned studies had considered aerobic fitness differences between groups.

Despite the consensus that increasing physical activity is a key aspect in the management of pediatric obesity, exercise appears to be a concern for unfit girls when performed in a warm climate. Such external conditions may serve as another excuse to limit even mild-to-moderate physical activities in sedentary obese girls. Clarification about the effect of obesity and fitness in youth during exercise in the heat will help clinicians and health professionals to recommend safe and enjoyable exercise to optimize body composition, aerobic fitness, and metabolic health. The purpose of this study was to verify thermoregulatory and perceptive responses of obese and lean girls, both fit and unfit, during exercise in the heat at a given $\dot{H}_p$.

Methods

Subjects

Thirty-four girls were studied, divided into four groups according to adiposity (obese and lean) and aerobic fitness (fit and unfit), resulting in 21 obese (12 fit and nine unfit) and 13 lean (5 fit and 8 unfit). Body fat was obtained by dual energy X-Ray absorptiometry (DXA) to classify the girls as lean or obese (<32 or ≥32% body fat),[14] and $\dot{V}O_{2peak}$ was evaluated to classify them as fit or unfit (≥69 or <64 mL.kg total muscle mass^{-1}.min^{-1}). For fitness, a $\dot{V}O_{2peak}$ cut-off point was set from the Gaussian curve of the girls $\dot{V}O_{2peak}$ measurements. A Standard Deviation (SD) of ±0.25 was adopted, ensuring a mean of 20 mL.kg total muscle mass^{-1}.min^{-1} difference between groups.

Girls and their parents/guardians were informed about procedures and provided written informed assent and consent to participate in the study, which was approved by the University Research Ethics Board.

Girls came to the laboratory for a preliminary and an experimental session, two to seven days apart, between March and May, which are predominantly warm months in Southern Brazil.

Preliminary session

Health condition was assessed by a questionnaire, which showed that the girls were healthy and not taking medications. Body mass and height were measured, and Body Mass Index (BMI) and BSA[15] were calculated. Biological maturation was determined using self-assessed Tanner staging.[16] Body composition was measured by using DXA (Lunar GE Pencil Bin, SmartScan pediatric program; GE Medical Systems Lunar – Diegem, Belgium).

To determine $\dot{V}O_{2peak}$, an incremental exercise test was performed in a thermoneutral room (∼24 °C) on a cycle ergometer (Ergo Fit, model 167 – Toledo, Spain) using the McMaster All-Out Progressive Continuous Cycling protocol.[5] Expired O_2 and CO_2 were continuously monitored using a calibrated metabolic cart (O_2 and CO_2 analyzer; Inbramed, model VO2000 – Porto Alegre, Brazil). The test was terminated if one of these four criteria was achieved: (1) Inability to maintain a cycling cadence >60 rpm, despite strong verbal encouragement; (2) Heart Rate (HR) >95% of HR_{max}[17]; (3) RPE >19; or (4) Respiratory Exchange Ratio (RER) >1.0. $\dot{V}O_{2peak}$ was considered as the highest $\dot{V}O_2$ value. $\dot{V}O_{2peak}$ was corrected by total muscle mass to avoid a confounding effect of fat mass and total body mass.[18]

At the end of this session, girls were instructed to refrain from any strenuous exercise and not to change their eating habits 24 h prior to the experimental trial, which happened 2–3 h after a major meal.

Experimental trial

Upon arrival to the laboratory, hydration status was verified from a sample of urine by examining the color.[19] This was followed by body mass measurement and baseline T_{re}, skin temperatures (T_{sk}), and HR. T_{re} was measured using a flexible thermometer (Physitemp Instruments, Inc. Ret-1 model – Clifton, NJ, United States) inserted 10–12 cm beyond the anal sphincter. T_{sk} at four sites were measured using skin thermometers (Physitemp Instruments, Inc., SST-1 model – Clifton, NJ, United States), placed on the arm (T_a), chest (T_c), upper back (T_b), and thigh (T_t). Mean T_{sk} was calculated according to the equation: $(0.3 * T_c) + (0.3 * T_b) + (0.2 * T_a) + (0.2 * T_t)$.

The girls received standardized instructions on how to answer four perceptual scales: (1) RPE,[20] (2) Thermal sensation (9 point scale from ''very cold'' to ''very hot''),[21] (3) Thermal comfort (6 point scale from ''very comfortable'' to ''very uncomfortable'')[21] and (4) Irritability (6 point scale from ''nothing'' to ''very intense'').

Prior to exercise, the girls rested in a seated position for five min in the climatic chamber (Russel Technical Products – Netherlands, 13 m^2) set at 36 °C and 40% relative humidity, resulting in a humidex factor of 44 °C. The girls exercised wearing a top, athletic shorts, and shoes.

The exercise cycling protocol consisted of two 25 min bouts at a fixed $\dot{H}_p$ per unit body mass (∼5.4 W.kg^{-1}) with a 10 min rest between bouts of cycling. $\dot{V}O_2$ and $\dot{V}CO_2$ were measured during the bouts for at least 10 min. T_{re}, T_{sk}, HR, and perceptual scores were recorded every 5 min during exercise. Total body temperature (T_{body}) was calculated as the following equation[22,23]: $T_{body} = (0.8 * T_{re}) + (0.2 * T_{sk})$

To keep euhydrated, each girl ingested a water volume at rest (between bouts) equivalent to her individual loss that was calculated from the body mass difference relative to her initial value. After the whole session, the girls dried their skin and body mass was evaluated with bare feet to calculate the sweat volume: Δbody mass + volume of water intake.

Table 1 Physical and physiological characteristics of obese and lean girls.

	Obese			Lean			*p*-Total	*p*-Group
	Total (21)	Fit (12)	Unfit (9)	Total (13)	Fit (5)	Unfit (8)		
Age (years)	13.2 ± 1.4	13.3 ± 1.5	13.1 ± 1.4	13.1 ± 1.6	13.0 ± 1.6	13.2 ± 1.7	0.91	0.97
Body mass (kg)	60.8 ± 13.7[a]	58.6 ± 12.9	63.6 ± 15.0[c]	44.1 ± 6.5[a]	44.7 ± 8.0[c]	43.8 ± 5.9[c]	<0.01	0.03
Body height (cm)	158 ± 0.1	158 ± 0.1	158 ± 0.0	156 ± 0.1	156 ± 0.1	156 ± 0.0	0.50	0.95
Body surface area (m^2)	1.6 ± 0.1[a]	1.5 ± 0.1	1.6 ± 0.2[c]	1.4 ± 0.1[a]	1.4 ± 0.1	1.3 ± 0.1[c]	<0.01	0.00
Total muscle mass (kg)	33.3 ± 5.8	31.8 ± 3.8	35.5 ± 7.4	30.9 ± 3.4	29.9 ± 4.3	31.5 ± 2.8	0.18	0.18
Lower limb muscle mass (kg)	11.7 ± 2.1	11.2 ± 1.3	12.5 ± 2.8	10.5 ± 1.4	9.9 ± 1.6	11.0 ± 1.1	0.08	0.10
Percentage body fat	40.5 ± 5.8	41.0 ± 6.8[c]	39.9 ± 4.6[c]	24.0 ± 4.8	25.1 ± 4.6	23.3 ± 5.1[c]	<0.01	<0.01
Aerobic fitness								
$\dot{V}O_{2peak}$ ($mL.min^{-1}$)	2243 ± 456	2408 ± 294[e]	2023 ± 553	1935 ± 347	2230 ± 329	1750 ± 209[e]	0.04	0.04
$\dot{V}O_{2peak}$ ($mL.kg^{-1}.min^{-1}$)	37.7 ± 7.8[a]	42.0 ± 6.7[b]	31.9 ± 5.4[b,f]	44.1 ± 6.9[a]	50.3 ± 4.3[b,φ]	40.3 ± 5.3[b,f]	0.02	<0.01
$\dot{V}O_{2peak}$ (mL.kg total muscle $mass^{-1}.min^{-1}$)	67.7 ± 12.1	76.0 ± 8.1[d]	56.6 ± 5.8	63.2 ± 10.2	74.5 ± 2.9[d]	56.2 ± 5.0[d]	0.27	<0.01
Heart $rate_{max}$ (beats min^{-1})	180 ± 13	181 ± 13	178 ± 16	180 ± 12	187 ± 7	175 ± 12	0.48	0.98
Biological maturation								
Tanner stage	4	4	4	4	4	3	0.10	0.65

[a] Obese > lean.
[b] Fit > Unfit.
[c] Obese unfit > Lean fit and lean unfit.
[d] Obese fit > Lean fit and lean unfit.
[e] Obese fit > Lean unfit.
[f] Obese unfit < Lean fit and lean unfit.
p-total, comparison between total obese and lean girls; *p*-group, comparison among groups (obese fit, obese unfit, lean fit, lean unfit).

Metabolic heat production

The rate of metabolic energy expenditure (M; W.m^{-2}) was estimated using the average $\dot{V}O_2$ (L.min^{-1}) and RER measured during exercise, calculated as[24]:

$M = \dot{V}O_2 \cdot \frac{\left[\left(\frac{RER-0.7}{0.3}\right)e_c\right]+\left[\left(\frac{1.0-RER}{0.3}\right)ef\right]}{60 \cdot BSA} \cdot 1000$; where e_c is the caloric equivalent per liter of O_2 for carbohydrate oxidation (21.13 kJ), and e_f for fat oxidation (19.62 kJ). $\dot{H}_p$ (W.m^{-2}) was calculated as the difference between M and the external work rate (W).

$$\dot{H}_p = M - W$$

Statistical analyses

The Shapiro—Wilk test was applied to verify data normality and Levene's test was used to determine the homogeneity of variance. Student t-test was used to compare groups (obese vs. lean) and characteristics (i.e., weight, height, BSA, % body fat, fat mass, total muscle mass, aerobic fitness, and HR$_{max}$). To analyze exercise intensity, urine color, sweat volume, and water balance by aerobic fitness and adiposity, one-way ANOVAs were conducted. Bonferroni post hoc analyses were used to examine significant interactions. The Generalized Estimating Equation (GEE) was used to compare groups (obese fit, obese unfit, lean fit, and lean unfit) over time (T_{re}, T_{sk}, HR, RPE, irritability, thermal sensation, and comfort). Pearson's correlation coefficient was used for the body fat and $T_{re.}$ Data are expressed as mean ± SD. Statistical significance was set at $p \leq 0.05$, and analysis were performed using SPSS v.18.0 (SPSS Inc — Chicago, IL, United States).

Results

Table 1 shows the physical characteristics by group. Obese groups were heavier, with greater BSA, BMI, body fat, muscle mass, and $\dot{V}O_{2peak}$; however, they presented lower $\dot{V}O_{2peak}$ by body mass. $\dot{V}O_{2peak}$ by total muscle mass was lower in the unfit compared to the fit girls ($p < 0.001$).

During exercise, obese fit girls had a higher absolute $\dot{H}_p$ compared to lean unfit girls (313 ± 62 vs. 232 ± 48 W; $p = 0.02$). $\dot{H}_p$ per unit body mass (W.kg^{-1}) was similar among obese and lean subjects, both fit and unfit. Obese and lean girls cycled at similar $\dot{H}_p$ (5.4 W.kg^{-1}, $p = 0.10$) and mean workload during exercise was 30 and 32 W, respectively (Table 2).

Participants arrived with similar hydration levels according to urine color (obese fit, obese unfit, lean fit, and lean unfit: 4 ± 2, 4 ± 2, 4 ± 1, and 4 ± 1, respectively). Table 3 shows the sweating response and body hydration status of the groups. Total sweat volume was similar among groups ($p = 0.30$), even when corrected by BSA ($p = 0.5$). Body water balance at the end of the experiment was similar among groups, resulting in a low deficit of 0.4 ± 0.2 and 0.5 ± 0.3 L, in the obese and lean groups, respectively.

Fig. 1 depicts T_{re}, T_{sk}, T_{body}, and HR over the two 25 min bouts of exercise. T_{re} response was similar between lean and obese for both the fit and unfit groups during exercise. No difference was observed among the four groups throughout the exercise in regional T_{sk} for the back, chest, arm, and thigh: 34.8 ± 0.8 obese fit; 35.1 ± 1.0 obese unfit; 34.4 ± 0.9 lean fit; and 35.2 ± 0.9 °C lean unfit, and T_{body}: 37.0 ± 0.2 obese fit, 37.0 ± 0.4 obese unfit, 36.8 ± 0.3 lean fit, and 36.9 ± 0.3 °C lean unfit. HR was similar between obese and lean girls at the beginning of exercise (101 ± 14 and 99 ± 12 beats min^{-1}) and it increased similarly among the four groups (obese fit, obese unfit,

Table 2 Average metabolic heat production ($\dot{H}_p$) and workload values during exercise in the heat in obese and lean girls.

	Obese			Lean			p-Total	p-Group
	Total (21)	Fit (12)	Unfit (9)	Total (13)	Fit (5)	Unfit (8)		
$\dot{H}_p$ (W)	304 ± 60[a]	313 ± 62[b]	292 ± 58	251 ± 53[a]	281 ± 52	232 ± 48[b]	0.01	0.04
$\dot{H}_p$ (W.m^{-2})	190 ± 38	199 ± 42	178 ± 30	179 ± 33	199 ± 26	166 ± 32	0.40	0.18
$\dot{H}_p$ (W.kg^{-1})	5.2 ± 1.2	5.5 ± 1.4	4.7 ± 0.9	5.7 ± 1.0	6.3 ± 0.7	5.3 ± 1.0	0.20	0.10
Workload (W)	30 ± 12	31 ± 12	28 ± 13	32 ± 11	35 ± 14	30 ± 9	0.40	0.84
% VO_{2max}	44.1 ± 7.5	41.5 ± 5.5	47.7 ± 8.6	43.2 ± 4.5	42.8 ± 4.2	43.6 ± 4.6	0.70	0.10

[a] Obese > Lean.
[b] Obese fit > Lean unfit.

Table 3 Sweating responses and total water balance during exercise in the heat in obese and lean girls.

	Obese			Lean			p Total	p Group
	Total (21)	Fit (12)	Unfit (9)	Total (13)	Fit (5)	Unfit (8)		
Sweat volume (mL)	361 ± 189	345 ± 121	454 ± 269	293 ± 146	237 ± 85	325 ± 180	0.3	0.5
Sweat volume/BSA (mL.m^{-2})	212 ± 115	221 ± 85	199 ± 152	183 ± 141	140 ± 111	209 ± 136	0.5	0.7
Total water balance	−0.4 ± 0.2	−0.3 ± 0.2	−0.3 ± 0.2	−0.5 ± 0.3	−0.3 ± 0.3	−0.5 ± 0.2	0.4	0.4

BSA, body surface area.

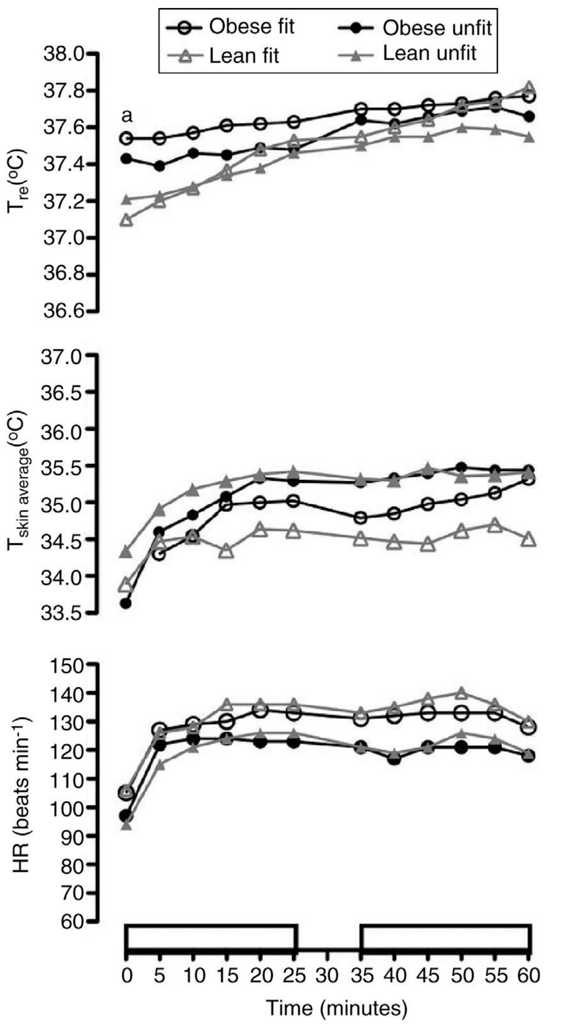

Figure 1 Physiological responses during exercise in the heat ([a]Obese > Lean).

lean fit, and lean unfit) (128 ± 18; 118 ± 12, 130 ± 16, and 119 ± 16 beats min^{-1}, respectively).

Body fat did not correlate with T_{re} (r = 0.32). There was no relationship between adiposity and time for T_{re} (p = 0.31), T_{sk} (p = 0.54), T_{body} (p = 0.97), HR (p = 0.98), throughout the exercise session. There were also no differences among groups for these variables over time according to the aerobic fitness: T_{re} (p = 0.99), T_{sk} (p = 0.99), T_{body} (p = 0.96) and HR (p = 0.92).

The four groups (obese fit, obese unfit, lean fit, and lean unfit) presented similar perceptual responses during exercise for RPE (11 ± 2, 12 ± 2, 11 ± 2, and 11 ± 2, respectively) (p = 0.98) (11 signifying ''slight effort''), irritability (3 ± 0.5, 2 ± 0.3, 3 ± 0.8, and 2 ± 0.3) (p = 0.96) (3 signifying ''moderate'' and 2 ''low'' irritability), thermal sensation (7 ± 0.4, 7 ± 0.5, 7 ± 0.7, and 6 ± 0.7) (p = 0.98) (7 signifying ''warm'' and 6 ''slightly warm''), and thermal comfort (3 ± 0.4, 3 ± 0.5, 3 ± 0.7, and 3 ± 0.5) (p = 0.99) (3 signifying ''just uncomfortable'').

Discussion

The main finding of this study is that thermoregulatory and perceptual responses were similar independent of the group during the 25 min cycling bouts at similar $\dot{H}_p$ per unit body mass in the heat. This suggests that under such exercise/heat conditions, obese and unfit girls did not differ regarding body temperatures and sweating responses compared to their lean and fit peers. Their perceived exertional, thermal sensation, and comfort responses throughout exercise were also similar among groups.

Although fit obese girls started exercise at a higher T_{re} than fit lean girls, responses were similar among groups during exercise. Compared to the lean, obese children may present greater absolute resting metabolic rate and metabolic heat production due to differences in body composition.[6,25] In addition, since fat mass has a specific heat that is approximately half of that of fat-free mass, it may result in greater heat storage in the obese. All girls were naturally heat acclimatized, and previous hydration and resting conditions were controlled to eliminate these factors as responsible for baseline value differences.

A few studies have verified thermoregulatory responses in obese children[6,10] and adolescents[1,2,13] during exercise in the heat; however, only two included females.[6,26]

There are inconsistent results about the influence of body fat on thermoregulation during exercise in the heat.Lean girls had a greater T_{re} increase toward the end of a 30 min exercise session, and the authors[6] suggested that it could be due to the greater muscle mass compared to that of the obese group. In the present study, the mean absolute fat free mass was similar between groups (33.3 vs. 30.9 kg), although the % fat was almost twice that of the lean girls (40.5 vs. 24.0). Such similar absolute muscle mass of the obese and lean girls could explain their similar T_{re} responses. The present study's cycling protocol properly achieved the goal of having the girls exercising at similar $\dot{H}_p$. Leites et al.[6] showed that lean girls completed the exercise-in-the heat protocol with a mean T_{re} 0.2 °C higher than the obese ones. It is possible that this difference occurred due to differences in exercise intensity (%$\dot{V}O_2$ vs. $\dot{H}_p$). Recently, $\dot{H}_p$ by body mass method has been suggested[12] to achieve similar heat storage when comparing thermoregulatory responses. Previous studies[11] may have been biased by setting an exercise intensity protocol as a % $\dot{V}O_{2peak}$ and absolute workload to compare groups that vary in their physical fitness.

The present authors are unaware of any other study in adolescents that compared girls with distinct adiposity and aerobic fitness levels under an exercise protocol that is based on similar $\dot{H}_p$ and heat stress. The current study suggests the use of $\dot{H}_p$ by unit of body mass as an exercise protocol when comparing thermoregulatory responses between lean and obese girls, regardless of their aerobic fitness. Previous studies that compared groups (adults) with high and low adiposity,[9] lean and obese,[27] or with high and low aerobic fitness,[28] found no T_{sk} difference between groups. Therefore, it appears that adiposity and aerobic fitness do not influence T_{sk} responses when a mild-to-moderate exercise intensity protocol is set by a given $\dot{H}_p$ per unit body mass.

The sweat volume showed great individual variability among the girls, as previously described,[29] resulting in similar mean values among the lean/obese and fit/unit groups, even when corrected by BSA. This agrees with what was found in prepubertal girls[6] and in pubertal boys.[2]

Regardless of the adiposity levels, adolescents appear to produce similar volumes of sweat by BSA when exercising in the heat.

Few studies gave evaluated perceptual responses of obese children and adolescents during exercise in heat.[2,6] In the present study, all groups perceived the exercise as mild. They reported a low-to-moderate irritability, despite feeling a warm and uncomfortable ambient temperature. Differently, Leites et al.[6] found that lean girls presented greater irritability during the exercise. Previous studies showed differences in RPE between lean and obese boys exercising in the heat.[15,30] Obese boys also felt worse thermal comfort (8 vs. 5) compared to lean boys during exercise in the heat.[2] It is possible that perceived responses are related to exercise intensity as well as gender. It is important to emphasize that exercise intensity was set to be low-to-moderate so that girls who are obese and sedentary could complete the exercise in the heat.

Regardless of the adiposity or aerobic fitness level, pubescent girls had similar thermoregulatory (T_{re}, T_{sk}), sweating (sweat volume and water balance), and perceptual responses (RPE, irritability, thermal sensation, and comfort) while cycling under heat stress during 50 min at a 5.4 W.kg^{-1}.

Conflicts of interest

The authors declare no conflicts of interest.

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