Responses of Obese and Lean Girls Exercising under Heat and Thermoneutral Conditions

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Objective To compare thermoregulatory and perceptual responses between lean and obese girls during and after exercise under heat (HC) and thermoneutral (TC) conditions.

Study design In a randomized order, 27 girls (14 lean [16.6 ± 6.7% fat and 9.1 ± 1.3 years] and 13 obese [41.3 ± 6.7% fat and 9.4 ± 1.1 years]) cycled 30 minutes at ~55% peak oxygen uptake in 2 sessions, which only differed in the thermal conditions (35°C and 40% relative humidity vs 24°C and 50% relative humidity).

Results Initial rectal temperature (T_{re}) was higher in obese versus lean during HC (37.5 ± 0.3°C vs 37.3 ± 0.3°C, $P = .03$) and TC (37.6 ± 0.3°C vs 37.3 ± 0.2°C; $P = .03$) sessions. During cycling, T_{re} remained higher in the obese, but the rate of increase was greater in the lean. This change occurred mainly in the HC, when final T_{re} of the lean surpassed that of the obese (37.8 ± 0.2 vs 38.0 ± 0.2°C, $P = .04$). Sweat volume (in $mL \cdot m^{-2}$) was similar between lean and obese in the HC (167 ± 119 and 120 ± 145) and TC (200 ± 196 vs 72 ± 20). Heart rate, rate of perceived exertion, and thermal sensation were similar between groups, independent of the thermal condition. Cycling in HC produced decreased thermal comfort ($P = .009$) and increased irritation ($P = .02$) within the lean girls.

Conclusion Thermoregulatory and perceptual responses of prepubescent obese girls during 30 minutes of cycling at a similar relative intensity do not seem to be impaired when comparing with a lean group either in TC or HC. *(J Pediatr 2013;162:1054-60)*.

Obesity in the pediatric population has been considered one of the various risk factors for exertional heat illness.[1] This is because obese children may present thermoregulatory[2] and perceptual[3-5] disadvantages, apart from the consequences of a lower physical fitness,[1] compared with their lean peers while exercising in the heat. However, thermoregulatory and perceptual responses, such as core temperature (T_{core}) and thermal sensation, between obese and lean girls with similar level physical activity have yet to be clarified.

Dougherty et al[3] demonstrated that sweat volume per body surface area (BSA) was lower in obese boys compared with their nonobese peers, indicating that evaporative cooling could be reduced in obese children. Haymes et al[2,6] found that the absolute amount of sweat was similar in overweight/obese and lean/nonobese girls and boys, but the sweat volumes in these studies were not adjusted for BSA.

Studies comparing thermoregulatory responses between lean and obese boys who exercised in HC of 35°C, 45% relative humidity (RH)[5] and HC of 38°C, 50% RH[3] at similar relative efforts (ie, percentage of peak oxygen uptake [VO_{2peak}]) found no difference in either rectal[5] or intragastric[3] temperatures. Despite similar body T_{core}, the obese boys in both studies[3,5] experienced greater heat sensation, as well as greater rate of perceived exertion (RPE). A greater heat sensation may affect thermal comfort of obese children while exercising. It is not clear, however, whether the warm environment is the main factor for a greater heat sensation of these obese children.

Comparable information is less clear in girls. When lean girls were compared with overweight girls during exercise in the heat (32.2°C and 13% RH), the lean showed a greater increase in rectal temperature (T_{re}) than their overweight/obese peers.[2] In this study, however, groups walked at the same absolute speed, and no perceptual responses were evaluated. Thus, the purpose of this study was to compare the thermoregulatory and perceptual responses of physically active prepubertal lean and obese girls during and after cycling at similar relative intensity under heat (HC) and thermoneutral (TC) conditions.

BSA	Body surface area
HC	Heat condition
HR	Heart rate
RH	Relative humidity
RPE	Rate of perceived exertion
TC	Thermoneutral condition
T_{core}	Core temperature
T_{re}	Rectal temperature
USG	Urine specific gravity
VO_2	Oxygen uptake
VO_{2peak}	Peak oxygen uptake

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Methods

A total of 27 prepubertal girls (14 lean and 13 obese) between 7 and 11 years of age participated in this study. Sample size was calculated with statistical power at 95% and level of significance at 5% (PEPI 4.0, Abramson JH, Gahlinger PM; Sagebrush: Salt Lake City, Utah) based on T_{re} from studies with obese and nonobese boys[2,5] and resulting in 12 participants per group. The body fat obtained from dual energy X-ray absorptiometry (Lunar GE Pencil Bin, SmartScan pediatric program, v. 4.7c; GE Medical Systems Luna, Kouterveldstraat, Diegem, Belgium) was used to classify the girls as either lean or obese (≤25 or ≥30 percent fat).[7] Inclusion criteria required the girls to be physically active (Physical Activity Questionnaire for Older Children) and not diagnosed with any chronic disease, except obesity. The girls were not using any medication that would affect their cardiovascular or thermoregulatory responses (health questionnaire). The physical characteristics of the groups are listed in the **Table**.

This study was approved by the Research Ethics Committee of the Federal University of Rio Grande do Sul. The participants and their guardians were informed and freely signed consent forms.

The study consisted of a preliminary session and 2 experimental sessions. All procedures were conducted between January and April, which are predominantly warm months (28-42°C and 40%-95% RH) in southern Brazil. The girls were naturally exposed to the heat as they used to practice similar outdoor activities. The environmental conditions in the previous 2 months (November and December) ranged from 19.9-29°C and 75%-82% RH. Data were obtained from the National Meteorological Institute.

Table. Physical characteristics, gradual exercise test, and level of physical activity of lean and obese girls

Characteristics	Lean (n = 14)	Obese (n = 13)
Age (y)	9.1 ± 1.3	9.4 ± 1.1
Body mass (kg)	25.4 ± 4.6	40.6 ± 8.8*
Height (cm)	131.5 ± 8.7	134.4 ± 5.9
Fat (%)	16.6 ± 6.7	41.3 ± 7*
Fat mass (kg)	4.2 ± 1.9	16.6 ± 6*
Muscle mass (%)	79.9 ± 5.0	56.9 ± 6.2*
Muscle mass (kg)	20.1 ± 2.9	22.7 ± 3.0*
Leg muscle mass (kg)	6.6 ± 1.2	7.7 ± 1.2*
Bone mass (kg)	1.1 ± 0.2	1.3 ± 0.2*
BSA (m^2)	1.0 ± 0.12	1.2 ± 1.14*
BSA/body mass ($m^2 \cdot kg^{-1}$)	0.038 ± 0.002	0.030 ± 0.003*
Gradual exercise test		
VO_{2peak} ($mL \cdot min^{-1}$)	1.120 ± 360	1.450 ± 270*
VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$)	44.9 ± 8.5	36.0 ± 8.5*
VO_{2peak} ($mL \cdot kg^{-1}$ $^{TMM.min-1}$)	60 ± 10	70 ± 10
VO_{2peak} ($mL \cdot kg^{-1}$ $^{LEMM.min-1}$)	184 ± 34	192 ± 33
HR_{max} ($beats \cdot min^{-1}$)	184 ± 14	188 ± 10
$Load_{max}$ (watt)	86.7 ± 16	88.5 ± 13
RER_{max}	1.1 ± 0.1	1.1 ± 0.1
Level of PA (PAQ-C)	3.4 ± 0.6	3.2 ± 0.4

HR_{max}, maximum heart rate at VO_{2peak}; *LEMM*, lower extremities muscle mass; *$Load_{max}$*, maximum load at VO_{2peak} test; *PA*, physical activity; *PAQ-C*, Physical Activity Questionnaire for Older Children; *RER_{max}*, maximum respiratory exchange rate at VO_{2peak}; *TMM*, total muscle mass. Values are expressed as mean ± SD.
*$P < .05$.

Physical activity was assessed using the Physical Activity Questionnaire for Older Children,[8] which classifies children as active or sedentary according to an average score of ≥3 and <3, respectively. The girls were also questioned about their outdoor physical activity. Stage 1 of biologic maturation (prepubertal) was confirmed through observation of breast and pubic hair development.[9] Height (stadiometer, Urano PS 180A, 0.01-m resolution; Urano, Canoas, Rio Grande do Sul, Brazil) and body mass (G-TECH scale, model Glass 3 control, 0.05 kg; G Tech Technology Ltd, Zhuhai, Guangdong, China) were assessed wearing minimal clothing (shorts and tops but no shoes). The BSA was determined using the Dubois and Dubois equation.[10]

To determine VO_{2peak}, incremental exercise testing was conducted on a cycle ergometer (Ergo Fit 167, 5-watt resolution; ERGO-FIT, Pirmasens, Germany) using the McMaster protocol.[11] The test began at 25 watts and had 25-watts increments every 2 minutes while maintaining a 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 the peak was considered the greatest oxygen uptake (VO_2) value. The test ended when 2 of the 5 following criteria were reached: (1) request by a girl to suspend the test; (2) inability to maintain a cycling cadence above 60 rpm; (3) heart rate (HR) (Polar S610; Polar Electro Oy, Kempele, Finland) >200 $beats \cdot min^{-1}$; (4) RPE > 19; and (5) respiratory exchange rate >1.0. The VO_{2peak} was also corrected for the total muscle mass and the mass of the lower extremities to avoid a confounding effect of fat mass and total body mass.[12-14]

The girls were instructed to refrain from any strenuous physical activity 24 hours prior to the experimental sessions and not to change their normative eating habits between sessions.

The experimental protocol was identical for the 2 sessions (**Figure 1**) aside from the environmental conditions (HC or TC) for which the order was randomized.

Sessions occurred in the morning, and the girls ate a standardized breakfast that included 2 portions of white bread (40 g), 1 portion of jelly (15 g), and a total of 400 mL of fruit juice and chocolate milk. To evaluate the initial state of hydration, a urine sample was collected to measure the urine specific gravity (USG) (Atago refractometer, 2722-E04; at a resolution of 1.000 to 1.050 density; ATAGO CO Ltd, Tokyo, Japan) and color[15] using an 8-point scale that ranges from very pale yellow (number 1) to brownish green (number 8). Body mass was measured. A HR monitor (Polar S610; Polar Electro Oy HQ) was used, and T_{re} was measured using a flexible thermometer (Ret-1; Physitemp Instruments, Inc, Clifton, New Jersey) with a disposable cover, inserted 10-12 cm beyond the anal sphincter.

The girls received standardized instructions regarding the use of the following 3 perceptual evaluations: thermal sensation, thermal comfort,[16] and irritability.[17] The thermal sensation was categorized on a 9-point scale ranging from very cold to very hot. The thermal comfort scale consisted of 6 points ranging from very comfortable to very uncomfortable,