EXERCISE TRAINING DOES NOT INFLUENCE WHOLE BODY HEAT STORAGE DURING EXERCISE IN PREVIOUSLY SEDENTARY INDIVIDUALS

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INTRODUCTION

Short-term exercise training improves cardiorespiratory fitness (i.e.VO_{2max}), body composition (i.e. % body fat), and has been linked with improvements to neuromuscular, metabolic, and endocrine functions (4). Further, exercise has been linked to improvements in the capacity of heat dissipation as evidenced by increases in local sweating and skin blood flow and reduced core temperature response during heat exposure. Repeated bouts of exercise create a thermal challenge which is thought to elicit adaptive changes in sudomotor and vasomotor activity similar those associated with heat acclimation (2, 3, 5, 8). However, there remains controversy regarding the effects of exercise per se on thermoeffector heat loss responses (1, 6, 10, 11). A possible reason for this discrepancy may be related to the experimental design itself. Some studies employed a parallel group design, comparing untrained and trained individuals whereas others employed a pre- and post-treatment study design (i.e., pre-treatment condition served as study control). In these studies, comparisons of thermoregulatory response were conducted during exercise performed in the heat. However, if differences in physical fitness were not considered when determining the exercise work rate, this can lead to erroneous conclusion.

The following study was conducted to compare the rates of whole-body evaporative and dry heat loss as well as the change in body heat content during 60-min of moderate intensity exercise performed at a constant rate of metabolic heat production prior to and following an 8-week exercise-training program.

METHODS

Following approval of the experimental protocol from the University of Ottawa Research Ethics Committee and obtaining written informed consent, 10 healthy sedentary participants (7 males, 3 females; age: 20 ± 4 years; body mass: 72.6 ± 15.3 kg; body fat: 24.04 ± 6.43%; body surface area: 1.84 ± 0.22 m^2; VO_{2max}: 47.7 ± 4.7 mL/kg/min) volunteered to participate for the study. Participants were not regularly engaged in physical activity for more than thirty minutes of exercise, two days per week for the last six months.

All participants who volunteered were required to participant in three separate laboratory testing days. On testing day 1, body adiposity and VO_{2max} were measured. Maximal oxygen consumption was measured during a progressive treadmill running protocol. The hydrostatic weighing technique was used to determine body density. Calculation of the percentage of body fat was based on the Siri equation (12) Also, during this session, the subjects were familiarized with all procedures to be performed during the investigation period.

Testing days 2 and 3 were performed prior to and following an 8-week exercise training protocol. During these study visits, the calorimeter experimental exercise protocol was performed. The modified Snellen direct air calorimeter was employed for the purpose of measuring the rate of evaporative and dry heat loss for the measurement of rate of total heat loss. Rate of metabolic heat production was measured using simultaneous indirect calorimetry (7).

Local heat loss responses of sweating and skin blood flow and rectal temperature were measured continuously. Local sweat rate was measured on upper trapezius using the ventilated capsule technique. Sweat rate was defined as the product of the difference in water content between effluent and influent air and the flow rate adjusted for the skin surface area under the capsule (expressed in $mg/cm^2/min$). Forearm skin blood flow (SkBF) was estimated using laser-Doppler velocimetry (PeriFlux System 5000, main control unit; PF5010 LDPM, function unit; Perimed, Stockholm, Sweden). At the end of the experiment, a heating element (PF 5020 temperature unit, Perimed) which houses the laster-Doppler flow probe, was activated to elevate local skin temperature to 42°C until maximum SkBF was measured.

All calorimeter trials were performed at the same time of day. Participants were asked to arrive at the laboratory after eating a small breakfast (i.e. dry toast and juice), but consuming no tea or coffee that morning, and also avoiding any major thermal stimuli on their way to the laboratory. Participants were also asked to not drink alcohol or exercise for 24 h prior to experimentation. For all experimentation, clothing insulation was standardized at ~0.2 to 0.3 clo (i.e. cotton underwear, shorts, sandals, and a sports bra for females). Following instrumentation, the participant entered the calorimeter regulated to an ambient air temperature of 30ºC and 15% relative humidity. The participant, seated in the semi-recumbent position, rested for a 60-min habituation period while a steady-state baseline resting condition was achieved. Subsequently, the participant performed semi-recumbent cycling at a constant rate of metabolic heat production 450 ± 30 W for 90-min or until volitional fatigue (minimum of 60-min).

Between testing days 2 and 3, participants underwent an 8-week exercise training program. Participants attended 4-5 supervised exercise-training sessions per week. The training sessions consisted of both aerobic and resistance training. Aerobic training included treadmill, stationary bike or elliptical machine exercise. The duration of the aerobic session increased progressively from 30 minutes per session in week 1 to 90 minutes per session in week 8 (including warm-up and cool-down time). The aerobic exercise component consisted of both continuous steady state training (between 55-75% of the participant's pre-determined heart rate reserve) and interval training (between 75-90% of the participant's pre-determined heart rate reserve). A circuit training program was performed for the resistance training component of the session which involved both stationary and free weights. Subjects performed 7-10 different exercises on weight machines or free weights at the maximum weight that could be lifted 12 to 15 times.

A two-way analysis of variance with repeated measures was performed to analyze the whole-body and local heat loss responses using the repeated factors of state of training (i.e., before and after the eight-week training program) and exercise time (2, 5, 8, 12, 15, 30, 45, 60, 90 min). Paired sample t-tests were used to perform pair-wise post-hoc comparisons as well as to compare changes in body heat content. Significance was assumed for $p < 0.05$.

RESULTS

All participants completed the 8-week exercise training program. Significant increases in VO_{2max} occurred over the eight-week training period; from 49.1 ± 4.7 to 53.8 ± 4.1 mL/kg/min ($p<0.001$), an equivalent increase of 10%. There was a trend ($0.05<p<0.10$) for percentage of body fat to be lower following the training program (22.5±7.3%) compared to pre-training (24.0±6.4%) ($p=0.069$) which was associated with a lower body mass (71.9±14.2kg, 72.6±15.3kg, $p=0.074$).

Due to the experimental protocol, the rate of metabolic heat production was not different during the pre- and post-training trials ($p=0.526$) as depicted in figure 1. This corresponded to a lower relative work rate of 6% (i.e., 46% to 40% of their pre-determined VO_{2max}) post- relative to pre-training ($p<0.001$). Exercise training did not modify whole-body heat loss between the pre- and post-training period ($p=0.140$) (Figure 1). Likewise, there was no main effect of training for evaporative ($p=0.171$) and dry ($p=0.121$) heat loss. No differences in the change in body heat content were observed at the end of exercise between pre- (441 ± 28 kJ) and post-training (430 ± 38 kJ) ($p=0.385$).

No differences in local sweat rate or skin blood flow was measured during exercise between the pre- and post-training periods. The temporal pattern of response was similar between pre- and post-training trials.

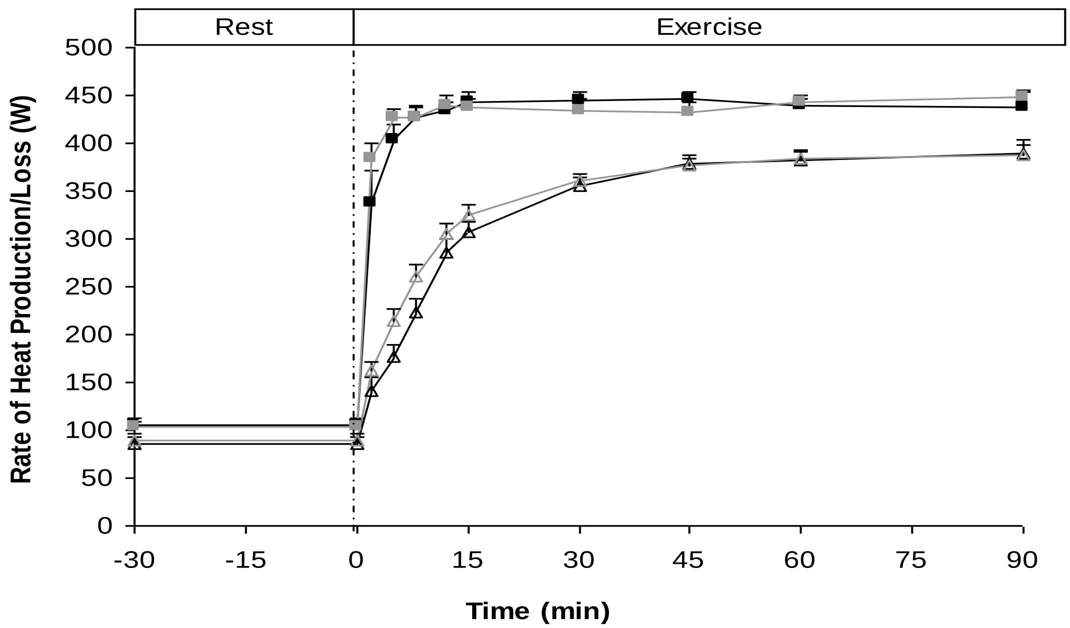

Figure 1. Mean whole-body calorimetry data for rate of metabolic heat production (pre-training (■) and post-training (▲)) and rate of total heat loss (pre-training (□) and post-training (∆)). Error bars indicate standard errors.

CONCLUSIONS

We show that while an eight-week exercise training program results in significant improvements in cardiorespiratory function, there were no observed improvements in whole-body and local heat loss responses. This was evidenced by similar whole-body heat loss responses and resultant changes in body heat content during exercise performed in the heat prior to and following an 8-week training program. Future studies should consider adjusting the rate of metabolic heat production when comparing exercise responses in order to match the heat load prior to and after a training intervention. This will allow researchers to study the effects of local heat loss responses due to exercise training during the same thermal stimulus. Since it has been reported that training during heat exposure will have a greater effect on local sweat rate and skin blood flow than just training alone in a non-heat stressed environment (5, 11, 13), further studies are needed to determine the effects of a passive heat exposure alone and in combination with exercise on whole-body heat loss. It is possible that the 8-week training program may have been too short in duration to induce thermal adaptations consistent with increases in the local heat loss responses of sweating and skin blood flow in endurance trained athletes. It is possible that a longer and/or more intense training program may be required to elicit significant improvements in heat tolerance. In the present study only individuals of moderate fitness were evaluated. As such, these results should be not generalized across all fitness levels.

In summary, our findings support current empirical evidence which suggests that exercise alone may be an insufficient stimulus to induce improvements in the capacity for heat dissipation (2). Indeed, exercise performed in the heat is likely the best stimulus for enhancing heat loss responses during work in the heat.

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REFERENCES

1. **Gisolfi C**. Work-heat tolerance derived from interval training. *J Appl Physiol.* 1973;35:349-354.
2. **Gisolfi C, Robinson S**. Relations between physical training, acclimatization, and heat tolerance. *J Appl Physiol*. 1969;26:530-534.
3. **Henane R, Flandrois R, Charbonnier JP**. Increase in sweating sensitivity by endurance conditioning in man. *J Appl Physiol: Resp and Environ Exer Physiol*. 1977;43:822-828.
4. **Jones AM, Carter HC.** The effect of endurance training on parameters of aerobic fitness. *Sports Med.* 2000;29:373-386.
5. **Nadel ER, Pandolf B, Roberts MF, Stolwijk AJ**. Mechanisms of thermal acclimation to exercise and heat. *Journal of Applied Physiology.* 1974;37:515-520.
6. **Nielsen B, Hales JRS, Strange S,Juel CN, Warberg J, Saltin B.** Human circulatory and thermoregulatory adaptations with heat acclimation and exercise in a hot, dry environment. *J Physiol (Lond).* 1993;460:467-485.
7. **Nishi Y**. Measurement of thermal balance in man. In: Cena K, Clark J (eds) Bioengineering, thermal physiology and comfort. Elsevier, New York, 1981; pp 29–39
8. **Roberts MF, Wenger CB, Stolwijk JA, Nadel ER**. Skin blood flow and sweating changes following exercise training and heat acclimation. *J Appl Physiol*. 1977;43:133-137.
9. **Reardon FD, Leppik KE, Wegmann R, Webb P, Ducharme MB, Kenny GP**. The Snellen human calorimeter revisited, re-engineered and upgraded: Design and performance characteristics. *Med and Biolog Eng Comp*. 2006;44:721-728.
10. **Shields CL, Giesbreech GG, Pierce GN, Ready AE**. The effect of a moderate physical activity program on thermoregulatory responses in a warm environment. *Can J Appl Physiol*. 2004;29:379-394.
11. **Shvartz E, Saar E, Meyerstein N, Benok D**. A comparison of three methods of acclimatization to dry heat. *J ApplPhysiol*. 1973;34:214-219.
12. **Siri WE**. Body composition from fluid space and density. In J. Brozek & A. Hanschel (Eds.), *Techniques for measuring body composition.* Washington, DC: National Academy of Science. 1961. pp. 223-244.
13. **Strydom NB, Wyndham CH, Williams CG, Morrison JF, Bradell GA, Benade AJ, Van Rahden GA.** Acclimatization to humid heat and the role of physical conditioning. *J Appl Physiol.* 1966;21:636-642.