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Acute Metabolic Responses of Exercise with a Sauna Suit

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Abstract

Introduction: The purpose of this short report was to examine the acute metabolic responses of exercise with a sauna suit (SS) under different exercise intensity and duration conditions. **Methods:** Twelve physically active men (age = 27.1±7.5 yrs, height = 175.4±6.3 cm, weight = 75.6±7.9 kg, maximal oxygen uptake – VO_2max = 38.6±7.8 $mL \cdot kg^{-1} \cdot min^{-1}$) completed four experimental trials on a cycle ergometer: 1) 30min moderate-intensity (MI) exercise (55-60% heart rate reserve–HRR) with SS, 2) 20min vigorous-intensity (VI) exercise (75-80% HRR) with SS, 3) 30min MI exercise (55-60% HRR) without a sauna suit (CON), and 4) 20min VI exercise (75-80% HRR) CON. Trials were separated by 24-96 hours and performed in randomized order. Exercise energy expenditure (EE), one hour excess post-exercise oxygen consumption (EPOC), and one hour post-exercise weight loss (PEWL) were measured for each trial. **Results:** There were significant differences ($p<0.05$) in exercise EE, one hour EPOC and one hour PEWL between SS and CON under both MI and VI conditions. MI results: exercise EE was greater with SS vs. CON (282.6±34.7 kcal vs. 247.8±40.2 kcal), one hour EPOC was greater with SS vs. CON (69.9±4.3 kcal vs. 45.2±3.0 kcal), and the SS condition resulted in greater change in one hour PEWL (0.52±0.14 kg vs. 0.37±0.15 kg). VI results: exercise EE was greater with SS vs. CON (204.7±24.2 kcal vs. 184.6±21.3 kcal), one hour EPOC was greater with SS vs. CON (87.7±7.0 kcal vs. 72.1±3.4 kcal), and the SS condition resulted in greater change in one hour PEWL (0.63±0.15 kg vs. 0.39±0.12 kg). **Conclusions:** Our findings support the feasibility of exercise training with a sauna suit–and the amplified exercise energy expenditure and EPOC–to contribute to long-term energy balance and thus improve cardiovascular health.

Key Words: Cardiovascular Health, Energy Expenditure, EPOC, Hyperthermic Conditioning, Weight Maintenance

Introduction

Cardiovascular disease (CVD) is the leading cause of death worldwide, accounting for 17.3 million deaths per annum, a figure that is projected to grow to more than 23.6 million by 2030[1]. It has been estimated that 80% of premature heart disease can be prevented through positive modification of CVD risk factors[2]. In particular, regular physical activity has been shown to confer a myriad of health benefits with research demonstrating a general dose-response relationship between energy expenditure and multiple CVD risk factors, including cardiorespiratory fitness, type 2 diabetes, and obesity[3]. The overall energy expenditure from exercise consists of both the energy expenditure during exercise itself and an increased caloric expenditure above resting metabolic rate that persists into the recovery period[4]. The elevated post-exercise energy expenditure is a phenomenon known as excess post-exercise oxygen consumption (EPOC). Given that EPOC contributes approximately 10% to overall exercise energy expenditure[5] it's an important parameter to account for when designing and evaluating the effectiveness of exercise training programs.

Contemporary evidence has demonstrated that systemic thermal therapy by regular administration of heat through a variety of methodologies (e.g., sauna and hot tub) affords a number of advantageous responses with respect to cardiovascular health. Indeed, chronic exposure to heat stress (in the form of sauna bathing) has been reported to be associated with a reduced risk of cardiovascular disease and mortality from all-causes[6]. Additionally, it has also been reported that heat therapy reduces fasting glycemia, glycated hemoglobin, body weight, and adiposity[7]. Moreover, there is also evidence that exercise in conjunction with heat therapy provides cardiovascular health benefits. For instance, it has been demonstrated that 3 weeks of post-exercise sauna bathing elicits an improvement in cardiorespiratory fitness, most likely due to an increase in plasma volume[8].

A practical and more portable heat treatment strategy may be use of a sauna suit; however, to our knowledge, no studies have investigated the combined effects of exercise training with a sauna suit on exercise metabolism and EPOC. Previous research has demonstrated that submaximal exercise performed in simulated heat stress conditions elicits an increase in exercise oxygen consumption (VO_2) and numerous factors that are known to contribute to a greater EPOC[9]. Hence, it is plausible that exercise in conjunction with a sauna suit may elicit a more pronounced increase in exercise energy expenditure and a concomitant greater EPOC. Nevertheless, research to quantify these specific responses is currently lacking. In this study we examined the acute metabolic responses of exercise with a sauna suit under different exercise intensity and duration conditions.

Methods

Participants

Twelve physically active men (mean ± SD age, height, weight, and maximal oxygen uptake (VO_2max): 27.1 ± 7.5 yrs, 175.4 ± 6.3 cm, 75.6 ± 7.9 kg, 38.6 ± 7.8 mL/kg/min respectively) participated in this study. Participants were eligible for inclusion into the study if they were low risk and physically active as defined elsewhere[3]. Exclusionary criteria included evidence of cardiovascular pulmonary, and/or metabolic disease. This study was approved by the Human Research Committee at Western State Colorado University in accordance with international standards and all participants gave their written informed consent[10].

Maximal exercise test

Participants completed an incremental maximal exercise on a cycle ergometer (Viasprint 150P; Sensormedics Corp., Palm Springs, CA) during which gas exchange data, power output, and maximal heart rate (HR) were assessed. Initially, participants rested quietly for 5min in a seated position to obtain resting HR. Participants completed 2 minutes of pedaling at 50 Watts as a warm up. Workload was then increased in a steplike manner equal to 8-12 Watts/20 seconds to elicit volitional fatigue in approximately 10-12 minutes. The specific workload increment for each test was matched to participant fitness level. Pedal cadence was maintained at 70-90 revolutions/minute, with volitional fatigue representing a failure to sustain pedal cadence greater than 40 revolutions/minute.

Prior to each maximal exercise test, the Oxycon Mobile (CareFusion, Yorba Linda, CA) portable calorimetric measurement system was calibrated with gases of known concentrations (16.02% O_2, 4.00% CO_2) and with room air (20.93% O_2 and 0.03% CO_2) as per the manufacture guidelines. Calibration of the pneumotachometer was done via a 3 Litre calibration syringe (Hans-Rudolph, Kansas City, MO). Throughout the maximal exercise test continuous gas exchange data was obtained. In order to determine VO_2max from the maximal exercise test, the final 15 seconds of data were averaged constituting the final data point. The next closest data point was calculated by averaging the data during the 15 seconds prior to the final 15 seconds. The VO_2max was represented by the mean of the 2 processed data points provided a plateau was exhibited ($\Delta VO_2 \leq 150$ mL/min)[11].

Experimental Design

Participants next completed four experimental trials: (1) 30min moderate-intensity exercise (55-60% heart rate reserve – HRR) with a sauna suit, (2) 20min vigorous-intensity exercise (75-80% HRR) with a sauna suit, (3) 30min moderate-intensity exercise (55-60% heart rate reserve – HRR) without a sauna suit (i.e., control), and (4) 20min vigorous-intensity exercise (75-80% HRR) without a sauna suit (i.e., control). Individual HRR was determined as the difference between resting HR and maximal HR values. Experimental trials were separated by 24-96 hours and performed in randomized order. All components of the experimental trials remained similar across all four trials except the exercise duration/intensity parameters and apparel (sauna suit vs. no sauna suit).

For each trial, participants arrived at our laboratory at either 6:00am, 8:00am, or 10:00am for a 2hr testing block following an overnight 8-12hr fast. Each participant completed each of their four trials at the same time of day. Participants were strictly instructed to avoid any physical activity whatsoever prior to arrival in the laboratory. Upon arrival participants were provided a standardized beverage (325 mL Nestle Carnation chocolate milk), attached to an Oxycon Mobile (CareFusion, Yorba Linda, CA) portable calorimetric measurement system, and placed in a seated position in a quiet room. Participants rested quietly for 30min while expired gases were collected. The final 10min of resting data were averaged and considered to be baseline resting VO_2. After the 30min rest period participants were weighed to the nearest 0.1kg and then placed on a cycle ergometer (Viasprint 150P; Sensormedics Corp., Palm Springs, CA). Participants completed the assigned experimental trial while continuous gas exchange data was collected, from which exercise energy expenditure was quantified using the VO_2 data. Immediately post-exercise participants were again weighed to the nearest 0.1kg and thereafter placed in a seated position. Participants subsequently rested quietly for 60min while post-exercise VO_2 was calculated from gas exchange data. Baseline VO_2 was deducted from the post-exercise VO_2 and the difference was determined to be the EPOC for each experimental trial. A final weight was recorded 1hr post-exercise. No water was permitted throughout each experimental trial other than the standardized beverage provided upon arrival. Furthermore, no movement was permitted across each experimental trial other than the prescribed exercise regimen.

Statistical analyses

All analyses were performed using SPSS Version 22.0 (Chicago, IL) and GraphPad Prism 6.0. (San Diego, CA). Measures of centrality and spread are presented as mean $\pm$ SD. Repeated-measures ANOVA were used to examine differences in exercise energy expenditure, EPOC, and weight loss across intensity (moderate vs. vigorous), with exercise condition (sauna suit vs. no sauna suit) used as a between-subjects factor. If a significant F-ratio was obtained, Tukey's post hoc test was used to identify differences between means. The probability of making a Type I error was set at $p < .05$ for all statistical analyses.

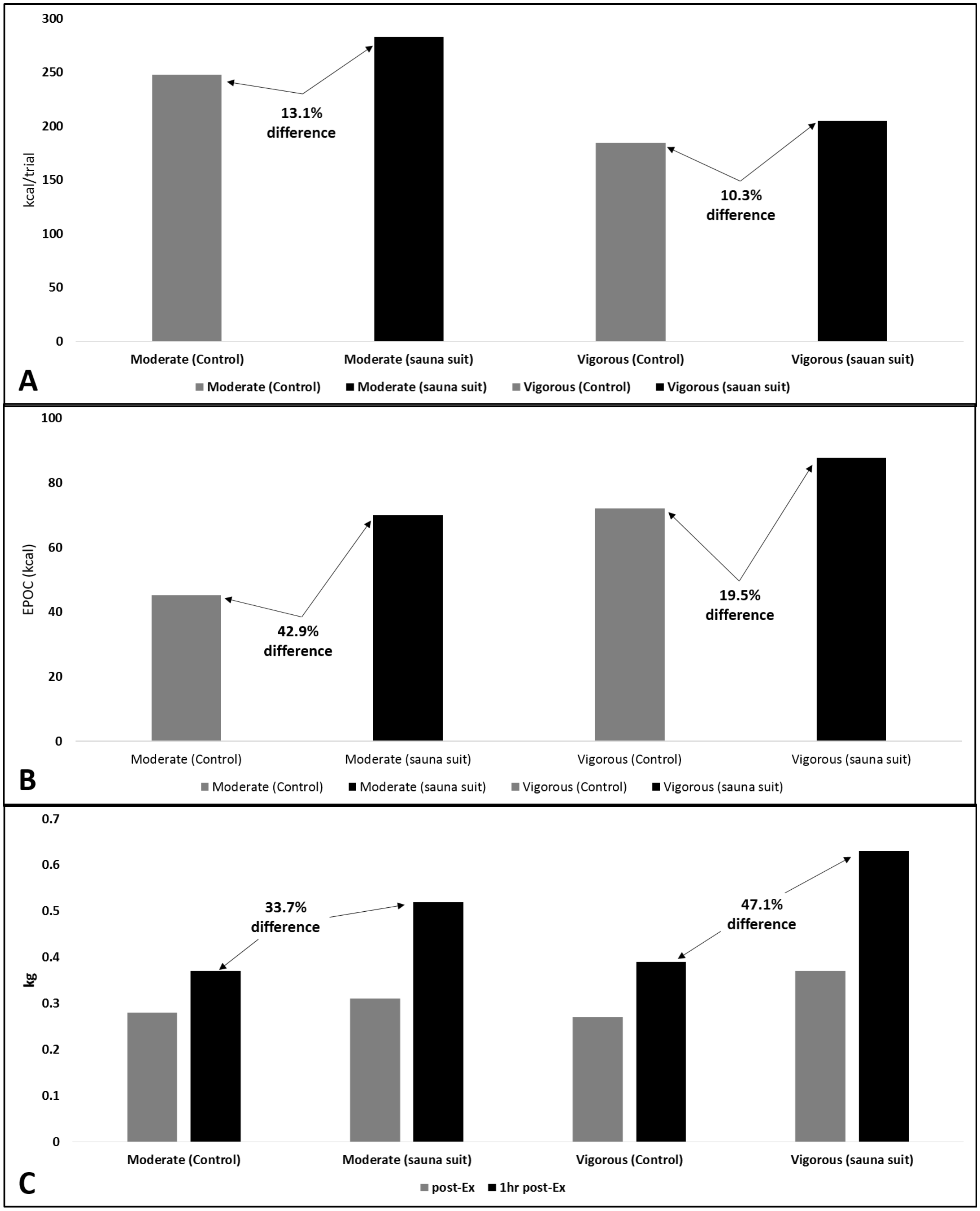

Figure 1. Acute metabolic responses (A – exercise energy expenditure; B – EPOC; C – post-exercise weight loss) to exercise under sauna suit and control conditions.

Results

The experimental trials was well tolerated for all 12 participants. Each of the 12 participants completed all 4 scheduled trials. Specifically, across 24 experimental trials involving exercise with a sauna suit that spanned a total of ~12 hours of moderate- and vigorous-intensity exercise, there were no adverse events experienced and all physiological and metabolic responses remained within normal ranges.

Exercise energy expenditure results

There were significant differences ($p < 0.05$) in the exercise energy expenditure when participants exercised with the sauna suit when compared to the control condition (Figure 1A). In the moderate-intensity exercise trial there was a **13.1%** greater caloric expenditure with the sauna suit vs. control condition (282.6±34.7 kcal vs. 247.8±40.2 kcal). Similarly, in the vigorous-intensity exercise trial there was a **10.3%** greater caloric expenditure with the sauna suit vs. control condition (204.7±24.2 kcal vs. 184.6±21.3 kcal). These differences existed despite the fact that participants maintained the same relative intensities for both moderate-intensity (55-60% HRR) trials and vigorous-intensity (75-80% HRR) trials during sauna suit and control conditions.

EPOC results

There was a significant increase ($p < 0.05$) in post-exercise metabolism, as evidenced by a greater EPOC, when participants exercised with the sauna suit when compared to the control condition (Figure 1B). In the moderate-intensity exercise trial condition there was a **42.9%** greater EPOC with the sauna suit vs. control condition (69.9±4.3 kcal vs. 45.2±3.0 kcal). Likewise, in the vigorous-intensity exercise trial condition there was a **19.5%** greater EPOC with sauna suit vs. control condition (87.7±7.0 kcal vs. 72.1±3.4 kcal).

Post-exercise weight loss results

There were significantly greater reductions ($p < 0.05$) in post-exercise weight loss values when participants exercised with the sauna suit when compared to the control conditions (Figure 1C). In the moderate-intensity exercise trial there was a **33.7%** greater decrease in post-exercise weight loss values with the sauna suit vs. control condition (0.52±0.14 kg vs. 0.37±0.15 kg). Similarly, in the vigorous-intensity exercise trial there was a **47.1%** greater decrease in post-exercise weight loss values with the sauna suit vs. control condition (0.63±0.15 kg vs. 0.39±0.12 kg).

Discussion

Previously, those studies that have tended to elicit a substantial EPOC (e.g., ~80-100 kcal) generally have consisted of regimens that are either high in intensity, long in duration, or both. In these scenarios it is questionable if an exercise program with these characteristics would be tolerated well by non-athletic populations. In fact, this particular issue can be underscored in a recent study[12] that required ten male participants to cycle for 45 minutes at an intensity of 73% VO_2max. The exercise bout itself resulted in an energy expenditure of 519 kcal. Energy expenditure remained elevated above resting levels for 14 hours postexercise with the total EPOC reported to be an impressive 190 kcal. However, the authors commented that the study protocol may be limited in its real world application as an exercise intensity of 70-75% VO_2max generally corresponds to the lactate threshold level of an endurance-trained individual.

An important methodological aspect of the present study is that the exercise trials completed were performed at durations (20min and 30min) and intensities (moderate and vigorous) that align with current widespread recommendations for physical activity[3]. Accordingly, it is much more probable that the exercise bouts performed in the present study could be adhered to on a regular basis. In turn, if the acute metabolic responses reported in the current study were projected long-term, in which an individual regularly performed a weekly standard exercise routine with a sauna suit, consisting of 2 sessions of vigorous-intensity exercise combined with 3 sessions of moderate-intensity exercise, each month there would be 1,000 more calories expended and each year approximately 2 kg of fat mass would be lost. These modest figures may have the potential to contribute to weight loss efforts and long-term energy balance (i.e., weight maintenance). Indeed, it has recently been reported that over the last 50 years in the United States (U.S.) that daily occupation-related energy expenditure has decreased by more than 100 calories, and this reduction in energy expenditure accounts for a significant portion of the increase in mean U.S. body weights for both women and men[13].

Conclusions

Our findings support the feasibility of exercise training with a sauna suit–and the amplified exercise energy expenditure and EPOC–to contribute to long-term energy balance and thus improve cardiovascular health.

Authors' contributions

The contributions of each author were as follows: LD contributed to manuscript writing, developing study concept and design, data acquisition, and data analysis; SV, IP, BB, JF, and LL contributed to manuscript revisions, data acquisition, and data analysis. All authors read and approved the final manuscript.

Competing interests

This investigation was supported financially by the American Council on Exercise (ACE). The American Council on Exercise (ACE) was not involved in development of the study design, data collection and analysis, or preparation of the manuscript. There are no other potential conflicts of interest related to this article.

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