Van de Velde et al. (2017) *Int J Res Ex Phys*. 13(1):1-11.

International Journal of Research in Exercise Physiology

Original Research Article

The Performance Benefits of Training with a Sauna Suit: A Randomized, Controlled Trial

Samuel S. Van de Velde[1], Bryant R. Byrd[1], Jennifer S. Fargo[1], Christina A. Buchanan[1], Lance C. Dalleck[1]
[1]High Altitude Exercise Physiology Program, Western State Colorado University, Gunnison, CO, USA

Abstract

Purpose: The purpose of this study was to quantify the performance-related benefits to training with a sauna suit. It was hypothesized that training with a sauna suit would elicit better improvements in maximal oxygen uptake (VO_2max), ventilatory threshold, and 5km time trial performance (in temperate and simulated hot environments). **Methods:** Apparently healthy and endurance-trained men and women (n=14) were match paired according to sex, VO_2max, and 5km personal best times and subsequently randomized to a control group and treatment group. Participants in both groups completed usual volume and intensity of training for 14 days with the treatment group performing all training sessions in a sauna suit. Participants performed a maximal exercise test and 2 x 5km time trials (in temperate and simulated hot environments) at baseline and post-training. Weight was obtained before and after time trial performances to quantify sweat rate. Additionally, body core temperature was monitored continuously throughout each time trial performance in both environmental conditions. **Results:** After 14 days of training with a sauna suit there were significant ($p < 0.05$) improvements in VO_2max (+9.1%) and ventilatory threshold (4.6%). The 5km time trial performances in both hot (52 sec) and temperate conditions (38 sec) were significantly faster ($p < 0.05$) in the sauna suit treatment group after 2wks of training. Relative to the control group, sweat rate and thermoregulation improved ($p < 0.05$) during the 5km heat time trial after 14 days of training with a sauna suit. **Conclusions:** Findings from the present study support the utility of training with a sauna suit as a novel form of heat acclimation. Indeed, the present study demonstrated that 14 days of training with a sauna suit elicited improvements in VO2max, ventilatory threshold, and time trial performances. A greater sweat rate and lower core temperature likely mediated improved time trial performances following training with a sauna suit.

Key Words: Heat Acclimation, Hyperthermic Conditioning, Maximal Oxygen Uptake, Time Trial

INTRODUCTION

Endurance-performance can be drastically impacted by various environmental stressors, including hot and/or humid conditions. Within the last several decades there has been an abundance of research looking at the physiological adaptations that take place with consistent heat exposure and how that might impact endurance performance[10]. Competing in hot environments (35°C) places an added environmental stressor on the human body[25]. Research in the field of thermoregulation has revealed that heat stress can impair performance during prolonged endurance exercise[6,12,23]. In some cases, time to exhaustion has been shortened due to increased body core temperature[6]. Therefore, a proposed mechanism for an early onset of fatigue during endurance performance in hot environments is elevated body core temperatures[3,6]. Indeed, it has previously been demonstrated that fatigue corresponds with body core temperatures of ~40° C[11,13]. To compensate for an increased body core temperature, heart rate and cardiac output for the same relative workload, all rise and increase burden on the cardiovascular system as blood flow is modulated to accommodate for the necessary heat loss[1].

Athletes and coaches are continuously seeking innovative ways to improve performance. One strategy for optimal performance is being adapted to the environment on competition day. For instance, if an individual is adapted to an environmental stressor like heat, and has consistently been exposed to the given environment, on the day of competition, the likelihood that environmental stressor will impact performance is minimized. Many championship events take place in hot environments in the middle of the day, such as the recent summer Olympics in Brazil. If individuals are not accustomed to performing in the heat, homeostasis will be disrupted quickly and performance will be compromised. Preparing the body to better cope with heat stress is a fundamental strategy to help optimize performance in heat[4]. Heat acclimation is the process of positive physiological adaptations occurring after an individual is exposed to repeated bouts of heat stress. Hallmark adaptations of heat acclimation have been revealed to produce: earlier onset of sweating, decreased heart rate, plasma volume expansion, and decreased body core temperature[9,14,19-20,25]. Endurance-trained individuals can begin to exhibit full heat acclimatization adaptations as quickly as 7-14 days upon consistent heat exposure during exercise[25]. For instance, it has been demonstrated that 10 days of repeated bouts of cycling at ~50% VO_2max in a room set to 40° C improved both cool (6%) and hot (8%) time trial performances[9].

Overall, the impact of heat acclimation to improve cardiovascular stability during exercise under heat stress has been well studied[9-10,18,20,24,26]. However, to our knowledge, no studies have investigated the effects of exercise training with a sauna suit on heat acclimation and performance. It is plausible that exercise training with a sauna suit may provide coaches and athletes with a practical and portable heat acclimation alternative when compared to other traditional strategies (i.e., relocation to hot climates or exposure to chamber-based artificial heat stress). Therefore, the purpose of this study was to quantify the performance-related benefits to exercise training with a sauna suit. It was hypothesized that exercise training with a sauna suit would elicit better improvements in maximal oxygen uptake (VO_2max), ventilatory threshold, and 5km time trial performance (in temperate and simulated hot environments).

METHODS

Participants

Fourteen (men n=12, women n=2) consented to participate in the study. Physical attributes of participants are presented in Table 1. Participants were eligible for inclusion into the study if they were low risk[17]. Exclusionary criteria included evidence of cardiovascular pulmonary, and/or metabolic disease. Participants had >6 yrs of endurance-training and competition experience and maintained weekly training loads ranging from 7 to 12 hrs. The study was conducted during a training phase when no competitions were planned. All participants were fully acclimatized to an altitude of 2350m. 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.

Table 1. Physical attributes of participants. (Values are mean ± SD).

Measure	Treatment (n=7)	Control (n=7)
Age (yrs)	27.0 ± 7.6	31.6 ± 12.1
Height (cm)	174.3 ± 3.4	171.0 ± 7.9
Weight (kg)	68.4 ± 6.7	70.6 ± 5.8

Experimental design

Participants completed a battery of physiological and performance assessments at baseline and post-program as shown in Figure 1. On the first visit participants performed a maximal exercise test to measure VO_2max The next visit was a 5km time trial performed on a treadmill in a simulated hot environment (~35° C). The third visit entailed a 5km time trial performed on a treadmill in temperate conditions (~18° C). All baseline and post-program measurements were obtained from each participant at similar times of the day (± 2 hours). All tests at baseline and post-program were separated by at least 48 hours. The order of testing for each participant was randomized to prevent an order effect. Participants were instructed to avoid consumption of alcohol or caffeine for at least 24 hours before each physiological measurement baseline and post-program.

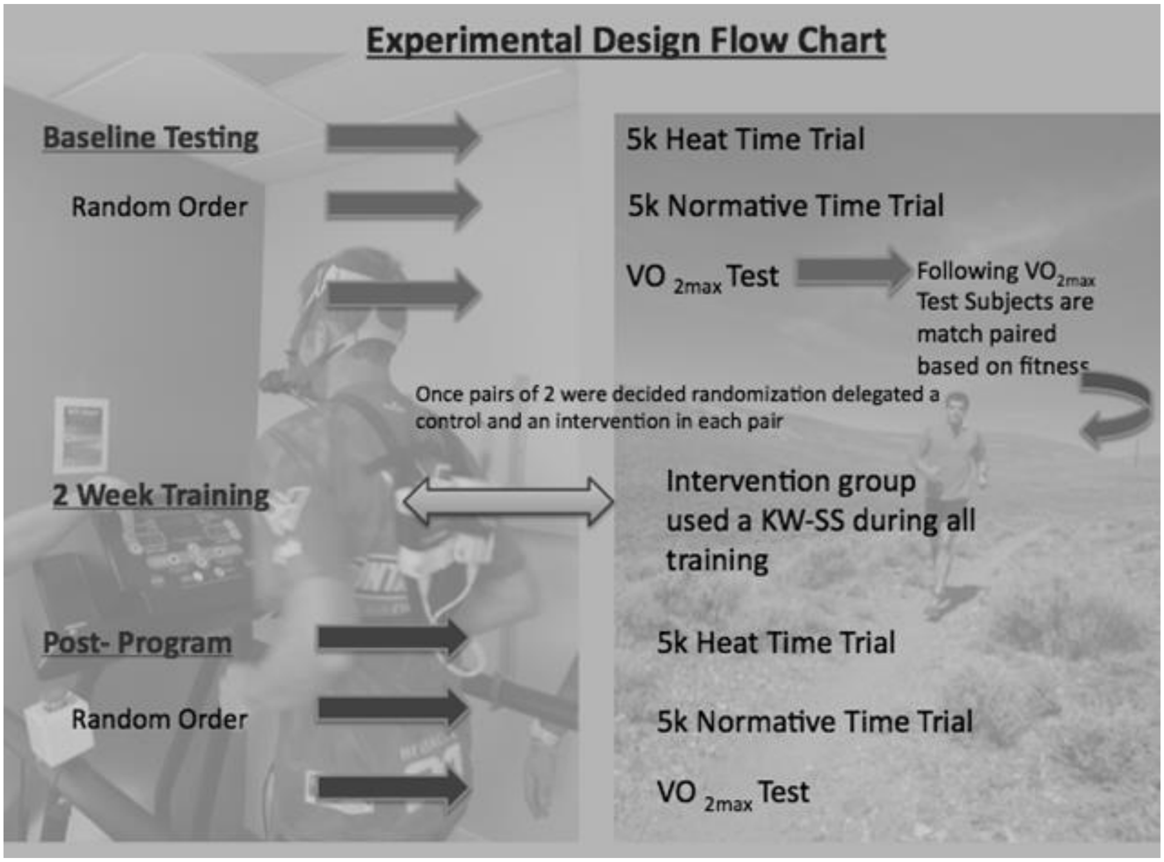

Figure 1. Flow chart of experimental procedures for each of the two groups (control and treatment). KW-SS, Kutting Weight sauna suit; VO_2max, maximal oxygen uptake.

After the completion of baseline testing, participants were initially match paired according to sex, VO_2max, and 5km personal best times and subsequently randomized to a control group and treatment group. Participants in both groups completed usual volume and intensity of exercise training for 14 days. Participants were instructed to log and maintain their usual training volume and intensity throughout the intervention. The treatment group was instructed to perform all training for the 14 day intervention wearing a sauna suit (Kutting Weight, LLC., Los Angeles, CA).

Protocols

Physical measurements

All physical measurements were obtained using standardized guidelines. Briefly, participants were weighed to the nearest 0.1 kg on a medical grade scale and measured for height to the nearest 0.5 cm using a stadiometer.

Maximal exercise test

Participants completed a modified-Balke, pseudo-ramp graded exercise test (GXT) on a power treadmill (Powerjog GX200, Maine). Participants ran at a self-selected pace. Treadmill incline was increased by 1%

every minute until the participant reached volitional fatigue. Participant heart rate was continuously recorded during the GXT via a chest strap and radio-telemetric receiver (Polar Electro, Woodbury, NY, USA). Expired air and gas exchange data were recorded continuously during the GXT using a metabolic analyzer (Parvo Medics TrueOne 2.0, Salt Lake City, UT, USA). Biological variability in VO2max was not quantified[7].

Gas exchange and data analysis

Prior to each maximal exercise test, the metabolic cart (TrueOne 2400, Parvo Medics, Sandy, UT) 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 pulmonary 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). Determination of both the first ventilatory threshold (VT1) and second ventilatory threshold (VT2) were made by visual inspection of graphs of time plotted against each relevant respiratory variable (according to 15 second time-averaging). The criteria for VT1 was an increase in VE/VO_2 with no concurrent increase in VE/VCO_2 and departure from the linearity of VE. The criteria for VT2 was a simultaneous increase in both VE/VO_2 and VE/VCO_2. Overall ventilatory threshold was recorded as the mean of VT1 and VT2. All assessments were done by two experienced exercise physiologists. In the event of conflicting results, the original assessments were reevaluated and collectively a consensus was agreed upon.

Temperate 5km time trial

Participants performed a 5km time trial on a treadmill at 1% grade in a temperate environment of ~18° C. Participants were instructed to give a maximal effort and pace was initially set to their 5k personal best pace to set the tone. Participants were instructed to arrive well-hydrated and consume 1L of water in the previous hour. Participants ingested CorTemp sensor pill 2-3 hours prior to the 5km time trial as suggested by the user manual. A resting body core temperature was first recorded then a near nude body weight (down to shorts) was recorded. Participants all performed self-selected pace 5-minute warm-up in a temperate condition on a treadmill prior to commencing the time trial. During the time-trial pace was self-selected by the subject throughout the whole time trial and they had access to adjust the speed. Total elapsed time was blinded to the participant throughout the time trial. No verbal feedback was provided throughout the time trial. Heart rate, rating of perceived exertion (RPE), body core temperature, and time was recorded every 400 meters, and at 5,000 meters. Near nude body weight was recorded immediately post time-trial.

<u>5km time trial in simulated heat</u>

Participants performed a 5k time trial on a treadmill at 1% grade in a simulated hot environment of 35° C. Participants were instructed to give a maximal effort and pace was initially set to their 5k personal best pace to set the tone. Participants were instructed to arrive well-hydrated and consume 1L of water in the previous hour. Participants ingested CorTemp sensor pill 2-3 hours prior to the 5km time trial as suggested by the user manual. A resting body core temperature was first recorded then a near nude body weight (down to shorts) was recorded. Participants all performed self-selected pace 5-minute warm-up in a temperate condition on a treadmill prior to commencing the time trial in the hot environment. During the time trial pace was self-selected by the subject throughout the whole time trial and they had access to adjust the speed. Total elapsed time was blinded to the participant throughout the time trial. No verbal feedback was provided throughout the time trial. Heart rate, RPE, body core temperature, and time was recorded every 400 meters, and at 5,000 meters. Near nude body weight was recorded immediately post time-trial.

Statistical analyses

All analyses were performed using SPSS Version 23.0 (Chicago, IL) and GraphPad Prism 6.0. (San Diego, CA). Measures of centrality and spread are presented as mean $\pm$ SD and percentage (%) change from baseline to post-program. Paired t-tests were used to compare the mean performance measures (VO_2max, ventilatory threshold, and 5km time trial performances) from baseline to post-program within each group (control and treatment). Independent t-tests were used to compare changes in performance measures between control and treatment groups. Repeated measures ANOVA were used to examine possible differences in body core temperature and heart rate responses throughout 5km time trial performances at baseline and post-program between treatment and control groups. When appropriate, main effects significance was examined using *post hoc* comparisons by Bonferroni-corrected t-tests. The probability of making a Type I error was set at $p \leq .05$ for all statistical analyses.

RESULTS

The intervention was well tolerated for all 14 participants. Each of the 14 participants completed 10-14 training sessions across the 2 week intervention. Moreover, there were no adverse events experienced in the treatment group (i.e., sauna suit) across all exercise training sessions and all physiological responses remained within normal ranges. There were no within-group changes from baseline to post-program in training volume and intensity. Additionally, there were no between-group differences in training volume and intensity.

Performance outcomes

The performance outcomes for participants at baseline and 2wk post-training in both control and treatment groups are shown in Table 2. After 2wk, there were significant improvements ($p < 0.05$) in VO_2max, ventilatory threshold, and 5km heat and temperate time trials in the treatment group. All performance outcomes in the control group were unchanged ($p>0.05$) after the 2wk intervention.

Physiological responses to time trial performances

The weight changes (mean ± SD) to all 5km time trial performances at baseline and 2wk for control and treatment groups are presented in Table 3. Weight change in the sauna suit treatment group was significantly greater ($p<0.05$) in the post-program 5km heat time trial. Repeated measures ANOVA showed that body core temperature responses (Figure 2-upper panel) throughout the 5km heat time trial were significantly lower ($p<0.05$) following 2wk of training in the sauna suit treatment group. Repeated measures ANOVA demonstrated that heart rate responses (Figure 2B-lower panel) throughout the 5km heat time trial were similar ($p>0.05$) after 2wk of training in the sauna suit. These similar heart rate responses existed despite the significantly faster 5km heat time trial performance post-training (Table 2).

Table 2. Performance variables at baseline and 2wk. (Values are mean ± SD).

	Control group (n=7)		Treatment group (n=7)	
Variable	**Baseline**	**2wk**	**Baseline**	**2wk**
VO_2max (mL/kg/min)	52.0 ± 7.0	52.5 ± 6.9	52.8 ± 7.3	57.6 ± 6.3*†
Ventilatory threshold (% VO_2max)	67.4 ± 4.9	67.7 ± 5.2	66.7 ± 5.9	71.3 ± 5.2*†
5km heat time trial (sec)	1344 ± 286	1355 ± 264	1322 ± 188	1270 ± 183*†
5km temperate time trial (sec)	1325 ± 220	1318 ± 263	1308 ± 193	1270 ± 181*

* Within-group change is significantly different from baseline, $p < 0.05$. † Change from baseline is significantly different than control group.

Table 3. Weight changes during time trials at baseline and 2wk. (Values are mean ± SD).

	Control group (n=7)		Treatment group (n=7)	
Variable	**Baseline**	**2wk**	**Baseline**	**2wk**
5km heat time trial				
Weight change (kg)	-0.61 ± -0.27	-0.60 ± -0.19	-0.64 ± -0.27	-1.01 ± -0.33*†
5km temperate time trial				
Weight change (kg)	-0.46 ± -0.24	-0.51 ± -0.21	-0.56 ± -0.10	-0.74 ± -0.30

* Within-group change is significantly different from baseline, $p < 0.05$. † Change from baseline is significantly different than control group.

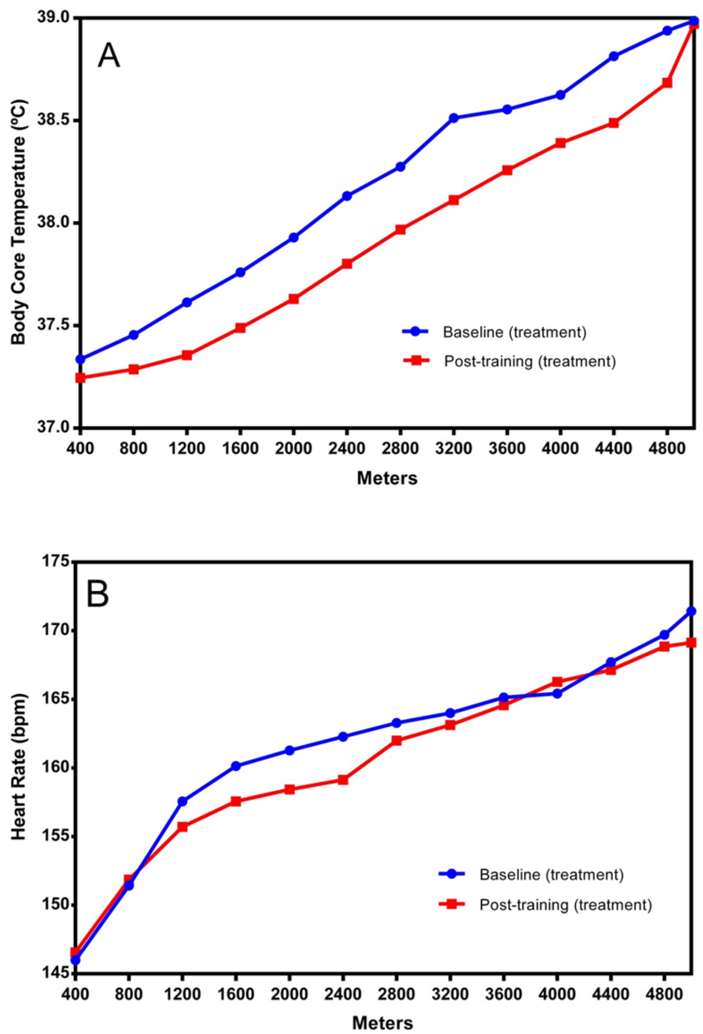

Figure 2. Physiological responses of the treatment group at baseline and post-training to the 5km heat time trial. Body core temperature responses are presented in the upper panel (A) while heart rate responses are highlighted in the lower panel (B).

DISCUSSION

The primary finding of the present study is that short-term training with a sauna suit improves heat acclimation and endurance performance. Although heat acclimation using a variety of methodologies has been well studied, to our knowledge, the training adaptations to exercise training with a sauna suit has not been scientifically explored in a randomized, controlled fashion. As such, the results of this novel study are encouraging and support use of a practical and portable sauna suit as a form of heat acclimation to enhance aerobic capacity and endurance performance.

Improvements in VO_2max (+ 9.1%) in the treatment group in the present study are comparable to those previously reported in the literature with heat acclimation. Heat acclimation elicits an increase in overall plasma volume which subsequently benefits stroke volume and maximal cardiac output[9]. The 5km time trial performances in the treatment group improved between 2% and 3% across temperate and hot conditions, respectively. This improvement in endurance performance is comparable to past literature which has demonstrated a 1.9% improvement in 5km time trial performance following heat acclimation[9]. The treatment group improvements were likely attributed to favorable heat acclimation adaptations[9-10,21]. Specifically, improved time trial performance in the treatment group was likely underpinned by a combination of improved VO_2max and an increased capacity for thermoregulation[2,16,27]. For instance, sweat rate (as evidenced by increased time trial weight loss) was increased during the 5km heat time trial following 14 days of training in a sauna suit. This favorable adaptation permitted individuals in the treatment group to dissipate heat more effectively and maintain a lower body core temperature throughout the 5km heat time trials post-intervention (Figure 2). Overall, these adaptations resulted in faster 5km time trial performance in both hot and temperate conditions following sauna suit training.

Heat acclimation has been well researched and it has been well-established that physiological adaptations from heat acclimation improve performance in the heat[5,22]. Therefore, sauna suit training provides a feasible alternative to simulate heat stress for individuals who plan to compete in hot environments. However, in the past, individuals wishing to heat acclimate have needed to relocate to a hot environment or exercise in an environmental chamber that simulates a hot environment[15,19-20]. Both of these options are expensive and may not be pragmatic for most individuals wishing to prepare for performance in the heat. In contrast, sauna suits are more practical as they can be applied to varying indoor or outdoor environments and only require a nominal initial investment. Furthermore, it has been demonstrated that heat acclimation decay is also quite slow after full heat acclimation is obtained with a decay rate of 1-3 weeks depending on fitness levels and further heat exposure[14]. Therefore, it is possible for coaches and recreational enthusiasts to front load training 1-2 months in advance of competition in a hot environment performance and gradually taper sauna suit sessions to 1 session per week as the scheduled competition approaches. In summary, sauna suit training prior to competition can be sensibly applied.

Possible limitations to the present study merit discussion. We recruited a convenience sample and findings may not necessarily be applicable to a wider population. Thermal stress from sauna suit use was not directly quantified with thermal skin sensors which is an important topic for future research. Last, it is unknown whether the improved endurance performance observed in the present study in a laboratory-based setting would be transferable to a real world competition.

CONCLUSIONS

Findings from the present study support the utility of exercise training with a sauna suit as a novel form of heat acclimation. Indeed, the present study demonstrated that 14 days of exercise training with a sauna suit elicited improvements in VO_2max and time trial performances. A greater sweat rate and lower core temperate likely mediated improved time trial performances following exercise training with a sauna suit.

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.

References

1. Armstrong L, Casa D, Millard-Stafford M, Moran D, Pyne S, et al. (2007). American college of sports medicine position stand. *Med Sci Sports Exerc*, 39, 556-72.
2. Chen W, Elizondo S. (1974). Peripheral modification of thermoregulatory function during heat acclimation. *J Appl Physiol*, 37, 367-373.
3. Cheung S, McLellan T. (1998). Heat acclimation, aerobic fitness, and hydration effects on tolerance during uncompensable heat stress. *J Appl Physiol*, 84, 1731-1739.
4. Costa R, Crockford M, Moore J, Walsh N. (2014). Heat Acclimation Responses of an Ultra-Endurance Running group Preparing for Hot Desert-Based Competition. *Eur J of Sport Sci*, 131-41.
5. Desai J, Senay L. (1984). Influence of endurance training and heat acclimation on blood volume and maximal aerobic capacity. *Fed Proc,* 43, 627.
6. González-Alonso J, Teller C, Andersen S, Jensen F, Hyldig T, Nielsen B. (1999). Influence of body temperature on the development of fatigue during prolonged exercise in the heat. J *Appl Physiol*, 86, 1032-9.
7. Katch V, Stanley S, Freedson P. (1982). Biological variability in maximum aerobic power. *Med Sci Sports Exerc,* 14, 21-5.
8. Laursen P, Francis G, Abbiss C, Newton M, Nosaka K. (2007). Reliability of time-to-exhaustion versus time-trial running tests in runners. *Med Sci Sports Exerc*, 39, 1374-9.
9. Lorenzo S, Halliwill J, Sawka M, Minson C. (2010). Heat acclimation improves exercise performance. *J Appl Physiol*, 109, 1140-1147.

10. Neilsen B, Hales C, Strange S, Christiensen W, Warberg J. (1993). Human Circulatory and Thermoregulatory adaptations and exercise in a hot, dry environment. *J Physiol*, 460, 467-85.
11. Neilsen B, Strange S, Christensen W. (1997). Acute and adaptive responses to exercise in a warm and humid environment. *Pflugers Arch*, 434, 49-56.
12. Nybo L, Secher N, and Nielsen B. (2001). Inadequate heat release from the human brain during prolonged exercise with hyperthermia. *J Physiol*, 545, 697–704.
13. Macdougal R., Layton C, Dempsey R. (1974). Effects of metabolic hyperthermia on performance during heavy prolonged exercise. *J Appl Physiol*, 36, 538-44.
14. Pandolf K. (1998). Time course of heat acclimation and its decay. *Int J Sports Med*, 19, 157-160.
15. Périard J, Racinais, Swaka M. (2015). Adaptations and mechanisms of human heat acclimation: Applications for competitive athletes and sports. *Scand J Med Sci Sports*, 1, 20-38.
16. Périard J, Racinais S. (2015b). Self-paced exercise in hot and cool conditions is associated with the maintenance of %VO2peak within a narrow range. *J Appl Physiol,* 118, 1258–1265.
17. Pescatello L. (2014). *ACSM's Guidelines for Exercise Testing and Prescription* (9th ed). Balitimore, MD: Lippincott Williams & Wilkins.
18. Roberts C, Wenger J, Stolwijk E, Nadel A. (1977). Skin blood flow and sweating changes following exercise training and heat acclimation. *J Appl Physiol Respir Environ Exerc Physiol,* 43, 133-7.
19. Sawka M, Périard J, Racinais S. (2015). Heat acclimatization to improve athletic performance in warm-hot environments. *Sports Sci Ex,* 28, 1-6.
20. Sawka M, Young A, Cadarette B, Levine L, Pandolf K. (1985). Influence of heat stress and acclimation on maximal aerobic power. *Euro J Appl Physiol*, 59, 294-298.
21. Scoon G, Hopkins W, Mayhew S, Cotter J. (2007). Effect of post-exercise sauna bathing on the endurance performance of competitive male runners. *J Sport Med*, 10, 259-62.
22. Stolwijk J. (1977). Responses to the thermal environment. *FedProc*, 36, 1655-8.
23. Tucker R, Marle T, Lambert E, Noakes T. (2006). The rate of heat storage mediates an anticipatory reduction in exercise intensity during cycling at a fixed rating of perceived exertion. *J Physiol*, 574, 905–915.
24. Van de Velde S, St. Pierre I, Byrd B, Fargo J, Loring L, Dalleck L. (2016). Effects of exercise training with a sauna suit on cardiovascular health: a proof-of-concept study. *Intern J Fit Res*, 1-8.
25. Wendt D, Van Loon L, Lichtenbelt W. (2007). Thermoregulation during exercise in the heat: strategies for maintaining health and performance. *Sports Med*, 37, 669-82.
26. Wenger C. (1988). Human heat acclimatization: 153–197 in *Human Performance Physiology and Environmental Medicine at Terrestrial Extremes*, K. B. Pandolf, editor; , M.N. Sawka, editor; , and R.R. Gonzalez, editor. , eds. Indianapolis, Ind.: Benchmark Press.
27. Yamazaki F, Hamasaki K. (2003). Heat acclimatization increases skin vasodilation and sweating but not cardiac baroreflex responses in heat-stressed humans. *J Appl Physiol*, 95, 1567-74.