Published in final edited form as:

J Burn Care Res. 2009 ; 30(4): 752–755. doi:10.1097/BCR.0b013e3181ac05d6.

Absence of Exertional Hyperthermia in a 17 Year Old with Severe Burns

Serina J. McEntire, MS, Jong O. Lee, MD, David N. Herndon, MD, and Oscar E. Suman, PhD
Shriners Hospitals for Children, Galveston, TX 77550 and Department of Surgery, The University
of Texas Medical Branch, Galveston, TX 77555

Abstract

Objective—An important safety concern when exercising burned patients is the potential for an excessive increase in core body temperature (hyperthermia = body core temperature > 39°C) during exercise.

Methods—We examined the thermoregulatory response to exercise in the heat (31°C, relative humidity 40%) in a 17 year old with a 99% total body surface area burn. A 30 minute exercise test was performed at an intensity of 75% of his peak aerobic capacity. Intestinal temperature was assessed via telemetry with an ingestible capsule. Intestinal temperature was measured pre-exercise, during, and post-exercise.

Results—The patient completed 12 minutes of the 30 minute exercise test. Starting core temperature was 36.98 °C and increased 0.69 °C during exercise. After exercise, intestinal temperature continued to increase, but no hyperthermia was noted.

Conclusion—It has been reported that burned children can safely exercise at room temperature, however, the response in the heat is unknown. This patient did not develop exertional hyperthermia, which we propose is due to his low fitness level and heat intolerance. However, the potential for hyperthermia would be increased if he were forced to maintain a high relative workload in the heat. We propose that severely burned individuals should be able to safely participate in physical activities. However, the decision to stop exercising should be accepted to avoid development of exertional hyperthermia.

Keywords

thermoregulation; hyperthermia; burns; exercise

Introduction

The body's thermoregulatory system is responsible for maintaining adequate heat production and ensuring sufficient heat dissipation. During periods of heat stress, heat production may exceed heat dissipation. This excessive heat load may result in hyperthermia with subsequent development of more serious or potentially fatal medical complications, such as heat exhaustion or heatstroke ¹.

Hyperthermia is characterized by excessive sweating, which results in fluid volume depletion (6-10% of body weight) and a rise in core body temperature between 38.0-40.0°C (100.4-104.9°F). There are decreases in circulation blood volume, blood pressure, sweat

production, and skin blood flow, which further inhibit heat loss¹. Exertional hyperthermia (EH), defined as core body temperature $>40.0^{\circ}\text{C}$, is influenced by exercise intensity, environmental conditions, clothing, equipment, and personal factors. Heat production during exercise is 15-20 times greater than at rest. Without proper heat dissipation, body temperature may increase 1°C for every 5 minutes of exercise and prolonged body heating may lead to exertional heatstroke^{1,2}. Exertional heatstroke (EHS) occurs when heat production (core body temperature $>40.5^{\circ}\text{C}$) exceeds heat dissipation and results in central nervous system changes. Acute mental impairments and significant tissue and organ damage occur with a mortality rate of 10%^{1,2}.

One population that is potentially susceptible to the development of hyperthermia and heatstroke during exercise is severely burned individuals. As addressed earlier, skin produces sweat, along with an increased blood flow, as a means of heat dissipation. Following severe burn injury, normal skin is destroyed along with sweat glands, nerves, and blood vessels and is replaced by scar tissue, skin grafts, and re-epithelialized areas. This results in healed burn scars that are unable to sweat or have altered circulatory function^{3,4}. In addition, burned individuals are left in a state of hypermetabolism with skeletal muscle catabolism and weakness, which is worsened by prolonged inactivity⁵⁻⁸. For these reasons, exercise is considered to be an ideal tool in burn rehabilitation, as it aids in the return to activities of daily living, school, work, or society⁹. However, severely burned individuals may be prone to developing EH¹⁰.

Currently, there is a concern in the medical community that severely burned patients should avoid or limit strenuous physical activity or exercise, particularly outdoors or in the heat. This concern may stem from the increases in core body temperature that occur during exercise and that may result in hyperthermia; even in populations that have intact or non-injured skin available for heat dissipation^{1,2}. Hyperthermia is a serious condition that can result in heat illness or even death. Therefore, this is an important safety concern when exercising burned patients or healthy individuals¹¹.

CASE REPORT

A 17 year old male, with history of 99% TBSA flame burn reported a prior history of headaches, dizziness, muscle aches, fatigue, and a feeling of being “very hot” during outdoor activities in the heat. He would need to move into a cool environment and rest for an extensive period of time for symptoms to pass. As part of our evaluation to determine the presence or absence of EH (defined as core temperature $>40.0^{\circ}\text{C}$)^{1,9,10}, he underwent a submaximal exercise treadmill test (ETT).

At 8 years of age, he sustained a 99% TBSA flame burn from a gasoline assault. The dorsal lateral left foot was the only non-burned skin. Initially, he presented with a 99% third degree burn. However, a portion of his anterior scalp was a partial thickness burn, which healed and he now has a patch of hair anteriorly. The palms of his hands and soles of his feet were also partial thickness burns, which healed. He had prolonged hospital course and underwent multiple skin graft operations using cultured epidermal autografts. The anterior and posterior trunk, circumferential arms, forearms, thighs, anterior portions of the legs and the dorsum of the feet and hands were all fascially excised. Third degree burns on the posterior aspect of his legs and face were tangentially excised. Total length of hospital stay was 153 days. Standing endurance upon discharge was thirty minutes in duration. Subsequently, he developed multiple severe burn scar contractures involving the major joints of all extremities. For the past 10 years, he has been followed at our institution and has undergone multiple reconstructive operations and physical rehabilitation. However, he is functional and able to perform his activities of daily living with assistance. Currently, he is able to walk

independently and ride his bicycle unassisted. His aerobic endurance is diminished, as evidenced by his peak aerobic capacity ($\dot{V}O_{2peak}$) of 35.3 ml/kg/min. Peak aerobic capacity of healthy non-burned male adolescents (12-17 years of age) has been reported to range from 44.5-66.8 ml/kg/min¹²⁻¹⁴.

A 30 minute ETT was performed at an intensity of approximately 75% of his previously determined $\dot{V}O_{2peak}$. Intestinal temperature (T_{core}) was assessed via telemetry using an ingestible capsule (Minimitter, Seattle, WA) which was taken the night before. The temperature of burned skin excised to fascia and burned skin excised tangentially were measured using a Mon-A-Therm Model 6510 temperature monitor (Mallinckrodt Co., Ciudad Juarez, Mexico). The probes were attached to the upper back (fascially excised skin) and right calf (tangentially excised skin). During the ETT, the patient wore loose comfortable clothing. All fans and ventilation outlets were turned off for the exercise session. All exercise sessions were performed at a room temperature of 31 °C DQG a relative humidity of 40%.

Treadmill speed and angle of elevation (set to a work load equivalent to 75% of his $\dot{V}O_{2peak}$) remained constant throughout the submaximal ETT. Heart rate was continuously monitored pre, during, and post-exercise. Room temperature, relative humidity, and barometric pressure were recorded for 6 minutes prior to exercise, every 2 minutes during exercise, and for 6 minutes of recovery. In addition, T_{core} and burned skin temperatures were recorded at similar intervals as room temperature.

The patient completed 12 minutes of the intended 30 minute ETT. Starting T_{core} was 36.98 °C and increased 0.69 °C (to 37.67 °C) during exercise. After exercise, T_{core} continued to increase (peak T_{core} of 38.06 °C), but no EH was noted. Fascially excised burned skin temperature increased from 35.60 °C to 37.90 °C ($\Delta = 2.30$ °C) while tangentially excised burned skin temperature increased from 32.50 °C to 36.90 °C ($\Delta = 4.40$ °C). At test termination, the patient complained of dizziness and fatigue.

DISCUSSION

It has been reported that children with severe burns can exercise at room temperature without the development of EH¹⁵. However, it is unknown whether children with severe burns will develop hyperthermia during exercise in a hot environment. Hyperthermia can be dangerous and may lead to the development of exertional heat exhaustion and heatstroke. The path that may lead to these dangerous consequences is not well understood, particularly due to the development of heat related illnesses in healthy individuals. Exertional heat exhaustion results in an inability to continue with exercise and may occur in any temperature. This is believed to be a result of central fatigue and may be a protective measure against the development of further heat related illnesses². In addition, heat intolerance is more commonly seen in individuals with the lowest $\dot{V}O_{2max}$ (<40 ml/kg/min)^{16, 17}. The greatest risks of EHS are seen in conditions of obesity, low physical fitness, lack of heat acclimatization, dehydration, a previous history of EHS, and sweat gland dysfunction². Many of these conditions are commonly seen in the burned population.

In this case report, the burned patient did not develop EH, but was unable to complete the full 30 minutes of the exercise bout. We propose that this is due to his low fitness level, along with his heat intolerance, which do not allow for hyperthermia to develop. However, we propose that if this patient would have been forced to or voluntarily maintained a prolonged and continued physical effort at this high percentage of his individual $\dot{V}O_{2peak}$, the potential for the development of hyperthermia would have been greatly increased. This typically occurs in elite athletes that “push” themselves or in individuals that are not fit, but

are “forced” (sporting or boot camp situations) to complete strenuous physical work at all costs. Prolonged, strenuous work in hot, humid conditions (such as a factory) may potentially produce similar conditions and result in the development of hyperthermia.

This patient had only 1% of unburned, healthy skin and healed partial thickness burns on the scalp, palms, and soles of the feet. During the exercise bout, he sweated from the palms of his hands, soles of his feet, and top of his head. However, we did not measure sweat rate or production during the exercise bout. We know that the surface area available for heat dissipation is reduced in this patient. Whether his sweat rate is significantly less than his non-burned counterpart or insufficient to avoid EH is speculative at this moment. This is an important point, since it is known that sweating plays a vital role in the body's ability to dissipate heat during exercise, as approximately 85% of all heat lost during exercise is due to evaporation (i.e. sweating) ¹. Further research is needed to understand the full impact of the role of sweat rate during exercise in the heat in burned children.

For comparison purposes, we tested a 17 year old healthy, non-burned male using the same 30 minute submaximal exercise test at 75% of this individuals' $\text{VO}_{2\text{peak}}$. This subject had a $\text{VO}_{2\text{peak}}$ measured at 55.0 ml/kg/min. He was able to complete the entire 30 minute exercise bout in the heat. Starting T_{core} was 36.79°C and increased 1.96°C during exercise. After exercise, T_{core} continued to increase (peak T_{core} = 38.82°C). His skin temperature increased from 35.50°C to 37.10°C (Δ = 1.60°C). We can envision that if forced to continue for 45 minutes or longer without periodic rest or water breaks, the non-burned male would be closer to a hyperthermic core temperature than his burned counterpart.

Finally, we propose that severely burned individuals should be able to safely participate in physical activities similar to their non-burned counterparts. However, if a burned individual signals that he/she needs to stop a physical activity, this decision should be accepted to avoid an increased potential for the development of EH. Further research is needed in this important safety and health related area of burn rehabilitation.

Acknowledgments

This study was supported by grants from the National Institute for Disabilities and Rehabilitation Research H133A70019 and H133A070026; a grant from the National Institutes of Health KO1-HL70451; and a grant from Shriners Hospitals for Children 8741.

REFERENCES

1. Barrow MW, Clark KA. Heat-related illnesses. *Am Fam Physician*. 1998; 58:749–56. 59. [PubMed: 9750542]
2. Armstrong LE, Casa DJ, Milliard-Stafford M, Moran DS, Pyne SW, Roberts WO. American College of Sports Medicine position stand. Exertional heat illness during training and competition. *MSSE*. 2007; 39(3):556–72.
3. McGibbon B, Van Beaumont W, Strand J, Paletta FX. Thermal regulation in patients after the healing of large deep burns. *Plastic Reconstructive Surgery*. 52:164–70. [PubMed: 4722676]
4. Shapiro Y, Epstein Y, Ben-Simchon C, Tsur H. Thermoregulatory responses of patients with extensive healed burns. *J Appl Physiol*. 1982; 53:1019–22. [PubMed: 7153111]
5. Ferrando AA, Lane HW, Stuart CA, Davis-Street J, Wolfe RR. Prolonged bed rest decreases skeletal muscle and whole body protein synthesis. *Am J Physiol*. 1996; 270:E627–33. [PubMed: 8928769]
6. Hart DW, Wolf SE, Mlcak R, et al. Persistence of muscle catabolism after severe burn. *Surgery*. 2000; 128:312–9. [PubMed: 10923010]

7. Suman OE, Herndon DN. Effects of cessation of a structured and supervised exercise conditioning program on lean mass and muscle strength in severely burned children. *Arch Phys Med Rehabil.* 2007; 88:S24–9. [PubMed: 18036977]
8. Alloju SM, Herndon DN, McEntire SJ, Suman OE. Assessment of muscle function in severely burned children. *Burns.* 2008; 34:452–9. [PubMed: 18243565]
9. Xiao J, Cai BR. Functional and occupational outcome in patients surviving massive burns. *Burns.* 1995; 21:415–21. [PubMed: 8554681]
10. Montain SJ, Latzka WA, Sawka MN. Impact of muscle injury and accompanying inflammatory response on the thermoregulation during exercise in the heat. *J Appl Physiol.* 2000; 89:1123–30. [PubMed: 10956359]
11. Armstrong LE, Epstein Y, Greenleaf JE, et al. American College of Sports Medicine position stand. Heat and cold illnesses during distance running. *Med Sci Sports Exerc.* 1996; 28:i–x.
12. Cumming GR, Friesen W. Bicycle ergometer measurement of maximal oxygen uptake in children. *Can J Physiol Pharmacol.* 1967; 45:937–46. [PubMed: 6064058]
13. Nage FJ, Hagberg J, Kamei S. Maximal O₂ uptake of boys and girls-Ages 14-17. *Europ J Appl Physiol.* 1977; 36:75–80.
14. Rivera-Brown AM, Rivera MA, Frontera WR. Applicability of criteria for VO₂max in active adolescents. *Pediatric Exercise Science.* 1992; 4:331–39.
15. McEntire SJ, Herndon DN, Sanford AP, Suman OE. Thermoregulation during exercise in severely burned children. *Pediatr Rehabil.* 2006; 9:57–64. [PubMed: 16352508]
16. Lavenne F, Belayew D. Exercise tolerance test at room temperature for the purpose of selecting rescue teams for training in a hot climate. *Rev Inst Hyg Mines.* 1966; 21:48–58.
17. Armstrong LE, De Luca JP, Hubbard RW. Time course of recovery and heat acclimation ability of prior exertional heatstroke patients. *MSSE.* 1990; 22(1):36–48.