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TITLE: Effects of Burn Injuries on Thermoregulatory and Cardiovascular Responses in Soldiers: Implications for the Standards of Medical Fitness

PRINCIPAL INVESTIGATOR: Craig G. Crandall, PhD

CONTRACTING ORGANIZATION: University of Texas Southwestern Medical Center
5323 Harry Hines Boulevard, Dallas, TX 75390

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Craig G. Crandall, PhD

Email: CraigCrandall@TexasHealth.org

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14. ABSTRACT
This final report summarizes the findings from the projects outlined in grant #: W81XWH-15-1-0647, which concluded September 29, 2021. A reoccurring finding is that a strict criterium of a 40% total body surface area burn as an exclusion from service in the US Army (e.g., AR 40-501) is excessively limited and show be broadened to include the size of the soldier, what the soldier is wearing (e.g., battle fatigues with and without body armor), the environmental condition the soldier is performing in, and the work intensity the soldier is working in. The results from this body of work have resulted in 6 published manuscripts, with the expectation of another ~3 published manuscripts either directly or indirectly associated with these research trials. Notably, this project assisted in the training of six post-doctoral fellows. With the exception of one post-doctoral fellow still working in our laboratory, each of these individuals have accepted faculty positions in academia or are working in governmental military research laboratories.

15. SUBJECT TERMS
Army's Standards of Medical Fitness; burn injury; thermoregulation; sweating; heat dissipation; environmental temperature; body surface area burned; donor site

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1. INTRODUCTION

The U.S. Army's Standards of Medical Fitness pertaining to a prior burn injury is based upon the findings of only three studies, from a total of 9 subjects with burns of >40% body surface area (BSA; N=4, 3, and 2), and report contradictory findings. Equally low number of subjects were assessed in individuals with <40% BSA burned in those studies. Notably, we know nothing about the interactive effects of differing workload requirements (e.g., metabolic heat generation associated with military service) and the environmental conditions soldiers often operate in on the safety and well-being of a soldier with a prior burn injury. Further, we know nothing about the effects of differing body sizes, location of burn injury, and/or how a soldier's uniform/body armor may affect thermoregulatory and cardiovascular responses during military operations of a soldier with a burn injury. Clearly, there is insufficient information to make conclusions regarding the potential detrimental effects of a prior burn injury at the level necessary to include such recommendations in the Standards of Medical Fitness. The proposed work will provide clear and scientifically supported guidelines that will culminate in recommendations for a revision of the US Army's Standards of Medical Fitness for burn injuries to more accurately predict the consequences of the injury on the safety and wellbeing of the burned soldier. This information will also have direct impact on the accession/retention of the burned soldier, potentially allowing highly trained, but burned, soldiers to remain in service and thereby realizing cost savings to the Army that would otherwise be spent on training replacements. Finally, the obtained information will benefit the civilian burn community, and those who treat such individuals, through specific recommendations that are dictated in part by the activity level and/or environmental conditions such individuals participate in, with a goal of mitigating the risk of heat-related injuries in this population.

Abbreviations:
BSA: Body surface area
HR: Heart rate
LDFcon: Laser Doppler flowmetry at the control (non-injured) site.
LDFdon: Laser Doppler flowmetry at the donor site.
LSRcon: Local sweat rate at the control (non-injured) site.
LSRdon: Local sweat rate at the donor site.
RPE: Ratings of perceived exertion
TBSA: Total body surface area
W: Watts

2. KEYWORDS

Army's Standards of Medical Fitness; burn injury; soldier; thermoregulation; sweating; heat dissipation; exercise; metabolic heat generation; environmental climate; temperature; humidity; body surface area burned; donor site; fitness.

3. ACCOMPLISHMENTS

What were the major goals of the project? (Goals to be accomplished and status.)

Specific Aim 1: *Identify whether the fraction of unburned skin is an accurate predictor of impaired heat dissipation*
- STATUS: Completed

Specific Aim 2: *Determine the extent to which a burn injury is detrimental for an individual's ability to thermoregulate is dependent upon ambient temperature and exercise intensity*
- STATUS: Completed

Specific Aim 3: *Evaluate the influence of burn location on thermoregulatory responses*
- STATUS: Completed

Specific Aim 4: *Identify whether the donor site contributes to impaired thermoregulatory responses in burned subjects*
- STATUS: Completed

Specific Aim 5: *Provide evidenced-based recommendations to revise the Standard of Medical Fitness*
- STATUS: Completed

What was accomplished under these goals? (Detailed progress and results.)

***Aim 1**: The absolute quantity of skin available for heat dissipation (i.e., m^2 of ungrafted skin) more accurately predicts the risk of a heat-related injury to a soldier relative to %BSA burned*

Rationale: At the time this work was proposed, the Standard of Medical Fitness dictates that an individual having a burn covering 40% or more of their TBSA does not meet that standard. However, this standard did not take into account differences in body size between individuals, and thus the available surface area for heat dissipation. For example, if a large person (e.g., 198 cm tall and 115 kg mass) having a TBSA of 2.5 m^2 sustained a 40% TBSA burn injury, that person would have ~1.5 m^2 uninjured skin available for heat dissipation. This is in contrast to a smaller person (e.g., 168 cm tall and 55 kg mass) with a TBSA of 1.6 m^2 sustaining a 40% TBSA burn injury, resulting in ~0.96 m^2 uninjured skin available for heat dissipation. Thus, despite the exact same relative burned area (40% of TBSA), the larger person would have ~56% more absolute surface area of uninjured skin to dissipate heat. We contend that the absolute amount of BSA available for heat dissipation (i.e., uninjured skin) is a better indicator of thermoregulatory capabilities in burned individuals than the percent of TBSA burned. The focus of this aim was to test the hypothesis that the absolute BSA available for heat dissipation (i.e., uninjured skin) more accurately predicts thermoregulatory and cardiovascular consequences of such an injury relative to the current standard of using %TBSA burned.

Results: In accordance with our hypotheses, the obtained findings indicate that with a "burn injury" of 40% TBSA, prolonged exercise performed at the same absolute level of heat production leads to greater elevations in core temperature among individuals of smaller body size due to a higher corresponding mass-specific H_{prod} ($W \cdot kg^{-1}$) (Figure 1 left panel). However, when exercise is performed by individuals of different body sizes at the same mass-specific heat production, the effect of body mass is normalized and core temperature increases to the same extent regardless of body size (Figure 1 right panel).

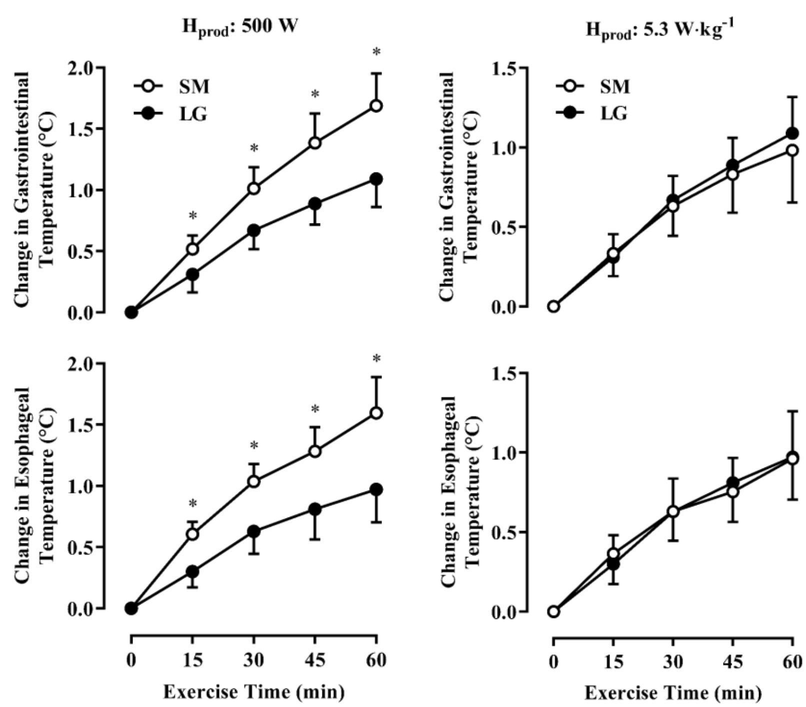


Figure 1 (left panel): Changes in gastrointestinal temperature (top) and esophageal temperature (bottom) throughout 60 min of exercise eliciting an absolute rate of metabolic heat production (Hprod) of 500 W. Right panel: Changes in gastrointestinal temperature (*top*) and esophageal temperature (*bottom*) throughout 60 min of exercise eliciting a mass-specific rate of metabolic heat production (H_{prod}) of 5.3 $W \cdot kg^{-1}$. Data represent mean ± standard deviation for groups of small (SM) and large (LG) body size (n=11 per group). * Significantly greater in SM ($P < 0.05$). Data published by Dr. Crandall's laboratory in PMID: 31524829.

Interpretations: These findings demonstrate that among morphologically-disparate Army soldiers or recruits with a burn injury of 40% TBSA, a larger body size is advantageous during non-weight-bearing tasks eliciting fixed rates of metabolic heat production (Figure 1 left panel), but is neither advantageous nor deleterious during weight-bearing tasks (Figure 1 right panel). A revision to the U.S. Army's Standards of Medical Fitness that takes into account the body size of the injured soldier/recruit, and thus the absolute surface area available to dissipate heat, may improve the retention of personnel with burn injuries covering 40%+ TBSA without impairing physical performance or increasing the risk of a heat illness.

Aim 2: *The level of metabolism required for a particular assignment/responsibility, as well as the expected climate where that assignment is performed, will greatly influence the extent to which a burn injury is detrimental to a soldier.*

Rationale: The extent to which a burn injury is detrimental for a soldier is very likely to be dependent upon the level of physical effort and the environment in which the effort takes place. Increases in core temperature during exercise are determined by the magnitude of imbalance between the heat load that is imposed upon the body (determined by exercise intensity and environmental temperature) and the maximum ability of the body to dissipate heat (determined by environmental temperature, ambient humidity, and BSA available for heat exchange).

Conceptually, the heat load imposed upon the body is defined as the required amount of evaporation to maintain heat balance, and can easily be calculated as the sum of metabolic heat production and heat exchange between the body and the environment. As such, any changes in exercise intensity and/or ambient temperature will alter the imposed heat load. For example, greater exercise intensity will lead to greater metabolic heat production which increases the heat load that must be removed to remain in heat balance. In contrast, hot environments (i.e., >35 °C) cause the body to gain heat from the environment, such that a greater heat load is imposed upon the body as ambient temperature increases. In both cases, the human body will need to produce more sweat to increase heat loss through evaporation with the aim of maintaining core temperature at a steady-state level. Prior to the work addressed in this project, the interactive effect of environmental temperature, exercise intensity, and body surface area burned on increases in core body temperature was unknown. Therefore, this aim tested the hypotheses that the extent to which a burn injury is detrimental to an individual is dependent upon both the ambient temperature and the exercise intensity, the latter of which will alter the rate of metabolic heat generation.

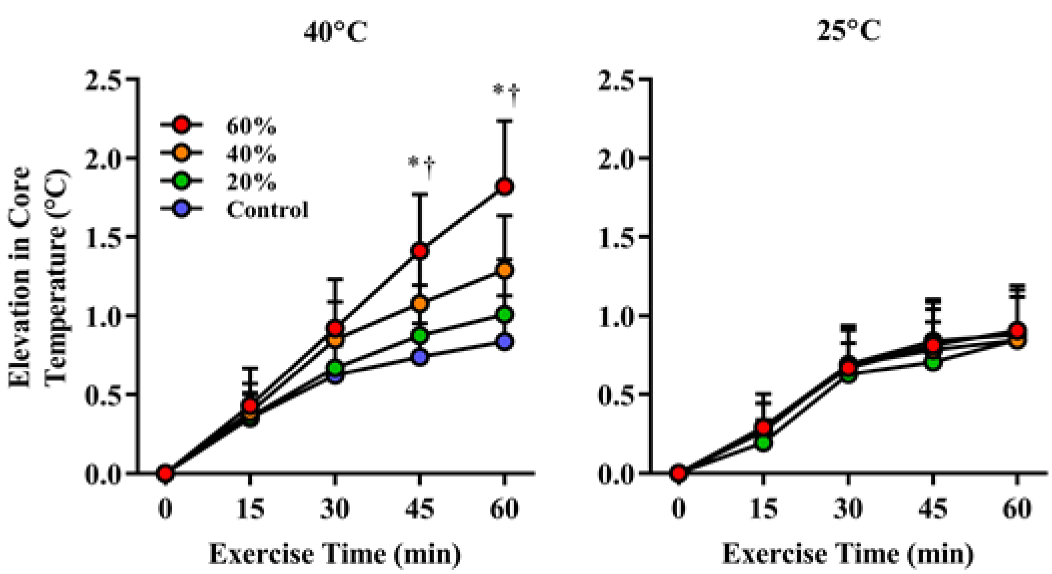


Figure 2: Elevations in core temperature after 60 min of exercise in air temperatures of 40°C (left) and 25°C (right) with burn injuries of 20%, 40%, or 60% total body surface area, as well as a Control condition (i.e., no burn injury). *Significantly greater with a 60% TBSA burn injury vs. Control at the indicated time point. †Significantly greater with a 40% TBSA burn injury vs. Control at the indicated time point. Data represent means ± standard deviations. Data published by Crandall's laboratory in PMID: 31609298.

Results A: For the ambient temperature inquiry, the results showed that burn injuries of 20%, 40%, and 60% TBSA exacerbate the elevation in core temperature during moderate-intensity exercise in a 40°C environment compared to a 25°C environment. Additionally, 40% and 60% TBSA burn injuries caused higher elevations in core temperature compared to a Control (non-injured) condition within a 40°C environment, but the elevation in core temperature with 20%, 40%, and 60% TBSA simulated burn injuries in a 25°C environment was not different than that observed in a non-injured Control condition (Figure 2). Overall, these findings indicate that the detrimental effect of a burn injury on exercise thermoregulation is influenced by air temperature.

Interpretations A: As such, the current U.S. Army standard for inclusion of recruits/soldiers with burn injuries should consider the air temperature in which that recruit or soldier will perform their duties. Specifically, if that individual is expected to perform only in temperate climates, there is no justification for a person with greater than 40% TBSA burn to be excluded from military service. However, if that individual is expected to perform in hotter environmental conditions (e.g., 40 °C), then a 40% TBSA burn injury is likely an appropriate cutoff for one with such an injury.

Results B: For the exercise intensity inquiry, the result show that exercise intensity modulates the detrimental effect of a burn on internal body temperature responses. During low-intensity exercise in a hot environment, at each time point, the increase in core body temperature was similar across all levels of burn when compared to the 0% coverage condition (Figure 3 left panel). However, during moderate-intensity exercise, the 40% and 60% burn trials exhibited greater increases in core body temperature than the 0% trials at minutes 45 and 60 of exercise (Figure 3 right panel).

Interpretations B: According to US Army training guidelines, in the assessed study's environmental conditions (~40 °C), light workloads (metabolic rates of 250 W) can be conducted without a duration limit, moderate workloads (metabolic rates of 425 W) can be conducted with an interval of 50 minutes work to 10 minutes for rest, and hard workloads (metabolic rates of 600 W) can be conducted at an interval of 30 minutes work to 30 minutes of rest. In the context of our findings (i.e., Low-intensity exercise, 362±46 W and Moderate-intensity exercise, 531±76 W), the percent TBSA burned has little impact on thermoregulation during relatively light work (e.g., rifle fire in a prone position, walking on a hard surface at 1.56 $m \cdot s^{-1}$, lift and carry 45-kg artillery shell at $3 \cdot min^{-1}$). Conversely, individuals with 40% or more TBSA burns would be at a greater risk for excessive hyperthermia compared to their "non-burned" counterparts during moderate to hard work activities (e.g., emplacement digging, walking on a hard surface at 2 $m \cdot s^{-1}$, field assaults) while in the assessed environmental conditions. These findings indicate that the Army's Standard for Medical Fitness guidelines should reflect both the intensity of the workload performed and the extent of grafting, with a burned-injured soldier having responsibilities requiring low exercise intensities could safely perform those duties even in conditions of elevated environmental temperatures. Conversely, tasks that require greater exercise intensities when performed in the heat could be detrimental to a soldier with a larger burn injury.

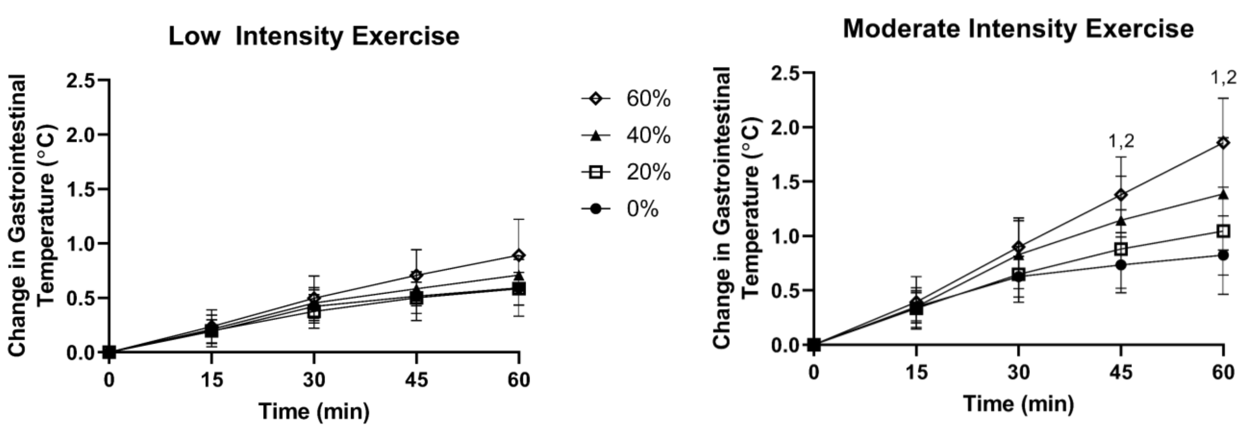


Figure 3: Change in gastrointestinal temperature during 60 minutes of exercise at a low (~4 W/kg; left panel) and moderate (~6 W/kg; right panel) exercise intensity with 0%, 20%, 40% and 60% body surface area burn. [1]40% burn size different from 0% at the indicated time points within exercise intensity ($p<0.05$). [2]60% burn size different from 0% at the indicated time points within exercise intensity ($p<0.01$). Data represent means ± standard deviations. Data published by Crandall's laboratory in PMID: 32826639.

Aim 3: *The location of the burn injury will influence the decrement of thermoregulatory capacity and thus the risk of a heat-related injury.*

Rationale A: U.S. Army Regulation 40-501, Medical Services Standards of Medical Fitness, states: "Prior burn injury involving less than 40 percent total body surface area, which results in a loss or degradation of thermoregulatory function does not meet the standard. Examination will focus on the depth of the burn, anatomic location (extensive burns on the torso will most significantly impair heat dissipation), and destruction of sweat glands." A likely basis for this standard is that local sweat rates are often found to be higher in the torso relative to the limbs. Therefore, an individual with a torso burn injury (who must rely more on the limbs for sweat production) could have a lower capacity for whole-body evaporative heat loss and thus a higher elevation in core temperature during physiologically uncompensable exercise-heat stress compared to a burn survivor with a limb injury of equivalent size and intact torso sweat function. Whether this is the case had not been investigated. The first objective of this aim was to determine whether torso burn injuries are more detrimental to core temperature regulation than burn injuries on the limbs during physiologically uncompensable exercise-heat stress.

Results A: Baseline rectal temperatures were not different between the Torso and Limb burn trials. Rectal temperature increased over time (Fig. 4; main effect: $P < 0.01$), but no condition-by-time interaction was observed for this variable ($P = 0.86$). The 60-min change in rectal temperature from baseline was not different between the Torso and Limb burn trials (Torso: 0.9 ± 0.3°C; Limbs: 0.9 ± 0.3°C; $P = 0.55$). Heart rate (Fig. 4), the ratings of thermal sensation, and perceived exertion increased over time (main effect: $P < 0.01$). However, the location of the burn injury (i.e., Torso versus Limb burns) did not affect the increase in heart rate (interaction: $P = 0.91$), ratings of thermal sensation (interaction: $P = 0.50$), or ratings of perceived exertion (interaction: $P = 0.65$).

Interpretations A: Findings from this work demonstrate that the elevation in core temperature following 60-min of exercise-heat stress does not differ with a burn injury on the entire torso compared to a burn injury on the limbs, matched for surface area. Further, no differences in heart rate, perception of exertion, or thermal sensation were evident. Collectively, these results suggest that a full torso burn injury is no more detrimental to thermal, cardiovascular, and perceptual strain than size-matched burn injuries on the limbs.

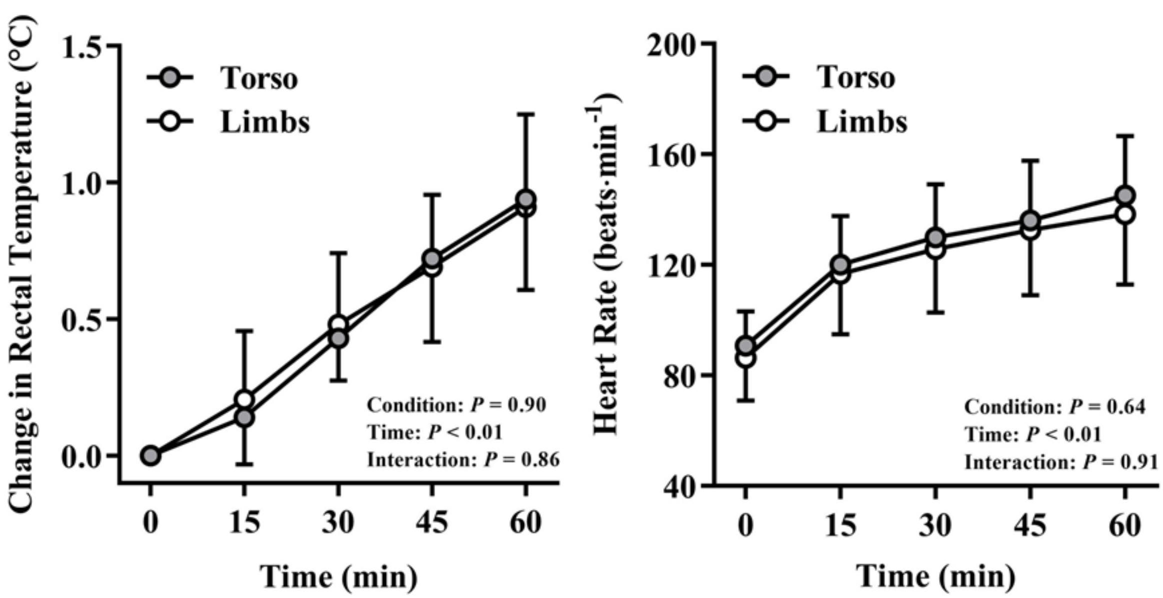


Figure 4 Change in rectal temperature (left panel) and heart rate (right panel) during 60 min of exercise in hot-dry conditions with burn injuries of equivalent size on the torso or limbs. Main effects of condition and time, and the condition-by-time interaction, are shown. These data demonstrate that a similar sized torso versus non-torso burn injury will result in equal elevations in rectal temperature and heart rate. Data published by Crandall's laboratory in PMID: 33935232.

Based on the absence of any difference in the core temperature or heart rate responses to exercise-heat stress between torso and limb simulated burns (see Figure 4), U.S. Army personnel performing prolonged work in the heat would be at no greater risk of heat-related illness or injury with a torso burn compared to a burn located on the limbs. Therefore, a revision to the Standard could be made that omits “anatomic location” from the list of burn injury-related factors under examination when determining whether a burned recruit or soldier meets the Standard.

Rationale B: In many occupations, workers are required to wear unique clothing and use equipment that protects them from physical and/or environmental hazards, but also impose a substantial thermoregulatory burden by restricting body heat dissipation. For example, to protect against projectile and fragmentation injury, military personnel typically wear a combat uniform and body armor, which simultaneously inhibit evaporative heat dissipation from the torso surface. Many police officers wear similar ensembles. Thus, compared to a minimal clothing ensemble, protective clothing with body armor exacerbate heat strain, increases the risks of heat illness, and impairs duty performance during prolonged periods of work and ambient heat stress. Whether a burn injury located on the torso underneath a protective clothing/body armor ensemble further increases thermoregulatory strain is currently unknown, as the detrimental effects of burn injuries are primarily identified under semi-nude conditions (i.e., only shorts, socks, and shoes were worn). Given the expectation that protective clothing and body armor impede sweat evaporation, then the absence of sweat production from extensively-grafted torso skin in a burned individual should not exaggerate the thermoregulatory strain. In other words, evaporative heat loss from the torso is likely negligible when protective clothing and body armor with low vapor permeability are worn. This question is particularly pertinent given that (i) ~20-25% of burn injuries in recent military conflicts include burns on the torso, and (ii) the US Army’s Standards of Medical Fitness Army Regulation 40-501 which states, pertaining to burn injuries as an exclusion, that “extensive burns on the torso will most significantly impair heat dissipation”. This second component of Aim 3 evaluated whether heat strain during exercise in a hot-dry environment, while wearing military protective clothing (combat uniform, tactical vest, with front and back replica armor plates), would be similar with and without a simulated torso burn injury. Specifically, we tested the hypothesis that exercise-heat stress will lead to similar levels of heat strain, regardless of a simulated torso burn injury, when protective clothing with low vapor permeability is worn.

Results B: Compared to a seminude condition (Control), wearing a combat uniform (Uniform) exaggerates the increase in core temperature during 60 min of exercise-heat stress (see Figure 5). However, when a simulated torso burn was imposed (Uniform + Burn), the elevation in core temperature did not differ from the non-burned Uniform trial. Similarly, elevations in HR and RPE were higher in Uniform compared to Control, but did not differ from

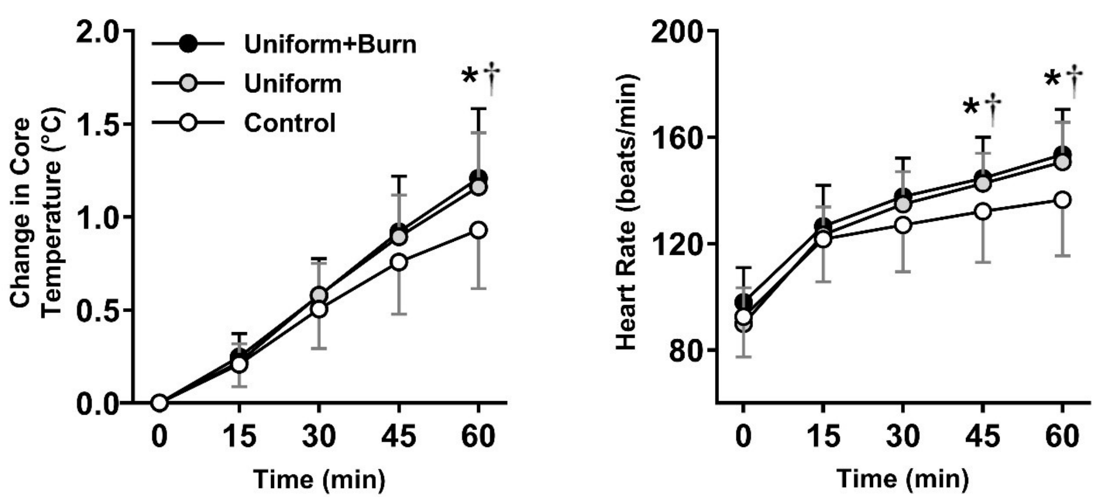


Figure 5: The change in core temperature (left) and heart rate responses (right) throughout exercise at 40°C and 20% RH while wearing military protective clothing (Uniform), military protective clothing with a simulated burn injury (Uniform + Burn), or shorts and shoes only (Control). * difference between Control and Uniform + Burn ($P < 0.05$). † difference between Control and Uniform ($P < 0.05$). Values are mean ± SD for 10 participants. Data published by Crandall’s laboratory in PMID: 32936596

Uniform + Burn trials. These findings indicate that a simulated torso burn injury of 20% TBSA does not cause any additional thermoregulatory burden during exercise in the heat, relative to solely wearing protective clothing.

Interpretation B: In summary, an approximate 20% TBSA simulated torso burn injury does not exacerbate thermoregulatory strain during exercise in a hot-dry environment while wearing a military combat uniform. These findings demonstrate that soldiers with burn injury to the torso are at no additional risk of heat strain compared to non-injured soldiers when both are wearing the same military combat ensemble. Considering these findings, the US Army's Standards of Medical Fitness, stating that an extensive torso burn "will most significantly impair heat dissipation", may require re-evaluation.

Aim 4*: Donor sites are not detrimental to temperature regulation and thus should not be included in the calculation of the US Army's Standards of Medical Fitness for burn injuries.*

Rationale: The aforementioned U.S. Army's Standards of Medical Fitness AR 40-501 state that "Prior burn injury (*to include donor sites*) involving a total body surface area of 40% or more does not meet the standard." (italics added for emphasis). The inclusion of donor sites in this standard implies that thermoregulatory function within donor sites is disrupted and should therefore be considered part of the burn injury when determining whether a burned soldier meets the standard. Permanently suppressed or severely attenuated elevations in skin blood flow and local sweat rate within grafted skin areas are well-documented; however, there is presently no evidence indicating that donor sites exhibit impaired thermoregulatory function. In fact, two previous studies from our laboratory demonstrated generally preserved cutaneous vasodilatory and local sweat rate responses within donor and an adjacent non-injured control sites. Although those studies challenge the inclusion of donor sites in the U.S. Army's Standards of Medical Fitness, it should be noted that in those studies, whole-body passive heat stress was imposed via encapsulation in a water-perfused suit covering ~85% of body surface area, while local cutaneous vascular and sweat rate responses were assessed from skin areas exposed to the surrounding thermoneutral environment. Whether donor and non-injured skin sites exhibit similar sweating and skin blood flow responses during combined exercise and environmental heat stress has not been investigated. The distinction between these sources of heat stress is of practical importance given that in training and operational settings, soldiers experience elevations in body temperature driven by both activity-related increases in metabolic heat production and high ambient temperatures. The purpose of this aim was to compare skin blood flow and sweating responses between a donor site and an adjacent non-injured control site in well-healed burn survivors during combined exercise and ambient heat stress. We hypothesized that the increase in skin blood flow and local sweat rate during exercise-induced hyperthermia and ambient heat stress would not be different between donor and non-injured control sites.

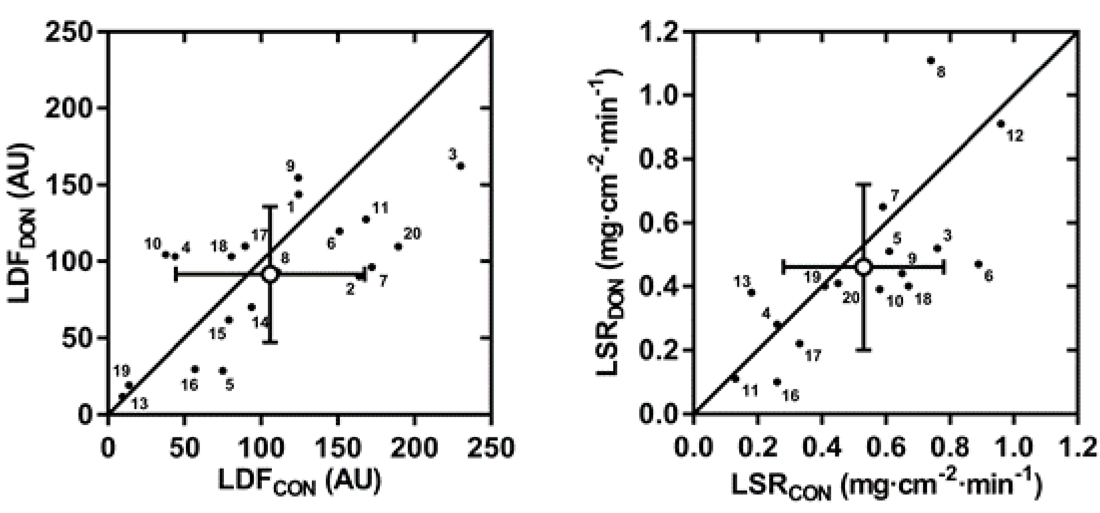


Figure 6: Comparison of the elevation in skin blood flow (left panel) at non-injured (LDFcon) and donor (LDFdon) skin sites, as well as local sweat rate (right panel) from non-injured (LSRcon) and donor (LSRdon) sites from baseline to the end of a 60-min bout of exercise in the heat. Individual (n=19; small closed circles with participant number) and mean (± SD; large open circle) skin blood flow values are expressed as laser-Doppler flux in arbitrary perfusion units (AU), while local sweat rate is expressed as milligrams of sweat produced per cm^2 surface area each minute. Data published by Crandall's laboratory in PMID: 30614899

Results: Individual and mean skin blood flow responses are presented in Fig. 6 left panel. The elevation in skin blood flow at the non-injured control site (LDFcon) and at the donor site (LDFdon) averaged 106 ± 62 and 92 ± 45 AU, respectively; however, no difference was found between the sites (P = 0.17). Fig. 6 right panel shows the individual and mean local sweat rate values within each skin site. Similar to the skin blood flow response, no difference in local sweat rate was observed between non-injured (LSRcon) and donor skin (LSRdon) sites, with mean values for LSRcon and LSRdon of 0.53 ± 0.25 and 0.46 ± 0.26 $mg \cdot cm^{-2} \cdot min^{-1}$, respectively (P = 0.14). The findings show that the combination of prolonged moderate-intensity exercise in hot/dry ambient conditions evokes comparable elevations in skin blood flow and local sweat rates within a donor site and an adjacent non-injured control skin.

Interpretations: In burn survivors, well-healed donor sites retain the capability to increase skin blood flow and sweat rate during exercise-heat stress. Given the lack of any discernable thermoregulatory impairment within donor sites, these findings suggest that donor sites should not be included with the amount of burned skin when considering whether the burn injury of a recruit or active duty soldier meets the U.S. Army's Standards of Medical Fitness.

Aim 5: This aim will provide evidence-based recommendations to revise the Army's Standards of Medical Fitness to consider burn and non-burned surfaced area, the environmental and metabolic conditions the soldier will be exposed to, the location of the burn injury, and the size of the donor site.

The Army's Standards of Medical Fitness reads as follows pertaining to burn injuries:

Army Regulation 40-501, Version dated 14 June 2017:

a) "Prior burn injury (to include donor sites) involving a total body surface area of 40 percent or more does not meet the standard.
b) Prior burn injury involving less than 40 percent total body surface area, which results in a loss or degradation of thermoregulatory function does not meet the standard. Examination will focus on the depth of the burn, anatomic location (extensive burns on the torso will most significantly impair heat dissipation), and destruction of sweat glands."

Data from the obtained studies provide evidence-based science to support a more flexible inclusion/exclusion criteria for burned soldiers. Specific recommendations regarding revisions of the Army's Fitness of Medical Standards are outlined in the prior section of this document and are included in the following sections of this recently accepted publication (PMID: 34734782).

- Individual and interactive effects of environmental temperature and exercise intensity on whole-body thermoregulation in burn survivors
- Influence of burn location on whole-body thermoregulation in burn survivors
- The donor sites and thermoregulatory function

To summarized, based upon the findings from these studies, we strongly recommend a re-orientation of the Army's current standard away from using a fixed %TBSA burn injury (e.g., 18% of 40% of TBSA) to evaluating the absolute body surface area that is available for heat exchange. Such changes should be made within the context of the heat load imposed by the required tasks (i.e., physical effort and associated heat generation), coupled with the environmental conditions the soldier is expected to perform under. Moreover, we recommend that the Standards remove the donor site from being included when calculating the TBSA injured. We also recommend the Standards drop the section pertaining to a torso burn injury as being more deleterious for heat dissipation, as there is no evidence supporting this suggestion. Finally, one with a torso burn injury will not be at a thermoreguatory disadvantage while wearing a combat uniform, inclusive of body armor, when compared to one without a torso burn injury. Though incorporating such information into the Standards of Medical Fitness may complicate the decisions being made by those who determine whether an individual is medically able to serve, inclusion of such considerations will also reduce the number of service personnel who are unnecessarily denied service opportunities.

We understand that getting the obtained information to those with decision making powers to change the Army's Standards of Medical Fitness can be challenging. To that end, we have discussed approaches/strategies to address this concern with Dr. Francis O'Connor. Dr. O'Connor is the Medical Director, Consortium for Health and Military Performance at the Uniformed Services University of the Health Sciences, Bethesda, MD and has insight into the decision points made in determining the criteria for the Standards of Medical Fitness as it pertains to heat-related risks and injuries.

What opportunities for training and professional development has the project provided?

Though the project was not designed to provide training or professional development opportunities, training has nonetheless taken place as a result of the performed work. Specifically, the following post-doctoral fellows (and one graduate student) received training either directly, or indirectly, related to this project: Matthew Cramer, Ph.D., Gilbert Moralez, Ph.D., Mu Huang, Ph.D., Paula Poh, Ph.D., Mads Fischer, B.S., Joseph Watso, Ph.D. and Luke Belval, Ph.D. With the exception of one post-doctoral fellow still working in our laboratory, each of the postdoctoral fellows hold a faculty position in academia or are employed at governmental military research laboratories. These individuals received training in the following areas: IRB approvals, subject recruitment (both uninjured and burned subjects), data collection and management, data analysis and reporting, and presentation of the data. Regarding the last point, data from these studies have been presented by trainees at weekly "Works in Progress" meetings, at the American College of Sports Medicine annual meeting, at the American Burn Association annual meeting, at the Experimental Biology annual meeting, and at the Military Health System Research Symposium conferences.

How were the results disseminated to communities of interest?

The obtained data have been presented at the following local, national, and international meetings in verbal and/or poster formats: internal "Works in Progress", the Military Health System Research Symposium meetings, the American Burn Association meetings, the Experimental Biology meetings, and the American College of Sports Medicine meetings. In addition, six manuscripts have been published from this work and are in the public domain. Finally, Dr. Crandall gave 18 invited oral presentations (local, national, and international) that contained data from this project. See below for the list of published manuscripts, conference abstract/oral presentations, and Dr. Crandall's invited oral presentations.

Plans for the next reporting period to accomplish the goals

N/A

4. IMPACT

What was the impact on the development of the principal discipline(s) of the project?

The primary conclusion is that a single burn surface area criterion (e.g., 40% total body surface area burned) is excessively limited and should be broadened to include the size of the soldier, what the soldier is wearing (e.g., battle fatigues with and without body armor), the environmental condition the soldier is performing in, and the work intensity the soldier is working in. Moreover, the donor site should not be included in that calculated body surface area burned and a torso burn injury is no more consequential for thermoregulation relative to a similar sized burn from a non-torso region.

What was the impact on other disciplines?

The obtained data will be of interest to the civilian burn rehabilitation community. Exercise is critical for appropriate rehabilitation. That said, burned individuals are often hesitant to perform aerobic exercise training for fear that they may experience a heat-related injury. The information presented herein will be very beneficial to the rehabilitation community by instructing them that burn survivors can perform exercise without an additional risk of hyperthermia if the exercise is moderate in intensity and the individuals are exercising in an air conditioned area. Moreover, even in settings of elevated environmental temperatures, if the work intensity is mild, individuals with severe burn injuries can exercise without a risk of excessive hyperthermia.

What was the impact on technology transfer?

Nothing to report.

What was the impact on society beyond science and technology?

Nothing to report.

5. CHANGES/PROBLEMS

IMPORTANT REMINDER – Award recipient organization is required to obtain prior written approval from the awarding agency Contracting/Grants Officer whenever there are significant changes in the project or its direction such as significant change in scope or the Statement of Work (e.g. removal, change, or addition of aims/tasks or animal model change), change in PI or key personnel, reduction of 25% FTE, or significant change in budget.

Changes in approach and reasons for change

Nothing to report.

Actual or anticipated problems or delays and actions or plans to resolve them

Nothing to report.

Changes that had a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects

TOTAL PROTOCOL(S): 4

PROTOCOL (1 of 4 total):
IRB Protocol Number:
HRPO Protocol Number: A-18991.1
Protocol PI: Craig G. Crandall, PhD
Protocol Site: University of Texas Southwestern Medical Center
Protocol Title: Effects of Burn Injuries on Thermoregulatory and Cardiovascular Responses in Soldiers: Implications for the Standards of Medical Fitness - Aim 1
Target approved for clinical significance: 85 subjects
IRB INITIAL APPROVAL DATE: 12/14/2015
HRPO INITIAL APPROVAL DATE: 12/24/2015
CONTINUING REVIEW APPROVAL DATES:

- 07/07/2016 HRPO
- 06/01/2017 HRPO
- 08/10/2018 HRPO
- 12/13/2019 HRPO
- 7/22/2021 HRPO

AMENDMENTS:

- Amendment 1, HRPO approved 06/01/2017, to add one study visit for non-burned subjects and remove the requirement to have a pregnancy test performed within the first 10 days of the menstrual cycle for women of child bearing age; also previously enrolled subjects who return to complete the added visit will be re-consented

ADVERSE EVENTS OR UNANTICIPATED PROBLEMS:

- None

ENROLLMENT STATUS:

- Number of subjects recruited/original planned target: 66/85
- Number of subjects screened/original planned target: 66/85
- Number of patients enrolled/original planned target: 44/85
- Number of patients completed/original planned target: 44/85

PROTOCOL (2 of 4 total):
IRB Protocol Number:
HRPO Protocol Number: A-18991.2

Protocol PI: Craig G. Crandall, PhD
Protocol Site: University of Texas Southwestern Medical Center
Protocol Title: Effects of Burn Injuries on Thermoregulatory and Cardiovascular Responses in Soldiers: Implications for the Standards of Medical Fitness - Aim 2
Target approved for clinical significance: 85 subjects
IRB INITIAL APPROVAL DATE: 12/14/2015
HRPO INITIAL APPROVAL DATE: 12/24/2015
CONTINUING REVIEW APPROVAL DATES:

- 07/06/2016 HRPO
- 06/09/2017 HRPO
- 08/10/2018 HRPO
- 12/13/2019 HRPO
- 7/22/2021 HRPO

AMENDMENTS:

- Amendment 1, HRPO approved 07/06/2016, to add a cohort of burn subjects to the protocol, thereby increasing enrollment to 85 subjects (from 35 subjects) plus other minor changes
- Amendment 1, HRPO approved 06/09/2017, to add Parkland as a recruiting site

ADVERSE EVENTS OR UNANTICIPATED PROBLEMS:

- None

ENROLLMENT STATUS:

- Number of subjects recruited/original planned target: 75/85
- Number of subjects screened/original planned target: 75/85
- Number of patients enrolled/original planned target: 67/85
- Number of patients completed/original planned target: 60/85

PROTOCOL (3 of 4 total):
IRB Protocol Number:
HRPO Protocol Number: A-18991.3
Protocol PI: Craig G. Crandall, PhD
Protocol Site: University of Texas Southwestern Medical Center
Protocol Title: Effects of Burn Injuries on Thermoregulatory and Cardiovascular Responses in Soldiers: Implications for the Standards of Medical Fitness - Aim 3
Target approved for clinical significance: 40 subjects
IRB INITIAL APPROVAL DATE: 08/06/2018
HRPO INITIAL APPROVAL DATE: 10/03/2018
CONTINUING REVIEW APPROVAL DATES:

- 12/13/2019 HRPO
- 8/23/2021 HRPO closure memo issued

AMENDMENTS:

- None

ADVERSE EVENTS OR UNANTICIPATED PROBLEMS:

- None

ENROLLMENT STATUS:

- Number of subjects recruited/original planned target: 22/20
- Number of subjects screened/original planned target: 22/20
- Number of patients enrolled/original planned target: 22/20
- Number of patients completed/original planned target: 20/20

PROTOCOL (4 of 4 total):
IRB Protocol Number:
HRPO Protocol Number: A-18991.4
Protocol PI: Craig G. Crandall, PhD
Protocol Site: University of Texas Southwestern Medical Center
Protocol Title: Effects of Burn Injuries on Thermoregulatory and Cardiovascular Responses in Soldiers: Implications for the Standards of Medical Fitness - Aim 4
Target approved for clinical significance: 30 subjects
IRB INITIAL APPROVAL DATE: 12/21/2015

HRPO INITIAL APPROVAL DATE: 12/24/2015
CONTINUING REVIEW APPROVAL DATES:
- 08/26/2016 HRPO
- 08/21/2017 HRPO
- 08/26/2018 HRPO
- 08/20/2019 HRPO closure memo issued

AMENDMENTS:
- Amendment 1, IRB approved 08/24/2016, minor changes for personnel change
- Amendment 2, IRB approved 09/28/2017, minor changes for enrollment increase from 18 subjects to 30 subjects

ADVERSE EVENTS OR UNANTICIPATED PROBLEMS:
- None

ENROLLMENT STATUS:
- Number of subjects recruited/original planned target: 21/30
- Number of subjects screened/original planned target: 21/30
- Number of patients enrolled/original planned target: 21/30
- Number of patients completed/original planned target: 20/30

Significant changes in use or care of vertebrate animals

No animal use research is involved.

Significant changes in use of biohazards and/or select agents

No biohazard or select agent research is involved.

6. PRODUCTS

Journal publications

- Cramer, M.N., G. Moralez, M. Huang, **C.G. Crandall**. No thermoregulatory impairment in skin graft donor sites during exercise-heat stress. *Med Sci Sports Exerc* 51:868-873, 2019. PMCID: PMC6465138.
- Cramer, M.N., G. Moralez, M. Huang, K. Kouda, P.Y.S. Poh, **C.G. Crandall**. Exercise Core Temperature Response with a Simulated Burn Injury: Effect of Body Size. *Med Sci Sports Exerc* 52:705-711. 2020. PMCID: PMC7024043.
- Cramer, M.N., G. Moralez, M. Huang, K. Kouda, P.Y.S. Poh, **C.G. Crandall**. Exercise Thermoregulation with a Simulated Burn Injury: Impact of Air Temperature. *Med Sci Sports Exerc* 52:712-719, 2020. PMCID: PMC7024026.
- Fischer, M, M.N. Cramer, M. Huang, L.N. Belval, J.C. Watso, F.A. Cimino, **C.G. Crandall**. Burn injury does not exacerbate heat strain during exercise while wearing body armor. *Med Sci Sports Exerc* 52:2235-2241, 2020. PMCID: PMC7503202.
- Belval, L.N., M.N. Cramer, G. Moralez, M. Huang, F.A. Cimino III, J.C. Watso, **C.G. Crandall**. Interaction of exercise intensity and simulated burn injury size on thermoregulation. *Med Sci Sports Exerc* 53:367-374, 2021. PMCID: PMC7995740.
- **Crandall, C.G.**, M.N. Cramer, K.J. Kowalske. It's More Than Skin Deep: Thermoregulatory and Cardiovascular Consequences of Severe Burn Injuries in Humans. *J Appl Physiol* (in press).

Books or other non-periodical, one-time publications

Nothing to Report.

Other publications, conference papers, and presentations

Each of the citations below are associated with an oral or poster presentation at a national or international conference.

- Crandall CG, Belval LN, Cramer MN, Huang M, Moralez G, Watso JC, Kowalske KJ (2021) Burn Survivors Can Perform Mild/moderate-intensity Exercise in Thermoneutral Conditions Without a Risk of Excessive Elevations in Core Body Temperature. *J Burn Care Res* 42(Supplement 1): S5-S6.
- Belval LN, Cramer MN, Huang M, Moralez G, Cimino III FA, Watso JC, Crandall CG (2020) Interaction Between Exercise Intensity and Burn Size on Body Temperature During Exercise in the Heat. *Med Sci Sports Exerc* 52(7S): 534.
- Cimino III FA, Cramer MN, Moralez G, Huang M, Belval LN, Watso JC, Crandall CG (2020) The effect of burn location on internal body temperature responses during exercise in the heat. *Med Sci Sports Exerc* 52(7S): 534.
- Fischer M, Cramer MN, Huang M, Belval LN, Watso JC, Cimino III FA, Secher NH, Crandall CG (2020) A Torso Burn Injury Does Not Exacerbate Thermoregulatory Strain During Exercise-Heat Stress While Wearing A Military Combat Uniform. *FASEB J* 34(S1):1-1.
- Crandall CG, Cramer MN, Moralez G, Huang M, Belval L, Watso J (2020) Burn Survivors Can Exercise For 30 min In The Heat Without A Risk of Excessive Hyperthermia. *American Burn Association, 52nd Annual Meeting, Orlando, USA*.
- Cramer MN, Moralez G, Huang M, Crandall CG (2018) No evidence of thermoregulatory impairment in donor skin during exercise-induced hyperthermia. *Med Sci Sports Exerc* 50(5) Supplement 1: 622.
- Cramer MN, Moralez G, Huang M, Crandall CG (2018) Critical Environmental Limits for Prolonged Work in the Heat Using a Simulated Burn Injury Model. *FASEB J* 32 (Meeting Abstract Supplement): 590.15.
- Crandall C, Cramer MN, Moralez G, Huang M (2018) Donor Sites Appropriately Contribute to Whole-body Thermoregulation During an Exercise-induced Hyperthermic Challenge. *J Burn Care Res* 39 (suppl 1): S55.
- Cramer MN, Kouda K, Moralez G, Poh PYS, Gagnon D, Crandall CG (2017) Core Temperature Responses to Exercise Using A Simulated Burn Injury Model: Impact of Body Size. *Med Sci Sports Exerc* 49(5) Supplement 1: 13.
- Cramer MN, Moralez G, Kouda K, Gagnon D, Crandall CG (2017) Impact of air temperature on core temperature regulation during exercise using a simulated burn injury model. *FASEB J* 31 (Meeting Abstract Supplement): 1018.9.

Other invited oral presentations given by Dr. Crandall that included findings that were funded by this project.

- "Thermal Regulation in Burn Survivors" World Burn Congress Annual Meeting, Dallas, TX Oct 4, 2017.
- "Thermoregulation in Adult Burn Survivors: Implications for Exercise and its Prescription" American Burn Association Annual Meeting, April 11, 2018, Chicago, IL
- "20 years of skin graft research – How we got to where we are" Integrative Human Cardiovascular Control Ph.D. Course, University of Copenhagen, Denmark, May 14, 2018.
- "40% body surface area burned is an inappropriate cutoff for the US Army's Standards of Medical Fitness for burn injuries: Effects of environmental temperature" Military Health System Research Symposium, Kissimmee, FL, Aug 21, 2018.
- "Thermoregulation in burn survivors" Physiology and Pharmacology of Temperature Regulation meeting. Split, Croatia. Oct 10, 2018.
- "Thermoregulatory and cardiovascular consequences of severe burn injuries: Implications for exercise and its prescription" University of British Columbia – Okanagan campus, Kewlona, British Columbia, Canada. March 8, 2019.
- "Hypothesis-driven research: 23 years of burn-related research" Integrative Human Cardiovascular Control Ph.D. Course, University of Copenhagen, Denmark, May 6, 2019.
- "Burn survivor research in the Thermal and Vascular Physiology Laboratory" Texas Community Burn Consortium, Houston, TX, June 8, 2019.
- "Thermoregulatory and cardiovascular consequences of severe burn injuries" University of Sydney, Australia March 5, 2020

- “Thermoregulatory and cardiovascular consequences of severe burn injuries” Auckland University, New Zealand, March 12, 2020
- “Revascularization and Reinnervation of Grafted Skin: Implications for Thermoregulation in the Burn Survivor” Center for Organogenesis Research and Trauma (CORT). Univ of Texas Southwestern Medical Center, October 23, 2020.
- “Thermoregulatory and cardiovascular consequences of severe burn injuries: Implications for exercise and its prescription” Brigham Young University, Provo, UT, (virtual) January 21, 2021
- “Burn injury does not exacerbate heat strain during exercise while wearing body armor” United States Army Annual Heat Forum, Fort Benning, GA, (virtual) February 23, 2021
- “Burn survivors can perform mild/moderate-intensity exercise in thermoneutral conditions without a risk of excessive elevations in core body temperature” American Burn Association Annual Meeting (virtual), April 9, 2021 (selected as one of the top 6 abstract submissions)
- “It’s more than skin deep: Thermoregulatory and cardiovascular consequences of severe burn injuries in humans” Edward F Adolf Distinguished Lectureship, Experimental Biology (virtual), April 27, 2021
- “Hypothesis-driven research: 25 years of burn-related research” Integrative Human Cardiovascular Control Ph.D. Course, University of Copenhagen, Denmark (virtual), May 17, 2021
- “Thermoregulatory and cardiovascular consequences of severe burn injuries in humans” 58th Annual Meeting of Japanese Association of Rehabilitation Medicine (virtual). June 10-15, 2021
- “Consequences of severe burn injuries on neural control of skin blood flow and sweating” Annual Meeting of the Japanese Peripheral Nerve Society (virtual). September 10, 2021

Website(s) or other Internet site(s)

Nothing to Report.

Technologies or techniques

Nothing to Report.

Inventions, patent applications, and/or licenses

Nothing to Report.

Other Products

Nothing to Report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Name:	Craig Crandall, PhD
Project Role:	PI
Researcher Identifier:	https://orcid.org/0000-0001-7792-9713
Contribution to Project:	Dr. Crandall has worked extensively with the lab team while planning and implementing data collection and analysis.
Funding Support:	Dr. Crandall receives extramural funding from the Department of Defense and the NIH.
Name:	Benjamin Levine MD
Project Role:	Collaborator
Researcher Identifier:	https://orcid.org/0000-0001-9064-7251
Contribution to Project:	Dr. Levine provides medical oversight to this project, as well as assists in the interpretation of the findings.
Funding Support:	Dr. Levine receives funding through the NIH, NASA, and from clinical revenue

Name:	Karen Kowalske, MD
Project Role:	Collaborator
Researcher Identifier:	https://orcid.org/0000-0003-2729-3328
Contribution to Project:	Dr. Kowalske assists with subject recruitment and the interpretation of the findings.
Funding Support:	Dr. Kowalske receives funding from the Burn Model Systems grant and from clinical revenue.
Name:	Matthew Cramer, Ph.D.
Project Role:	Postdoctoral Fellow
Researcher Identifier:	https://orcid.org/0000-0001-7400-8353
Contribution to Project:	Dr. Cramer assists with all aspects of the study, from recruitment through data analysis. This contribution has been quite extensive as each subject requires multiple visits to the laboratory to accomplish the stated aims.
Funding Support:	Dr. Cramer receives extramural funding support from the Department of Defense, the NIH, and the Canadian government.
Name:	Paula Poh, Ph.D.
Project Role:	Postdoctoral Fellow
Researcher Identifier:	https://orcid.org/ 0000-0003-0915-6119
Contribution to Project:	Dr. Poh provided assistance in data collection and interpration.
Funding Support:	Dr. Poh receives extramural funding support from the ORISE program.
Name:	Luke Belval, Ph.D.
Project Role:	Postdoctoral Fellow
Researcher Identifier:	https://orcid.org/0000-0003-0929-8061
Contribution to Project:	Dr. Belval took over the primary responsibilities of this project follow the departure of Dr. Matthew Cramer who to a Research Scientist position within the Canadian government. Dr. Belval assists with all aspects of the study, from recruitment through data analysis. This contribution has been quite extensive as each subject requires multiple visits to the laboratory to accomplish the stated aims.
Funding Support:	Dr. Belval receives extramural funding support from the Department of Defense and the NIH.
Name:	Joseph Watso, Ph.D.
Project Role:	Postdoctoral Fellow
Researcher Identifier:	https://orcid.org/0000-0001-7840-0643
Contribution to Project:	Dr. Watso assists with data collection.
Funding Support:	Dr. Watso receives extramural funding support from the Department of Defense.
Name:	Mu Huang, Ph.D.
Project Role:	Postdoctoral Fellow
Researcher Identifier:	https://orcid.org/0000-0001-9526-7944
Contribution to Project:	Dr. Huang assists with data collection.
Funding Support:	Dr. Huang received intramural funding support from the School of Health Professions at the University of Texas Southwestern Medical Center.
Name:	Gilberto Moralez, Ph.D.
Project Role:	Postdoctoral Fellow
Researcher Identifier:	https://orcid.org/0000-0002-0654-2383
Contribution to Project:	Dr. Moralez assists with data collection.
Funding Support:	Dr. Moralez received intramural funding support from the NIH and the Department of Defense.
Name:	Naomi Kennedy RN, BSN

Project Role:	Research Nurse
Researcher Identifier:	N/A
Contribution to Project:	Ms Kennedy has assisted with subject screening and consenting, data collection, and subject safety.
Funding Support:	Ms. Kennedy's salary was funded by grants to Dr. Crandall from the Department of Defense and the NIH.
Name:	Ileana Hill, RN, BSN
Project Role:	Research Nurse
Researcher Identifier:	N/A
Contribution to Project:	Ms. Hill assisted with subject screening and consenting, data collection, and subject safety.
Funding Support:	Ms. Hill's salary was funded by grants to Dr. Crandall from the Department of Defense and the NIH.
Name:	Courtney Hakes, RN, BSN
Project Role:	Research Nurse
Researcher Identifier:	N/A
Contribution to Project:	Ms. Hakes assisted with data analytics and subject safety.
Funding Support:	Ms. Hakes' salary was funded by grants to Dr. Crandall from the Department of Defense and the NIH.
Name:	Mads Fischer, B.S.
Project Role:	Visiting researcher
Researcher Identifier:	https://orcid.org/ 0000-0002-6403-1100
Contribution to Project:	Mr. Fischer assists with data collection and reduction.
Funding Support:	Mr. Fischer received a travel scholarship from the University of Copenhagen.
Name:	Frank Cimino, M.S.
Project Role:	Research Associate
Researcher Identifier:	N/A
Contribution to Project:	Mr. Cimino assists with subject recruitment, scheduling, and assisted with data collection and reduction.
Funding Support:	Mr. Cimino's salary was funded by grants to Dr. Crandall from the Department of Defense and the NIH.
Name:	Manall Jaffery, M.S.
Project Role:	Research Associate
Researcher Identifier:	N/A
Contribution to Project:	Ms. Jaffery assists with subject recruitment, scheduling, and assisted with data collection and reduction.
Funding Support:	Ms. Jaffery's salary was funded by grants to Dr. Crandall from the Department of Defense and the NIH
Name:	Sarah Bailey, M.S.
Project Role:	Research Associate
Researcher Identifier:	N/A
Contribution to Project:	Ms. Bailey assists with subject recruitment, scheduling, and assisted with data collection and reduction.
Funding Support:	Ms. Bailey's salary was funded by grants to Dr. Crandall from the Department of Defense and the NIH
Name:	Amy Adams, M.S.
Project Role:	Research Associate
Researcher Identifier:	N/A
Contribution to Project:	Ms. Adams assists with subject recruitment, scheduling, and assisted with data collection and reduction.

Funding Support:	Ms. Adams' salary was funded by grants to Dr. Crandall from the Department of Defense and the NIH
Name:	Bonnie Orth, M.S.
Project Role:	Research Associate
Researcher Identifier:	N/A
Contribution to Project:	Ms. Orth assists with data reduction and processing.
Funding Support:	Ms. Orth's salary was funded by grants to Dr. Crandall from the Department of Defense and the NIH

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Dr. Crandall has received one grant funded by the NIH addressing cooling strategies for burn survivors. This grant did not impact the support for the present project.

What other organizations were involved as partners?

Nothing to Report.

8. SPECIAL REPORTING REQUIREMENTS

QUAD CHART

Convert this report to a PDF file and append updated quarterly Quad Chart in PDF as an appendix.

9. APPENDICES

Attach all appendices that contain information that supplements, clarifies or supports the text. Examples include original copies of journal articles, reprints of manuscripts and abstracts, a curriculum vitae, patent applications, study questionnaires, and surveys, etc.

Nothing to report.

Effects of Burn Injuries on Thermoregulatory and Cardiovascular Responses in Soldiers: Implications for the Standards of Medical Fitness
BA150093
W81XWH-15-1-0647

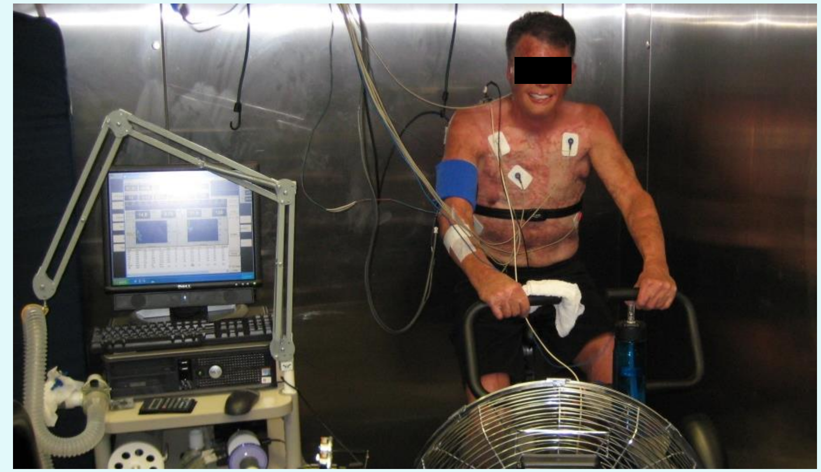
PI: Craig Crandall, Ph.D. **Org:** Univ of Texas Southwestern Medical Center **Award Amount:** $2,017,168

Study/Product Aim(s)

- Aim 1: Absolute body surface area (BSA) available for heat dissipation (i.e., uninjured skin) more accurately predicts thermoregulatory and cardiovascular consequences during a thermal stress relative to the current standard of using %BSA burned.
- Aim 2: The extent to which a burn injury is detrimental to an individual is dependent on the ambient temperature at a given exercise intensity and the exercise intensity within a given environment.
- Aim 3: Does the location of the burn injury influence thermoregulatory responses?
- Aim 4: Does the donor site contribute to compromised thermoregulatory responses in burned individuals.
- Aim 5: Identification of an upper limit for which a soldier with a prior burn injury could be expected to maintain a safe core body temperature across differing metabolic demands and environmental conditions.

Approach

The above questions will be addressed primarily by measuring thermoregulatory responses (e.g., core and skin temperatures) during exercise in neutral and hyperthermic environments at various workloads (e.g. rate of metabolic heat generation) in individuals with simulated burn injuries and in actual burn patients.



Accomplishment: We have closed data collection and are focusing on data analysis and writing the associated manuscripts. We are also working towards the completion of Aim 5 (integration of findings and recommendations).

Timeline and Cost

Activities CY	16	17	18	19	20
Aim 1: Body surface area					
Aim 2: Effect of workload and climate					
Aim 3: Burn location					
Aim 4: Donor site					
Aim 5: Compilation					
Estimated Budget ($K)	**$431**	**$375**	**$395**	**$399**	**$419**

Updated: 12/7/2021

Goals/Milestones

CY16 Goal – Obtain IRB and HRPO approvals. Initiate data collection for Aim 1.
CY17 Goals – Continue data collection for Aim 1 and initiate Aim 2.
CY18 Goal – Continue data collection for Aims 1, 2, and 4.
CY19 Goal – Complete data collection for Aim 2 and initiate data collection for Aim 3.
CY20 Goal – Complete all data collection. Complete the synthesis of the obtained data and provide guidelines regarding burn injury size/location, environmental condition, and workload by which a burned soldier could safely perform his/her duties.

Comments/Challenges/Issues/Concerns

None

Budget Expenditure to Date

Projected Expenditure: $2,017,168
Actual Expenditure: $2,017,168