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

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# REPORT DOCUMENTATION PAGE

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<b>14. ABSTRACT</b> This project tested the hypothesis that burn survivors could exercise for 30 min without excessive elevations in core body temperature, regardless of the total body surface area (%TBSA) burned or environmental temperature. Ten subjects cycled for 60 min at 1) a moderate intensity (97±8 watts) in a thermoneutral environment (24°C, MOD_NEU), 2) a moderate intensity (100±17 watts) in a hot environment (39°C, MOD_HOT), and 3) a low intensity (65±10 watts) in a hot environment (39°C, LOW_HOT). Burn injuries were simulated by covering 0%, 20%, 40%, or 60% of the individual's %TBSA with an absorbent material that prevented sweat evaporation. Changes in gastrointestinal temperature ( $\Delta T_{core}$ ) were analyzed at 15-min increments throughout exercise. For the MOD_NEU trial, there were no differences in $\Delta T_{core}$ between the %TBSA coverage bouts at any time point during exercise. For the MOD_HOT trial, there were no differences in $\Delta T_{core}$ at 15 and 30 min of exercise regardless of the %TBSA coverage, while $\Delta T_{core}$ was appreciably elevated ( $P < 0.05$ ) at 45 and 60 min of exercise for 20%+ TBSA bouts. For the MILD_HOT trial, there were no differences in $\Delta T_{core}$ at any time point between %TBSA bouts, with the sole exception of 60% simulated burn having a slightly greater $\Delta T_{core}$ ( $0.3 \pm 0.34^\circ\text{C}$ ; $P < 0.05$ ) at 60 min of exercise relative to the 0% TBSA bout. These data indicate that individuals with up to 60% of their TBSA burned could exercise at a moderate intensity for 30 min, even in hot environmental conditions, without excessive elevations in body core temperature. Thus, burn survivors can benefit from exercise, without the risk of excessive hyperthermia, for up to 30 min in the heat or at least 60 min in an air-conditioned space.						
<b>15. SUBJECT TERMS</b> 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.

## 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?** For year 4 of this project (October 1, 2018 – September 30, 2019) the Statement of Work indicates that (i) we will complete data collection for protocols 2B, 2C, and 2D and we will reduce the data such that they could be disseminated to the scientific community. (ii) we will initiate and complete data collection for protocols 3A and 3B. (iii) we will obtain IRB and HRPO approvals for Aim 4.

Protocol 2B evaluates the effect of exercise intensity on individuals exercising in hyperthermic environments with simulated burns covering 0, 20%, 40%, and 60% of their body surface area. We would like to note that to complete the battery of tests required for this protocols, each subject visits the laboratory on 9 occasions. Protocol 2C assesses the relationship between one's maximal evaporative capacity and body surface area burned. For this protocol, subjects exercise at a fixed workload, having simulated burns covering 0, 20%, 40%, and 60% of their body surface area, which is followed by escalating humidity to identify the relative humidity at which core temperature inflection point occurs. To complete this protocol, subjects visit the laboratory on 5 occasions. Protocol 2D evaluates the effects of the size of the burn injury on an individual's maximum ability to dissipate

heat, and requires 4 visits to the laboratory. Protocol 3A evaluates whether burn location influences thermoregulatory responses. This protocol requires just one visit per participant. Protocol 3B evaluates whether a torso burn injury that is covered by the combination of body armor and the military uniform, is or is not detrimental toward thermoregulatory control when compared to the body armor/uniform combination without an underlying burn injury. This protocol also takes just one visit per participant. Protocol 4 identifies whether donor sites have preserved cutaneous vasodilatory and sweating responses during exercise in hyperthermic environmental conditions; please note that this protocol was completed during the prior funding year.

### **What was accomplished under these goals?**

Protocol 2B: We need to complete only one additional subject and then data collection for this protocol will be completed. That subject has been recruited and has initiated the 9 visit series of trials. Data from this protocol are depicted below in the abstract that was presented at the 2019 MHSRS meeting.

### **TITLE: 40% body surface area burned is an inappropriate cutoff for the US Army's Standards of Medical Fitness for burn injuries: Effects of work intensity**

**Background**: Grafted skin has impaired cutaneous vasodilation and sweating responses, resulting in potentially dangerous elevations in core temperature during activities often performed by the soldier. The US Army's Standards of Medical Fitness (AR 40-501) states "Prior burn injury ... involving a total body surface area (BSA) of 40 percent or more does not meet the standard." Thus, an individual having a burn injury covering  $\geq 40\%$  of his/her BSA will be prohibited from enlisting or continued service in the Army. However, this metric does not account for work intensity, and thus metabolic heat generation, that a soldier is expected to perform. It may be that at mild work intensities a soldier with  $\geq 40\%$  BSA burn could safely perform his/her duties without excessive elevations in core body temperature, while a soldier with burns covering  $< 40\%$  BSA may exhibit substantial elevations in body core temperature when a moderate intensity work is performed. This study tested the hypothesis that the extent to which the size of a burn injury compromises thermoregulatory responses during exercise in the heat is influenced by the work intensity. **Methods**: Eight healthy subjects ( $31 \pm 8$  years;  $76.5 \pm 11.0$  kg;  $1.92 \pm 0.15$  m<sup>2</sup> BSA) were recruited to perform eight randomized trials of 60 min of cycle ergometry exercise in a 40 °C and 20% relative humidity environmental chamber at a work intensity that was mild (rate of metabolic heat generation of  $\sim 4$  W/kg body mass;  $\sim 30\%$  VO<sub>2max</sub>) or moderate (rate of metabolic heat generation of  $\sim 6$  W/kg body mass;  $\sim 45\%$  VO<sub>2max</sub>), with a simulated burn injury covering 0%, 20%, 40% or 60% of their BSA. Burn injuries were simulated by precisely covering the desired area of skin (torso and limbs) with a highly absorbent vapor-impermeable material that prevents evaporative cooling. The magnitude of the increase in core body temperature, measured from gastrointestinal temperature, was the primary variable of interest. **Results**: After 60 min of mild intensity work in the heat, the magnitude of the elevation in core body temperature did not differ ( $P > 0.05$ ) across the trials despite differing percentages of BSA simulated burn (0%:  $0.68 \pm 0.16$  °C; 20%:  $0.63 \pm 0.18$  °C; 40%:  $0.77 \pm 0.15$  °C; 60%:  $0.96 \pm 0.35$  °C). However, after 60 min of moderate intensity work in the heat, the magnitude of the elevation in core body temperature was higher in the 60% BSA simulated burn injured state ( $1.64 \pm 0.50$  °C;  $P < 0.013$ ) compared to the other three

simulated burn injured states (0%:  $0.92 \pm 0.41$  °C; 20%:  $1.05 \pm 0.45$  °C; 40%:  $1.05 \pm 0.46$  °C); there were no differences in the magnitude of the increase in core body temperature between 0%, 20%, and 40% simulated burn states. **Conclusion:** During mild intensity work in the heat, the severity of the burn injury (up to 60% body surface area) does not affect the magnitude of the elevation in body core temperature during 60 min of exercise. Conversely, during moderate intensity work, 60% BSA burn injury will result in potentially dangerous elevations in core body temperature during 60 min of moderate intensity exercise in the heat. These data suggest that the Army's Standard of Medical Fitness cutoff of  $\geq 40\%$  BSA burned is overly cautious for soldiers who are expected to perform mild intensity work in the heat, while this BSA cutoff is appropriate for soldiers who are expected to perform moderate intensity work in the same climate. Project funded by Department of Defense – Army: W81XWH-15-1-0647

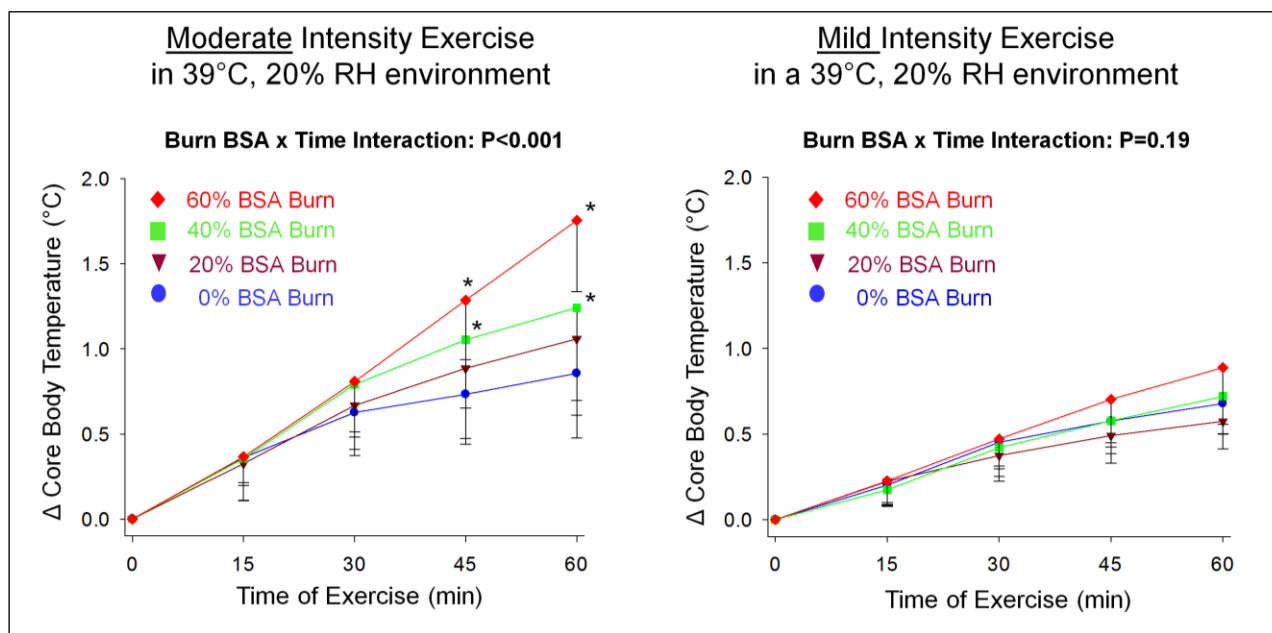


Figure 1: Core body temperature responses during 60 min of exercise across three levels of simulated burn injury during moderate intensity exercise (left panel) and mild intensity exercise (right panel) in hyperthermic environmental conditions. \*Different from 0% BSA burn.

**Protocol 2C:** Data collection for this protocol has been completed and we are in the process of writing the accompanying manuscript. These data were presented at the 2019 ICEE meeting in Amsterdam, Netherlands. Following a deep burn injury, excision of devitalized skin and subsequent grafting impair sweat production within grafted sites. Since the capacity for whole-body evaporative heat dissipation is dependent on sweat production and the total non-injured skin area available for heat dissipation, burn injuries likely reduce the capacity for whole-body heat dissipation in proportion to the size of the burn injury. This question was evaluated by subjects completing an incremental humidity protocol while cycling at a fixed metabolic heat production (5 W/kg, equivalent to  $\sim 35\%$  maximum oxygen uptake) in  $40^\circ\text{C}$  with and without simulated burn injuries of 20%, 40%, or 60% of total body surface area. During each trial, exercise was performed at an initial relative humidity (RH) of 25% for 30 min to achieve thermal equilibrium, after which

exercise continued as relative humidity was increased by 3% every 5 min up to 90 min. A 'critical' RH was identified as the relative humidity value above which a steady-state esophageal temperature could no longer be maintained, thus providing an indication of maximum evaporative heat dissipation. The primary finding is the average critical relative humidity declined with an increasing size of the simulated burn injury (see Figure 2). Of note, a critical relative humidity could not be achieved in any subject with a 60% body surface area simulated burn injury. These data suggest that under the current environmental conditions, burn survivors with injuries of  $\geq 40\%$  have a substantially attenuated capacity for heat dissipation, placing them at greater risk of heat-related illness during prolonged work and heat stress.

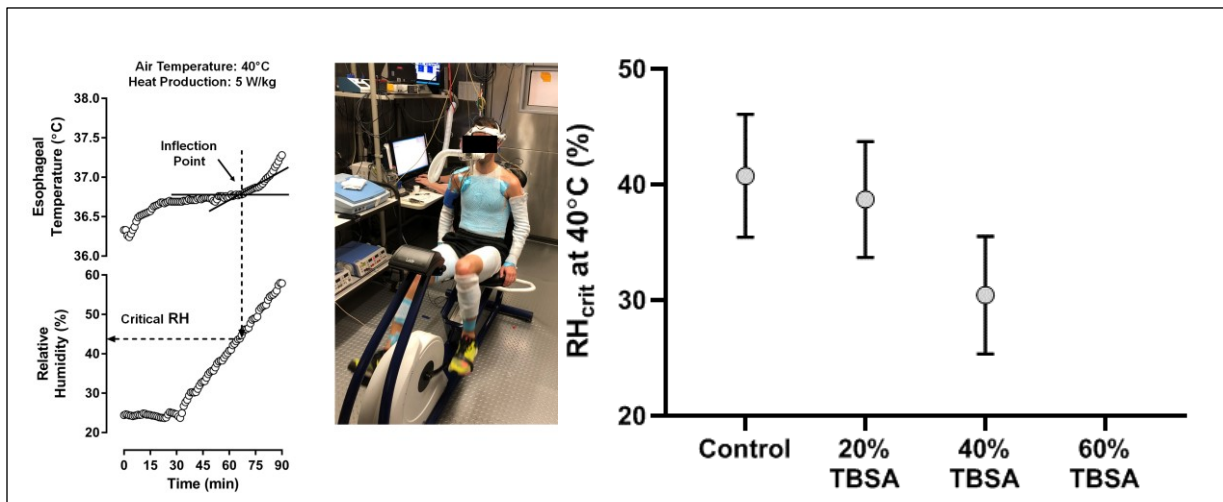
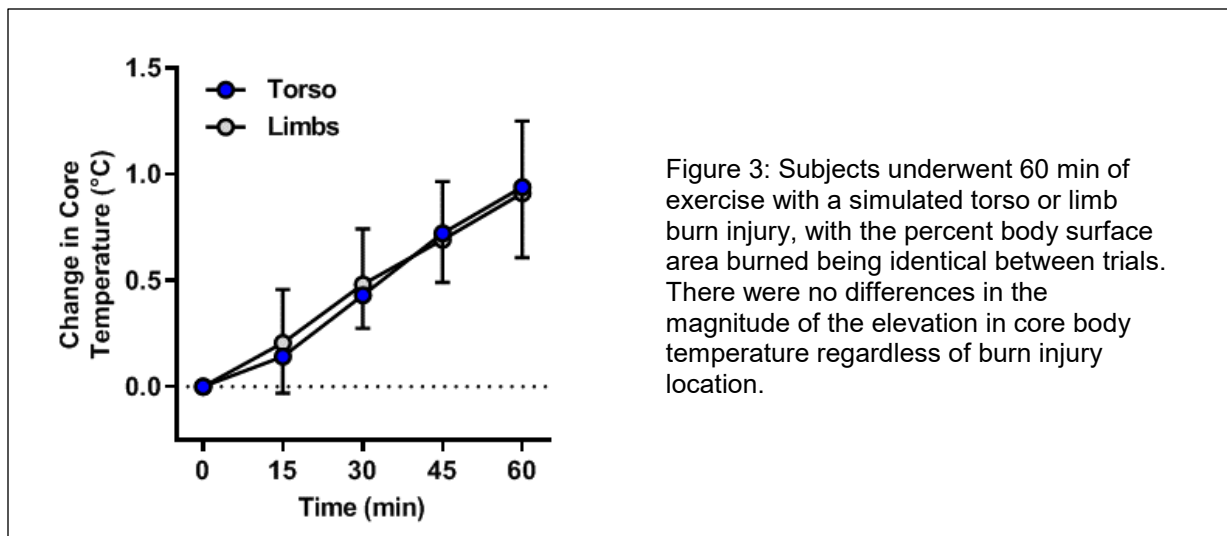


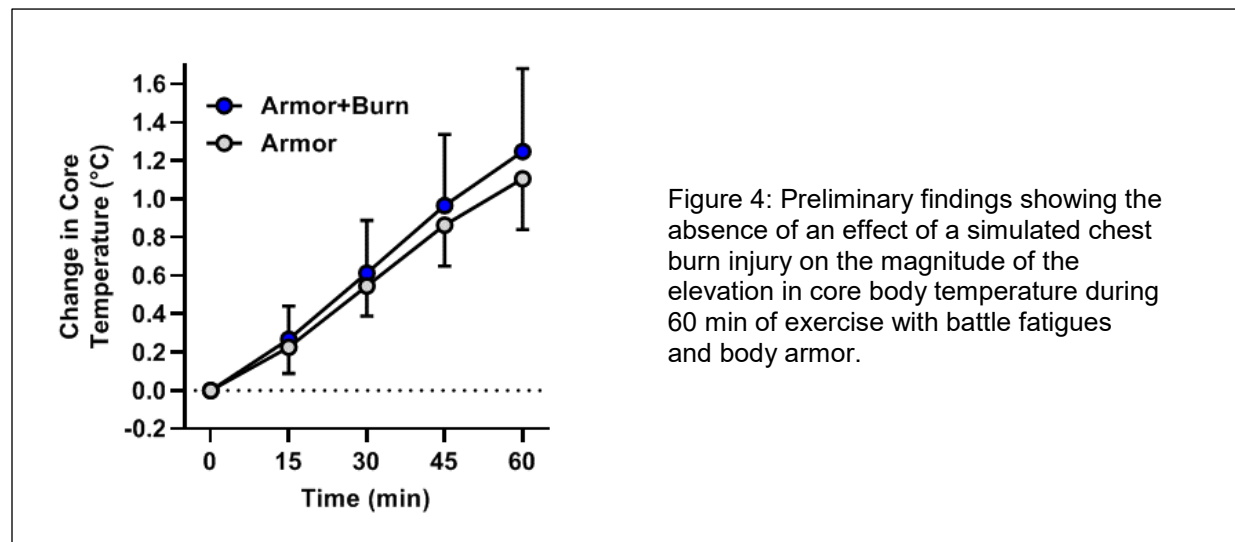
Figure 2: Left panel: Illustration of the incremental humidity protocol and experimental setup. The relative humidity at the indicated inflection point is the data reported in the right panel. Right panel: Critical relative humidity values at each simulated burn area. The absence of data at 60% total body surface area (TBSA) indicates that at this coverage subjects are in a non-compensable state even at very low relative humidities (e.g., 20% RH).

**Protocol 2D:** Data collection for this protocol is ongoing. This protocol compares thermoregulatory responses to exercise in hyperthermic conditions between groups of burn survivors with burn injuries spanning 20%, 40%, or 60% of total body surface area. Thus far we have completed data collection in 32 subjects, with data collection for the 20% burn group completed, and we need to enroll five individuals with 40% burns and three individuals with 60% burns. Three burn survivors are scheduled to complete these trials by Dec 2019, while we continue to work on recruitment for the remaining five subjects.

**Aim 3A:** The objective of this protocol as to test the hypothesis that a burn on the torso would be more detrimental to temperature regulation relative to the exact same size burn on the limbs. We completed data collection for this protocol with the primary findings depicted below in Figure 3. Despite the US Army Standards of Medical Fitness document proposing that a torso burn would be more detrimental than a limb burn, the obtained data do not support that statement. Data collection has been completed for this protocol.



**Aim 3B:** Given that body armor covers the chest area, this aim tested the hypothesis that a chest burn would be inconsequential to the magnitude of the elevation in core body temperature when that burn is covered with body armor. We have only 1 subject remaining until data collection for this protocol will be complete; that subject has been recruited and has initiated the data collection trials. The figure below illustrates the obtained findings thus far. Given these findings, we do not expect there to be any differences in the magnitude of the elevation in core body temperature between body armor only and body armor plus a simulated chest burn injury trials.



**Aim 4:** Data collection for Aim 4 was completed in 2018 and the manuscript has been published.  
 Cramer, M.N., G. Morales, 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. PMID: PMC6465138.

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

Though the project was not intended to provide training or professional development opportunities, training has nonetheless taken place as a result of the performed work. Specifically, Matthew Cramer, Ph.D., Gilbert Moralez, Ph.D., and Mu Huang, Ph.D. were postdoctoral fellows working on this project during the prior reporting period. They have since each obtained faculty positions and two new post-doctoral fellows are now assisting with this project (Joseph Watso, Ph.D. and Luke Belval, Ph.D). As a result of this project, each of 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 Experimental Biology annual meeting, and the International Conference on Environmental Ergonomics meeting.

**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 or poster formats: internal “Works in Progress”, the Military Health System Research Symposium, and the International Conference on Environmental Ergonomics meetings. The manuscript for Aim 4 was published in *Medicine and Science in Sports and Exercise*. The manuscript for Aim 1A was accepted for publication in *Medicine and Science in Sports and Exercise*. The manuscript for Aim 2A is under review *Medicine and Science in Sports and Exercise*. We anticipate that three more publications will originate from Aims 2B, 2C, 3A/B within the next year.

**What do you plan to do during the next reporting period to accomplish the goals?**

In addition to completing data collection for the final two subjects for Aims 2B and 3B (one subject each), a primary focus over next 12 months will be devoted to completing the objectives in Aim 2D (outlined above). We need 8 more burn survivors to complete the battery of tests, though 3 of those 8 have been identified and are scheduled. To identify those final 5 subjects, we are aggressively working with regional burn throughout the United States to inform potential candidates about the research. We are also working with Brooke Army Medical Center (San Antonio, TX) to get approvals to have recruitment materials sent to burn survivors in their database. We anticipate that through these two approaches we will identify, recruit and complete data collection on these final burn survivors. During this period we will also address the objectives in Aim 5, which synthesizes the obtained data to provide the Army with 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, environmental conditions, and burn size/location.

**4. IMPACT**

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

Impact statements from work completed during the prior reporting period:

Data from Aim 2A informs the military that individuals with  $\leq 20\%$  body surface area burns are fully capable of regulating their internal temperature, when compared to a non-burned individual, exercising at moderate intensities in both normothermic and hyperthermic

environments. However, individuals with 40-60% body surface area burn are at a greater risk for a hyperthermic injury, but only when exercising in conditions of elevated environmental temperatures.

Data from 2B suggest that the Army's Standard of Medical Fitness cutoff of  $\geq 40\%$  BSA burned is overly cautious for soldiers who are expected to perform mild intensity work in the heat, while this BSA cutoff is appropriate for soldiers who are expected to perform moderate intensity work in the same climate

Data from Aim 2C will inform the military that maximum evaporative heat dissipation decreases as the size of a burn injury increases. Individuals with a burn injury of 40% are still able to thermoregulate appropriately during prolonged moderate-intensity work in hot conditions at a relative humidity of no higher than  $\sim 30\%$ .

Data from Aim 3A/B will inform the military that a burn on the torso should not be treated any differently relative to a similar size burn on a non-torso area. Moreover, this Aim will inform the military that a burn on the chest is not detrimental for body temperature regulation when the individual is wearing body armor.

**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 is 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**

**Changes in approach and reasons for change:**

None

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

None

**Changes that had a significant impact on expenditures:**

None

**Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents:**

**Significant changes in use or care of human subjects:**

There were no significant changes pertinent to human subject experimentation. During the reporting period the only changes to the IRB were: 1) related to changes in personnel and 2) an increase in enrollment by 15 subjects due to an unexpectedly high number of individuals being excluded, due to low aerobic fitness, after they signed the consent form.

**Significant changes in use or care of vertebrate animals:**

None

**Significant changes in use of biohazards and/or select agents:**

None

**6. PRODUCTS**

**Publications, conference papers, and presentations**

**Journal publications**

**Published Manuscripts During the Prior Reporting Period:**

Cramer, M.N., G. Morales, 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. Yes, Federal support acknowledged.

Cramer, M.N., G. Morales, 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* (in press). Yes, Federal support acknowledged.

Cramer, M.N., G. Morales, 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* (in press). Yes, Federal support acknowledged.

**Other Published Works During the Prior Reporting Period:**

In addition, 3 published presentations were given (either poster or oral formats) at national and international meetings during the prior reporting period. Federal support was acknowledged at each of these presentations.

**Books or other non-periodical, one-time publications:**

None

**Other publications, conference papers, and presentations:**

Oral and poster presentations from this project were given at the following meetings during the prior reporting period (Federal support was acknowledged at each presentation).

-Military System Health Research Symposium

-International Conference on Environmental Ergonomics\*

**Website(s) or other Internet site(s):**

None

**Technologies or techniques:**

None

**Inventions, patent applications, and/or licenses:**

None

**Other Products**

None

**7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS**

**What individuals have worked on the project?**

Name:	Craig Crandall, Ph.D.
Project Role:	PI
Researcher Identifier (e.g. ORCID ID):	<a href="https://orcid.org/0000-0001-7792-9713">https://orcid.org/0000-0001-7792-9713</a>
Nearest person month worked:	4
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 (e.g. ORCID ID):	<a href="https://orcid.org/0000-0001-9064-7251">https://orcid.org/0000-0001-9064-7251</a>
Nearest person month worked:	1
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 (e.g. ORCID ID):	<a href="https://orcid.org/0000-0003-2729-3328">https://orcid.org/0000-0003-2729-3328</a>
Nearest person month worked:	1

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 (e.g. ORCID ID):

<https://orcid.org/0000-0001-7400-8353>

Nearest person month worked:

5

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 grants to Dr. Crandall from the NIH and the Department of Defense. He also receives salary support through the Natural Sciences and Engineering Research Council of Canada.  
NOTE: Dr. Cramer recently accepted a Research Scientist position within the Canadian government.

Name:

Gilbert Moralez, Ph.D.

Project Role:

Postdoctoral fellow

Researcher Identifier (e.g. ORCID ID):

<https://orcid.org/0000-0002-0654-2383>

Nearest person month worked:

1

Contribution to Project:

Dr. Moralez assists with data collection. Dr. Moralez receives extramural funding support from grants to Dr. Crandall from the NIH.

Funding Support:

NOTE: Dr. Moralez recently accepted a faculty position with the University of Texas Southwestern Medical Center

Name:

Mu Huang, Ph.D., DPT

Project Role:

Postdoctoral fellow

Researcher Identifier (e.g. ORCID ID):

<https://orcid.org/0000-0001-9526-7944>

Nearest person month worked: 1  
Contribution to Project: Dr. Huang assists with data collection.  
Funding Support: Dr. Huang receives salary support from the School of Health Professions at the University of Texas Southwestern Medical Center.  
NOTE: Dr. Huang recently accepted a faculty position with the University of Texas Southwestern Medical Center

Name: Naomi Kennedy RN, BSN  
Project Role: Research Nurse  
Researcher Identifier (e.g. ORCID ID): N/A  
Nearest person month worked: 3  
Contribution to Project: Naomi has assisted with subject screening and consenting, data collection, and subject safety.  
Funding Support: Ms. Kennedy receives extramural funding support from grants to Dr. Crandall from the Department of Defense and the NIH.

Name: Sarah Bailey Adams, M.S.  
Project Role: Research Associate  
Researcher Identifier (e.g. ORCID ID): N/A  
Nearest person month worked: 2  
Contribution to Project: Ms. Bailey Adams assists with subject recruitment, scheduling, and with data collection and reduction.  
Funding Support: Ms. Baily Adams receives extramural funding support from grant to Dr. Crandall from the NIH and the Department of Defense  
NOTE: Ms Bailey accepted a position within the American Heart Association.

Name: Manall Jaffrey, M.S.  
Project Role: Research Associate  
Researcher Identifier (e.g. ORCID ID): N/A  
Nearest person month worked: 2  
Contribution to Project: Ms. Jaffrey assists with subject recruitment, scheduling, and assisted with data collection and reduction.

Funding Support:

Ms. Jaffrey receives extramural funding support from grant to Dr. Crandall from the NIH and the Department of Defense  
NOTE: Ms Jaffrey accepted a position within at the University of Texas at Arlington.

Name:  
Project Role:  
Researcher Identifier (e.g. ORCID ID):  
Nearest person month worked:  
Contribution to Project:

Luke Belval, Ph.D.  
Postdoctoral Fellow  
<https://orcid.org/0000-0003-0929-8061>  
1  
Dr. Belval has taken 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. Dr. Belval receives extramural funding support from the Department of Defense.

Funding Support:

Name:  
Project Role:  
Researcher Identifier (e.g. ORCID ID):  
Nearest person month worked:  
Contribution to Project:  
Funding Support:

Joseph Watso, Ph.D.  
Postdoctoral Fellow  
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1  
Dr. Watso assists with data collection  
Dr. Watso receives extramural funding support from the Department of Defense

Name:  
Project Role:  
Researcher Identifier (e.g. ORCID ID):  
Nearest person month worked:  
Contribution to Project:

Frank Cimino, M.S.  
Research Associate  
N/A  
2  
Mr Cimino assists with subject recruitment, scheduling, and assisted with data collection and reduction.  
Mr Cimino receives extramural funding support from grant to Dr. Crandall from the Department of Defense and the NIH.

Funding Support:

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

Yes, Dr. Crandall serves as a collaborator on an NIH grant to Qi Fu, MD, PhD addressing chronic lower leg heating for the treatment of hypertension in older women. This effort does not impact the support for the present project.

**What other organizations were involved as partners?**

Nothing to report.

**8. SPECIAL REPORTING REQUIREMENTS**

COLLABORATIVE AWARDS:

Not applicable

QUAD CHART:

See attachment

**9. APPENDICES**

Not applicable

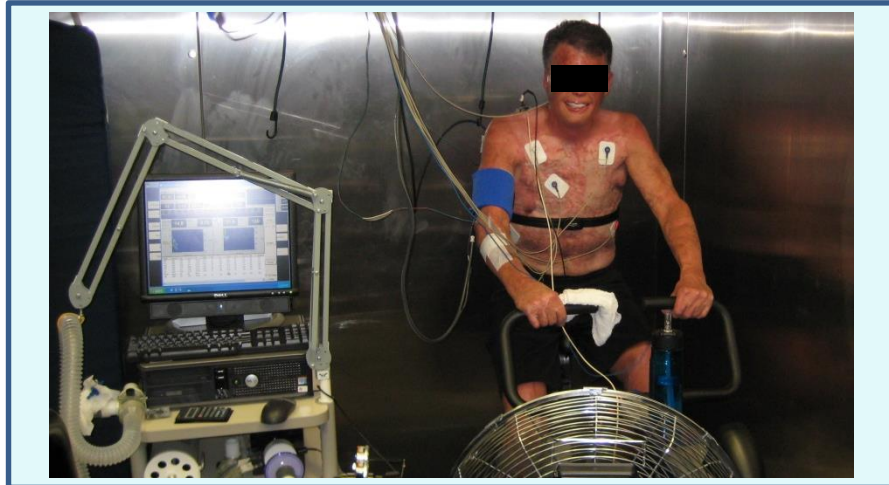


**Study/Product Aim(s)**

- 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 are very close to completing Aim 2B (only 1 subject needed and she has completed 5 of the 9 visits). We completed Aims 2C, 3A, and 3B.

**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						█
<b>Estimated Budget (\$K)</b>		<b>\$431</b>	<b>\$375</b>	<b>\$395</b>	<b>\$399</b>	<b>\$419</b>

**Goals/Milestones**

**CY16 Goal** – Obtain IRB and HRPO approvals. Initiate data collection for Aim 1A.

**CY17 Goals** – Complete Aims 1A and initiate Aims 2.

**CY18 Goal** – Continue data collection for Aims 1B, all Aim 2s, and Aim 4.

**CY19 Goal** – Complete data collection for Aim 2 and initiate data collection for Aim 3.

**CY20 Goal** – Complete data collection for Aims 1B, 3, and 4 (data collection for Aim 4 will occur throughout the funding period as suitable burned subjects are identified). 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**

- We have done an exceptional job at recruiting subjects and accomplishing the grant’s objectives. The only exception is identifying 2 small males to complete Aim 1B. With that said, we remain on track relative to our expected goals.

**Budget Expenditure to Date**

Projected Expenditure: \$1,599,416

Actual Expenditure: \$1,368,260