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Impact of a Flame Resistant Synthetic Material Base Layer on Heat Stress Factors

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IMPACT OF A FLAME RESISTANT SYNTHETIC MATERIAL BASE LAYER ON HEAT STRESS FACTORS

By

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B.S. Utah Valley University, Orem, UT, 2012

Thesis Paper

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Protective clothing worn by wildland firefighters (WLFF) may increase physiological strain and heat stress factors due to increased insulation and decreased ventilation. PURPOSE: To examine the effects of a flame resistant synthetic material base layer on heat stress factors. METHODS: Ten recreationally active males (25 ± 6.1 yrs, 80.9 ± 8.4 kg, 11.1 ± 5.3% fat, 4.4 ± 0.6 L·min⁻¹ VO₂ max) completed two trials of intermittent (50 min walking, 10 min sitting) treadmill walking (4km/hr, 4% grade) over 3 hours in a hot, dry environment (35⁰C, 30% rh). Participants wore standard WLFF Nomex green pants, Nomex yellow shirt with either a 100% cotton (C) or flame resistant synthetic material base layer (S), while carrying a 16kg pack, hard hat, and gloves. Exercise was followed by a 30 minute rest period without the pack, hard hat, gloves, and Nomex yellow shirt. Core (T_c) and skin (T_sk) temperatures were measured continuously throughout the trial. Physiological strain index (PSI) was calculated using heart rate and T_c. Skin blood flow (SBF) was recorded for two minutes prior to walking, for five minutes during each break, and for three, five minute periods during the 30 minutes following exercise. Water was scripted at 8 ml/kg/hr. RESULTS: No significant differences were found for T_c (p=0.077) and T_sk (p=0.086) between C and S. Significant main effects for time were found for T_c (p<0.001) and T_sk (p=0.003). Significant main effects for time (p<0.001) and trial (p=0.04) were found for PSI. SBF increased significantly in S following the second hour of exercise, resulting in a time*trial interaction (p=0.001). No significant differences for SBF were found between C and S post-exercise (p=0.089). CONCLUSION: These data indicate that a flame resistant synthetic material base layer negatively affects physiological factors that have been shown to indicate an increased risk of heat-related injuries.
Table of Contents

**Chapter One: Introduction** 1
Introduction 1
Problem 2
Purpose 2
Null Hypotheses 3
Significance of Study 3
Limitations 3
Delimitations 4
Definition of Terms 4

**Chapter Two: Review of Literature** 5
Uncompensated Heat Stress 5
Personal Protective Equipment 6
Alleviating Heat Stress and Physiological Strain 7
Practical Applications 9

**Chapter Three: Methodology** 10
Participants 10
Experimental Testing Design 10
Preliminary Testing 10
Experimental Trials 11
Statistical Analysis 15

**Chapter Four: Results** 16
Participants/Environment 16
Physiological Measures 16
Graphs 18

**Chapter Five: Discussion** 28
Conclusion 31

**Appendix I: IRB-Approval** 33

**Appendix II: PAR-Q/Data Collection Sheets** 38

**Appendix III: Tables** 43

**References** 44
Chapter 1: Introduction

Introduction

Types of clothing, hot and humid environments, and the amount of physical exertion can influence the amount of heat strain experienced by occupational athletes, such as soldiers and wildland firefighters (WLFF’s). Heat stress may manifest by muscle cramping, heat exhaustion, heat stroke, and hyperthermia (2, 10, 48). Heat sources that factor into heat stress are external to the body (environmental) and internal to the body (metabolic heat due to exertion) (2, 30). Heat stress that is created while wearing protective equipment is termed uncompensable heat stress and occurs from an inability to dissipate heat when performing routine operations while wearing personal protective clothing (PPC) and other forms of equipment (ie., gear, vests, and packs) (9, 15, 23, 26, 28, 43, 44, 45). When heat stress leads to an impairment or cessation of job tasks it is referenced as a heat related illness or injury (HRI). On average, two of every 1,000 outdoor workers are at risk of HRI and some occupations, including wildland firefighting, are at a greater risk due to metabolic demands, hydration challenges, and PPC (41, 52). Even as awareness of HRI has increased, the number of reported cases remains relatively unchanged (Table 2). Additionally, during one-on-one interviews, many WLFF’s reported symptoms consistent with mild to moderate HRI yet admitted to never having reported the injury or illness (7). An Australian study on work productivity among bush firefighters indicated that efficient PPC was a key factor in reducing uncompensable heat stress. It was noted that two-thirds of the firefighter’s heat load was generated internally, with only one-third coming from the radiant heat of the fire. The authors recommended that the design of PPC should focus on letting heat out, not keeping heat out (4).

Thermoregulation is dependent upon temperature gradients within the body (core-to-periphery), facilitated by skin blood flow (SBF), and between the body and the environment. As ambient temperature increases, skin temperatures increase narrowing the core-to-skin gradient (37). During
exercise, a rise in core temperature helps to widen the gradient, however it is not proportionate to the increase in heat production. As a result, SBF increases to accentuate core-to-skin heat transfer (38). Therefore, a primary concern during exercise in the heat is to concurrently supply enough blood flow to the skin to dissipate heat, and enough blood flow to the working muscle to meet the demands of exercise. In hot environments, evaporative heat loss becomes more important in maintaining thermal homeostasis. The rate of evaporative heat loss is heavily influenced by the water vapor pressure gradient between the skin and environment, and is also effected by air movement, skin wetness, and the water-vapor permeability of clothing (26, 28, 43).

There have been many advancements in PPC for WWLF’s, however the focus has mainly been on increasing radiant protection and thermal resistance while air permeability and moisture evaporation has been seemingly overlooked. When worn as a single layer, synthetic material base layers have been shown to retain less water and increase sweat evaporation, yet during high heat exposure, melting and charring of synthetic materials has been shown (34). Important to the present study however is the attenuation of these advantages as layers of PPC is added (31).

**Problem**

Protective clothing often exacerbates the challenge of thermoregulation, decreasing the rate of heat exchange, resulting in uncompensable heat stress. The need for adequate environmental protection is generally contradictory to adequate ventilation, which may lead to increased heat related injuries. Therefore, it is necessary to evaluate the physiological cost of a flame resistant synthetic material base layer.

**Purpose**

The purpose of this study was to evaluate the effects of a flame resistant synthetic material base layer on heat stress factors [skin temperature ($T_{sk}$), core temperature ($T_c$), physiological strain index (PSI), skin blood flow (SBF), rating of perceived exertion (RPE), hydration indicators, and blood
measures] during exercise in a hot environment, when compared to a typical cotton base layer, at a fixed work rate.

**Null Hypotheses**

1. No significant difference in $T_c$, $T_{sk}$, or PSI with flame resistant synthetic material compared to control.
2. No significant difference in SBF with flame resistant synthetic material compared to control.
3. No significant difference in RPE with flame resistant synthetic material compared to control.
4. No significant difference in dehydration percentage, hematocrit (Hct), or hemoglobin (Hb) with flame resistant synthetic material compared to control.

**Significance of Study**

The findings of this research has implications on current and future wildland firefighters who are at risk of HRI (52). If more effective flame resistant clothing does not further decrease tolerance to physiological strain this may result in increased safety for WLFF’s and similar populations.

**Limitations**

Subjects were recruited by convenience and cannot be randomly sampled.

Human error in data collection and the usage of instruments was minimized through training of all members involved prior to collection and monitoring during trials.

Participants’ lifestyles cannot be controlled and in an attempt to minimize extraneous variables, a physical activity and dietary log for the day prior to testing was used so that participants could repeat for succeeding trials. Participants were asked to refrain from strenuous exercise and alcohol the day prior to each trial.
Delimitations

All participants in this study were males. Due to the effects of the menstrual cycle on core temperature, females were excluded from this study.

Definition of Terms

- Heat Stress: sum of the heat generated from the body plus heat gained from the environment minus heat loss due to evaporation (30).

- Physiological Strain Index (PSI): method of calculating heat stress on the body utilizing $T_c$ and heart rate (HR). PSI stratifies the risk of an HRI on a scale of 0-10 and is based on the following equation:

$$\text{PSI} = 5 \left( \frac{(T_{c(t)} - T_{c(0)})}{(39.5 - T_{c(0)})^{-1}} \right) + 5 \left( \frac{(HR_t - HR_0)}{(180 - HR_0)^{-1}} \right)$$

Where $T_{c(0)}$ and $HR_0$ are the core temperature and heart rate measured at the start of exercise and $T_{c(t)}$ and $HR_t$ are from any one time during the bout of exercise (29).

- Dehydration: a 1% or greater loss of body weight as a result of fluid loss, for the purpose of this study, dehydration will be expressed as a percentage of body weight loss (21).

$$\% \text{ Dehydration} = \frac{(BW_{pre}(\text{kg}) - BW_{post}(\text{kg}))}{BW_{pre}(\text{kg})}$$

- Skin Blood Flow (SBF): blood flow through vessels located in the dermis, epidermis and epidermal appendages. SBF can fluctuate from < 200mL/min during cold exposure, to > 7 L/min during severe hyperthermia (8).
Chapter Two: Review of Literature

Uncompensable Heat Stress (UCHS) and Heat-Related Illness (HRI)

Under conditions of high ambient temperature and/or relative humidity, or with the wearing of personal protective clothing (PPC), evaporative heat loss is restricted. Heat stress is the sum of heat generated by the body plus heat gained from the environment minus evaporative heat loss (30). The evaporative heat loss needed to maintain thermal steady state can easily be exceeded by the evaporative capacity of the environment leading to UCHS situations in which the body constantly stores heat (26). UCHS can occur during light exercise and even at rest, especially while wearing PPC. One study reports that neither exercise intensity nor climate altered physiological tolerance to heat strain, although higher heart rate and shorter time to exhaustion were reported for high-intensity exercise (28). HRI occurs when heat stress increases to the point at which the body’s attempt at cooling itself is no longer effective. The different forms of HRI include (listed in order of severity) heat rash, heat cramps, heat syncope (fainting), heat exhaustion and heat stroke. In extreme cases HRI has led to severe permanent damage and even death (31).

Exercise, especially in the heat, imposes a strain on the cardiovascular system as it tries to supply blood to working muscle to continue exercise and increase cutaneous circulation to allow for heat dissipation. One metabolic by-product of ATP hydrolysis is energy given off in the form of heat (20). As the internally generated heat is trapped, combined with radiant heat from the environment, rises in $T_c$ occur. HRI, which can result in irreparable damages or death, is attributed to significant rises in $T_c$. Both the amount of layers and the types of materials those layers are composed of are factors in UCHS. Brazaitis et al. (3) reported increased sweating efficiency with a base layer made of polyester compared to cotton, however there were no significant differences in $T_c$, $T_{sk}$, or HR. There are documented instances of UCHS and HRI in crop workers (7), WLFF’s (13, 23), military personnel (11, 51), and other occupational athletes. A report by Missoula Technology and Development Center
discusses that HRI are a substantial risk during WLFF job performance due to exposure to frequent high ambient temperatures, high work intensity, fatigue, hydration challenges and PPC (41).

**Personal Protective Clothing**

PPC is an ensemble designed to protect the human body from the ambient environment (9). An Australian study on work productivity among bush firefighters showed that PPC is a key factor in reducing UCHS and HRI (4). This study noted that approximately two-thirds of a firefighters heat load was generated internally, with only one-third coming from the radiant heat of the fire. The researchers recommended that PPC should therefore be designed to “let heat out, not keep heat out”. PPC contributes to physiological strain in WLFF’s largely by reducing heat dissipation and increasing energy expenditure (43). The California Department of Forestry and Fire Protection currently requires WLFF’s to wear two layers of clothing during fire suppression activities. This practice was developed in response to evidence that multiple layers provide additional protection against burn injuries. As a result, lower productivity and longer, or more frequent breaks were necessary to alleviate fatigue and metabolically-generated heat stress (46). The researchers identified four main areas of concern for the design of PPC; 1) radiant protective performance, 2) thermal resistance (both designed to keep heat out), 3) air permeability, and 4) moisture evaporation (both designed to let heat out). There are several studies that have looked at multiple combinations of different materials, most with similar results, heavier and bulkier = better radiant protection while lighter and thinner = better evaporative capabilities, respectively (5, 6, 11, 26, 28, 43, 44, 45, 46, 50). In all research reviewed, studies have shown that PPC increases physiological strain by increasing subjects metabolic cost and/or decreasing subjects evaporative capabilities. Fogarty et al. (17) studied the influence of base layer material on physiological responses when worn underneath a combat uniform. They found no difference in that of a tight-fitting polyester base layer compared to a cotton shirt, thus negating advantages found when wearing this fabric alone (3).
Synthetic material undergarments have been designed to increase moisture removal which can maintain comfort levels and possibly increase productivity. However, these synthetic materials may be more likely to melt, ignite, or char when exposed to direct flame or radiant heat. Petrelli and Ackerman (34) examined the potential for burn injury associated with newer synthetic material undergarments compared to those made from natural fibers and flame-resistant materials. Using a mannequin with heat sensors, full flame engulfment and radiant exposure tests were conducted. Predicted injury was higher for synthetic materials during the full flame engulfment test and there were no differences in the exposure test. It is noted, and importantly so, that the sensors only measure and use heat transfer to predict injury, not accounting for the melting and adhering of the fabrics to the skin. In both tests, the synthetic materials absorbed energy as they melted resulting in decreased heat transfer to the sensors and increased injury risk as melting occurred. The natural fiber undergarments showed no signs of melting or charring. Research conducted by Van Den Huevel et al. (49) demonstrated no significant thermoregulatory or comfort advantages during exercise in a hot, dry environment for armored individuals when comparing five different undergarment conditions (no t-shirt, cotton t-shirt, woolen t-shirt, synthetic t-shirt, hybrid t-shirt). If radiant protection and/or thermal resistance can be increased without jeopardizing air permeability and/or moisture evaporation this can lead to increased safety for WLFF’s and other occupational athletes.

**Alleviating Heat Stress and Physiological Strain**

When heat is generated through increased metabolic activity, humans are generally successful in maintaining a thermal steady state by activating heat-loss mechanisms to dissipate excess heat. These mechanisms of heat-loss are grouped into two categories; 1) dry pathways-including radiative, conductive, convective, and 2) wet pathways-including evaporative (9). Dry pathway mechanisms are dependent upon temperature gradient differences both within the body (core to periphery) and between the body and the environment. Wet pathway mechanisms are activated through a water
vapor pressure gradient between the body surface and the environment, resulting in the evaporation of water secreted by sweat glands within the skin (9).

Dry pathway mechanisms are influenced by the rate of cutaneous blood flow which transports heat from the core to the periphery. While at rest and in thermoneutral environments (~25°C), the control of body temperature depends almost entirely on the manipulations of skin blood flow (SBF) and the maintenance of an appropriate skin to air temperature gradient (37). As $T_e$ increases, blood flow is redirected to the skin resulting in increased SBF. Saumet et al. (36) demonstrated that laser-Doppler flowmetry (LDF) is an effective measure of SBF and is not influenced by underlying tissue blood flow. Tankersley et al. (47) used LDF to show the positive correlation of $T_e$ and SBF. Additionally, a similar relationship exists between SBF and sweat rate (22, 47). Previous research has demonstrated SBF peaks shortly after the cessation of exercise, as less blood is needed by the inactive muscles, and returns to near baseline levels within 10 minutes post-exercise (19, 25, 36).

Several authors have concluded that adequate hydration is among the most effective countermeasures to UCHS and HRI during exercise in the heat, with and without PPC (9, 23, 32). However, a case study reported that despite elevated intake of fluids subjects still suffered HRI while less hydrated individuals did not (13). This suggests that additional strategies along with proper hydration recommendations are necessary to alleviating heat stress and physiological strain. Previous studies have shown that the cessation of work, resting in a cool environment, and when applicable, removal of PPC are effective ways of relaxing PSI and limiting the likelihood of a HRI (26, 32, 39, 44). These effects are attributed to reducing the heat (internal and/or external) and increasing air permeability and moisture evaporation allowing greater dissipation of excess heat.

**Practical Applications**

Through the examination of this flame resistant synthetic material base layer, improvements may be made to the existing WLFF uniform resulting in safer working conditions for this and similar
populations. The purpose of this study is to determine if this material, which provides added flame resistance, will alter tolerance to heat stress factors during simulated WLFF activity.
Chapter Three: Methodology

Participants
Subjects for this study were 10 recreationally active male volunteer participants from the Missoula, MT area who are within the age range of 18 and 40 years, and had a \( VO_2 \) peak \( \geq 40 \text{ ml/kg/min} \). Subjects filled out the Physical Activity Readiness – Questionnaire to assess cardiovascular disease risk factors. Subjects signed an informed consent form approved by the Institutional Review Board of the University of Montana. Preliminary data was collected in the Human Performance Laboratory at the University of Montana in Missoula, MT. Data was collected and trials were conducted in an environmental chamber (Tescor, Warminster, PA) in the Montana Center for Work Physiology and Exercise Metabolism (WPEM).

Experimental Testing Design

Preliminary Testing

*Physical Activity Readiness Questionnaire (PAR-Q)*

Preliminary testing included a pre-screening of participants involving a PAR-Q assessment for any known coronary artery disease risk factors to prevent potential complications during the exercise trials.

*Hydrodensitometry*

Body composition was measured using a hydrostatic weighing tank with 3 force transducers using data collecting software (Exertech, Dresbach, MN) while estimating residual volume from subject’s height and weight. Subjects arrived fasted for > 3 hours prior to body density assessment. Dry body weight was recorded using a weight scale (Befour Inc., Cedarburg, WI) and height was measured. Subjects were submerged and weighed repeatedly, until a 100g consistency between measurements.
was recorded. Underwater weight is used to calculate body density to predict percent body fat using estimated residual volume and the Siri equation (42).

**Maximal Aerobic Capacity (VO2 peak)**

Subjects arrived fasted for > 3 hours prior to performing a VO2 peak test. VO2 peak tests were done on a treadmill ergometer (Fullvision, Inc., Newton, KS). A 5-minute warm-up (4 km/hr and 1 % grade) was done prior to conducting the Bruce Protocol to measure VO2 peak. The Bruce Protocol’s first stage: 2.7 km/hr and a 10% grade for 3 minutes, after the first stage the workload is raised to 4 km/hr and 12% grade, 5.5 km/hr and 14% grade, 6.8 km/hr and 16% grade, and 8 km/hr and 18% grade after 3 minutes on each stage has elapsed, respectively. Expired gases were collected and analyzed every 15 seconds via a metabolic cart (Parvomedics, Inc., Sandy, UT). VO2 peak was met when two of the following criteria was reached: 1) plateau in VO2 despite an increased workload; 2) Respiratory Exchange Ratio (RER) is greater than 1.10; 3) heart rate within 10 beats of the subjects’ predicted heart rate maximum (206bpm – (AGE * 0.6667)); and 4) rate of perceived exertion (RPE) > 17 and volitional fatigue.

**Experimental Trials**

**Exercise Protocol**

The day prior to the first experimental testing session subjects were allowed to eat and drink as normal, but were instructed not to consume any alcoholic beverages. For the subsequent testing session, subjects replicated this eating and drinking situation. Subjects arrived to the WPEM laboratory in the early morning following a 10 hour fast. After voiding, subjects had their nude body weight recorded. A blood sample was taken before commencement of exercise. Subjects were equipped with a skin temperature sensor on their pectoralis (chest) muscle five centimeters posterior and two centimeters lateral to costal tuberosity and a heart rate monitor strap. Prior to exercise, each
subject inserted a rectal thermometer in privacy so that core body temperature could be monitored. A 100% cotton shirt (C) or a flame resistant synthetic shirt (S) (Longworth Industries, Inc., Southern Pines, NC), was worn underneath typical WLFF Nomex outerwear and subjects were equipped with a 16kg pack, leather gloves and a helmet. Subjects exercised (walked on a treadmill) for 180 minutes (50 minute exercise followed by a 10 minute break each hour) at 4 Km/hr and 4% grade at 35°C and 30% RH in an environmental chamber (Tescor, Warminster, PA). Subjects removed their pack and gloves and rested in a chair during each 10 minute break. This exercise intensity matches the average work rate recorded for a group of wildland firefighters (U.S. Forest Service personal communication). Expiratory gases were collected and measured after the first 5 minutes of exercise and at minute 40 of each 50 minute exercise period. This required the subjects to breathe through a mouthpiece while wearing a nose clip, a similar setup that was used during the maximal oxygen uptake test. SBF was obtained via LDF for 5 minutes following each 50 minute exercise period. Exercise was followed by a recovery time of 30 minutes inside the environmental chamber, during which SBF was recorded during minutes 2-7, 15-20 and 25-30, respectively. In addition to removing their pack and gloves, subjects also removed their helmet and Nomex shirt during the 30 minutes of recovery. After completion of the trial a second blood sample was taken, subjects provided a final nude body weight prior to voiding after the trial. This protocol was repeated no less than 12 days later with subjects using the other base layer material.

Dietary and Activity Recall

For the 24-hours before the subjects first exercise trial they were asked to record the foods that they consumed (time and quantity). Subjects were instructed not to consume any alcohol during this time period, as it is a diuretic and compromises hydration status. For the second trial, subjects were asked to consume the same foods (time and quantity) of those foods that they consumed prior to the first trial. Two days before each subject’s first trial day they were allowed to exercise as they wish,
but this was to be repeated at the same time of day and the same exercise prior to the second trial. For
the 24-hours before each trial subjects could not participate in any physical exercise.

*Body Weight*

Nude body weight was measured in private on a calibrated scale (Ohaus, Pine Brook, NJ). Weights were taken before and after each trial.

*Blood Samples*

A total of 4 blood samples (2 per trial x 2 trials) were collected using a venipuncture technique. The antecubital space was cleaned with alcohol prior to the blood draw, and wiped clean afterwards. Blood samples were collected a) prior to the exercise trial, and b) after the exercise trial. ~2 mL of blood were drawn each time for a total of ~4 mL per trial. All of the blood samples were obtained under the direction of Dr. Charles Dumke, Ph.D. These samples were collected to calculate changes in BV, CV, and PV from Hct and Hb values using equations from Dill and Costill (14).

*Clothing*

Subjects were provided with one of the base layer shirts, control or experimental, typical WLFF outerwear and were equipped with a 16kg pack, gloves and helmet. Subjects provided their own gym shoes and socks. The same clothing was worn during both trials with the exception of the base layer shirt.

*Fluid Administration*

During each exercise trial subjects were administered 8 milliliters of water per kilogram of body weight each hour. Cool tap water (temperature not measured) was weighed out and given to subjects at the start of each 50 minute walking period with instructions to finish prior to the 10 minute rest period.
Core Temperature and Skin Temperature

Skin ($T_{sk}$) and core temperature ($T_c$) were monitored and recorded throughout the exercise trials. $T_c$ was measured with a hard wired rectal thermometer (Mallinckrodt Medical, St. Louis, MO) and $T_{sk}$ was collected with a hard wired skin temperature sensor (Mallinckrodt Medical, St. Louis, MO) placed on the left pectoralis (chest) muscle five centimeters posterior and two centimeters lateral to costal tuberosity. $T_{sk}$ and $T_c$ data were monitored and collected by DASYLab Software (Measurement Computing Co., Norton, MA).

VO$_2$/Energy Expenditure

Expired gases were collected during exercise using Douglas bags. Samples were analyzed using a metabolic cart (Parvomedics, Inc., Sandy, UT) to obtain $O_2$ and $CO_2$ content. Collection and sample times were standardized and the remaining gas was measured for volume and temperature. Expired gases are used to calculate the respiratory exchange ratio (RER), which is used to determine expended kcals*LO$_2$ consumed, allowing the estimation of energy expenditure during exercise (53).

Skin Blood Flow

SBF was obtained via LDF (Moor Instruments, Wilmington, DE) for 5 minutes following each 50 minute bout of exercise. This was obtained by placing a small probe on the right pectoralis (chest) muscle five centimeters posterior and two centimeters lateral to costal tuberosity underneath the subject’s shirt. During collection times subjects were seated and asked to remain as still and quiet as possible. Time synched SBF data were downloaded by DASYLab Software (Measurement Computing Co., Norton, MA). SBF data is expressed as arbitrary units.

Sweat Loss/Percent Dehydration

Subjects voided prior to obtaining pre-trial weight and weighed themselves prior to voiding after the trial. If a subject needed to void during the trial, urine was collected, weighed, and discarded. Sweat
rate was calculated using pre- and post-exercise body weights (BW) and corrected for urine excreted, fluid intake, and respiratory water loss (27). Sweat rate is expressed relative to body surface area. Percent dehydration was determined by changes in pre and post-exercise nude BW and adjusted for fluid intake.

\[
\text{Sweat rate (g}\cdot\text{m}^{-2}\cdot\text{min}^{-1}) = (BW_{\text{pre}} + \text{Fluid Intake}) - (BW_{\text{post}} + \text{Urine weight} + \text{Resp Water Loss})
\]

\textbf{Urine}

Urine was collected pre and post-exercise in a disposable container for hydration status indicators (USG). Urine was pipetted onto a pocket refractometer (ATAGO U.S.A., Inc. Bellevue, WA) from which urine specific gravity was measured and recorded. The remaining urine was then discarded.

\textbf{Statistical Analysis}

\(T_c, T_s, HR, VO_2, \text{SBF}, \text{USG}, \text{Hb}, \text{Hct}, \text{BV}, \text{PV}, \text{CV}, \text{PSI}, \) and RPE were analyzed using a two way ANOVA with repeated measures for time in 2x2, 2x3, 2x4, and 2x5 analyses. T-tests were performed on sweat rate, BV shift, PV shift, CV shift, percent dehydration, and weight loss. Data is presented as Mean ± SEM. Significance was set at \(p \leq 0.05\). All analyses were performed using SPSS 22.0.
Chapter Four: Results

Participants/Environment

Ten recreationally active men (Table 1) successfully completed both trials which were conducted in a climate chamber at a temperature of 35°C and a relative humidity of 30%.

<table>
<thead>
<tr>
<th>Table I. Participant Descriptives</th>
<th>Mean ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>25.0 ± 1.9</td>
</tr>
<tr>
<td>Height (in)</td>
<td>71.0 ± 1.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>80.9 ± 2.7</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>11.1 ± 1.7</td>
</tr>
<tr>
<td>$VO_{2peak}$ (ml*kg^{-1}*min^{-1})</td>
<td>55.0 ± 2.3</td>
</tr>
<tr>
<td>Maximum Heart Rate (bpm)</td>
<td>192 ± 2</td>
</tr>
</tbody>
</table>

Physiological Measures

Core and Skin Temperatures

Figures 1-2 illustrate changes over the course of each trial for $T_c$ and $T_{sk}$. Significant main effects for time were observed for $T_c$ (p < 0.001) (Fig. 1) and $T_{sk}$ (p = 0.003) (Fig. 2). Main effect for trial approached significance for $T_c$ (p = 0.052), as did time*trial interaction for both $T_c$ (p = 0.077) and $T_{sk}$ (p = 0.086), respectively.

Skin Blood Flow

Figures 3-6 illustrate changes in SBF over the course of each trial and during 30 minutes of recovery. Significant main effects for time were observed for peak SBF (Fig. 4), nadir SBF (Fig. 5) and post SBF (Fig. 6). There was a significant time*trial interaction (p = 0.001) in SBF at minute 112, after the second bout of walking exercise, with S (171.3 ± 25.1 AU) being significantly higher than C (140.4 ± 20.5 AU) (Fig. 3).
Heart Rate, PSI, and Metabolic Data

As expected, HR increased during exercise resulting in a significant main effect for time \((p < 0.001)\) (Fig. 8). As shown in Figure 7, PSI increased throughout the trial resulting in a significant main effect for time \((p < 0.001)\) and a main effect for trial \((p = 0.04)\), with S being elevated over C. There was a significant main effect for time \((p = 0.024)\) for \(VO_2\) which increased at the end of the second hour of exercise compared to initial steady state for both C and S, as shown in Figure 9. In addition, a significant main effect for time \((p = 0.002)\) for RER which decreased at the end of the second hour of exercise (Fig. 10).

Perceptual Measures

There were no differences in participants RPE at the end of each 50 minute exercise period between C and S trials. A main effect for time was seen during both trials \((p = 0.001)\) (Fig. 11).

Hydration and Mass Changes

As Figures 12-15 illustrate, there were no differences in sweat rate \((p = 0.122)\), total weight loss \((p = 0.142)\), dehydration percentage \((p = 0.137)\), or USG \((p = 0.594)\) between C and S.

Blood Measures

There were no significant differences in hemoglobin or PV shift in C and S trials (Figs. 17, 18, and 19, respectively). Hematocrit decreased from pre-exercise to post-exercise, main effect for time \((p = 0.041)\) in both C and S trials (Fig. 16).
Figure 1. $T_c$ using 2x4 ANOVA during C and S trials. † Main effect for time.

Figure 2. $T_{sk}$ using 2x4 ANOVA during C and S trials. † Main effect for time.
Figure 3. SBF during rest periods using 2x5 ANOVA during C and S trials. Data were collected pre-exercise and for five minutes during each ten minute rest period. ǂ Trial*time interaction.

Figure 4. Peak SBF using 2x3 ANOVA during C and S trials. Data were collected pre-exercise and for five minutes during each ten minute rest period. † Main effect for time.
Figure 5. The nadir of SBF using 2x3 ANOVA during C and S trials. Data were collected pre-exercise and for five minutes during each ten minute rest period. Nadirs were the lowest recorded value during each collection period. † Main effect for time.

Figure 6. SBF post-exercise using 2x3 ANOVA during C and S trials. Data were collected two minutes, 15 minutes, and 25 minutes post-exercise. Helmet and outer Nomex shirt was removed prior to collection. † Main effect for time.
Figure 7. PSI score using 2x3 ANOVA during C and S trials. † Main effect for time. * Main effect for trial.

Figure 8. HR using 2x3 ANOVA during C and S trials. HR was monitored continuously and recorded at the end of each 50 minute exercise period. † Main effect for time.
Figure 9. \( VO_2 \) using 2x4 ANOVA during C and S trials. \( VO_2 \) was collected five minutes before the end of each 50 minute exercise period. † Main effect for time.

Figure 10. RER using 2x4 ANOVA during C and S trials. RER was collected five minutes before the end of each 50 minute exercise period. † Main effect for time.
Figure 11. RPE using 2x3 ANOVA during C and S trials. RPE was recorded at the end of each 50 minute exercise period. † Main effect for time.

Time p = 0.001
Trial p = 0.545
Time*Trial p = 0.370

Control
Synthetic
Figure 12. Sweat rate in g\(\cdot\)m\(^{-2}\)min\(^{-1}\) between C and S trials.

Figure 13. Total weight loss between C and S trials.
Figure 14. Percent dehydration between C and S trials.

Figure 15. Urine specific gravity between pre and post exercise in C and S trials.
Figure 16. Hematocrit pre and post exercise in C and trials. † Main effect for time.

Figure 17. Hemoglobin pre and post exercise in C and S trials.
Figure 18. Plasma volume between pre and post exercise in C and S trials. Plasma volume was calculated using Hct and Hb.

Figure 19. Plasma volume shift between C and S trials.
Chapter Five: Discussion

This is the first study to examine the effects of a flame resistant base layer worn beneath WLFF Nomex protective garments on physiological factors of heat stress. In addition to flame resistance, the base layer in the current study was designed to increase breathability and offer superior moisture wicking, leading to increased comfort and performance (54). Because subjects exercised in the heat during the two trials, $T_c$ increased continually throughout the exercise protocol. $T_{sk}$ rapidly increased during the first hour of exercise followed by a plateau and slight increase during the second and third hours, respectively. HR consistently increased throughout the exercise protocol. There were no significant differences in $T_c$, $T_{sk}$, or HR between C and S. Previous research examining different base layer materials (including cotton, polyester, wool, synthetic, hybrids, and none) under several job specific PPC reported similar results, showing no significant differences in $T_c$, $T_{sk}$, or HR between base layers (3, 11, 17, 33, 49). In contrast to previous results, the results of the current study approached significance in both $T_c$ and $T_{sk}$ after the third hour of exercise. PSI was significantly higher during S, indicating an increased work demand and heat load. This difference occurred during the first hour of exercise, followed by similar increases in both C and S during the second and third hours. Consequences of these results may include decreased time to fatigue, decreased work output, and increased risk of HRI. These results contradict previous research by Cheuvront et al. (11) and Van Den Huevel et al. (49) who found no difference between base layers. Cheuvront et al. evaluated the impact of a Kevlar protective vest with and without a spacer garment on physiological strain. Subjects performed four hours of intermittent treadmill walking in a climate chamber (35°C, 30% RH). Although they found no difference with a spacer garment, the ending $T_c$ and HR were similar to the current study. Van Den Huevel et al. examined five undergarment configurations (including cotton and synthetic) beneath military combat body armor. Subjects performed two hours of intermittent treadmill walking followed by 20 minutes of alternating walking/running in the heat.
(41°C, 30% RH). Both of these studies reported no differences in PSI among the different clothing configurations.

RPE was used as an overall measure of how the subjects felt during the bout of exercise. There was no difference in RPE between the C and S trials. These results are supported by Fogarty et al. (17), who measured differences between cotton, polyester, and no base layer underneath a long sleeve combat uniform. A comparatively shorter (40 minutes) walk/run protocol was used in conditions of 34°C and 62% RH.

Fluid intake was scripted at 8 mL $H_2O \times Kg^{-1} \times hour^{-1}$ during the exercise protocol as there was no interest in achieving significant levels of dehydration, however mild levels of dehydration (< 1%) were seen. Weight loss was seen during both C and S with no difference between trials. Similarly, hydration measures of sweat rate, percent dehydration and USG did not differ between trials. Noonan and Stachenfeld (33) compared a cotton and synthetic material base layer underneath ice hockey equipment during a simulated game and reported results analogous with those of the present study in relation to USG. Dill and Costill (14) used measures of hematocrit and hemoglobin before and after exercise to calculate shifts in PV. Following two hours of moderate intensity exercise, Dill and Costill reported increased hematocrit and hemoglobin levels, with decreases in PV. Several others (11, 17, 33, 49) have reported similar results. In the current study, there was not a significant difference in PV pre- to post-exercise, or between C and S. These seemingly contradicting results are due to the scripted water intake of the current study. The present study however, reported a decrease in hematocrit across both trials, with no difference between trials. Subjects in the present study began trials with a relatively high hematocrit which may have influenced results. It should be noted that blood was handled and aliquoted by multiple lab technicians differing between pre- and post-exercise measures.
As $T_c$ increases during exercise, blood flow to the skin is increased to maintain thermoregulation. The current study investigated if the composition of base layer fabric had an impact on both $T_c$ and SBF. SBF was measured on the chest underneath the base layer garment using LDF during each ten minute rest period. SBF increased relative to $T_c$, similar to results reported by Lorenzo et al. (22). A significant difference was seen during the second rest period of the exercise protocol, with SBF higher in S compared to C. This result is consistent with the slightly higher $T_c$, though not significant, and significantly elevated PSI values seen during the S trial of the present study. SBF was also measured post-exercise for 30 minutes, without the outer Nomex shirt and helmet. SBF peaks occurred shortly after cessation of exercise and approached pre-exercise values within 15 minutes post-exercise, concurrent with previous research (19, 25, 36). There were no significant differences between C and S during this recovery period. SBF has not been previously reported in studies examining base layer materials in the heat. In showing a significant difference, changes in SBF may be of benefit to seeing subtle changes that may not be reflected in other measurements of heat stress. Gonzalez et al. (19) demonstrated that combined elevations of $T_c$, $T_{sk}$, and SBF reduced cardiac output during moderate intensity exercise in the heat. This decrease in cardiac output is attributed to a large decline in stroke volume. The authors hypothesize that increased SBF reduces stroke volume by reducing ventricular filling due to a displacement of blood from central circulation to the periphery. As stroke volume decreases, HR increases in an attempt to maintain circulation to working muscles and organs leading to increasing $T_c$ and decreased time to exhaustion (19).

It is common during endurance exercise to see cardiovascular and $VO_2$ drift, identified as increased metabolic responses without an increase in workload (2, 14, 20, 44). Cardiovascular drift (CVD) is characterized by an increase in HR paralleled by a decrease in stroke volume, partially due to increasing SBF which reduces central venous blood pressure. Ambient and internal temperatures as well as hydration influence CVD (14, 23, 44). $VO_2$ drift can be partially attributed to a shift in
substrate utilization from more oxygen efficient carbohydrates to less oxygen efficient fats, as well the increased cost of breathing and decreased movement economy. CVD can manifest itself as soon as 20 minutes after the initiation of exercise, whereas $VO_2$ drift is typically only measurable after 90 minutes of exercise (2, 31, 44). Increasing HR, $T_c$, SBF, RPE and decreasing RER (signifying an increase in fat utilization) values within the current study support the $VO_2$ drift seen after the second hour of exercise.

Budd et al. (7) examined the thermal burden imposed by different possible configurations of PPC worn by WLFF. As insulation and radiant protection increased so did $T_c$, HR, energy expenditure and several other factors associated with increased risk of heat strain and other HRI. Previously, Budd et al. (6) had shown that 2/3 of the total heat load experienced by WLFF was a result of exertion and the inability to dissipate internally generated heat, while radiant heat from fire and the environment were secondary to this metabolically created heat stress. Therefore, they concluded that PPC for WLFF should be designed to let heat out, as opposed to keep heat out.

**Conclusion**

The current study is the first, to the author’s knowledge, to assess the impact of a flame resistant synthetic material base layer on heat stress factors during exercise in a hot environment. These data show that this undergarment composition has a negative effect on various factors that contribute to HRI, namely PSI and SBF, which increases risk for WLFF. Furthermore, other factors that were approaching significance may have considerable impacts as exercise bouts extend beyond three hours, $T_c$ and $T_{sk}$, respectively. An average WLFF work shift is between 10-16 hours, during which time any small differences reported within the present study may be amplified. This amplification may result in a greater overall internal heat load, increasing risk of HRI. In addition, previous research has shown that cotton is a suitable base layer during extreme heat exposure (34) and has not been shown to decrease performance or comfort in comparison to a synthetic blend (3, 33, 49). Based
on the results of the current study, the flame resistant synthetic material base layer decreases
tolerance to physiological heat strain factors and may increase risk of HRI while performing typical
WLFF activities.
SUBJECT INFORMATION AND CONSENT FORM


SPONSOR: United States Forest Service (MTDC)

RESEARCHERS: Dr. Charles Dumke (406) 243-6176  
Dr. Brent Ruby  
Dr. Joseph Domitrovich

The University of Montana  
32 Campus Drive  
McGill Hall – HHP  
Missoula, MT 59812

Please read the following information carefully and feel free to ask questions. Only sign the final page when you are satisfied procedures and risks have been sufficiently explained to you.

REQUIREMENTS

This research study requires that you meet the following criteria:

➢ Participants must be males between the ages of 18 and 40.
➢ Participants must have a VO2 max ≥ 40 ml/kg/min.

PURPOSE OF THE STUDY

There have been advancements in the development of personal protective equipment (PPE) for wildland fire suppression. The purpose of this study is to evaluate the effects of a flame resistant synthetic material base layer fabric on heat stress factors during exercise in a hot environment. This study will involve randomized, controlled design where each subject will perform two trials with different shirts. Subjects will be blinded as to the order of the experimental or control shirt.

TEST PROCEDURES

3 VISITS TO THE LABORATORY WILL BE REQUIRED, AS SUMMARIZED BELOW

PRE TESTING (Visit 1, ~ 1 hr)

1. A screening assessment which involves a health/exercise questionnaire (Par-Q) and family history questionnaire.

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a. Prior to any testing, you will complete a physical activity readiness questionnaire (PAR-Q) to screen for known risk factors of coronary heart disease and a family history questionnaire to screen for history of heat related illness or death.

2. If you successfully complete the PAR-Q, you will then provide written informed consent following the reading of this document.

3. A measure of percent body fat obtained using underwater weighing
   a. This test session will require that you do not eat for a minimum of 3 hours prior to the testing. Prior to the test, body weight will be recorded in your bathing suit. You will then be asked to complete between 3 – 6 underwater weighing procedures. The underwater weight requires that you are submersed in our weighing tank (similar to a hot tub) and that you maximally exhale as much air as possible while underwater. The underwater weight will be recorded within 2-4 seconds and then you will be signaled to surface. This procedure will be repeated until three measurements have been obtained that are within 100 grams of each other. A nose clip will be provided upon request. This test will take approximately 20 minutes.

4. A maximal treadmill ergometer test to measure aerobic fitness
   a. This test will consist of walking and running on a laboratory treadmill to volitional fatigue. The speed and/or grade of the treadmill will increase every minute and will progress to fatigue. You will be encouraged to continue to walk/run until volitional fatigue. During this test you will wear a nose clip and headgear that will support a mouthpiece. This will allow us to measure the amount of oxygen that the body uses during this exercise. Heart rate will be measured using an elastic chest strap that is worn on the skin under your shirt around your chest. This test will take approximately 30 minutes. You will fast for approximately 3 hours prior to this test.

EXPERIMENTAL TESTING SESSIONS (Visits 2 and 3, ~4 hrs each)

Experimental Protocol
a. The day prior to the first experimental testing session you are allowed to eat and drink as normal, but must NOT consume any alcoholic beverages. For the subsequent testing session, you will replicate this eating and drinking situation. You will arrive to the laboratory in the early morning following a 10 hour fast. After voiding, you will have your nude body weight recorded. A blood sample will be taken before commencement of exercise. You will be equipped with skin temperature sensors on your chest. Prior to exercise, the participant will insert a rectal thermometer while in privacy so that core body temperature can be monitored. You will be given one of the two shirts, control or experimental, and equipped with a jacket, pants and 35 lb pack. You will exercise (walk on a treadmill) for 180 minutes (50 minutes exercise followed by a 10 minute break each hour) at 3.5 MPH and 5% grade in a hot room (35°C or 95°C and 40% RH). This exercise intensity mimics the work rate identified for wildland firefighting. This will be followed by a recovery time of 30 minutes inside the chamber after removal of jacket and pack, during which skin blood flow will be recorded every 10 minutes. During the 180 minute exercise session you will consume 12 ml/kg body weight of water each hour. Skin blood flow will be obtained via laser doppler flowmetry immediately following each 50 minute exercise period. Expiratory gases will be measured during the last 10 minutes of each exercise bout prior to the 10 minute rest. This requires you to breathe through a mouthpiece while wearing a nose clip, the same setup that will be used during the maximal oxygen uptake test. After completion of the trial you will then void if necessary, and provide a final nude body weight, to be used in determining sweat rate. This trial will be repeated for visit 3 separated by one week with the converse shirt.

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**Dietary and Activity Recall**

For 24-hours before your first exercise trial you will be asked to record the foods and quantity that you consume. You are not allowed to consume any alcohol during this time period, as it is a diuretic and compromises hydration status. For the second trial, you will consume the same foods and quantity of those foods that you consumed for the first trial. Two days before your first trial day you can exercise as you wish, but this must be repeated at the same time of day and the same exercise prior to the second trial. For the 24-hours before each trial you cannot participate in any physical exercise.

**Body Weight**

Nude body weight will be measured in private on a calibrated scale. Weights will be taken before and after the trials.

**Blood Samples**

A total of 4 blood samples (2 per trial x 2 trials) will be collected using a venipuncture technique. The site will be cleaned with alcohol prior to the blood draw, and wiped clean afterwards. These samples will be collected to measure changes in plasma volume. All of the blood samples will be obtained under the direction of Dr. Charles Dumke, Ph.D. Blood samples will be taken a) prior to the exercise trial, b) post exercise trial, ~2 ml will be drawn each time for a total of ~4 ml (~ 1 teaspoon) per trial.

**Laser Doppler Flowmetry**

Skin blood flow will be recorded using a laser doppler ultrasound. This is collected by holding a wand up to the chest underneath the clothing. This is non-invasive and presents no harm.

**Skin and Core Temperature**

Skin temperature patches will be placed on the pectoralis major (chest) prior to commencing exercise. This involves (potentially) shaving some hair from the specific sensor area and sticking the sensor on. A rectal thermometer thermistor will be used so that your core body temperature can be monitored throughout the exercise period.

**Urine**

You will be asked to void your bladder before the trial. After the initial void, urine will be collected in a disposable plastic container for hydration status indicators (urine specific gravity). The urine will then be discarded.

**RISKS AND DISCOMFORTS**

1. Mild discomfort may result during and after the exercise. These discomforts include shortness of breath, tired or sore legs, nausea and possibility of vomiting.
2. Exercising in the heat chamber at 95°F will result in profuse sweating and the perception of feeling very hot. Adverse reactions to heat stress can include heat exhaustion, heat stroke, and fainting. However, core body temperature will be monitored during every testing session; if core temperature goes above 40°C, the exercise test will be terminated. Fluids will be provided to you as well to mitigate these risks. If you feel too hot to continue exercise, the test will be terminated and you will be removed from the heat chamber.
3. Muscle soreness after the tests may occur as a result of the exercise, but should not persist.
4. Certain changes in body function take place when any person exercises. Some of these changes are normal and others are abnormal. Abnormal changes may occur in blood pressures, heart rate, heart rhythm or extreme shortness of breath. Vary rare instances of

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heart attack have occurred. Every effort will be made to minimize possible problems by the
preliminary evaluation and constant surveillance during testing. The laboratory has
standard emergency procedures should any potential problems arise.

5. Mild symptoms of dehydration such as headache and general fatigue may result during and
after the exercise. To minimize the risk of excessive dehydration, your core temperature will
be monitored continuously during exercise. If core temperature goes above 40°C, the
exercise test will be terminated.

6. You will be informed of any new findings that may affect your decision to remain in the
study.

7. During any of the exercise tests should symptoms, such as chest discomfort, unusual
shortness of breath or other abnormal findings develop, the exercise physiologist conducting
the research will terminate the test. Guidelines by the American College of Sports Medicine
will be followed to determine when a test should be stopped. These symptoms include
moderate to severe angina (chest pain), increased dizziness, shortness of breath, fatigue
and your desire to stop.

8. When blood samples are collected for this study, participants may feel a slight sting or
“pinch” in their arm, they may suffer a small bruise, and there is a very slight possibility of
infection. Should participants notice unusual redness, bruising, or swelling at the blood
sampling site they should seek medical attention and contact the study director; Charles
Dumke. During the blood draw, precautions (cleaning the site with alcohol, sterile supplies,
and wearing a band-aid) will be taken to minimize deleterious effects.

9. Certain medications could increase the risk for adverse effects during this heat related
study. If you are taking any medications, you must check with your physician before
participating in the study.

BENEFITS OF PARTICIPATION

1. The information from these tests will provide you with an accurate assessment of your
aerobic fitness and body composition that can be compared with norms for your age and
sport but may be of little benefit to your understanding of your personal fitness. There are no
other direct benefits to the participants in the study.

2. The scientific benefit includes expanding current understanding of heat stress with the
current wildland firefighter uniform.

CONFIDENTIALITY

1. Your records will be kept confidential and not be released without consent except as
required by law.
2. Only the researcher and his research assistants will have access to the files.
3. Your identity will be kept private.
4. If the results of this study are written in a scientific journal or presented at a scientific
meeting, names will not be used.
5. All data, identified only by an ID #, will be stored in our laboratory.
6. The signed consent form and information sheet will be stored in a locked cabinet separate
from the data.

COMPENSATION FOR TIME

After completion of all trials, subjects will receive $100.
COMPENSATION FOR INJURY

In the event that you are injured as a result of this research you should individually seek appropriate medical treatment. If the injury is caused by the negligence of the University of Montana or any of its employees, you may be entitled to reimbursement or compensation pursuant to the Comprehensive State Insurance Plan established by the Department of Administration under the authority of M.C.A., Title 2, Chapter 9. In the event of a claim for such injury, further information may be obtained from the University's Risk Manager (406-243-2700; kathy.krebsbach@umontana.edu) or the Office of Legal Counsel (406-243-4742; legalcounsel@umontana.edu). (Reviewed by University Legal Counsel, May 9, 2013)

VOLUNTARY PARTICIPATION AND WITHDRAWAL

It is important that you realize that you are free to withdraw from the study at any time. If you decide to drop out of the study you will receive compensation for the test sessions you completed.

QUESTIONS

You may wish to discuss this with others before you agree to take part in this study. If you have any questions about the research now or during the study contact Dr. Charles Dumke, PhD at (406) 243-6176 (office). If you have any questions regarding your rights as a subject, you may contact the chair of the IRB through the University of Montana Research Office at (406) 243-6672.

STATEMENT OF CONSENT

I have read the above statements and understand the risks involved with this study. I authorize Dr. Charles Dumke, PhD, and such assistants that he may designate, to administer and conduct the testing as safely as possible with a minimal amount of discomfort. If I have additional questions, I may contact Dr. Charles Dumke, PhD, at (406) 243-6176.

Participant (print) ________________________________

Signature ________________________________

Date ________________________________

STATEMENT OF CONSENT TO BE PHOTOGRAPHED DURING DATA COLLECTION

During the study, I understand that pictures may be taken. I provide my consent to having my picture taken during the course of the research study. I provide my consent that my picture may be used in some presentations related to this study. If pictures are used at any time for presentation, names and/or physiological data will not be associated with them.

Signature ________________________________ Date __________

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Appendix II

Physical Activity Readiness Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES  NO
1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
2. Do you feel pain in your chest when you do physical activity?
3. In the past month, have you had chest pain when you were not doing physical activity?
4. Do you lose your balance because of dizziness or do you ever lose consciousness?
5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
7. Do you know of any other reason why you should not do physical activity?

If you answered YES to one or more questions, talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.

Find out which community programs are safe and helpful for you.

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

• start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
• take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

Please Note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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Supported by: Canada Health Sané Canada

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<td>TECH 2:</td>
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<tr>
<td>TECH 1:</td>
<td>TECH 2:</td>
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<table>
<thead>
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<th>PRE URINE SPECIFIC GRAVITY</th>
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Douglas Bag Metabolic Testing

Subject's Name: ___________________________  Date: ______
Subject's Mass: __________  A or B: ______
Investigator: _____________________________

Respiratory Data

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<td>Collection time =</td>
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<td>F_E O_2 (%) =</td>
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<td></td>
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<tr>
<td>F_E CO_2 (%) =</td>
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<tr>
<td>Sampling Duration =</td>
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<td>Volumeter:</td>
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<tr>
<td>Vol Initial (l)=</td>
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<tr>
<td>Vol Final (l)=</td>
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<tr>
<td>Gas Temp ( °C) =</td>
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<tr>
<td>PH_2O (mmHg) =</td>
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Notes:

Environmental Data

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<td>Barometric Pressure (mmHg) =</td>
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<td>Sampling Flow Rate (l/min) =</td>
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Appendix III

Table 2. Reported cases of "Heat" or "Dehydration" by activity from 2000 to 2011

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(NIOSH, 2012)
References


13. Cuddy, J.S. and Ruby, B.C. High Work Output Combined With High Ambient Temperatures


