12-2012

Evaluation of Heat Stress in Migrant Farmworkers

Stephen L. McQueen
East Tennessee State University

Evaluation of Heat Stress in Migrant Farmworkers

A thesis

presented to

the faculty of the Department of Environmental Health

East Tennessee State University

In partial fulfillment

of the requirements for the degree

Master of Science of Environmental Health

---

by

Stephen L. McQueen

December 2012

Dr. Ken Silver, Chair

Dr. Kurt Maier

Dr. Joseph Florence

Keywords: heat stress, migrant worker, WBGT

ABSTRACT

Evaluation of Heat Stress in Migrant Farmworkers

by

Stephen L. McQueen

The rate of heat-related fatalities in crop production workers is almost 20 times that of other industries. Heat stress was investigated in migrant tomato workers in July, 2012, using measurements of body temperature, heart rates, body weight loss, evaluation of the thermal environment, and survey data. Using occupational safety criteria, these workers were found to work in an environment that should require protective measures to prevent heat strain. Increases in body temperature, heart rate, and physiological strain correlated with heat exposure. One third of workers had body weight percentage losses that indicated dehydration. However, working in hot environments appears to elicit a low magnitude of strain in well acclimated workers who self-pace. Key findings suggest the need for worker and employer safety training regarding acclimation and hydration. Survey data showed that less than 30% have had any heat-related safety training.

DEDICATION

I dedicate this to my father Kirk Thomas McQueen, who was a great father and an even greater man. He worked hard to afford me the opportunities he never had and always encouraged me to go to places he never could.

ACKOWLEDGEMENTS

First and foremost, I wish to thank Michael Bradfield for his assistance and support in the field in conducting this study. Michael is one of the finest persons I have had the privilege to know or work with. I wish to thank Dr. Ken Silver for taking interest in my education and learning and providing assurance and guidance as my mentor. I wish to thank Dr. Kurt Maier and Dr. Joseph Florence for serving on my committee and providing input and advice. I wish to also thank Clara McClure for also assisting in this study, Dr. Edith Seier for guidance on data analysis, Chuck Patton for administrative assistance and support, and Karin Hoffman and the fine folks at Rural Medical Services for allowing us to work with them. Also, thanks to Dr. Nate Fethke for assistance in calculating metabolic rates for workers.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Specific Research Objectives

1. To conduct an assessment of environmental heat exposure for tomato farmers working in east Tennessee. This was conducted using a wet bulb globe thermometer to determine if migrants were working in temperatures above established Threshold Limit Values.

2. To evaluate the physiological response of workers to heat exposure. This was evaluated using measurements of tympanic temperature, heart rate, blood pressure, and pre- and postshift weight. These measurements are used to evaluate the response of the thermoregulatory system and dehydration status.

3. To use survey methods to evaluate the prevalence of heat-related symptoms in workers and to obtain worker-derived data concerning heat stress focused on training, coping behaviors, and perception of risk. Surveys were implemented during health screenings and then analyzed.

Literature Review

Migrant and seasonal farmworkers (MSFWs) represent a medically underserved and impoverished United States population that suffers higher mortality and morbidity rates than most of the rest of the country. This disparity exists due to a combination of factors, including poverty, lack of access to medical services, cultural and language barriers, substandard housing, and occupational health hazards (Hansen and Donohoe 2002). The true costs of crop production may be externalized to the environment and the people producing crops.

Agriculture is already the most hazardous occupation in the US with 24.7 deaths per 100,000 agricultural workers, 243 agricultural workers experiencing lost-work-time injuries daily, and 5% of these injuries resulting in permanent impairment (Centers for Disease Control 2012). Problems that are specific to MSFWs for occupational health include pesticide exposure, respiratory problems, dermatitis, acute traumatic injuries, musculoskeletal problems, and heat-related illnesses (Mobed et al. 1992).

Focusing on occupational health hazards, the overall goal of this study was to evaluate heat exposure in migrant workers. The relevance of this project is not limited to this population. The workers for this study do not just represent a specific population; they represent anyone who may be working on farms or outdoors during the summer in the southeast region. Many occupations are at risk for heat-related illnesses, but MSFWs are especially at risk due to the challenges of their workplace (Jackson and Rosenberg 2010). Our selected population performs their work in direct sunlight and must perform work during the hotter parts of the day to minimize dew collected on tomatoes. This population also works on a piece rate system, rather than hourly, where filled buckets are traded for tokens. This system may reduce safe work practices, as workers may be reluctant to take time away from picking, which would reduce daily income. Workers should ideally take frequent, shaded water breaks, but this may not occur due to the compensation system. There is no impetus to stop or slow work for safety measures. As workers continue to push through the hours without resting, the body may begin to accumulate heat from the external environment and the metabolic load. Workers may become disoriented, with impaired judgment, as heat stress increases. This increases the risk of injury as the ability to take protective measures is reduced due to impaired decision making (Glazer 2005; Jackson and Rosenberg 2010). Eventually, the body is no longer able to thermoregulate and rid itself of excess heat, resulting in heat exhaustion or heat stroke. These outcomes are largely preventable by monitoring environmental and work conditions, applying the appropriate preventative measures, and training employees and supervisors about heat exposure safety (Environmental Protection Agency 1993). However, with a lack of regulation, it is difficult to require and implement these steps.

Migrant Farmworkers

The National Agricultural Workers Survey (NAWS) defines 5 different types of farmworkers. Nonmigrant farmworkers are seasonal or settled farm workers. They comprised 58% of the farmworker population in the 2002 NAWS survey. The remaining workers are migrants who may be classified under 3 different categories. The first group is foreign born newcomers who have travelled to the United States for the first time. The second group is shuttle farmworkers, which includes both international shuttle farmworkers and domestic shuttle farmworkers. International shuttle denotes workers who travel from a foreign permanent residence but work within 75 miles of one location within the United States. Domestic shuttle workers live in the U.S. but travel more than 75 miles to a location within the U.S. and stay within 75 miles of that location during the working season. A final category is “follow the crop” workers. This group travels with crops as they ripen, moving from north to south. According to NAWS, on the east coast, settled workers comprise 57% of the farmworker population followed by shuttle workers at 17%, and newcomer and follow the crops workers, both 13%. Also, according to NAWS 75% of agricultural workers are Mexican-born, 44% cannot speak English, and only 13% have completed the 12th grade. The average family income ranges from $15,000 to $17,499 and only 8-12% have health insurance as a benefit of employment. This is demonstrative of the socioeconomic problems of migrant workers that contribute to lack of access to healthcare (Department of Labor 2005).

Regulation

There are currently no federal occupational safety regulations for the prevention of heat-related illness. Occupational heat exposure is only addressed by section 5(a)(1) of the Occupational Health and Safety Health Act’s General Duty Clause, which could be considered reactive, rather than preventive. The only states with existing standards are California and Washington. The heat prevention regulations for both states address hydration, training, program documentation, and preventive measures for cooling. Both states require a minimum of one quart of water per worker per hour. The California regulation includes language requiring employers to encourage frequent drinking.

Both states also require extensive training for employees and supervisors. Training topics included are environmental and personal risk factors for heat-related illness, the importance of acclimatization, types and symptoms of heat-related illnesses, and the importance of reporting and responding to heat symptoms and illnesses. The California regulation also educates employees on the employer's responsibilities for complying with the regulations and procedures for heat-related illness response. Supervisors must be trained in all employee training topics, along with the procedures for implementing heat-related illness prevention in addition to what to do in emergency situations. California requires that written procedures be available for workers and inspectors, while Washington employers must include an outdoor heat safety program within their written accident prevention program.

Regarding preventive measures, Washington employees must be relieved from duty, provided means for reducing body temperature, and monitored when showing signs of heat stress. California requires shade access for employees when temperatures are above 85°C, or upon request, with 5-minute breaks when the employee believes it is needed as a preventive measure (CCR T8 3395; WAC 296-62-095 and 296-307-097). From our own experiences working in the field for the 2012 summer, shade may be sparse as workers move down long rows of crops which can take an hour to complete picking. The only option may be to sit under a work truck, which is a danger in itself. However, despite these requirements, many employers are still neglecting regulations. In 2008-2009, 28% of California's site inspections resulted in one or more heat exposure citations, while Washington had violations at 76% of its 1500 site inspections (Jackson and Rosenberg 2010).

Epidemiology

According to the CDC, 423 workers were reported to have died from exposure to environmental heat from 1992 to 2006, with 68 of these occurring in crop production or activities related to crop production (CDC 2008). This is nearly 20 times the death rate of heat-related deaths for all other industries combined. This may be an underestimate as well. When heat is considered as a "contributing" factor for death, the number of heat-related deaths may be 2 to 3 times higher (CDC 2006).

Data from the southeast region in North Carolina show 40 heat-related fatalities for farm workers from 1977 to 2001, with fatality rates increasing with average summer temperature. Many additional workers may die unnoticed, without medical attention, going unreported due to a lack of surveillance (Mirabelli and Richardson 2005). North Carolina has the highest rate of heat stroke fatalities for crop workers in the country, at 2.36 per 100,000 full-time equivalent workers (Jackson and Rosenberg 2010). Systematic studies and surveillance are lacking for the agricultural community in Tennessee, with deaths going unnoticed or underreported. North Carolina has a similar climate and similar crop production procedures, so it is conceivable that a similar number of deaths could be occurring in east Tennessee. North Carolina participates in NIOSH-SENSOR programs and has a central reporting system for fatalities for medical examiners, which may account for the higher reporting of occupationally-related heat fatalities. Tennessee's Occupational Safety and Health Agency (TOSHA) has so far been unable to provide substantial data on heat-related fatalities in crop workers. A representative from the agency stated that part of the problem is that farms with 10 or fewer employees are not investigated by TOSHA, so any relevant statistics are not reported to TOSHA. Many of Tennessee's farms that employ migrant workers may fall under this exempt category (Personal Communication with Steve Hawkins, TOSHA Administrator, 2012).

Heat and Response

Outdoor laborers are the largest percentage of patients that demonstrate heat-related illness (Glazer 2005). MSFWs face multiple occupational health risks, which may be compounded by their disparate social position. MSFWs may be more at risk due to a lack of training and understanding of the risks associated with environmental heat stress (Hansen and Donohoe 2002). Occupational studies have found that there is an important interplay between the environment, work rate metabolic load, and core temperature. While working, core temperature will remain relatively constant for a given metabolic rate. Even with increasing environmental temperatures, the core temperature will stay constant until a threshold temperature is reached. At this point, core body temperature will steeply rise in correlation with increased ambient heat. As work rate increases, the amount of environmental heat a worker can tolerate decreases. Inversely, as environmental heat increases, work rate should be decreased for an exposed employee (Bernard et al. 1994).

The classification of the most severe heat-related illnesses typically falls into 2 categories: heat stroke, and mild heat-related illness. These 2 conditions occur when the body cannot physiologically maintain homeostasis through thermoregulation. The body is no longer able to dissipate built-up heat due to extrinsic factors such as physical effort and extreme environmental conditions (Glazer 2005). When environmental temperatures are higher, the body gains heat. Heat transfer is dependent on the 4 mechanisms of conduction, convection, radiation, and evaporation. The environmental factors affecting heat transfer are air temperature, wind speed, relative humidity, and radiation. In addition, human factors affecting heat transfer include age, sex, individual workload, medications that interfere with thermoregulation, pre-existing conditions, clothing, and metabolic rate (Keim et al. 2002).

Thermal stress is best described by the thermal balance equation. The 3 factors contributing to thermal stress are climatic environmental conditions, clothing, and work demands. Thermal balance has been traditionally described by equation 1. The equation includes the major pathways of heat exchange between the human body and the external environment.

$$(equation\ 1)\ \ S = (M \pm W) \pm R \pm C \pm K \pm (C_{resp} \pm\ E_{resp}) \pm E$$

Within this equation, S signifies the heat storage rate. If S is zero the body is in thermal equilibrium, with positive values indicating heat gain and negative values indicating heat loss. Metabolic rate (M) indicates values of basal metabolism and muscle metabolism. Because the conversion of chemical energy to kinetic energy is inefficient, increased metabolism can result in an increase in body heat. External work rate (W) is the amount of energy successfully converted from chemical energy into mechanical work. The body generates heat by both the cellular metabolism and through the mechanical work of skeletal muscle. Radiant heat exchange (R) is the heat flow from hotter surfaces to cooler surfaces by electromagnetic radiation. Convective heat exchange rate (C) is the exchange between the skin and the surrounding environment. If C is positive, heat is moving from the air to the skin. If it is negative, heat is flowing from the body. Conductive heat exchange rate (K) describes heat flow when 2 solid bodies are in contact with each other, where heat will flow from the warmer body to the cooler body. With conduction, heat leaves from the body core to the periphery. The rate of convective heat exchange by respiration, (C_{resp}) describes the opportunity to lose heat through air movement in and out of the lungs, which depends on the air temperature and the volume of air inhaled. Rate of evaporative heat loss by respiration (E_{resp}) describes evaporative heat loss by the lungs, determined by humidity and the volume of air inhaled. The rate of evaporative heat loss (E) is the cooling of the skin by the evaporation of sweat, which in turn cools the body. In summary, the regulation of body heat occurs by balancing heat that is created, absorbed, and dissipated (Plog and Quinlan 2002).

The human body can be quite resilient to heat stress with physiological adaptation occurring among those living or working in hot environments. The process of acclimatization allows for individuals to withstand heat stress without the morbidity of heat-related illnesses. This involves a number of physiological and biochemical changes, with the first being physical conditioning to improve cardiac performance. This allows for substantial increases in blood flow to the skin without excessively limiting oxygen delivery to other critical tissues. Second, the plasma volume of the circulatory system is increased, renal blood flow is increased, and blood is shunted away from noncritical circulatory beds such as the splanchnic circulation system. This reduces kidney damage that would otherwise result from from mild to moderate levels of exertional rhabdomyolysis (Charkoudian 2003). Finally, acclimation enhances the activation of the renin-angiotensin-aldosterone system, allowing the kidneys and sweat glands to retain adequate sodium and prevent volume depletion (Wenger 2001).

Physically fit, healthy individuals generally acclimatize more quickly. Acclimatization, or adaptation to exposure to heat, is a temporary physiological response. Once workers are acclimatized, they are able to tolerate heat and better able to dissipate heat from the body (Wenger 2001).

Acclimatization may be one of the most important steps for preventing heat-related illness in the workplace. Analysis of workers' compensation claims from the State of Washington highlights the lack of acclimatization as a risk factor for workers becoming ill in their first few days on the job (Bonauto et al. 2007). The California Division of Occupational Health and Safety's investigation of heat-related illnesses and deaths in 2005 found that for all cases, 46% of workers were on their first day on the job, and 80% of cases were within the first 4 days of being on the job (Prudhomme and Neidhardt, 2006 & 2007). Employees working in hot environments for at least 2 hours will adapt to hot weather in 4 to 14 days. Acclimatization is maintained for about 1 week away from the heat and disappears completely in 3 weeks. Increased fluid intake facilitates the acclimatization process (Wenger 2001).

Heat-Related Illness

The worst manifestation of heat-related illness is heat stroke. Heat stroke from environmental exposure is defined as core hyperthermia with an abnormally high core temperature above 41°C, or 105.8°F. The symptoms often include headache, difficulty speaking, irrational behavior, dizziness, exhaustion, hallucination, cramps, confusion, and, lastly, coma. This is a medical emergency that requires immediate recognition and treatment or intervention. If the core body temperature is too high, death from organ system failure may occur (OSHA 1999). Within agriculture, heat stroke typically occurs by exertional strain resulting from the combination of high increased metabolic loads and high temperatures (Cecchini et al. 2010).

Heat stroke is a complicated illness that may be best described as a form of hyperthermia characterized by a systemic inflammatory response leading to a syndrome of multi-organ dysfunction in which encephalopathy predominates (Bouchama and Knochel 2002). As the body temperature rises above 40°C to 42°C, hyperthermic changes to cells begin that increase permeability and fluidity of membranes, increase metabolic rate, and increase the activity of ATPase pumps which decreases cellular ATP content. Splanchnic blood flow begins to decrease resulting in ischemic conditions causing injury to the gut wall. This damage causes an increase in circulating cytokines as well as toxic lipopolysaccharides (LPS) from gram positive bacteria residing in the gut. Circulating LPS activates the Hageman blood clotting factor which causes disseminated intravascular coagulation and an increase in blood viscosity. The thermal damage to endothelia and elevation of circulating cytokines causes increases in: omega-6 fatty acid metabolism, levels of thromboxanes and leukotrienes, oxygen free radicals, production of toxic nitric oxide, and vascular permeability. Fluid begins to be lost into the tissues, which reduces venous return and central venous pressure, reducing cardiac output according to Starling's Law of the Heart, and is exacerbated by electrolyte changes in the blood. Blood pressure begins to fall leading to reduced tissue perfusion that in the lungs results in systemic hypoxia and further ischemia of other tissues and organs and further cellular damage. Centrally mediated homeostatic mechanisms are damaged from reduced blood flow to the brain and probable thermal denaturation. Damage to these mechanisms reduces skin blood flow, cooling rates, and respiration. Without immediate medical treatment, heat stroke fatality is likely to occur due to multisystem failure (Hubbard et al. 2003).

Besides heat stroke, other heat-related conditions that can occur include heat fatigue, heat cramps, heat syncope, heat rash, and heat exhaustion. These can result in lost wages due to days of work lost and increased accidents (EPA 1993). Heat cramping occurs from performing hard physical work in a hot environment, resulting in electrolyte imbalance due to sweating. Heat syncope results from a lack of oxygen to the brain because of pooling of blood in the extremities, resulting in fainting. Heat exhaustion exhibits symptoms similar to heat stroke but responds readily to treatment. However, heat exhaustion may result in fainting. Workers may be operating machinery, fall, and injure themselves or may not be discovered by coworkers. Workers exhibiting signs of heat exhaustion should be removed from work and allowed sufficient means of cooling as the next step is heat stroke (OSHA 1999; Glazer 2005). The characteristics of each heat-related illness may be viewed and compared in Table 1.

Table 1. Description of Heat-related Illnesses. Adapted from Guideline for Thermal Stress, Manitoba Labour and Immigration Workplace Safety & Health Division (2007).

Signs and Symptoms	Causes	Prevention	Treatment
Heat Fatigue Irritability and tiredness, loss of skill for fine or precision work and a decreased ability to concentrate.	Lack of acclimatization, emotional or psychological stresses, discomfort in heat.	Proper acclimatization to heat exposure, breaks during work.	None necessary. Removal should be implemented if acclimatization is ineffective.
Heat Rash Prickling sensation during heat exposure. Itchy, tiny red spots on skin covered by clothing, resulting from plugged sweat glands.	Skin continuously moist from sweat and humidity.	Showering to keep skin clean. Application of powder and mild drying lotions.	Keeping skin dry. Resting in cool place. May take several days to subside.
Heat Syncope Giddiness and fainting while standing in hot environment.	Pooling of blood in legs causing drop in blood pressure. Lack of acclimatization. Loss of body fluid from sweating.	Moving from time to time. Proper acclimatization. Drink extra fluids.	Rest in cool area. Recovery usually fast. May need to see physician.
Heat Cramps Sharp pains in muscles of arms, legs, or abdominal muscles. May occur during or after work.	Heavy sweating causing loss of salt. Drinking large amounts of water without salt replacement.	Add salt to foods. Drink fluids naturally containing salt (e.g. fruit and vegetable juices).	Move to cool place. Give salted fluids. If severe, may need to see physician.
Heat Exhaustion Headache, nausea, dizziness, weakness, intense thirst. Skin moist and clammy. Rapid, weak pulse.	Loss of water and salt from heavy sweating. Lowered volume of circulating blood. Lack of acclimatization. Sustained exertion in high temperatures.	Drink cool fluids often. Take extra salt in food. Drink fruit juices. Proper acclimatization	Rest lying down in cool area. Replace body fluids and salt. If vomiting, refer to physician.
Heat Stroke Nausea, headache, dizziness. Hot dry skin (may still be moist) Body temperature above 40°C. Rapid strong pulse. Convulsions and coma may occur.	Failure of central control of sweating. Prolonged work in hot environment. Unfit, unacclimatized workers. High humidity. Preexisting medical conditions, use of medications, high alcohol intake.	Medical assessment prior to hot work. Acclimatization. Monitoring of workers during periods of work in heat. Work-rest regimes. Adequate fluid/salt replacement.	Immediate medical Attention. Immediate first aid-remove clothing, spray with cool water, fanning, cool wet sheets.

Thermoregulatory mechanisms may also increase exposure to chemical toxicants, or pesticides, by facilitating entry into the body. With increased heat stress, respiratory ventilation is increased that can increase the inhalation of airborne pollutants such as volatilized pesticides (Mautz 2002). The primary mechanisms for dissipating bodily heat, increased skin blood flow and sweating, can increase the transcutaneous absorption of toxicants. Because of the increased thermoregulatory responses by workers in the field, absorption is likely to be exacerbated by increases in ambient temperature. It has been demonstrated that dermal absorption of parathion in human subjects increased by 17% when ambient temperature increased from 21°C to 28°C, and increased 227% when ambient temperature was increased from 21 to 40.5°C (Funckes, Hayes, & Hartwell, 1963). Decrease in cholinesterase activity has been found to correlate with increasing yearly temperatures for year-round landscape workers where pesticides were used in the workplace (Yeary et al. 1993). Also, anticholinesterase pesticides themselves stimulate sweating by inhibiting cholinesterase activity. This increases moisture on the skin and may increase absorption in the sebaceous glands as well (Gordon 2003).

Heat-related illness goes beyond acute sicknesses and may contribute to more chronic health problems. Damage to the renal, hepatic, coronary, digestive, integumentary, and the central nervous systems are thought to be linked to long-term heat exposure, but evidence is inconclusive. In recent years researchers in Latin America have begun to hypothesize that current epidemics of chronic kidney disease (CKD) may be linked to the interaction of chronic dehydration and other occupational risk factors. Laborers are often paid by the amount of product harvested. They may work to the point of severe dehydration, harming their kidneys each shift (Torres et al. 2010). Heat stress is not currently a recognized cause of CKD but it is associated with volume depletion and muscle damage (rhabdomyolysis), both of which are recognized risk factors for acute kidney injury and the later development of CKD. Acute kidney damage from volume depletion and rhabdomyolysis is well known in marathon runners, but data are lacking on chronic or repeated episode of volume depletion and no studies have documented outcomes chronic or repeated exposure outcomes (Peraza 2012). Volume depletion is associated with nephrolithiasis with hot environment occupations.

With the prospect of global climate change leading to increasing temperatures and heat waves, it is possible that most outdoor workers will face increased risk for heat exposure if this problem is not addressed more effectively (Crowe et al. 2010). A tradeoff exists between preventative measures and productivity and costs. More workers will be needed or longer hours will have to be worked at a reduced pace as temperatures increase (Kjellstrom et al. 2009).

Measurement and Evaluation of Heat Exposure

The WBGT is the most well-known, most frequently used method for the assessment of occupational heat stress, and its use has been adopted as an international standard (ISO 7243). The WBGT readings provide a composite measure used to estimate the effect of temperature, humidity, and solar radiation on humans. The WBGT temperature is a combination of 3 readings: the globe temperature, dry-bulb temperature, and natural wet-bulb. The globe temperature measures radiant heat from solid surroundings and convective heat from the ambient air and is commonly measured by a temperature sensor placed into a 6-inch copper ball that is painted black. The dry bulb temperature is a measure of what is commonly referred to as air temperature and is usually a temperature sensor that is shielded from the sun but still allows air to freely move about it. The natural wet bulb temperature is a measure of the amount of evaporative cooling that can occur and is sensitive to humidity and air movement. This temperature sensor is covered with a wetted wick with a supply reservoir that ensures the wick remains moist the entire time of measurement (Plog and Quinlan 2001).

The WBGT thermometer collects all 3 parameters simultaneously and it calculates values. The WBGT index is an empirical index representing heat stress that an individual may be exposed to. The WBGT index is used to estimate if a problem exists by determining whether measured values exceed reference values. The WBGT is most correlated with temperature rather than heart rate or sweat loss. The WBGT uses the following equation for outdoor working conditions with a solar load, where T_{nwb} is the wet bulb temperature, T_g is the globe temperature, and T_{db} is the dry bulb temperature:

$$\textit{(equation 2)} \quad WBGT = 0.7T_{nwb} + 0.3T_g + 0.1T_{db}$$

The WBGT method predicts core body temperature and provides guidance for limiting work activities when the core temperature exceeds 38°C. This instrument does not predict individual body temperatures but is protective at the population level. These values may be used to advise employers and supervisors on how to best implement practices to ensure worker safety. The most commonly used approach for using WBGT values is to use work rest schedules based on metabolic rates and clothing adjustment factors. The WBGT is a recommended evaluation method by OSHA (1999), ACGIH (2001), and NIOSH (1986).

Increased heart rate, increases in body temperature, and sweating are the physiological responses to heat stress and the focus of data collection for the monitoring component of this study. Heart rate and body temperature are some of the simplest measurements for assessing heat strain. The ACGIH has several recommendations for when work should be stopped or reduced for workers exposed to heat. ACGIH recommends that worker heart rate should be below 110 beats per minute (bpm) after 1 minute of rest, average heart rate should not exceed 115 bpm over the course of an 8-hour shift, and there should not be a sustained heart rate of 180 bpm minus the worker's age for several minutes (ACGIH 2001). Common measurements for heart rate include counting the radial pulse, using athletically-oriented heart rate monitors, or pulse oximeters. Heart rate has been cited as the easiest measurement to obtain, and may be the first to manifest and reach threshold values before increases in body temperature and the onset of sweating (Lumingu and Dessureault 2009). For temperature, it is recommended that core body temperature not exceed 100.4°F for the daily average, and work should be stopped or reduced at this point. Acclimated individuals may have temperatures up to 101.3°C intermittently, as long as there is sufficient time for recovery. Core temperatures can be taken a number of ways: rectally, orally, and tympanically (OSHA 1999).

Excessive sweating depletes the body of water weight if proper hydration is not maintained. The loss of weight over several hours reflects a depletion of extracellular fluid when water is lost due to sweating and from respiration. Pre- and postshift weighing can evaluate this loss to determine dehydration. A 1.5% loss reflects mild dehydration, while greater than 1.5% indicates an increased risk of heat stress (NIOSH 1986).

Justification for Research

Data for the southeastern U.S. regarding the environmental exposure and physiological response of MSFWs are lacking. Recent research has focused on evaluating WBGT values in agricultural workers in environments different from the southeast (Cecchini et al. 2010; Crowe et al. 2010). These studies have suggested increased risk for these workers. But in areas of the southeastern United States it is difficult to find any exposure assessments to which comparisons might be drawn. Also, these studies suggest increased risk but failed to physiologically evaluate workers' response during heat exposure that exceeded WBGT threshold values. Preliminary data for this area are needed in order to evaluate working conditions for migrant workers. These types of exposure assessments are needed to evaluate workers' exposures, behaviors in response to heat, and the applicability of occupational health interventions. Information is needed to delineate the correct approach for mitigating hazardous conditions that may range from a regulatory approach to educational training. With the prospect of climate change and more extreme weather, it will be better to identify problems and implement interventions in a preventive manner rather than report reactively after negative health outcomes have occurred.

CHAPTER 2

MATERIALS AND METHODS

Environmental and physiological monitoring was conducted during July 2012 at a community partnership farm in east Tennessee. We first entered the field 1 week prior to attempting to recruit participants for our project to familiarize ourselves with work organization and build trust with workers. The farm produces several crops with tomatoes being the primary product under large-scale commercial production. Workers pick unripened green tomatoes of varying sizes during the work shift and exchange each filled bucket for a “ficha” or ticket with monetary value that is traded in at the end of the shift. Workers are paid based on production; however, if their bit rate pay falls below minimum wage, they receive minimum wage on their weekly check. Buckets are dumped into large plastic crates on trucks that travel along rows with the workers as they pick. As each truck reaches capacity, it goes to the local packing house to be emptied and loaded with empty crates. Usually, a second truck immediately takes the place of the departing truck to ensure that work flow is not interrupted.

Between the main rows being picked, there are usually two vehicles carrying water or selling beverages. Water coolers are often available on the back of the larger trucks as well. Shade structures are absent from the field, with the only option being resting under a truck, which can be a hazard in itself. Bathrooms and hand washing facilities are not readily accessible and can often be at the far side of the field. The lunch break generally occurred between noon and 2 PM, varying each day with no exact schedule. Due to the lack of shade availability, many workers sit inside of vans during the lunch break. At the second location there was a storage shed available that workers used rather than work vans. Work began and ended at varying times of the day.

We attempted to recruit workers upon arriving at the picking location each day. The study was explained to workers in Spanish, and Spanish informed consent forms were signed. These contained a written explanation of the study in Spanish. Approval from the ETSU Institutional Review Board was obtained via protocol c0512.22s-ETSU. A copy of the consent form may be viewed in Appendix A. The workers were paid $25 at the end of each day for their participation. We were unable to randomly select participants for this study due to the hesitancy of the workers.

Data were collected on the dates of July 18th, 23rd, 24th ,25th, and 26th. We attempted to collect data on July 17th but were unable to do so because of the rain. Environmental parameters were collected using a tripod mounted Wet Bulb Globe Thermometer (WBGT) QuestTemp°10 Area Heat Stress Monitor from Quest Technologies. Calibration was verified in the morning before data collection by using the sensor module that accompanies the QuestTemp°10 for calibration. Readings were within 0.5°C of calibration values, which met the manufacturer's instructions for usage. The unit was allowed to equilibrate for 10 minutes in the morning before data were recorded, also per the manufacturer's directions. Workers were followed down rows as they picked with WBGT values collected every 15 minutes for the first day of sampling. We increased recording to approximately every 5 minutes for the other 4 days as it was noticed that WBGT values can rapidly fluctuate in the field. Because the QuestTemp°10 does not measure relative humidity directly, these values were calculated from dry bulb and wet bulb temperatures using an Excel analysis package from heat stress expert Thomas Bernard, one of the ACGIH authors for the heat stress TLVs (Bernard 2012). These values were confirmed using a psychrometric chart.

Heart rate and tympanic temperature were collected at hour increments for evaluation with predictive heat stress WBGT values and to monitor for heat stress. Physiological monitoring varied and depended on the work schedule for the day, but each measurement had 1 hour of environmental data to evaluate with the hourly time weighted average for heat exposure. Baseline values for blood pressure, heart rate, and temperature were collected before the beginning of the work shift. Workers were also weighed before and after the work shift to evaluate dehydration, or water loss, resulting from the day’s work. Heart rate was collected using an FDA approved clinical fingertip pulse oximeter from Cooper Medical Supplies (Model CMS - 50DLP) with an accuracy of ±2 beats per minute. Tympanic temperatures were collected using an FDA approved clinical thermometer from Mabis DMI Healthcare (Model 18-607-000). Bodyweights were measured using a Doran DS6100 digital medical scale, accurate to ± 0.20 pounds. The characteristics of our participants and baseline values may be seen in Table 2, with full data seen in Appendix B. The country of origin for all workers was Mexico, with Spanish their primary language.

Table 2. Worker Characteristics and Baseline Values (N=18).

Variable	Average	Minimum	Maximum
Age	32.6±10.7	18	54
Sex			
Male	14(88%)		
Female	4(22%)		
Weight	150.89±21.04	103.4	199.20
Baseline Body Temperature°C	36.7±0.2	37.0	36.2
Baseline Heart Rate	77.9±12.2	50	95

We used WBGT values and estimated metabolic rates to evaluate environmental heat exposure for workers following the methodologies of NIOSH and ACGIH. Besides using the directly measured environmental parameters, the methodology for using the WBGT requires an estimation of the metabolic rate. The metabolic rate is used to determine threshold limit values (TLVs) for workers in hot environments. Once TLVs are reached, the appropriate ratio of work-rest scheduling should be implemented to keep core body temperature from rising above 38.0°C, or 100.4°F. This determination is summarized in Table 3. Our workers were determined to have a moderate metabolic workload. Metabolic rates for our workers were estimated by ergonomics expert, Dr. Nate Fethke, at the University of Iowa and are discussed further within the results.

Table 3. Guide to Permissible Heat Exposure Threshold Limit Values.

Work/Rest Regimen	Work Load		
	Light (<200 kcal/hr)	Moderate (200-350 kcal/hr)	Heavy (350-500 kcal/hr)
Continuous Work	30.0°C (86°F)	26.7°C (80°F)	25.0°C (77°F)
75% Work, 25% rest, each hour	30.6°C (87°F)	28.0°C (82°F)	25.9°C (78°F)
50% Work, 50% rest, each hour	31.4°C (89°F)	29.4°C (85°F)	27.9°C (82°F)
25% Work, 75% rest, each hour	32.2°C (90°F)	31.1°C (88°F)	30.0°C (86°F)

*Values are in °C and °F, WBGT. These TLV's are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38°C (100.4° F). (ACGIH, 2001)

Data Analysis

Pearson's correlation coefficient was used to evaluate the relationship between the physiological response for heart rate, body temperature, and physiological strain and each environmental heat exposure parameter measured by the various bulbs that comprise a WBGT unit. We also evaluated the effect of age and weight on changes in body temperature, heart rate, and strain. Minitab (2010) was used to evaluate correlation data and construct figures. Repeated measures regression analysis was used to evaluate the magnitude of each of the parameters controlled for age and weight on body temperature, heart rate, and physiological strain. To reduce the bias between subjects, a random effect was adopted for each subject, with first order autoregressive covariance structure. To evaluate intra-subject variability due to heat exposure repeated measures regression was calculated for each subject. There were 4 to 6 repeated measures for each of the 18 test subjects. Statistical analysis for these tests was conducted using

SAS (2008). SAS coding used mixed procedures (proc mixed) with the first order autoregressive covariance structure. All tests were 2-sided with a confidence level less than 0.05 considered significant. We used the Physiological Strain Index (PSI) to calculate strain for each worker at measurement intervals using the following formula from Moran et al. (1998).

$$\text{(equation 3) } PSI = 5(T_{tyt} - T_{ty0}) \times (39.5 - T_{ty0})^{-1} + 5(HR_t - HR_0) \times (180 - HR_0)$$

Within this equation, T_{tyt} and HR_t are measurements for tympanic temperature and heart rate taken at any time during the evaluation. HR_0 and T_{ty0} are the baseline measurements for a given study. The measurements of T_{ty} and HR are used to depict the combined loading on the cardiovascular and thermoregulatory systems, and are assigned the same weight using a constant of 5. This strain index is scaled from 0-10 corresponding with 10 demonstrating the most physiological strain. The PSI has the following limitations: $36.5 \leq T_{ty} \leq 39.5$°C and $60 \leq HR \leq 180$ bpm. These reflect a maximum range that body temperature and heart rate can exceed from exercise or work-heat stress, changing from normothermia to hyperthermia with increases of 3°C and 120 bpm. The index is not accurate when changes in body temperature or heart rate exceed these values (Moran et al. 1998).

Using our partnership with Rural Medical Services, a survey was implemented this year to evaluate several aspects of occupational heat stress. The inclusion and use of the survey was also approved by the Institutional Review Board via protocol c0512.22s-ETSU. Specifically, we sought to investigate:

- symptoms of heat stress in the past week while working in hot weather for the previous 7 days
- if workers had received any heat-related training while in the United States

- worker knowledge of heat index or maximum temperature for the day
- their strategies for coping with extreme heat during work
- preferred beverage on hot days.

The symptoms we asked about included headache, nausea and vomiting, weakness and dizziness, and cramps. All data from the screening were entered on site or the next week afterwards by the use of EpiInfo (2012). Comparing pickers and a nonpicker work group, odds ratios were calculated for individual symptoms and combinations of symptoms using Fisher's exact test. The heat stress survey questions can be viewed in Appendix C.

Quality assurance and quality control for the survey consisted of ensuring that duplicate participants did not enter into the final analysis. Duplicate participant surveys were collected during screenings, and these were eliminated by identifying duplicates by birthdate, sex, and home province in the country of origin.

Limitations

There were many limitations to this study primarily due to a single growing season in which to gather data, modest financial resources, and a lack of prior experience in heat stress studies by the investigators. The study was designed to be a workplace evaluation where we expected to find many high body temperatures based on an analysis of body temperatures of workers seen at RMS screenings in 2011. We discovered that the clinical thermometer used by RMS at the screenings became heated during transportation to field clinics. This resulted in false high numbers in the 2011 analysis. This was confirmed by using our clinical thermometer protected from heat exposure with RMS's thermometer on a screening date. The RMS thermometer gave readings over 100.0°F for persons who had been inside in air conditioning all day long, while ours reported normal body temperatures.

Having continuous heart rate monitors would have provided many more data points for this study. Using continuous heart rates, it might have been possible to detect heat stress based on time weighted averages of heart rates as opposed to intermittent measurements. Such monitors cost over $80 each, compared to the $35 paid for the pulse oximeter we used. Our data set was relatively small because we were only able to recruit a small number of workers due to modest funding. An additional 4 participants could have been recruited for every $100 of additional funding.

Work organization reduced the number of data points we were able to collect as well. The original goal was to gather 6 to 8 data points throughout the day at hour increments. However, work was shortened on 4 out of 5 days of monitoring. Work only lasted for 8 hours on 1 day of this study. On the 2 hottest days of monitoring, work did not begin until approximately noon. This happened because on the first of these two days workers had moved to a new field, and the farm labor contractors arrived on site with the trucks later than usual. On the second of these 2 days, the Department of Labor and Wages made a visit to the field. The farm labor contractors were aware this visit was going to occur and did not allow workers to begin until 12:30.

CHAPTER 3

RESULTS

WBGT Measurements and TLVs

Pursuant to our first research objective, WBGT measurements were collected in the field to evaluate if work occurred in an environment that exceeded the TLV values (see "Methods"). In order to determine the TLV for our workers, the work load had to be estimated based on the metabolic rate in kcal/hr. This was determined by our ergonomics expert Dr. Nate Fethke using an Excel analysis package from the ACGIH thermal stress author Thomas Bernard (Bernard 2012). The metabolic rate was determined to be 266.18 kcal/hr and was modified by using a conversion factor recommended by NIOSH. For the conversion, each worker's weight was divided by 154 lbs., the weight of an average worker. Each conversion factor may be viewed in Appendix B. The average of these conversion factors, 0.98 was multiplied by the metabolic rate giving a value of 260.86 kcal/hr. An example formula for this calculation for a worker with a weight of 145 lbs may be viewed in equation 3.

$$(equation\ 3) \quad \frac{145\ lbs.}{154\ lbs.} = 0.94$$

$$0.94 \times 266.18\frac{kcal}{hr} = 250.6\frac{kcal}{hr}$$

According to Table 3, this established a moderate workload for our group, with TLVs at 28.0°C, 29.4°C, and 31.1°C. These TLVs indicate that in order to prevent the body temperature from exceeding 38.0°C, work should only occur for 45, 30, and 15 minutes once the hourly average temperatures exceed 28.0°C, 29.4°C, and 31.1°C respectively.

Figure 1 shows the mean daily WBGT measurements with TLVs. TLVs set at 28.0°C and 29.4°C were exceeded on all days. The TLV set at 31.1°C was exceeded on the fourth monitoring day. Measurements of the WBGT and contributing values are shown in Table 4, and all measured environmental data may be viewed in Appendix D.

Table 4. Summary of WBGT, Dry Bulb, globe, Wet Bulb, and Relative Humidity Values.

Dates	WBGT	Dry Bulb	Globe	Wet Bulb	RH%[1]
7/18/2012 (N=24)					
Mean(SD)[2]	30.0(1.4)	32.5(1.7)	40.5(4.6)	26.9(1.0)	66.17(6.5)
Maximum	32.5	36.7	47	28.9	79
Minimum	26.5	28.5	30.4	25	46
7/23/2012 (N=82)					
Mean(SD)	29.8(1.4)	33.1(1.7)	41.4(4.2)	26.1(0.7)	57.9(4.8)
Maximum	32.1	36.2	48.8	27.6	72
Minimum	26.8	28.6	28.8	24.5	50
7/24/2012 (N=54)					
Mean(SD)	30.9(1.0)	34.4(1.6)	43.4(3.0)	27.3(1.6)	56.5(5.3)
Maximum	32.9	36.9	49.7	28.2	71
Minimum	28.7	30.6	36.9	26	49
7/25/2012 (N=45)					
Mean(SD)	31.7(1.4)	35.2(1.9)	45.4(4.1)	27.5(1.5)	55.1(5.2)
Maximum	33.9	38.3	51.1	28.6	67
Minimum	28.9	31.5	37.5	25.6	47
7/26/2012 (N=59)					
Mean(SD)	31.1(0.9)	35.9(1.5)	45.2(2.8)	26.5(0.6)	48.8(5.8)
Maximum	33	38.5	50.8	28	62
Minimum	28.6	31.9	36.4	25.6	39

[1]Relative Humidity, [2]Standard Deviation.

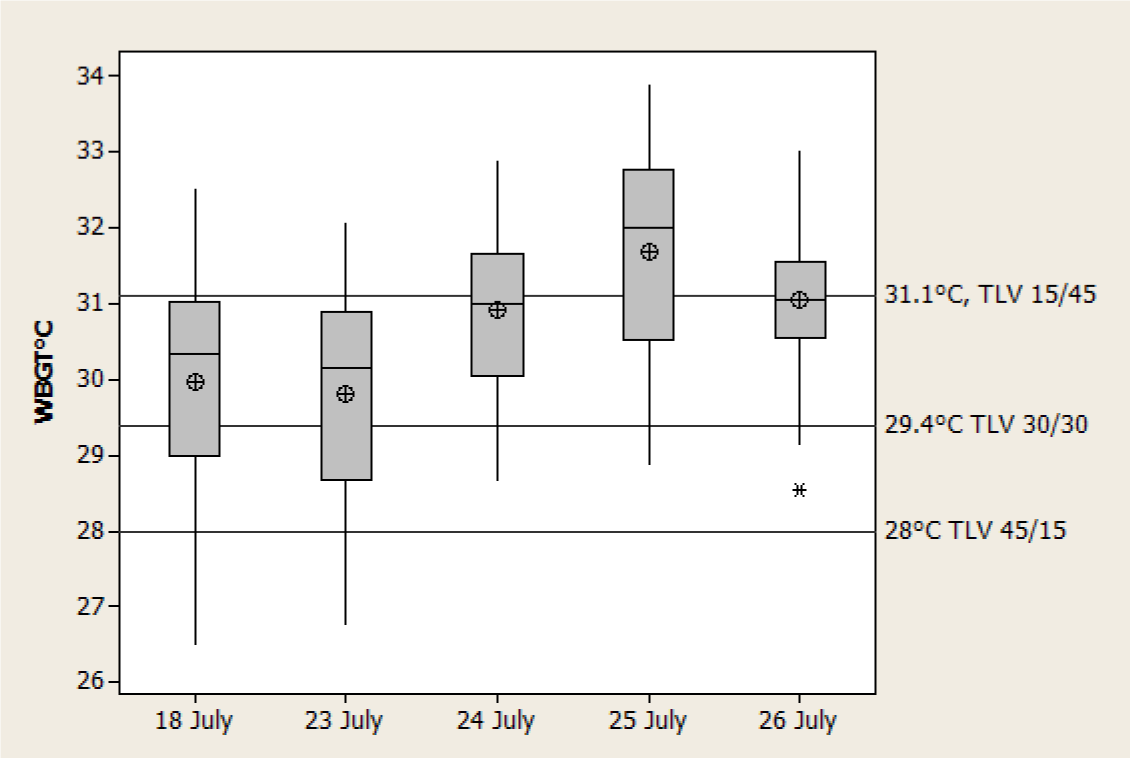

Figure 1[1]. WBGT Measurements with TLVs Designated By Y Axis Lines at 28.0°C, 29.4°C, and 31.1°C, and Recommended Work Rest Ratios (Time Of Work/Time Of Rest).

Physiological Monitoring

Based on WBGT TLVs, we would expect body temperatures to exceed 38.0°C if proper rest time is not achieved; however, this never occurred in any study participant. Only one participant reached a body temperature of 38.0°C throughout the study. Group means ranged from 36.8°C to 37.3°C, with minimum and maximum measurements of 36.4°C and 38°C (Figure 2). Group means for heart rate ranged from 96.67 to 128.13 bpm, with minimum and maximum measurements of 75 and 161 bpm (Figure 3). Changes in heart rate from baseline for group means ranged from 6.75 to 44.62 bpm with minimum and maximum changes of -19 to 79 bpm (Table 5). Changes in body temperature from baseline for group means ranged from 0.15 to

[1] Within boxplots, the box represents the 25th and 75th percentile. The line through the center of the box represents the median. The whiskers extend to the outermost sampling points 1.5 times from the 25th and 75th percentile. The cross hair symbol represents the mean.

0.42°C with minimum and maximum changes 0.07 to 1.22°C (Table 5). PSI group means ranged from 0.658 to 3.492 with a minimum and maximum of -0.621 and 5.263 (Figure 4). PSI values indicate low to moderate physiological strain for study participants. The mean percent body weight change for all participants was -1.0% with values ranging from -2.4% to a positive weight gain of 0.1% (Figure 5). Full data for all measurements may be viewed in Appendix E.

All measurements except for the PSI were used as criteria for identifying heat strain in study participants. These criteria from OSHA and NIOSH, mentioned previously, included:

- exceeding a body temperature of 38.0°C
- a heart rate exceeding 110 bpm after one minute of rest
- a body weight loss of over 1.5%

While no participants exceeded a body temperature of 38.0°C, 6 study participants exceeded the resting heart rate criteria a total of 11 times. For body weight change, 6 participants lost over 1.5%. The frequency of exceeding these criteria, along with work times and frequency of sampling points, is shown in Table 6.

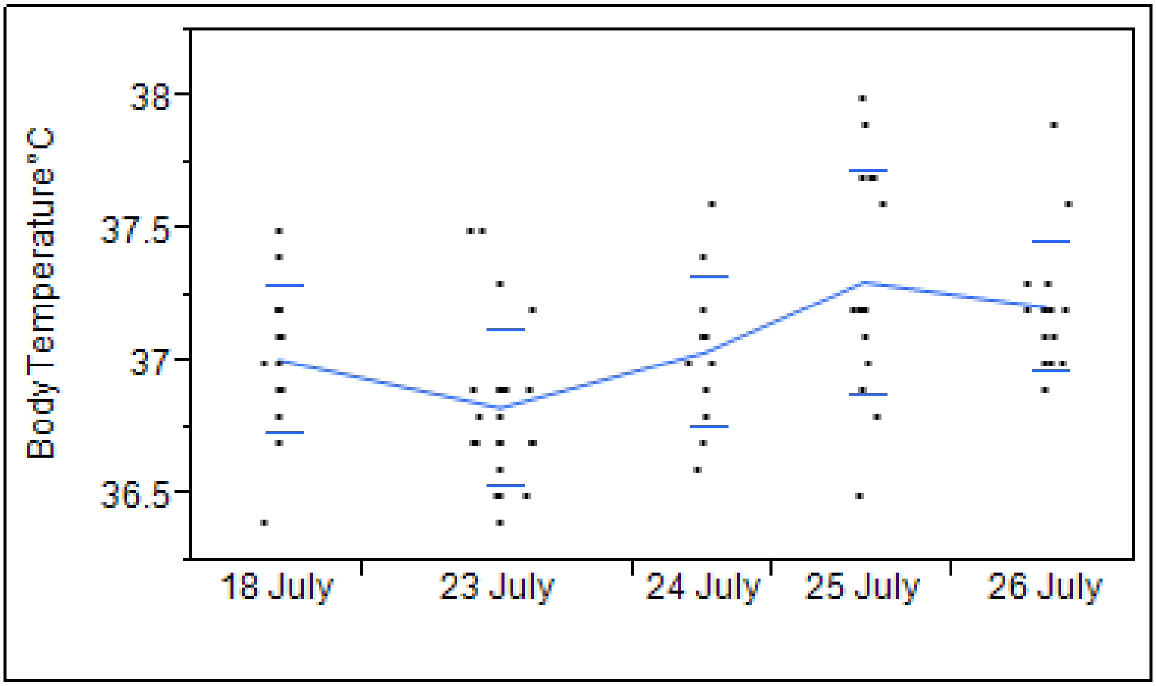

Figure 2[2]. Distribution of Body Temperature Measurements.

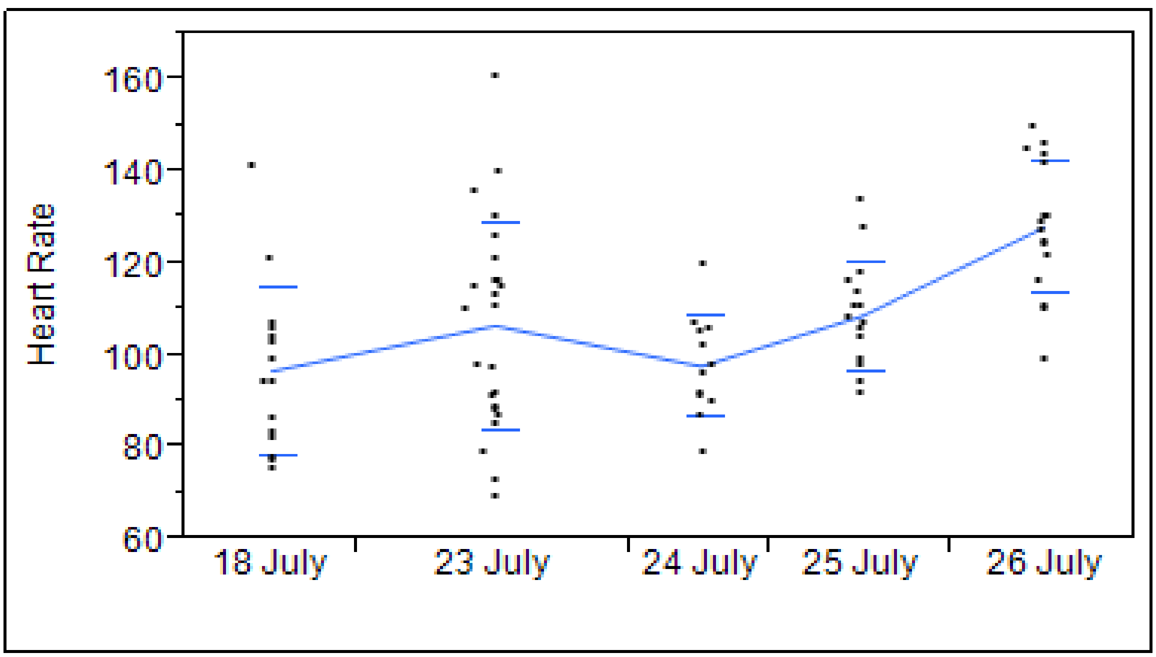

Figure 3. Distribution of Heart Rate Measurements.

---

[2] Means are connected by the blue line running through each sampling date. Blue hash marks represent the standard deviation of the sample.

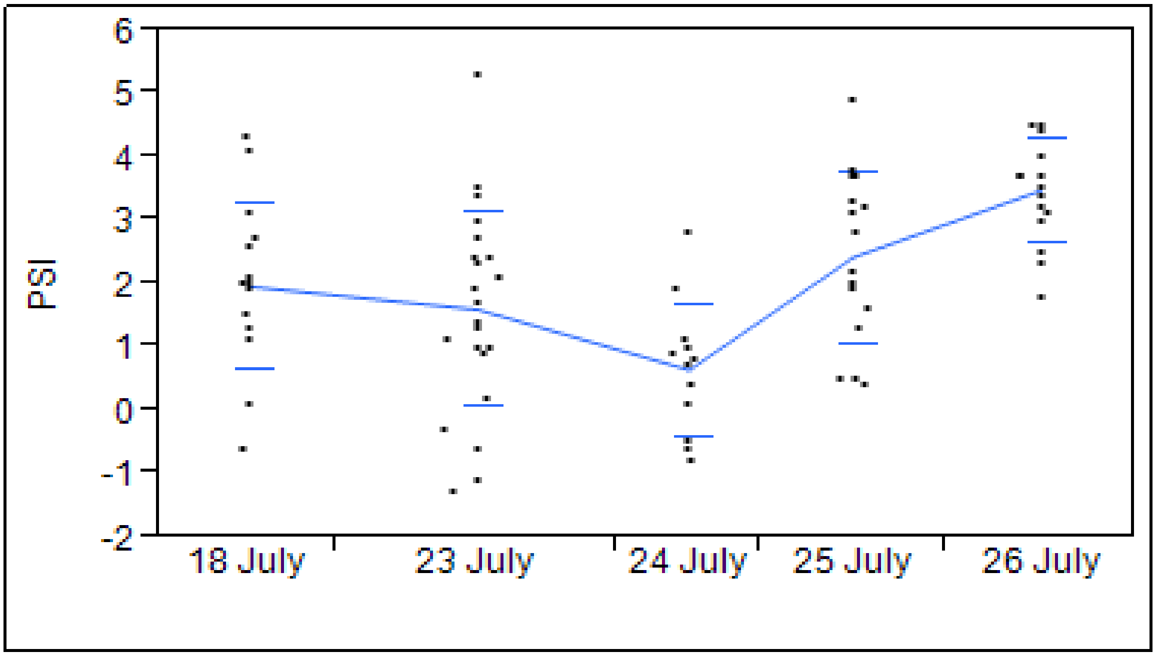

Figure 4. Distribution of Physiological Strain Index Measurements.

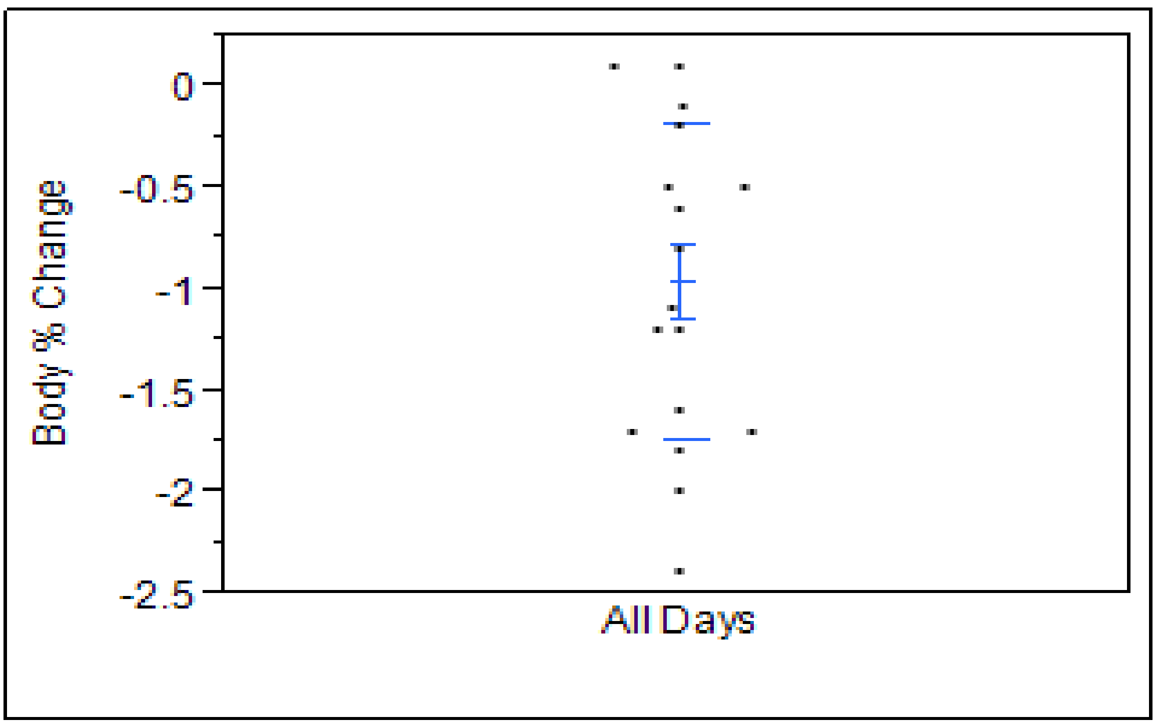

Figure 5. Distribution of Body Weight Percentage Change.

Table 5. Group Delta Values for Heart Rate and Body Temperature.

Date	N	Mean	SD	Minimum	Maximum
HR[1]BPM					
7.18	15	35.67	19.54	4	79
7.23	24	27.58	25.42	-19	74
7.24	12	6.75	10.99	-10	35
7.25	16	30.87	15.95	5	61
7.26	16	44.62	15.13	15	69
BT[2]°C					
7.18	15	0.22	0.31	0.02	0.76
7.23	24	0.17	0.29	-0.04	0.93
7.24	12	0.15	0.27	-0.06	0.72
7.25	16	0.42	0.40	0.17	1.00
7.26	16	0.71	0.26	0.57	1.22

[1]Heart Rate [2]Body Temperature

Table 6. Physiological Monitoring for Indicators of Heat Strain.

Worker ID	Date	Work Shift	Measurement Points Taken	Core Body Temperature Exceeding 38°C	Heart Rate Exceeding 110 bpm After One Minute Rest	Body Weight Loss Over 1.5%
1	7/18/2012	11:27-4:45	5	No	No	No
2	7/18/2012	11:27-4:45	5	No	No	No
3	7/18/2012	11:27-4:45	5	No	No	No
4	7/23/2012	9:30-6:00	6	No	No	No
5	7/23/2012	9:30-6:00	6	No	No	Yes
6	7/23/2012	9:30-6:00	6	No	No	No
7	7/23/2012	9:30-6:00	6	No	Yes(2)[1]	No
8	7/24/2012	10:45-3:00	4	No	No	Yes
9	7/24/2012	10:45-3:00	4	No	No	Yes
10	7/24/2012	10:45-3:00	4	No	No	Yes
11	7/25/2012	12:08-5:32	4	No	No	No
12	7/25/2012	12:08-5:32	4	No	Yes(1)	Yes
13	7/25/2012	11:43-5:32	4	No	No	No
14	7/25/2012	11:43-5:32	4	No	No	No
15	7/26/2012	11:43-5:32	4	No	Yes(1)	Yes
16	7/26/2012	11:43-5:32	4	No	Yes(1)	No
17	7/26/2012	11:43-5:32	4	No	Yes(4)	No
18	7/26/2012	11:43-5:32	4	No	Yes(2)	No

[1]Indicates frequency of occurrence in measurements.

Correlation Data

Correlation is shown between physiological response and measured environmental temperatures in Table 7. The combination of all 3 values for dry bulb, wet bulb, and globe temperatures expressed as the WBGT value correlated most strongly with body temperature (r^2 0.613, $p<0.001$). Body temperature also correlated strongly with the dry bulb, wet bulb, and globe temperatures with r^2 values of 0.562, 0.527, and 0.531 ($p<0.001$). Heart rate had a significant correlation with the WBGT, dry bulb, and globe temperature measurements with values of 0.293, 0.394, and 0.376 ($p<0.001$). Though heart rate was significantly correlated with 3 out of 4 temperature measurements, the correlation was weaker in comparison to the body temperature. Physiological strain also significantly correlated with all environmental temperatures except for the wetbulb. Correlation r^2 values for the WBGT, dry bulb, and wet bulb were 0.393, 0.438, and 0.417 ($p<0.001$). Low correlation values suggest that the variation of physiological response of these workers to heat is only partially explained by environmental exposure. The rest of the variance is likely attributable to exertion by the worker. Results may be confounded by the amount of rest each worker takes per hour. Worker heart rates and PSI values were significantly negatively correlated with age and body weight, while body temperature was negatively correlated with age (Table 8). This agrees with our field observations. Younger and thinner workers appeared to be moving faster compared to older or heavier workers. Figures 6 through 10 display matrix correlations for the described data. All data are available in Appendix E.

Table 7. Pearson Correlation Coefficient Values for Physiological Measurements and Environmental Temperatures. (p-values)

	WBGT	Dry Bulb	Wet Bulb	Globe	RH	BT	HR	PSI
WBGT	1	0.857 (<0.001)	0.79 (<0.001)	0.942 (<0.001)	-0.651 (<0.001)	0.613 (<0.001)	0.293 (<0.001)	0.393 (<0.001)
Dry Bulb		1	0.567 (<0.001)	0.834 (<0.001)	-0.915 (<0.001)	0.562 (<0.001)	0.394 (<0.001)	0.438 (<0.001)
Wet Bulb			1	0.58 (<0.001)	-0.192 (-0.082)	0.527 (<0.001)	-0.017 (-0.11)	0.177 (-0.11)
Globe				1	-0.729 (<0.001)	0.531 (<0.001)	0.376 (<0.001)	0.417 (<0.001)
RH					1	-0.413 (<0.001)	-0.481 (<0.001)	-0.43 (<0.001)
BT						1	0.389 (<0.001)	0.643 (<0.001)
HR							1	0.867 (<0.001)
PSI								1

RH=Relative Humidity, BT=Body Temperature, HR=Heart Rate, PSI=Physiological Strain Index

Table 8. Pearson Correlation Coefficients for Physiological Measurements and Age and Weight. (p-values)

	Body Temp	Heart Rate	PSI	Age	Weight
Body Temperature	1	0.389 (<0.001)	0.643 (<0.001)	-0.227 (<0.011)	-0.156 (0.159)
Heart Rate		1	0.867 (<0.001)	-0.243 (<0.011)	-0.335 (0.002)
PSI			1	-0.250 (0.023)	-0.353 (0.001)
Age				1	-0.076 (0.494)
Weight					1

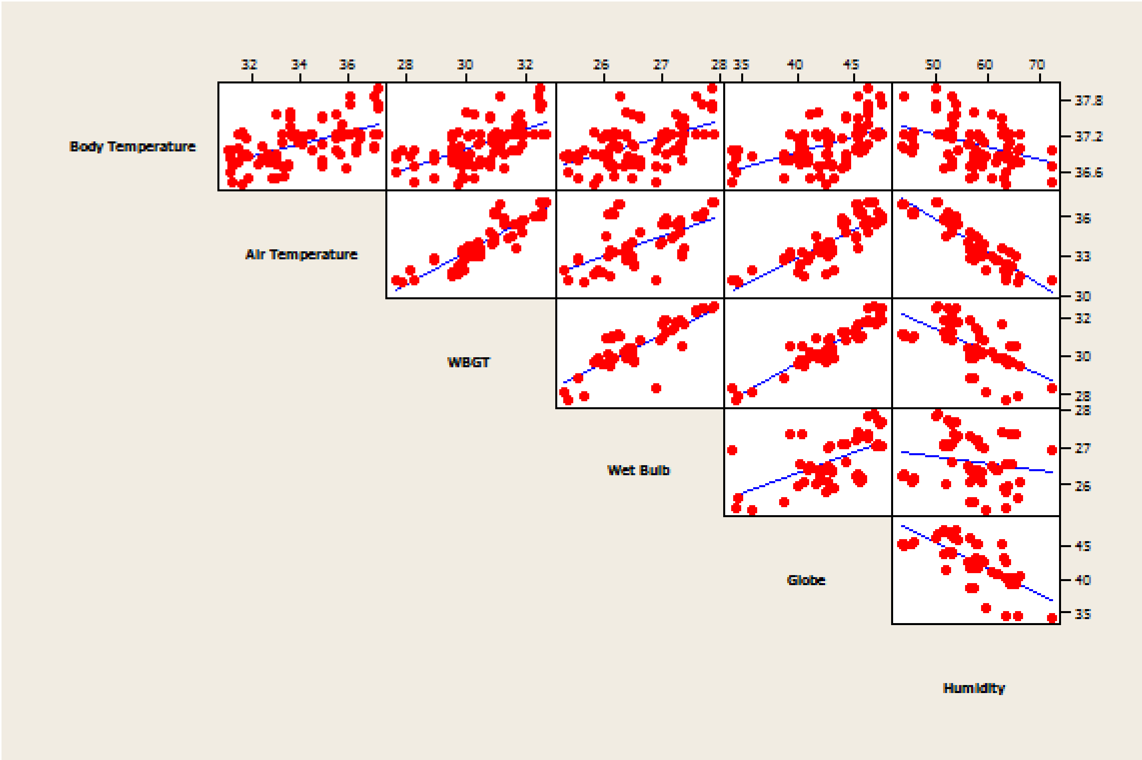

Figure 6. Matrix Correlation Plots of Body Temperature and Environmental Temperatures.

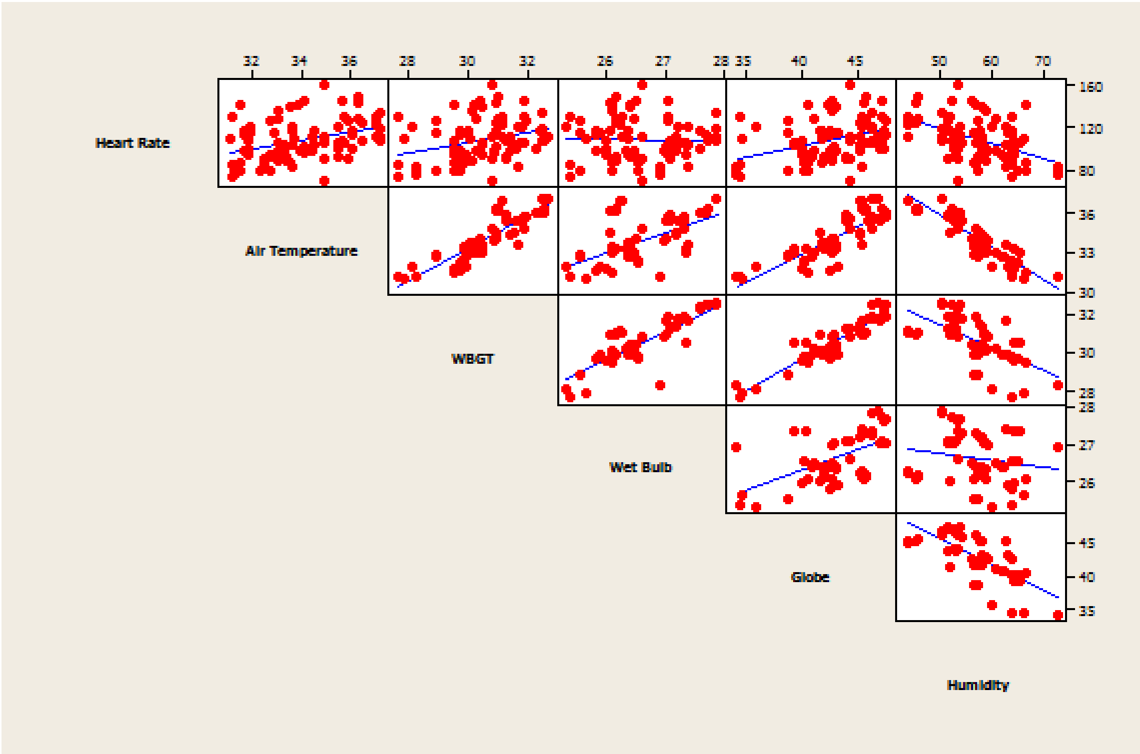

Figure 7. Matrix Correlation Plots of Heart Rate and Environmental Temperatures.

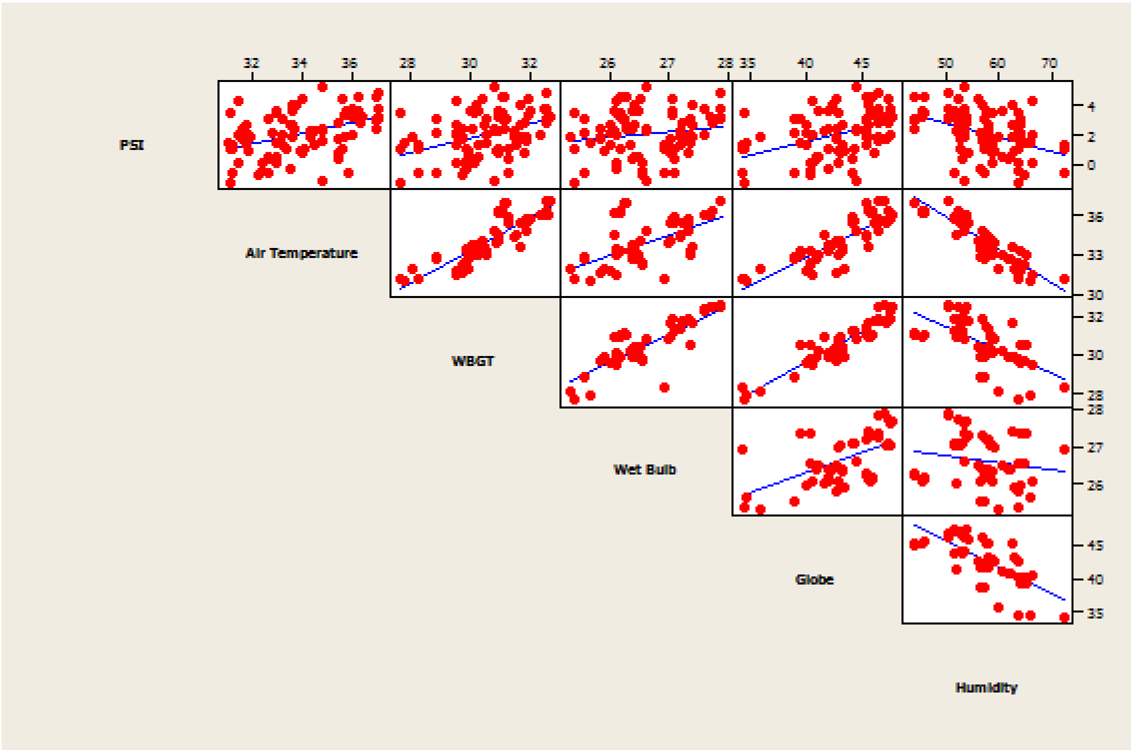

Figure 8. Matrix Correlations Between the Physiological Strain Index and Environmental Temperatures.

Figure 9. Matrix Correlation of Body Temperature and Heart Rate with Age and Weight.

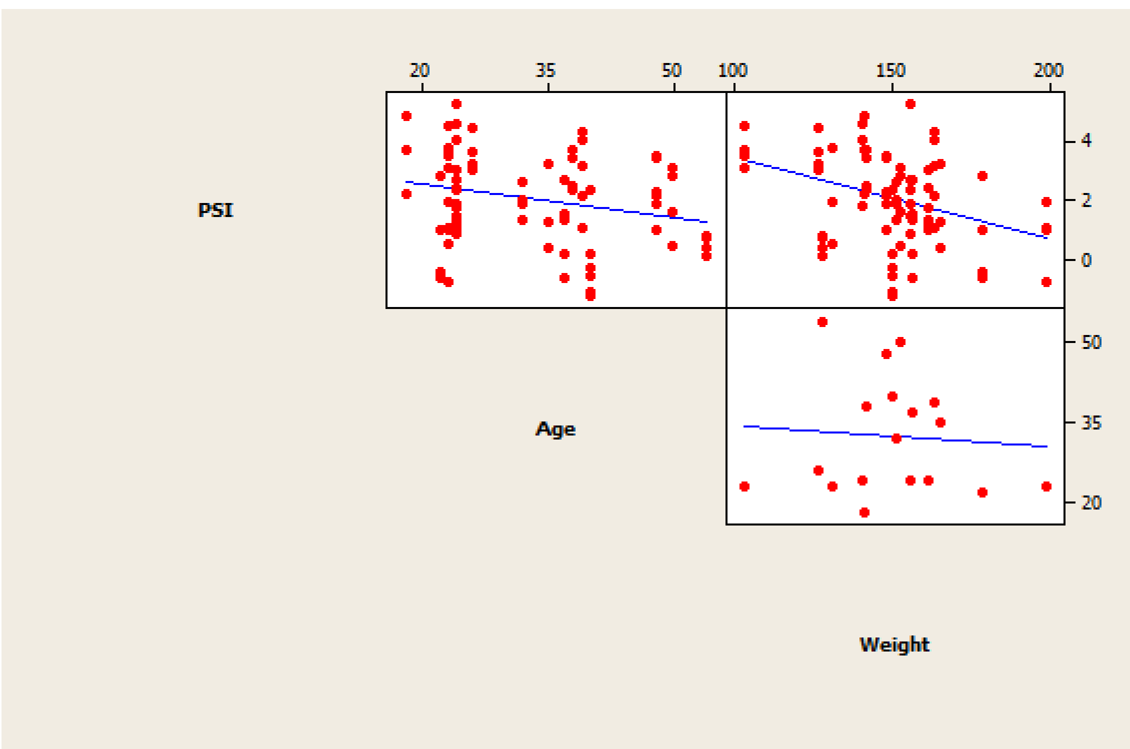

Figure 10. Matrix Correlation Between Physiological Strain Index and Age and Weight.

Regression Analysis

The effects of each observed environmental parameter on body temperature, heart rate, and physiological strain were modeled and controlled for age and weight (Table 9). Each effect was evaluated independently. Evaluating effects together confounded results due to colinearity. For every increase of 1°C in the WBGT, body temperature increased 0.148 (±0.051°C). For every increase of 1°C in dry bulb, there was a 0.093°C (±0.050°C) increase in body temperature. For every increase of 1°C of the globe temperature, there was a 0.044°C (±0.020°C) increase in body temperature. An increase in the WBGT, dry bulb, and globe of 1°C was associated with an increased heart rate of 3.498 (±3.23), 2.803 (±2.30), and 1.456 (±0.48) beats per minute, respectively. The wet bulb, or evaporative cooling, did not show a significant effect on heart rate. Physiological strain also increased from the effects of the environmental parameters. An increase in 1°C was correlated with increased strain index values of 0.403 (±0.220), 0.288 (±0.169), 0.551 (±0.482), and 0.135 (±0.076) for WBGT, dry bulb, wet bulb, and globe respectively. Relative humidity had a negative effect on all 3 physiological responses. This is likely because humidity dropped as the dry bulb temperature increased, with an increasing dry bulb eliciting a positive effect on physiological response. This modeling supports and quantifies the positive effect that working in a hot environment has on body temperature, heart rate, and strain. However, the small magnitude of the effects per 1°C increase in temperature suggests that exposure to much higher temperatures would be necessary for body temperatures to begin to exceed 38°C. This analysis was done with hourly data as shown in Appendix E.

.

Table 9. The Effect of Environmental Temperatures on Body Temperature, Heart Rate, and Physiological Strain Using Repeated Measures Regression Analysis.

Response	Effect	Estimate[1]	SE	Upper[2]	Lower[2]	F Value	Pr > |F|	DF	χ2	Pr > χ2
BT °C	WBGT	0.148	0.026	0.199	0.098	33.58	<.0001	1	9.88	0.0259
	Dry Bulb	0.093	0.020	0.132	0.055	22.52	<.0001	1	5.30	0.0213
	Wet Bulb	0.267	0.051	0.367	0.168	27.64	<.0001	1	2.30	0.1295
	Globe	0.044	0.010	0.062	0.025	21.11	<.0001	1	6.07	0.0138
	RH	-0.020	0.006	-0.008	-0.032	10.42	0.002	1	10.13	0.0015
HR	WBGT	3.498	1.647	6.726	0.271	4.51	0.038	1	5.39	0.0203
	Dry Bulb	2.803	1.175	5.105	0.500	5.69	0.020	1	4.26	0.0391
	Wet Bulb	0.702	3.354	7.276	-5.872	0.04	0.835	1	5.86	0.0155
	Globe	1.456	0.570	2.573	0.339	6.53	0.013	1	4.32	0.0376
	RH	-1.041	0.330	0.394	-1.688	9.94	0.003	1	3.35	0.0670
PSI	WBGT	0.403	0.112	0.623	0.182	12.84	0.001	1	16.15	<.0001
	Dry Bulb	0.288	0.086	0.455	0.120	11.31	0.001	1	15.93	<.0001
	Wet Bulb	0.551	0.246	1.032	0.070	5.04	0.028	1	15.91	<.0001
	Globe	0.135	0.039	0.212	0.059	11.93	0.001	1	15.54	<.0001
	RH	-0.082	0.026	-0.056	-0.108	10.29	0.002	1	17.21	<.0001

BT, body temperature, HR, heart rate, PSI, Physiological Strain Index, SE, standard error, RH, relative humidity. [1]Estimates are results from multivariate models that included weight and age, which were negatively correlated with each response.[2]Intervals are at 95% confidence.

Survey Data

From survey data collected at RMS screenings, we investigated if there was a higher prevalence of symptoms that could be attributed to heat exposure comparing outside pickers to a nonpicker work group (Table 10). The difference in the reporting of symptoms was not significant between the 2 groups for symptoms or combinations of symptoms. However, the higher reporting of cramps by the picker group is trending toward statistical significance in the survey (p=0.0672). This observation supports our physiological monitoring for dehydration in the field using percentage change in body weight where several workers lost over 1.5% bodyweight. Cramps are associated with dehydration, and these results are possibly indicative of hydration problems for workers in the fields.

From the survey, it also appears that few workers have had any occupational training regarding heat safety, with less than 30% of the 85 workers responding "yes" to training. Less than a tenth of workers claimed to know the heat index for the day, and only 12 claimed to know the maximum temperature (Figure 11). We did not ask the source of their weather information, however. Asked their degree of concern regarding heat exposure as a health hazard, over half responded they were very concerned; over 30% responded they were a little concerned, and 14 (16%) said they were not concerned at all (Figure 12). There was no association between degree of concern and age of workers or time in the U.S.

For coping mechanisms for working in hot weather, almost all workers responded that they drink more fluids. Nearly half responded that they rested in the shade; eleven (13%) responded that they went to a cool place after work, and only one responded to working more slowly (Figure 13). It is interesting that only one worker admitted to slowing their work pace, because it's likely that self-pacing is key for these workers in maintaining low body temperatures while working in higher temperatures. Over half of the workers responded that water was their preferred beverage during hot days was water. Nearly one-third responded with Gatorade, and 7 for soda (Figure 14). Survey data may be viewed in Appendix F.

Table 10. Comparison of Reporting of Possible Heat-Related Symptoms Between Pickers and Nonpickers.

Heat-related Symptoms	Pickers (N=85)	Nonpickers (N=50)	Odds Ratio	95% CI	P-Value
Nausea & Vomiting	14	6	1.446	0.5174-4.0409	0.618
Weakness or Dizziness	26	12	1.3955	0.6294-3.0942	0.4362
Headache	41	20	1.3977	0.6886-2.8370	0.376
Cramps	26	8	2.3136	0.9541-5.6099	0.0672
2 Symptoms	28	13	1.3981	0.6427-3.0412	0.4428
3 Symptoms	9	3	1.8553	0.4779-7.2021	0.5342
Avg.Age(SD)	30.2(±10.6)	37.3(15.7)			
Minimum	18	12			
Maximum	66	69			
Sex	-	-			
Male	71	26			
Female	7	23			

*Sex not recorded for 7 individuals for pickers and 1for nonpicker in the surveys.

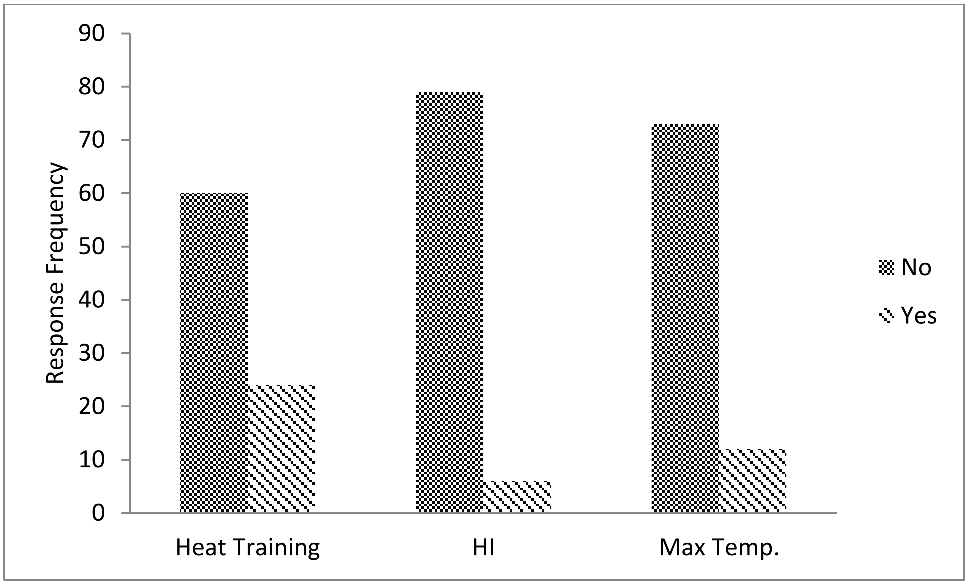

Figure 11. Survey Responses for Having Received Heat Training, Having Knowledge of the Heat Index for the Workday, and Having Knowledge of the Maximum Temperature.

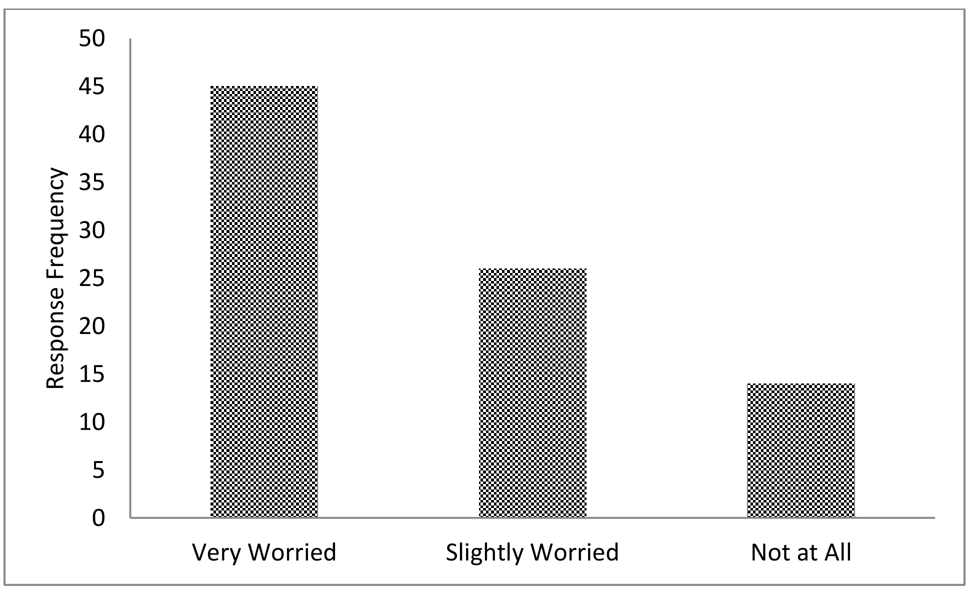

Figure 12. Response of Workers for Degree of Concern Regarding Heat Exposure as a Health Hazard.

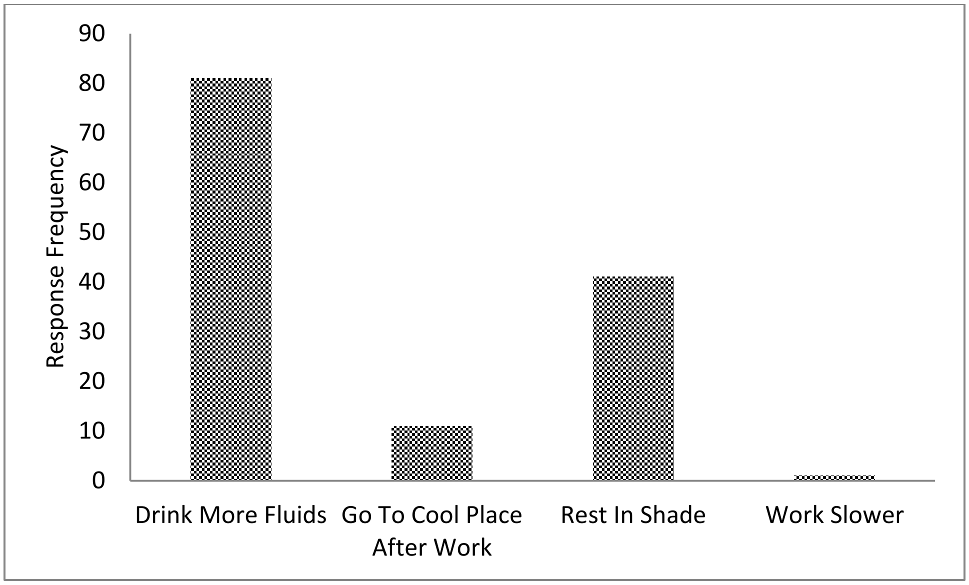

Figure 13. Reported Coping Mechanisms for Working in hot Weather.

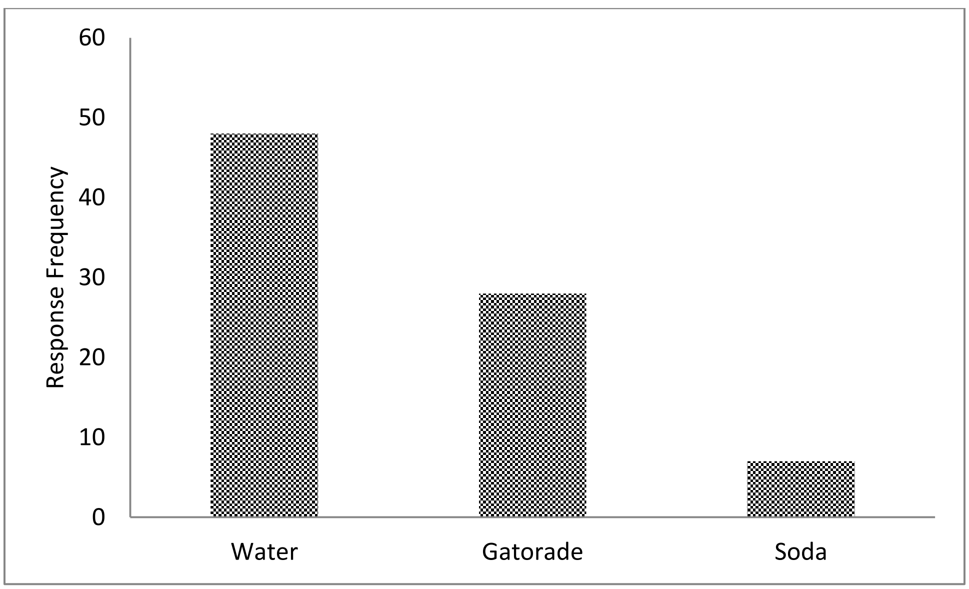

Figure 14. Reporting of Preferred Beverage on Hot Days by Workers.

CHAPTER 4

DISCUSSION AND RECOMMENDATIONS

Physiological Monitoring

Heat strain criteria were rarely exceeded by workers during the study. Body temperatures never exceeded 38.0°C, indicating the possibility that workers are well-acclimated and are pacing and resting for adequate periods to maintain low body temperatures. Another possibility is that the WBGT is too conservative as a heat stress index. Workers shown to work in environments that exceed WBGT TLVs without implementing the recommended rest period have been shown not to exceed a body temperature of 38.0°C. This is believed to be due to the index's insensitivity to the cooling effect of air movement (Budd 2001; Bates and Miller 2002).

Maintenance of low body temperatures may be due to self-pacing by workers at the individual level. Brake and Bates (2002) showed that well-informed workers in industrial environments adjusted work rates during increased heat exposure, allowing work to continue at safe levels despite increasing temperatures. This is interesting, as the workers studied here may not be considered well-informed and are not managed or directed to self-pace through workplace management. The ability of workers to avoid physiological strain in hot environments is likely a combination of adaptation and the behavioral response of self-pacing. This is consistent with findings from Miller and Bates (2011), who cited self-pacing as the reason for unchanged heart rates and aural temperatures in outdoor workers when exposed to conditions expected to elicit heat strain responses. Physiological response, while affected by environmental conditions, is most likely influenced by individual work behaviors and variable physiology among participants. Workers who are acclimated and respond to heat through self-pacing may be able to be productive in severe conditions. Given the lack of heat safety training, it is possible that this is an innate, unlearned response, or learned but unspoken. Only one worker within our study reported working more slowly as a coping mechanism. The encouragement of self-pacing could be an effective management tool for supervisors.

Several workers exceeded the threshold of heart rates greater than 110 bpm after resting for 1 minute, but their body temperatures stayed below 100.4°C. NIOSH uses a stringent value of 180 bpm minus age over a 5-minute period for assessing heat strain when conducting health hazard evaluations. None of our workers ever reached this value, and without heart rate monitors, we could not evaluate if this occurred during work. While many workers appear to self-regulate through pacing, younger, motivated individuals had the most elevated heart rates measured. Elevated heart rate was negatively correlated with age and weight. This was observable in the field as younger, fitter workers appeared to be moving and working faster than older or heavier workers.

In support of the hypothesis of self-pacing, workers who are older or less fit may be working within their known limits. Younger workers may be more physically fit, providing them with heat tolerance to work and recover at accelerated rates. Heat tolerance has been shown to be significantly improved with increased fitness (Cheung and McLellan, 1998). Some of the Australian studies (Brake and Bates 2002; Miller and Bates 2007) demonstrated that few workers will voluntarily work at a pace that requires sustaining a heart rate of greater than 110 bpm. However, this was seen frequently in our worker population, probably due to the bit rate system.

The primary contributor to heat stress for these workers may be the metabolic heat load rather than the environmental heat load. Internally generated heat must be transported to the skin via the cardiovascular system, while environmental heat may be deflected through the evaporation of sweat from the skin, with less strain on the cardiovascular system. Studies of Australian wildland firefighters have found that the heat load of the body during outdoor work can mainly be attributed to the work rate (Budd 2001). Also, when the WBGT heat TLVs were exceeded for this group, body temperatures did not often exceed 38.0°C. Regression analysis of mean rectal temperatures and the WBGT index were not statistically significant. Heart rates and body temperatures remained constant despite 6-fold variations in work duration, energy expenditure, air temperature, and WBGT measurements. In fact, in this study, WBGT measurements were observed that exceeded the recommended level by 9°C, with little indication of heat strain. Also, dissipation of large heat loads was attributed to free evaporation and increased air movement (Budd et al. 1997; Budd 2001). This demonstrates once again the possibility that the WBGT index may be insensitive to the effects of cooling by air movement.

While we did not collect airspeed measurements, our low wet bulb temperatures and low relative humidity levels indicate that a high degree of evaporative cooling occurred in our workers' environment. For our workers, physiological adaptations of increased, even profuse, sweating and rapid increase in circulatory blood flow may allow the body to maintain temperature homeostasis.

One of the Australian studies (Budd 2001) also emphasized the use of self-pacing by workers to keep body temperatures reduced. As the heat exposure increased on the body, productivity decreased rather than physiological strain increasing. For comparison to these studies, collecting measurements for wind speed and daily productivity would have greatly improved our evaluation of our workers' heat stress.

One third of our workers were observed to have lost over 1.5% body weight, indicating dehydration. Over 30% of survey respondents reported cramping, another indicator of dehydration. This is in agreement with studies of other outdoor workers exposed to hot environments. Evaluation of workers in Australian mines and manual construction laborers in the United Arab Emirates have shown dehydration in a large proportion of the workers (Miller and Bates 2009; Bates et al. 2010). These studies showed that the level of hydration status in workers did not vary greatly throughout the day, but workers often began the day dehydrated based on urine specific gravity. Workers' fluid intake over the day was adequate to maintain their current level of hydration but not to improve it. The workers in these studies still appeared to operate through the day at poor to marginal hydration levels. Researchers have concluded that the key to preventing dehydration at work is to begin the shift in a well-hydrated state (Miller and Bates 2009; Bates et al. 2010). Workers in our study were not observed to be heavily increasing fluid intake in the morning in preparation for work, and water was not available to workers on site until the shift actually began. Workers could be onsite for 1 to 3 hours each day before the water truck arrived. Workers were also observed drinking caffeinated and alcoholic beverages and Cokes in the morning which could contribute to dehydration through the day.

Training

Over 70% of workers surveyed indicated that they had not received any occupational training regarding working in hot environments. The EPA Worker Protection Standard is often the only training that is required for workers and is focused on pesticide safety, which is not specific to pickers and includes little information regarding heat safety. It is likely that these workers have observed WPS pesticide application videos that may have included a small segment on heat stress. Workers may not have felt this applied to them because it was not specific to the job. Survey studies of migrant farmworkers in North Carolina found that only 35% of workers had received the EPA's WPS training (Arcury 1999). Of the workers who reported having WPS training, additional survey responses showed they did not have knowledge of or understand the protective mechanisms concerning pesticide exposure. It is likely they did not retain information regarding heat safety either. The current methodologies for health and safety training for agriculture may not be effective or widely used. Workers should be empowered with more specific knowledge regarding heat exposure, similar to training guidelines under the California heat stress standard (CCR 3395). Training that moves away from videos, which is the medium for WPS training in Tennessee, to more engaging methods can facilitate greater worker understanding and reduce injuries and illnesses (Burke et al. 2006). Workers may retain knowledge and understanding more in discussion style exercises that use individual experiences and allow for collaborative learning.

That WPS training does not include information about acclimation, which is pertinent, considering that the majority of cases of heat-related illness and death occur within the first 4 days at the work site (Prudhomme and Neidhardt 2006). We observed unacclimated workers arriving at the worksite who were either local residents or new arrivals from Florida waiting for openings in the packing house. They had not previously worked in hot weather for crop handling during this picking season. These workers did not usually make it an entire work day, and often left after a half day.

There is a risk for these workers, as they are not advised of the acclimation process when they show up, and simply jump right in to working. Among all workers observed in this study, this group is likely the most at risk of heat stress and heat stroke. One worker became sick during the day and had to rest in a shaded barn for the rest of the day. These workers should be educated on the importance of acclimation before beginning work. Also, employees and supervisors with an understanding of the signs of heat-related illness may be more prepared to advise a new employee, and realize when this employee may be succumbing to heat-related illnesses.

Although many of these workers may be well acclimated by the time they arrive in Tennessee, some workers still exhibited signs of heat stress. Several workers showed signs of dehydration with lower body weights at the end of the day. These workers may understand the importance of hydrating throughout the day but not the importance of being well-hydrated before the work day begins. Also, they may not understand the effects of alcohol and caffeine consumption on dehydration. Workers primarily drink water through the day, but can commonly be observed purchasing and drinking sodas, caffeinated energy drinks, and beer. Except for beer, these were available from the labor contractor's personal vehicle that followed along with the water truck throughout the day. Beer could be purchased from a vendor who arrived for breakfast and lunch onsite in the fields. Also, workers with pre-existing conditions such as diabetes and hypertension should be aware that these conditions and medications or treatment may make them more susceptible to heat-related illnesses.

Agriculture is a very hazardous industry. This, along with a lack of access to medical services, results in health disparities for a marginalized migrant population. While we did not demonstrate a significant occupational heat stress problem in these workers, data from clinical field screenings has demonstrated rates of occupational health problems commonly reported for migrant worker populations. To improve the workplace safety climate, additional safety training should be implemented for workers and employers that addresses all issues, ranging from musculoskeletal disease to prevention of occupational dermatoses. This training could be offered by existing county cooperative extension agencies (Arcury et al. 2012).

We are attempting to work with the local agency that conducts training for the farms in our study and forge a new community partnership between the agency and RMS. Next summer the Hispanic outreach specialist for RMS will be working with the local agent to facilitate training. It may be possible to implement new training materials that focus on other occupational health concerns besides pesticide exposure through this partnership. This partnership will hopefully provide the outreach specialist with credibility among workers at the beginning of the season and allow him to conduct onsite safety discussions throughout the summer.

Recommendations

1. Employees, farm labor contractors, and farm owners should have increased education regarding heat stress. Acclimation needs to be emphasized for new employees. While we observed only 5 new workers arriving to work with our crew, the number of unacclimated individuals beginning work mid-summer could be high when considering all of the farms in Tennessee. Supervisors should be educated on the concept of self-pacing and strongly encourage it in workers.
2. Follow-up studies should be pursued on this subject. I was unable to find published literature regarding actual physiological monitoring of workers for heat strain in U.S. crop workers. With a small data set, this study might be considered exploratory. Additional studies should employ continuous heart rate monitors, attempt to quantify production rates or rest times for study participants throughout the day, and measure workplace air velocity. Also, an evaluation of hydration status would directly

quantify levels of hydration for workers and could be an easier indicator of heat strain than physiological monitoring.

3. Recently OSHA has been petitioned to establish a heat standard based on the WBGT index. The WBGT index may not be predictive of body temperatures for well-acclimated workers. The establishment of a heat standard should focus on ensuring water availability, empowering employees through education, and educating employers and supervisors to reduce the possibility of heat-related illnesses.
4. Research should be expanded regarding occupational health for Tennessee's migrant farmworkers. We have a large population of workers, but little research has been conducted in comparison to other areas such as North Carolina. Collaborations between East Tennessee State University, the University of Tennessee Agricultural Extension Service, and community partners have the potential to stimulate new research and funding opportunities to improve occupational health for migrant workers.

REFERENCES

American Conference of Governmental Industrial Hygienists ,ACGIH). 2001. Documentation of Threhold Limit Values and Biological Exposure Indices. Cincinatti: ACGIH

Arcury TA, O'Hara H, Grzywacz JG, Isom S, Chen H, Quandt SA. 2012. Work safety climate, musculoskeletal discomfort, working while injured, and depression among migrant farmworkers in North Carolina. Am J Public Health. 102 Suppl 2: S272-8.

Arcury, TA, Quandt SA, Austin, CK, Preisser, J, Cabrera, L. 1999. Implementation of EPA's Worker Protection Standard Training for Agricultural Laborers: An Evaluation Using North Carolina Data. Public Health Reports. 114: 459-468.

Barrow, M, Clark, K. 1998. Heat-related illness. Am Fam Physician 58 (3): 749-56.

Bates GP, Miller VS, Joubert DM. 2010. Hydration status of expatriate manual workers during summer in the Middle East. Ann Occup Hyg; 54: 137–43.

Bates, GP and Miller, VJ. 2002. Empirical validation of a new heat stress index. J Occup Health. 18(2): 145-153.

Bernard, T. 2012, “Occupational Heat Stress”. http://personal.health.usf.edu/tbernard/thermal/index.html Accessed 9/24/2012.

Bernard, T., Dukes-Dobos, F., Ramsey, J. 1994. Evaluation and control of hot working environments. Part II-The scientific bases (knowledge base) for the guide. Int Journal of Industrial Ergonomics. 14: 119-138.

Bonauto, D, Anderson, R, Rauser, E, Burke, B. 2007. Occupational heat illness in Washington State, 1995-2005. Am J Industrial Hygiene. 50: 940-950.

Bouchama, A, & Knochel, J. P. 2002. Heat stroke. New England Journal of Medicine, 346(25), 1978-1988

Brake DJ, Bates GP. 2002 Deep body core temperatures in industrial workers under thermal stress. J Occup Environ Med. 44: 125–35.

Budd GM, Brotherhood JR, Hendrie AL, Jeffery SE, Beasley FA, Costin BP. 1997. Project Aquarius. 6. Heat load from exertion, weather, and fire in men suppressing wildland fires. Int J Wildland Fire. 7(2): 119-31.

Budd, GM. 2001. How do wildland firefighters cope? Physiological and behavioural temperature regulation in men suppressing Australian summer bushfires with hand tools. Journal of Thermal Biology. 26(4): 381-386.

Burke M, Sarpy S, Smith-Crowe K, Chan-Serafin O, Salvador R, Islam, G. 2006. Relative Effectiveness of Worker Safety and Health Training Methods.. Am J Public Health. 96(2): 315-324.

California Code of Regulations, Title 8, Section 3395 Heat Illness Prevention. Sacramento, CA: 2006. Available at: http://www.dir.ca.gov/Title8/3395.html.

Cecchini M, Colantoni A, Massantini R, Monarca, D. 2010. Estimation of the risks of thermal stress due to the microclimate for manual fruit and vegetable harvesters in central Italy. Journal of Agricultural Safety and Health. 16(3): 141-159.

Centers for Disease Control (CDC). 2008. Heat-Related Deaths Among Crop Workers-United States, 1992-2006. Morbidity & Mortality Weekly Report. 57(24): 649-653. 2008.

CDC. 2006. Heat-related deaths, United States, 1999-2003. Morbidity & Mortality Weekly Report. 50(29): 796-799.

CDC. 2011. NIOSH Workplace and Safety Health Topics: Agricultural safety. Accessed 4/15/2012. http://www.cdc.gov/niosh/topics/aginjury/default.html.

Charkoudian, N. 2003. Skin blood flow in adult human thermoregulation: how it works, when it does not, and why. Mayo Clin Proc 78: 603–12.

Cheung S, McLellan T, 1998. Heat acclimation, aerobic fitness, and hydration effects on tolerance during uncompensable heat stress. Journal of Applied Physiology. 84(5): 1731-1739

Crowe J, Moya-Bonilla J, Roman-Solano B, Robles-Ramirez A. 2010 Heat exposure in sugarcane workers in Costa Rica during the non-harvest season. Global Health Action. 3: 1-9.

Environmental Protection Agency (EPA). A Guide to Heat Stress in Agriculture. Washington DC, EPA. 1993.

EpiInfo 7 Software. 2012. Atlanta, GA: CDC. wwwn.cdc.gov/epiinfo/

Funckes AJ, Hayes Jr GR, Hartwell WV. 1963. Urinary excretion of paranitrophenol by volunteers following dermal exposure to parathion at different ambient temperatures. J.Agric. Food Chem. 11: 455–457.

Glazer J. 2005. Management of Heatstroke and Heat Exhaustion. American Family Physician 71(11): 2133-2140.

Hansen E, Donohoe, M. 2002. Health issues of migrant and seasonal farmworkers. Journal of Health Care for the Poor and Underserved. 14(2): 153-164.

Hubbard R, Gaffin S, Squire D. 2003. Heat-related Illnesses In Auerback PS, ed. Wilderness Medicine:Management of Wilderness and Environmental Emergencies. St. Louis, MO. Mosby; 1995.

Jackson L, Rosenberg H. 2010. ASCHA/NIOSH Conference: Panel Presentation: Preventing Heat-Related Illness Among Agricultural Workers. Journal of Agromedicine. 15: 200-215.

Keim S, Guisto J, Sullivan J. 2002. Environmental thermal stress. Ann. Agric Environmental Medicine. 9: 1-15.

Kjellstrom T, Kovats R, Lloyd S, Holt T, Tol R. 2009. The direct impact of climate change on regional labor productivity. Archives of Environmental and Occupational Health. 64(4): 217-227.

Lumingu H, Dessureault P. 2009. Physiological responses to heat strain: A study on personal monitoring for young workers. Journal of Thermal Biology 34: 299-305.

Manitoba Labour and Immigration Workplace Safety & Health Division. 2007. Guideline for Thermal Stress. Workplace Safety & Health Division. Winnipeg, Manitoba.

Mautz WJ. 2002. Exercising animal models in inhalation toxicology: interaction with ozone and formaldehyde. Environmental Research 92(1): 14-26.

Miller V, Bates G. 2007. Hydration of outdoor workers in northwest Australia. J Occup Health Saf. 23: 79–87.

Miller V, Bates G, Schneider J, Thomsen, J. 2011. Self-Pacing as a Protective Mechanism against the Effects of Heat Stress Ann Occup Hyg. 55(5): 548-555.

Minitab 16 Statistical Software. 2010. State College, PA: Minitab, Inc. (www.minitab.com)

Mirabelli M, Richardson D. 2005. Heat-Related Fatalities in North Carolina. American Journal of Public Health. 95(4): 635-637.

Mobed K, Gold E, Schenker M. 1992. Occupational health problems among migrant and seasonal farm workers, In Cross-cultural Medicine-A Decade Later [Special Issue]. West J Med. 157: 367-373.

Moran DS, Shitzer A, Pandolf KB. (1998). A physiological strain index to evaluate heat stress. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology. 275(1): R129-R134

National Institute for Occupational Health and Safety. 1986. Criteria for a Recommended Standard: Occupational Exposure to hot Environments. NIOSH Publication No. 86-113.

Occupational Safety and Health Administration (OSHA). 1999 “Heat Stress.” Section III, Chapter 4. OSHA Technical Manual. Washington DC: U.S. Department of Labor, OSHA.

Peraza S. 2012. Decreased Kidney Function Among Agricultural Workers in El Salvador. American Journal of Kidney Disease. 59(4): 531-540.

Plog B, Quinlan P. 2002. Fundamentals of Industrial Hygiene, 5th Edition. National Safety Council. Chicago, IL.

Prudhomme J, Neidhardt A. 2006. Cal/OSHA investigations of heat-related illnesses 2005. State of California Memorandum.

Prudhomme J, Neidhardt A. 2007. Cal/OSHA investigations of heat-related illnesses 2006. State of California Memorandum.

SAS 9 Statistical Software. 2008. SAS Institute Inc, Cary, NC. www.sas.com

Torres C, Aragón A, González M, López I, Jakobsson K, Elinder CG. 2010. Evidence of widespread chronic kidney disease of unknown cause in Nicaragua, Central America. Am J Kidney Disease. 55(3): 485-496.

U.S. Department of Labor (DOL). 2005. Findings from the National Agricultural Workers Survey (NAWS) 2001-2002; A Demographic and Employment Profile of United States Farm Workers.Washington, DC: DOL.

Washington Administrative Codes 296-62-095 & 296-307-097 Outdoor Heat Exposure. Olympia WA; 2008. Available at: http://www.lni.wa.gov/rules/AO06/40/0640Adoption.pdf; and http://apps.leg.wa.gov/WAC/default.aspx?cite=296-

Yeary RA, Eaton J, Gilmore E, North B, Singell J. 1993. A multiyear study of blood cholinesterase activity in urban pesticide applicators. Journal of Toxicology and Environmental Health, Part A Current Issues. 39(1): 11-25.

APPENDICES

Appendix A: Consent Form

Investigador principal: Steve McQueen

TITULO DEL PROYECTO: Evaluación e intervención de la exposición al estrés térmico en los trabajadores migrantes.

EAST TENNESSEE STATE UNIVERSITY

Junta de Revisión Institucional

Documento de Consentimiento Informado

Este consentimiento informado se explica por ser un participante en un estudio de investigación. Es importante que usted lea este material cuidadosamente y luego decidir si desea ser un voluntario. El material será leído a usted por un trabajador de salud laico.

OBJETIVO: El objetivo de este estudio de investigación es evaluar las respuestas fisiológicas de los trabajadores del tomate la exposición al calor mientras se trabaja durante todo el día.

DURACIÓN: Este experimento se utiliza de 30 a 40 minutos de su día, y recibirá 25 dólares por participar en la final de la jornada.

Procedimientos: Vamos a comprobar su temperatura oral, el ritmo cardíaco y la presión arterial 6 veces durante el día mientras usted está trabajando. Estos son los mismos procedimientos que se producen cuando usted visita un consultorio médico, utilizando los mismos instrumentos. También nos gustaría que usted pesa al principio de cada turno y al final de cada turno para comprobar si la pérdida de agua después de un día de trabajo.

PROCEDIMIENTOS tratamientos de alternative: No hay formas alternativas de participar en este estudio.

POSIBLES RIESGOS Y MOLESTIAS Los posibles riesgos y / o molestias de su participación son: conseguir la temperatura, el pulso y la presión arterial. Esto no será diferente de una visita al consultorio médico.

POSIBLES BENEFICIOS: Los posibles beneficios de su participación son el mayor conocimiento sobre el peligro de la exposición al calor para usted, los dueños de fincas, y los médicos locales. Esta información será utilizada en futuros proyectos que se centrarán en aumentar la protección del trabajador y la productividad.

COSTOS FINANCIEROS No hay ningún costo para usted por participar en este estudio.

INDEMNIZACIÓN EN LA FORMA DE PAGO A LOS PARTICIPANTES DE INVESTIGACIÓN Se le pagará $ 25 por lo que nos permite evaluar la temperatura, la presión arterial, frecuencia cardiaca y el peso corporal. Este pago se hará al final del día.

PARTICIPACIÓN VOLUNTARIA: La participación en este experimento de investigación es voluntaria. Usted puede negarse a participar. Puede salir en cualquier momento. Si sale o se niegan a participar, los beneficios o el tratamiento al que usted tiene derecho no se verá afectada.

CONTACTO PARA PREGUNTAS: Si usted tiene alguna pregunta, problemas o problemas relacionados con la investigación médica en cualquier momento, usted puede llamar a Steve McQueen en 865-384-8738, el Dr. Ken Silver en el 423-439-4542 o con el Dr. Sharon Loury a 423 - 439-4057. Usted puede llamar al Presidente de la Junta de Revisión Institucional en 423/439-6054 para cualquier pregunta que usted pueda tener acerca de sus derechos como sujeto de investigación. Si usted tiene alguna pregunta o inquietud acerca de la investigación y quiere hablar con alguien independiente del equipo de investigación o no puede comunicarse con el personal del estudio, puede llamar a un coordinador de IRB en 423/439-6055 o 423/439/6002.

CONFIDENCIALIDAD: Se hará todo lo hizo ver que los resultados del estudio son confidenciales. Una copia de los registros de este estudio se almacenará en Cordero, Sala 52 en ETSU en Johnson City, TN durante al menos 5 años después del final de esta investigación. Estos registros no contienen información de identificación en la que podrá identificarse a partir de este estudio. Los resultados de este estudio pueden ser publicados y / o presentados en congresos sin nombrar a usted como un sujeto. A pesar de sus derechos y la privacidad se mantiene, el Secretario del Departamento de Salud y Servicios Humanos, el IRB ETSU y personal propios de esta investigación (Steve McQueen - Salud Ambiental, Michael Bradfield - Medicina de Familia, el Dr. Ken Silver - Salud Ambiental; el Dr. Joe Florence - Medicina de Familia, el Dr. Sharon Loury - Enfermería) tengan acceso a los registros del estudio. Los registros de este estudio no será revelada a menos que requerido por la ley, o como se señaló anteriormente. Esta información de este estudio no se pasará a su empleador.

Al firmar abajo, usted confirma que ha leído o ha tenido este documento le lea a usted. Se le dará una copia firmada de este documento de consentimiento informado. Se le ha dado la oportunidad de hacer preguntas y para discutir su participación con el investigador. Es libre y voluntariamente decide participar en este proyecto de investigación.

FIRMA DEL PARTICIPANTE FECHA

____

Nombre del participante FECHA

FIRMA DEL INVESTIGADOR FECHA

____

FIRMA DEL TESTIGO (si procede) FECHA

Appendix B: Worker Characteristics

Age	Sex	Weight	Conversion Factor*	Temperature	Heart Rate
18	M	141.2	0.917	98.60	73
22	M	179.2	1.164	98.30	95
23	M	103.4	0.689	97.07	90
23	M	131.6	0.854	98.53	66
23	M	199.2	1.294	98.33	89
24	M	140.6	0.913	97.97	84
24	M	161.8	1.051	97.80	74
24	M	156.0	1.013	98.20	87
26	F	126.8	0.823	97.90	76
32	M	151.4	0.983	98.47	50
36	F	165.8	1.077	98.27	85
37	F	156.8	1.018	98.33	71
38	M	141.8	0.921	97.90	84
39	F	163.9	1.064	97.90	62
39	M	166.8	1.083	97.50	63
40	M	150.6	0.978	98.30	88
48	M	148.4	0.964	97.70	67
50	M	153.2	0.995	98.13	87
54	M	128.4	0.834	98.67	89

Appendix C. Heat Stress Survey Questions.

Occupational Health/ Salud Ocupacional

¿En qué trabaja usted?*(What is your job?)* □ Piscando Tomate(Picking) □ Empacadora(Packing) □ Otra__________________

¿Ha recibido alguna entrenamiento de seguridad de calor en los Estados Unidos? □ Yes□ No
Have you received any heat safety training in the United States?

¿Qué estrategias utilizar para hacer frente a climas cálidos? □ Beba más _______________ □ Vaya a un lugar fresco después del trabajo □ descanso en la sombra □ trabajar más lentamente □ otra
(What strategies do you use to cope with hot weather?) Drink more (write choice) go to cool place, rest in shade, work slower

¿Ha tenido alguno de los siguientes síntomas en los últimos 7 días? □ náuseas o los vómitos □ debilidad o mareos □ dolores de cabeza □ Diarrea □ Calambres
Have you experienced any of the following symptoms in the past 7 days? i.e. Nausea and Vomiting, Weakness and Dizziness, Headaches, Diarrhea, Cramps

¿Cuántos vasos de bebidas bebes cada día? □ 0-5 □ 5-10 □ 10-15 □ 15-20 □ 20-25 □ 25+
How many cups of water do you drink each day?

¿Cuál es su bebida preferida durante los días calurosos? □ agua □ jugo de fruta □ Gatorade □ soda/refresco□ otra
What is your preferred beverage during hot days?

¿Le preocupa el calor puede dañar su salud? □ Muy preucupado □ un poco preocupado □ No, en absolute
Are you worried that the heat can damage your health? □Very □Somewhat □ Not at all

¿Que es el índice de calor hoy en día? ___________ □ no sé
(What is the heat index today?)

¿Que es la temperatura máxima hoy? ____________ □ no sé
(What is the maximum temperature today?)

¿Le gustaría recibir textos sobre las clínicas de salud gratis o avisos meteorológicos peligrosos? □ Yes□ No
Would you like to receive texts about free health clinics or dangerous weather warnings?

¿Utiliza alguna red social como Facebook o Twitter? □ Yes□ No ¿Cuál? / Which one?
(Do you use any social networking like facebook or twitter?)

Appendix D: Environmental Measurement Data.

Descriptive Statistics: WBGT Values

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
17 July	24	0	29.975	0.279	1.369	26.500	29.000	30.333	31.042
23 July	82	0	29.808	0.150	1.359	26.778	28.667	30.167	30.889
24 July	54	0	30.912	0.142	1.040	28.667	30.042	31.000	31.667
25 July	45	0	31.688	0.211	1.417	28.889	30.528	32.000	32.778
26 July	59	0	31.065	0.117	0.896	28.556	30.556	31.056	31.556

Variable	Maximum
17 July	32.500
23 July	32.056
24 July	32.889
25 July	33.889
26 July	33.000

Descriptive Statistics: Globe Values

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
18 July	24	0	40.447	0.933	4.571	30.389	37.194	41.556	43.472
23 July	82	0	41.394	0.464	4.203	28.778	38.681	42.111	45.000
24 July	54	0	43.384	0.412	3.030	36.889	41.389	43.056	45.639
25 July	45	0	45.404	0.604	4.051	37.500	41.000	46.278	48.333
26 July	59	0	45.153	0.359	2.756	36.278	44.167	45.500	46.778

Variable	Maximum
18 July	47.000
23 July	48.778
24 July	49.667
25 July	51.056
26 July	50.778

Descriptive Statistics: Dry Bulb(Air) Values

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
18 July	24	0	32.477	0.341	1.672	28.500	31.375	32.167	33.486
23 July	82	0	33.141	0.183	1.659	28.556	31.833	33.167	34.778
24 July	54	0	34.433	0.222	1.635	30.556	33.278	34.694	35.778
25 July	45	0	35.200	0.286	1.918	31.500	33.583	35.389	36.583
26 July	59	0	35.911	0.192	1.472	31.889	35.000	36.500	37.000

Variable	Maximum
18 July	36.667
23 July	36.167
24 July	36.889
25 July	38.278
26 July	38.500

Descriptive Statistics: Wet Bulb Values

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
18 July	24	0	26.917	0.206	1.009	25.000	26.306	26.778	27.556
23 July	82	0	26.113	0.0747	0.677	24.500	25.556	26.056	26.778
24 July	53	1	27.247	0.217	1.581	26.000	26.528	27.000	27.500
25 July	45	0	27.480	0.222	1.492	25.556	26.778	27.500	27.778
26 July	59	0	26.451	0.0713	0.548	25.556	26.000	26.500	26.667

Variable	Maximum

```
18 July    28.889
23 July    27.556
24 July    35.167
25 July    36.111
26 July    28.000
```

Descriptive Statistics: Relative Humidity

```
Variable   N  N*    Mean  SE Mean  StDev  Minimum      Q1  Median      Q3
18 July   24   0   66.17     1.33   6.52    46.00   63.25   65.00   69.50
23 July   82   0  57.890    0.531  4.805   50.000  53.000  58.000  61.000
24 July   54   0  56.537    0.717  5.269   49.000  52.000  56.000  61.000
25 July   45   0  55.111    0.781  5.236   47.000  51.500  53.000  58.500
26 July   59   0  48.763    0.749  5.755   39.000  44.000  48.000  53.000

Variable  Maximum
18 July     79.00
23 July    72.000
24 July    71.000
25 July    67.000
26 July    62.000
```

Environmental Data 7/18/2012

WBGT	Globe	Dry Bulb	Wet Bulb	Humidity
30.38889	43	31.77778	26.77778	68
30.38889	43.38889	32.16667	26.38889	64
28.55556	38.55556	30.5	25.55556	68
28.66667	37.27778	31.27778	25.66667	65
29	40.55556	31.27778	25.38889	63
29.05556	37.55556	31.66667	26.27778	66
29.55556	41.05556	32.05556	26	64
30.5	43.5	32.5	26.55556	64
31.55556	45.77778	33.27778	27.5	65
31.05556	44.38889	33.88889	27.77778	63
31.55556	46.5	33.27778	27.16667	68
32.5	47	35.16667	28	59
30.66667	43	32.88889	28.88889	75
31.77778	46.61111	33.77778	27.55556	63
30.27778	42.77778	36.66667	26.5	46
29	34.88889	30.55556	26.72222	74
31.05556	42.05556	33.55556	27.55556	64
30.5	39.77778	33.27778	27.55556	65
31	42.27778	34	27.55556	62
29.38889	37.16667	32.16667	26.77778	66
29.38889	35.38889	32.05556	27.38889	70
28.66667	33.77778	32.16667	28.88889	79
28.38889	34.05556	31	26.55556	71

26.5	30.38889	28.5	25	76

Environmental Data 7/23/2012

WBGT	Globe	Dry Bulb	Wet Bulb	Humidity
27.16667	36.38889	29.27778	24.5	68
28.66667	41.05556	29.38889	25.16667	72
29.77778	42.05556	32.05556	26.16667	63
29.38889	42.05556	30.55556	25.55556	67
30.55556	43.27778	33.16667	26.77778	61
30.27778	44.66667	32.38889	26	61
30	42.55556	32.27778	26.16667	62
31	46.38889	32.88889	26.38889	60
30.38889	45.16667	32.5	25.66667	58
29.27778	42.38889	31.5	25.27778	61
29	39.55556	32.38889	25.88889	60
29.05556	40.55556	31.88889	25.55556	61
29.88889	42	32.66667	26.05556	60
29.88889	42.5	32.88889	25.88889	58
30.66667	44.16667	33.27778	26.27778	58
30	41.66667	33.38889	26.27778	58
30	42.16667	32.66667	26.05556	60
31.77778	45.27778	35.5	27.27778	54
31.27778	45.55556	34.05556	26.77778	57
31.77778	45.5	35.5	27.55556	55
30.66667	45.05556	32.88889	26.05556	59
30.05556	40.5	34.27778	26.77778	56
28.38889	38.38889	31.55556	25.38889	61
29.77778	40.5	33.77778	26.16667	55
30.16667	43.66667	33.16667	25.88889	56
30.38889	41.88889	34.88889	26.88889	54
28.66667	38.77778	31.5	25.38889	62
29.05556	39.05556	32.77778	25.66667	57
29.88889	41.66667	33.55556	25.61111	53
29.77778	42.77778	33.27778	25.77778	55
30.66667	44.77778	35	26.05556	50
31.38889	45.38889	34.88889	26.88889	54
31.16667	45.27778	34.05556	26.5	55
30.77778	43.66667	34.77778	26.27778	52
31	45	34.55556	26.27778	52
31.5	46.55556	34.66667	26.38889	52

30.88889	45	34.66667	26.05556	51
30.55556	45.27778	34.16667	25.66667	51
30.55556	44.88889	34.77778	26.5	53
31.16667	45.88889	34.88889	26.38889	52
30.16667	43.88889	33.88889	25.77778	53
29.66667	41.55556	33.16667	25.66667	55
28.38889	36.55556	32.5	25.38889	57
28.5	37.05556	32.38889	25.38889	57
28.16667	36.55556	32.16667	25.27778	58
27.88889	36.16667	31.66667	25	58
27.88889	35.55556	31.66667	25.27778	60
27.66667	34.66667	31.5	25.16667	60
27.38889	34.05556	31.05556	25.16667	62
27.5	34.16667	31.05556	25.05556	62
28	34.27778	31.66667	25.5	61
27.66667	33.55556	31.16667	25.66667	65
27.77778	34.38889	31.27778	25.55556	64
27.55556	34.5	31	25.27778	63
27.5	34.38889	30.88889	25.05556	63
27.55556	34.55556	31.16667	25.27778	62
27.44444	34.88889	31.05556	25.66667	65
27.88889	35.05556	30.88889	25.55556	66
26.77778	28.77778	30.55556	26	68
30.16667	41.55556	32.88889	26.88889	63
31.27778	46.05556	33.77778	26.88889	63
32.05556	47.38889	35.16667	27.16667	54
30.55556	42.05556	33.16667	26.77778	61
30.16667	39.88889	33.55556	26.88889	60
30.66667	43.77778	33.27778	26.27778	58
29	38.38889	32.16667	26.16667	63
29.27778	39.27778	32.5	26.05556	61
30.27778	39.77778	34.27778	27.16667	58
30.77778	42.38889	34.77778	27	55
31.55556	45.88889	35.05556	27.16667	55
31.66667	45.38889	36.16667	27.5	52
31.16667	45.38889	34.88889	26.55556	53
31.55556	46.05556	35.5	27	52
30.55556	43.38889	34.88889	26.55556	53
31.05556	48.77778	35.38889	26.88889	52
30.5	41.66667	35	26.77778	53
31.05556	44.05556	35.5	27	52

31	45.66667	35	26.5	52
30.16667	41.77778	34.38889	26.27778	53
30.88889	44.27778	34.88889	26.5	52
31.16667	44.66667	35.27778	27	53
30	43.16667	33	25.66667	56

Environmental Data 7/24/2012

WBGT	Globe	Dry Bulb	Wet Bulb	Humidity
30	42.5	32.05556	26.38889	64
29.5	38.77778	32.16667	26.66667	65
29.88889	40.44444	32.27778	26	61
29.16667	39.16667	31.16667	26	67
28.88889	36.88889	31.66667	26.16667	65
28.66667	38.27778	30.55556	26.1667	71
29.27778	37.66667	32.38889	26.55556	64
29.55556	40.66667	32.05556	26.16667	63
30.05556	41.05556	32.77778	26.66667	62
30.38889	41	33.27778	27	62
30.16667	42.16667	32.66667	26.38889	61
30.77778	42.66667	33.5	26.77778	60
31.05556	42.88889	34.16667	27.05556	58
30.38889	42.16667	33.5	26.77778	60
30.77778	38.44444	34	27.16667	59
31	43.38889	33.77778	27.16667	60
29.66667	40.05556	32.38889	26.27778	62
29.16667	39.44444	32.05556	26.05556	63
32.05556	45.27778	36	27.77778	54
31.77778	44.55556	35.27778	28	58
31.66667	45.27778	35.27778	27.55556	56
31.55556	47	34.5	26.88889	56
30.88889	44.05556	34.16667	26.66667	56
30	41.66667	33.27778	26	56
29.66667	40.38889	33.5	26.27778	57
31.5	42.5	34.88889	28.16667	61
31.55556	47.66667	33.88889	26.38889	56
30	41.77778	33.55556	26.16667	56
30.66667	43.05556	34.38889	26.66667	55
31.77778	46.38889	35.05556	27.27778	55
32.16667	47.16667	35.77778	27.5	53
32.05556	47.27778	35.55556	27.38889	54

31.05556	43.05556	35.38889	27.27778	54
32.16667	46.77778	36.05556	27.77778	53
32.88889	49.66667	36.88889	28	51
32.88889	49.66667	36.88889	27.5	49
32.55556	47.5	36.88889	27.66667	50
32.16667	47.05556	36.55556	27.5	50
31.66667	46.27778	35.55556	27	52
30.88889	43.88889	35.27778	26.7778	52
30.55556	43.66667	34.16667	27.5	60
31	43	35.16667	26.77778	52
30.27778	41.5	34.5	26.5	54
30.88889	43.5	35.38889	26.88889	52
31.55556	44.27778	36	27.5	52
31.66667	45.05556	36.5	27.55556	51
32.16667	47.38889	36	27.38889	52
31.05556	43	35.5	27.16667	53
31	42.55556	35.38889	27	52
30.55556	43.27778	36.05556	26.88889	49
31.66667	45.88889	36.27778	27	49
31.77778	45.55556	36.11111	27.16667	51
31.5	45.55556	35.77778	26.77778	50
31.55556	42.88889	35.5	27.55556	55

Environmental Data 7/25/2012

WBGT	Globe	Dry Bulb	Wet Bulb	Humidity
33.27778	50.55556	36.16667	27.7789	53
29.66667	40.88889	32.55556	28.1546	55
29.5	39.55556	32.27778	26.0912	62
29	39.38889	31.66667	25.55556	62
29.05556	39	32.16667	26	61
30.38889	41.55556	33.88889	26.77778	58
31.55556	46.05556	34.38889	27.05556	57
31.16667	45.66667	32.77778	26.55556	62
30.38889	41	33.05556	26.77778	62
29.77778	40.38889	32.38889	26.55556	64
28.88889	37.5	31.5	26.16667	66
29.55556	38.88889	32.55556	26.66667	63
33.27778	51	36.5	27.11111	56
32.66667	51.05556	34.66667	27.38889	57
29.27778	38.27778	32.27778	26.27778	63

30.27778	40.88889	33.27778	27	67
30.66667	40.27778	34.38889	27.5	59
32.05556	47.77778	35.16667	27.55556	56
31.88889	47.05556	34.55556	27.27778	57
33.05556	49.66667	36.16667	27.77778	53
32.38889	48.27778	35.77778	27.38889	53
33	49.27778	36.16667	27.77778	53
31.66667	43.66667	36	27.66667	53
32.5	47.66667	35.88889	27.5	53
33.55556	50.5	37.5	28.55556	52
31.55556	47.55556	35.16667	26.77778	52
31.38889	45.27778	35.27778	27.05556	53
31.38889	44.55556	35.16667	26.77778	52
31.66667	46.27778	35.05556	27.16667	55
32.27778	47.05556	35.55556	27.55556	55
30.88889	41	35.77778	27.5	53
32.88889	48.16667	36.61111	27.72222	51
33.55556	49.88889	37.16667	28.38889	52
32.27778	48.27778	35.16667	27.27778	55
33	48.38889	37.5	28	49
32.55556	49.16667	35.38889	27.5	55
33.88889	51.05556	37.16667	28.16667	51
31.27778	42.16667	36.55556	27.55556	51
32.66667	46.16667	37.55556	28.05556	49
32.38889	45.55556	37.55556	28.05556	49
33.55556	49	38.27778	28.38889	48
32.66667	47.5	37	27.55556	49
32.66667	45.88889	38.05556	28.05556	47
32	47	36.27778	27.27778	50
32.88889	47.38889	38	28	47

Environmental Temperature Data 7/26/2012

WBGT	Globe	Dry Bulb	Wet Bulb	Humidity
30.55556	42.55556	33.88889	26.5	57
30.77778	44.77778	33.38889	26.5	59
29.38889	41.16667	31.88889	25.66667	62
29.27778	38.55556	32.88889	26.05556	59
30.5	43.16667	34.66667	26.5	53
30.77778	45	33.77778	26.5	57
29.66667	39	33.77778	26.5	57

29.16667	39.77778	32.38889	25.66667	59
28.55556	36.27778	32.5	26.05556	61
29.88889	40.5	34.27778	26.5	55
30.77778	45.66667	35	26.66667	53
30.5	43	34.77778	26.66667	54
31.5	45.88889	35.05556	27.16667	55
32	47.66667	35.16667	26.77778	53
32.66667	49.16667	36.66667	27.77778	51
32.88889	50.16667	36.55556	27.55556	51
31.05556	44.5	34.55556	26.66667	55
31.27778	44.88889	35.77778	27.05556	52
32.66667	50.5	35.77778	27.16667	52
32.05556	47.27778	35.77778	27.16667	52
33	50.77778	36.77778	27.5	50
31.05556	45.66667	35.16667	26.55556	52
32	47.55556	37	27.38889	49
32	48.16667	36	26.38889	48
31.27778	45.66667	36	26.5	48
32.16667	45.27778	37.38889	28	50
30.27778	44.55556	35	25.55556	48
30.77778	44.38889	35.77778	26.27778	48
31.27778	47.38889	36.5	26.38889	46
30.66667	45	35.55556	25.77778	47
31.38889	46.66667	36.5	26.27778	46
30.77778	46.27778	36.16667	25.77778	44
31.5	47.38889	37	26	43
31.27778	46.77778	37.05556	26.16667	43
30.55556	45.66667	36.55556	25.66667	44
30.55556	44.55556	36.16667	26	44
30.88889	45.55556	36.55556	26	44
31.77778	45.38889	37.5	26.88889	45
30.27778	42.88889	35.77778	26.16667	49
30.5	42.55556	36.88889	26.55556	45
31.5	47.38889	36.66667	26.5	45
30.5	44.55556	34.77778	25.88889	56
32	46.05556	37.66667	27.05556	45
31.77778	48	36.55556	26.55556	46
31.05556	46	37.05556	25.88889	42
30.66667	44.16667	36.66667	26.16667	44
31.27778	45.88889	37.5	26.55556	43
31.27778	46.88889	36.16667	25.66667	44

31.55556	46.16667	37.5	26.66667	44
31.5	46.16667	37	26.5	45
31.38889	45.38889	37.27778	26.55556	44
31.88889	47.66667	37.5	26.66667	44
30.66667	44.77778	36.5	26	44
30.27778	42.77778	36.77778	26	43
31.05556	45.5	37.16667	25.88889	41
31.16667	45.27778	37.88889	26.66667	42
30.5	43.38889	36.77778	26	43
30.77778	44.05556	36.88889	26.05556	43
32.05556	46.27778	38.5	26.38889	39

Appendix E. Physiological Data and Physiological and Environmental Hourly Measurements

Descriptive Statistics: Group Heart Rates

Heart Rate	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
7.18	15	0	96.67	4.67	18.10	75.00	82.00	94.00	106.00
7.23	24	0	106.58	4.64	22.74	69.00	88.25	110.50	119.75
7.24	12	0	97.75	3.17	10.99	79.00	90.25	97.00	105.75
7.25	16	0	108.63	2.92	11.67	92.00	98.25	107.50	115.50
7.26	16	0	128.13	3.66	14.65	99.00	117.50	128.00	143.50

Variable	Maximum
C1	141.00
C2	161.00
C3	120.00
C4	134.00
C5	150.00

Descriptive Statistics: Group Body Temperatures

Body Temp	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
7.18	15	0	37.014	0.0736	0.285	36.426	36.796	37.000	37.241
7.23	24	0	36.836	0.0593	0.291	36.389	36.685	36.787	36.889
7.24	12	0	37.056	0.0761	0.264	36.648	36.847	37.065	37.190
7.25	16	0	37.301	0.106	0.424	36.500	36.991	37.222	37.708
7.26	16	0	37.219	0.0585	0.234	36.926	37.046	37.204	37.255

Variable	Maximum
C8	37.500
C9	37.519
C10	37.556
C11	38.000
C12	37.870

Descriptive Statistics:% Body Weight Loss

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
bwl2	18	0	-1.044	0.180	0.764	-2.400	-1.700	-1.150	-0.425

Variable	Maximum
bwl2	0.100

Descriptive Statistics: Physiological Strain Index

Variable	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3
18 July	15	0	1.968	0.339	1.312	-0.621	1.303	1.960	2.692
23 July	24	0	1.596	0.312	1.529	-1.267	0.908	1.774	2.369
24 July	12	0	0.658	0.302	1.046	-0.759	-0.325	0.753	1.045
25 July	16	0	2.422	0.336	1.346	0.370	1.363	2.514	3.574
26 July	16	0	3.492	0.206	0.825	1.788	3.024	3.573	4.336

Variable	Maximum
18 July	4.315
23 July	5.263
24 July	2.825
25 July	4.850
26 July	4.541

Summary of physiological monitoring.

Worker ID	Work Date	Average Heart Rate(SD)	Minimum and Maximum	Average Temperature C°(SD)	Minimum and Maximum	Weight Change
1	7/18/2012	90.4(10)	82-107	98.8(0.20)	98.5-99.0	-1.2
2	7/17/2012	92.2(15)	75-106	98.4(0.7)	97.6-99.5	-0.2
3	7/18/2012	107(25)	77-141	98.7(0.5)	98.0-99.3	-1.2
4	7/23/2012	98(14)	85-126	98.4(0.5)	98.0-99.5	+0.1
5	7/23/2012	116(17)	88-136	97.9(0.3)	97.5-98.4	-2.4
6	7/23/2012	86(17)	69-116	98.3(0.4)	97.9-99.1	-1.1
7	7/23/2012	127(20)	110-161	98.5(0.7)	97.7-99.5	-0.5
8	7/24/2012	96(7)	91-106	98.8(0.2)	98.5-99.0	-1.6
9	7/24/2012	97(13)	79-107	98.7(0.5)	98.1-99.3	-2.0
10	7/24/2012	100(15)	87-120	98.7(0.7)	98.0-99.6	-1.8
11	7/25/2012	103(10)	98-118	98.9(0.9)	97.7-99.9	-0.8
12	7/25/2012	122(11)	111-134	99.8(0.6)	99-100.4	-1.7
13	7/25/2012	103(8)	92-108	99.0(0.6)	98.3-99.8	-0.1
14	7/25/2012	106(9)	94-114	98.9(0.8)	98.2-99.9	-0.1
15	7/26/2012	124(16)	110-144	98.8(0.2)	98.5-99	-1.7
16	7/26/2012	130(22)	99-150	99.3(0.6)	99-100.2	+0.1
17	7/26/2012	131(10)	122-146	99.3(0.6)	99-100.2	-0.6
18	7/26/2012	128(12)	116-145	99.1(0.5)	98.6-99.7	-0.5

Data for hourly intervals. Subj=participant, hrate=heart rate, wgt=weight, btemp=body temperature, air=dry bulb, wbgt=wet bulb globe temperature, wetb=wetbulb, hum=relative humidity

day	subj	time	hrate	psi	Age	wgt	btemp	air	wbgt	wetb	Globe	hum
7.18	1	1	86	2.0	32	151	37.2	31.4	29.5	26.1	40.6	66.2
	1	2	107	2.6	32	151	37.1	31.8	29.5	26.0	40.0	63.9
	1	3	83	1.9	32	151	37.2	33.6	31.7	27.4	45.4	62.6
	1	4	94	2.0	32	151	37.1	33.3	30.5	27.4	40.3	64.2
	1	5	82	1.3	32	151	37.0	31.2	28.2	26.9	34.2	72.3
	2	1	78	0.1	37	157	36.8	31.4	29.5	26.1	40.6	66.2
	2	2	99	1.3	37	157	36.9	31.8	29.5	26.0	40.0	63.9
	2	3	103	2.7	37	157	37.5	33.6	31.7	27.4	45.4	62.6
	2	4	106	1.5	37	157	36.8	33.0	30.5	27.4	39.3	65.3
	2	5	75	-0.6	37	157	36.4	31.2	28.2	26.9	34.2	72.3
	3	1	141	4.3	39	164	37.0	31.4	29.5	26.1	40.6	66.2

	3	2	94	2.1	39	164	36.9	31.8	29.5	26.0	40.0	63.9
	3	3	121	4.1	39	164	37.4	33.6	31.7	27.4	45.4	62.6
	3	4	104	3.1	39	164	37.2	33.3	30.5	27.4	39.3	64.2
	3	5	77	1.1	39	164	36.7	31.2	28.2	26.9	34.2	72.3
7.23	4	1	98	1.7	24	162	36.9	31.6	29.7	25.8	42.6	63.7
	4	2	97	1.3	24	162	36.7	33.2	30.2	26.3	43.1	58.7
	4	3	92	1.1	24	162	36.7	33.4	29.9	26.2	41.9	57.2
	4	4	126	3.0	24	162	36.9	32.7	28.9	25.5	38.8	57.1
	4	5	85	1.0	24	162	36.8	31.1	27.6	25.4	34.4	63.6
	4	6	91	2.4	24	162	37.5	34.9	30.8	26.6	44.4	53.1
	5	1	113	1.9	48	148	36.4	31.6	29.7	25.8	42.6	63.7
	5	2	136	3.5	48	148	36.7	33.0	30.1	26.1	42.8	58.7
	5	3	88	1.0	48	148	36.5	33.4	29.9	26.2	41.9	57.2
	5	4	115	2.1	48	148	36.5	32.9	28.9	25.5	38.8	56.4
	5	5	130	3.4	48	148	36.9	31.1	27.6	25.4	34.4	63.6
	5	6	111	2.3	48	148	36.7	34.9	30.8	26.6	44.4	53.1
	6	1	116	2.4	40	151	37.3	31.6	29.7	25.8	42.6	63.7
	6	2	89	0.2	40	151	36.9	33.0	30.1	26.1	42.8	58.7
	6	3	87	-0.3	40	151	36.7	33.5	29.9	26.1	41.9	56.3
	6	4	79	-0.6	40	151	36.8	32.7	28.9	25.5	38.8	57.1
	6	5	73	-1.3	40	151	36.6	31.1	27.6	25.4	34.4	63.6
	6	6	69	-1.1	40	151	36.8	34.9	30.8	26.6	44.4	53.1
	7	1	115	0.9	24	156	36.5	31.9	29.9	25.9	43.3	63.0
	7	2	140	2.7	24	156	36.7	33.5	30.5	26.4	43.2	57.8
	7	3	116	2.3	24	156	37.2	34.5	30.9	26.0	41.6	51.8
	7	4	121	1.9	24	156	36.9	31.9	28.1	25.3	35.8	59.6
	7	5	110	1.4	24	156	36.9	31.0	27.8	25.6	34.6	65.8
	7	6	161	5.3	24	156	37.5	34.9	30.8	26.6	44.4	53.1
7.24	8	1	91	0.1	54	128	37.0	32.4	29.8	26.5	40.2	63.7
	8	2	96	0.7	54	128	37.2	34.1	30.9	27.0	42.9	58.6
	8	3	106	0.8	54	128	37.0	35.5	31.8	27.3	46.0	54.0
	8	4	92	0.4	54	128	37.1	35.5	31.2	27.1	44.0	52.9
	9	1	79	-0.8	23	199	36.7	32.2	29.7	26.5	40.2	64.6
	9	2	98	0.9	23	199	37.1	33.9	30.8	27.0	42.8	59.1
	9	3	105	1.9	23	199	37.4	35.7	31.9	27.3	46.3	53.2
	9	4	107	1.1	23	199	36.9	35.6	31.3	27.1	44.3	52.3
	10	1	87	-0.5	22	179	36.8	32.4	29.8	26.5	40.2	63.7
	10	2	102	1.0	22	179	37.1	34.1	30.9	27.0	42.9	58.4
	10	3	120	2.8	22	179	37.6	35.5	31.8	27.2	46.4	53.7
	10	4	90	-0.6	22	179	36.6	35.9	31.3	27.1	44.0	51.3
7.25	11	1	98	0.5	23	132	36.5	33.0	30.2	26.5	41.1	60.7

	11	2	98	1.9	23	132	37.2	34.4	31.4	27.2	45.3	58.0
	11	3	99	2.0	23	132	37.2	36.1	32.3	27.6	47.4	53.1
	11	4	118	3.8	23	132	37.7	37.2	32.5	27.9	46.3	50.0
	12	1	128	3.7	18	141	37.6	33.0	30.2	26.5	41.1	60.7
	12	2	111	2.2	18	141	37.2	34.4	31.4	27.2	45.3	58.0
	12	3	116	3.7	18	141	37.9	36.1	32.4	27.6	47.4	53.1
	12	4	134	4.9	18	141	38.0	37.2	32.5	27.9	46.3	50.0
	13	1	92	0.5	50	153	36.9	32.7	29.9	26.4	40.9	61.9
	13	2	106	1.6	50	153	37.1	34.9	31.9	27.3	46.4	56.6
	13	3	107	2.8	50	153	37.2	36.4	32.5	27.7	47.2	52.2
	13	4	108	3.1	50	153	37.7	37.2	32.5	27.9	46.3	50.0
	14	1	94	0.4	35	166	36.8	32.7	29.9	26.4	40.9	61.7
	14	2	104	1.3	35	166	37.0	34.5	31.5	27.2	45.3	57.5
	14	3	114	3.2	35	166	37.7	36.1	32.6	27.7	47.7	53.6
	14	4	111	3.3	35	166	37.2	37.2	32.7	27.9	46.9	50.1
7.26	15	1	110	2.3	38	142	37.2	33.7	30.1	26.4	41.9	57.9
	15	2	130	3.4	38	142	37.2	35.8	31.9	27.1	47.3	51.7
	15	3	144	3.7	38	142	36.9	36.3	30.9	26.1	45.6	45.2
	15	4	111	2.5	38	142	37.2	37.0	31.1	26.3	45.2	43.6
	16	1	142	4.0	24	141	37.2	33.8	30.2	26.4	42.3	56.6
	16	2	99	1.8	24	141	37.2	35.5	31.6	27.0	47.1	52.6
	16	3	150	4.5	24	141	37.3	36.3	31.0	26.2	45.8	45.6
	16	4	130	4.5	24	141	37.9	37.1	31.1	26.3	45.4	43.6
	17	1	146	4.5	23	103	37.1	34.1	30.4	26.5	42.7	56.0
	17	2	127	3.7	23	103	37.2	35.9	32.0	27.1	47.5	51.3
	17	3	129	3.5	23	103	37.0	36.4	31.0	26.2	45.8	45.5
	17	4	122	3.1	23	103	37.0	37.1	31.2	26.3	45.4	43.4
	18	1	116	3.7	26	127	37.6	33.6	30.0	26.4	41.9	57.4
	18	2	145	4.4	26	127	37.3	35.7	31.9	27.1	47.3	52.0
	18	3	124	3.2	26	127	37.1	36.5	30.9	26.2	45.4	45.1
	18	4	125	3.0	26	127	37.0	37.0	31.1	26.2	45.2	43.4

Appendix F: Survey Data

Symptom Data, JOB=1,picker 2,packer or other NV=Nausea & Vomiting WD=Weakness & Dizziness HA=Headache, DI=Diarrhea, CR=Cramps

JOB	BD	Age	SEX	NV	WD	HA	DI	CR
0	8/24/1989	24	0	No	No	No	No	No
0	9/2/1981	31	0	No	No	No	No	No
0	2/16/1991	21		No	No	No	No	No
0	12/7/1981	30	1	No	Yes	No	No	No
0	12/4/1984	26	0	Yes	No	Yes	No	No
0	11/8/1976	35		No	Yes	No	No	No
0	7/6/1982	30	0	No	No	Yes	No	No
0	4/8/1980	32	0	No	No	No	No	No
0	4/12/1974	38	0	Yes	Yes	No	No	Yes
0	4/29/1987	25	0	No	No	No	No	No
0	2/18/1991	21	0	No	No	Yes	No	No
0	3/1/1977	43	0	No	Yes	No	No	Yes
0	6/15/1991	22	0	No	No	No	No	Yes
0	12/6/1991	21	0	No	No	No	No	No
0	1/19/1988	24	0	No	No	Yes	No	No
0	2/18/1991	21		No	Yes	Yes	No	No
0	10/25/1990	22	0	No	No	No	No	No
0	5/9/1991	21	0	No	No	No	No	No
0	12/24/1976	37	0	No	Yes	No	No	Yes
0	3/15/1990	22	0	No	No	No	No	No
0	10/18/1968	44	0	No	No	No	No	Yes
0	5/20/1966	46	0	Yes	Yes	No	No	No
0	7/30/1982	30	0	No	No	No	No	No
0	5/1/1989	23	0	Yes	No	No	No	No
0	1/17/1975	36	0	No	No	No	No	Yes
0	10/26/1964	48	0	No	No	Yes	Yes	Yes
0	2/20/1982	30	0	No	Yes	Yes	No	No
0	11/4/1990	21	0	No	No	No	No	Yes
0	4/2/1980	32	0	No	No	Yes	No	Yes
0	2/16/1974	37	0	No	No	Yes	No	Yes
0	4/25/1992	19	0	No	No	No	No	No
0	6/24/1991	20	0	No	No	Yes	No	Yes
0	8/29/1985	24	0	Yes	Yes	Yes	No	No
0	10/10/1988	23	0	No	Yes	Yes	No	No
0	12/28/1957	55		No	Yes	Yes	No	Yes
0	9/16/1967	44	0	No	No	No	No	No

0	7/15/1992	20	0	No	No	Yes	No	No
0	2/28/1990	22		No	No	Yes	No	No
0	5/6/1966	56	0	No	No	No	No	No
0	1/24/1976	37	0	No	No	No	No	Yes
0	8/12/1973	38		No	No	No	No	No
0	4/24/1977	35	1	Yes	Yes	Yes	No	Yes
0	5/31/1990	22	0	No	No	Yes	No	Yes
0	12/5/1983	28	0	No	Yes	Yes	No	Yes
0	11/26/1981	28	0	Yes	Yes	Yes	No	Yes
0	3/4/1945	66	0	No	No		No	No
0	3/2/1982	30	0	No	No	No	No	No
0	3/5/1992	20	0	No	No	Yes	No	No
0	10/4/1990	21	0	No	Yes	Yes	No	No
0	9/9/1989	23	0	No	Yes	Yes	No	No
0	6/4/1967	45	0	No	No	Yes	No	No
0	8/25/1971	40	1	No	No	No	No	No
0	2/14/1991	21	0	No	No	No	No	No
0	7/24/1950	61	0	No	Yes	No	No	Yes
0	5/20/1987	25	0	No	Yes	Yes	No	No
0	1/12/1972	39	0	Yes	Yes	Yes	No	Yes
0	4/8/1992	20	0	No	No	Yes	No	No
0	12/21/1987	23	0	No	No	No	No	No
0	11/4/1990	21	0	Yes	Yes	No	No	Yes
0	4/7/1987	24	0	Yes	No	Yes	No	No
0	2/27/1990	22	0	No	No	Yes	No	Yes
0	9/9/1975	37	0	No	No	No	No	No
0	11/1/1990	21	1	Yes	Yes	No	No	No
0	2/15/1963	45	0	Yes	No	Yes	No	Yes
0	8/18/1975	36	1	No	Yes	No	No	No
0	6/23/1986	23	1	No	No	Yes	No	No
0	12/6/1988	23	0	No	No	No	No	Yes
0	3/25/1994	18	0	No	No	Yes	No	Yes
0	4/21/1989	23	1	No	Yes	Yes	No	No
0	5/9/1991	21	0	No	No	Yes	No	No
0	5/11/1984	27	0	No	No	No	No	No
0	2/18/1991	21	0	No	Yes	Yes	No	No
0	5/7/1987	25	0	No	Yes	Yes	No	No
0	4/21/1988	24	0	Yes	Yes	Yes	No	No
0	10/4/1985	26	0	No	No	No	No	No
0	10/26/1964	48	0	No	No	Yes	No	No
0	7/24/1991	21	0	No	No	No	No	No

0	6/20/1977	34	0	No	No	No	No	No
0	1/27/1989	23	0	No	No	Yes	No	Yes
0	9/11/1967	45	0	No	No	No	No	No
0	11/20/1979	32	0	No	No	Yes	No	No
0	9/1/1972	39	0	No	No	No	No	No
0	6/7/1989	23	0	No	No	Yes	No	No
0	6/3/1973	38	0	No	No	No	No	Yes
0	7/12/1977	35	1	Yes	No	Yes	No	No
1	8/20/1984	27	1	No	No	No	No	No
1	12/28/1972	39	1	No	No	No	No	No
1	8/21/1968	42	1	No	No	Yes	No	No
1	5/27/1984	28	1	No	No	No	No	No
1	8/25/1942	68	1	No	Yes	No	No	No
1	2/7/1975	37	1	No	No	No	No	Yes
1	12/14/1977	34	1	Yes	Yes	No	No	No
1	7/13/1964	54	1	Yes	No	Yes	No	No
1	8/6/1980	38	1	No	Yes	Yes	No	No
1		60	1	No	No	No	No	Yes
1	5/19/1986	26	1	No	No	No	No	No
1	4/1/1979		1	No	No	Yes	No	No
1	11/23/1999	12	1	No	Yes	Yes	No	No
1	2/26/1990	22	1	No	No	Yes	No	No
1	7/2/1986	26	1	Yes	No	No	No	No
1	11/14/1955	57	1	No	No	Yes	No	No
1	2/2/1966	47	0	No	Yes	Yes	No	No
1	7/4/1962	50	1	No	No	No	No	No
1		20	1	No	No	No	No	No
1	6/5/1966	46	0	No	No	No	No	No
1	4/7/1960	51	1	No	No	No	No	No
1		57	1	No	No	Yes	No	Yes
1	12/29/1943	68	0	No	No	No	No	No
1	1/19/1982	30	0	No	Yes	Yes	No	No
1	2/7/1943	69	0	Yes	Yes	No	No	Yes
1	11/19/1983	28	1	No	No	No	No	No
1	11/5/1953	59	0	No	Yes	No	No	No
1	5/15/1972	40	0	No	No	No	No	No
1	12/1/1992	20	0	No	No	Yes	No	No
1	8/26/1969	42	0	No	No	Yes	No	Yes
1	1/17/1973	39	1	Yes	Yes	Yes	No	No
1	6/1/1967	44		No	No	No	No	No
1	2/5/1963	49	0	No	Yes	Yes	No	Yes

1	9/10/1988	23	1	No	No	No	No	No
1	12/17/1991	21	0	No	No	No	No	No
1	5/5/1998	14	1	No	No	No	No	No
1	4/2/1986	26	0	Yes	Yes	No	No	No
1	5/15/1982	30	1	No	Yes	Yes	No	No
1	12/14/1955	56	0	No	No	No	Yes	Yes
1	5/22/1961	51	0	No	No	No	No	No
1	10/14/1986	24	0	No	No	No	No	No
1	6/12/1984	27	0	No	No	No	No	No
1	11/21/1969	42	1	No	No	Yes	No	No
1	2/2/1970	42	0	No	No	No	No	No
1	4/26/1949	62	0	No	No	No	No	No
1	9/4/1991	20	0	No	No	No	No	Yes
1	9/3/1991	20	0	No	No	Yes	No	No
1	2/25/1991	21	0	No	No	Yes	No	No
1	11/3/1990	21	0	No	No	Yes	No	No
1	6/23/1991	20	0	No	No	Yes	No	No

Survey Data, SEX, 0=Male 1=Female, BEV= Preferred beverage, 0=water, 2=Gatorade, 3=SodaTrain=Have you had heat training? CONC=How concerned are you about the heat harming you? 0=Very, 1=Slighty, 2=Not at All DRI=Coping mechanism, do you drink more fluids? GO=Coping mechanism, do you go to a cool place after work? SHA=Coping mechanism, do you rest in the shade? SLOW=Coping mechanism, do you work slower?

BD	AGE	SEX	BEV	TRAIN	CONC	DRI	GO	SHA	SLOW
8/24/1989	24	0	0	Yes	0	Yes	No	Yes	No
9/2/1981	31	0	0	No	2	Yes	No	No	No
2/16/1991	21		2	Yes	0	Yes	No	No	No
12/7/1981	30	1	0	No	1	Yes	No	No	No
12/4/1984	26	0	0	No	0	Yes	No	Yes	No
11/8/1976	35		2	No	1	Yes	No	No	No
7/6/1982	30	0	2	No	2	Yes	No	No	No
4/8/1980	32	0	2	No	0	Yes	No	Yes	No
4/12/1974	38	0	0	No	0	Yes	No	No	No
4/29/1987	25	0	2	No	1	Yes	No	Yes	No
2/18/1991	21	0	2	No	1	Yes	No	Yes	No
3/1/1977	43	0	0	Yes	0	Yes	No	No	No
6/15/1991	22	0	0	Yes	2	Yes	No	No	No
12/6/1991	21	0	2	No	1	Yes	No	Yes	No
1/19/1988	24	0	2	Yes	2	Yes	No	No	No
2/18/1991	21		0	No	2	Yes	No	No	No

10/25/1990	22	0	0	No	0	Yes	Yes	Yes	No
5/9/1991	21	0	0	Yes	0	Yes	Yes	Yes	No
12/24/1976	37	0	0	No	0	Yes	No	No	No
3/15/1990	22	0	2	No	0	Yes	No	No	No
10/18/1968	44	0	0	No	1	Yes	Yes	Yes	No
5/20/1966	46	0	2	No	2	Yes	No	No	No
7/30/1982	30	0	2	No	2	Yes	No	No	No
5/1/1989	23	0	0	No	1	Yes	No	No	No
1/17/1975	36	0	0	Yes	0	Yes	No	Yes	No
10/26/1964	48	0	0	No	0	Yes	No	Yes	No
2/20/1982	30	0	2	Yes	0	Yes	No	No	No
11/4/1990	21	0	0	No	2	Yes	No	No	No
4/2/1980	32	0	2	Yes	0	Yes	No	Yes	No
2/16/1974	37	0	2	No	0	Yes	No	No	No
4/25/1992	19	0	0	No	1	Yes	Yes	Yes	No
6/24/1991	20	0	2	Yes	0	Yes	No	Yes	No
8/29/1985	24	0	0	Yes	1	Yes	No	Yes	No
10/10/1988	23	0	2	No	0	Yes	No	Yes	No
12/28/1957	55		0	No	0	Yes	Yes	Yes	No
9/16/1967	44	0	0	No	1	Yes	No	Yes	No
7/15/1992	20	0	2	Yes	1	Yes	Yes	Yes	No
5/6/1966	56	0	2	No	1	Yes	Yes	Yes	No
1/24/1976	37	0	0	No	0	Yes	No	Yes	No
8/12/1973	38		3	No	1	Yes	No	No	No
4/24/1977	35	1	2	No	1	No	No	Yes	No
5/31/1990	22	0	2	Yes	2	Yes	No	Yes	No
12/5/1983	28	0	0	No	0	Yes	No	No	No
11/26/1981	28	0	3	No	0	Yes	No	No	No
3/4/1945	66	0	0	Yes	0	Yes	No	Yes	No
3/2/1982	30	0	4	Yes	2	Yes	No	No	No
3/5/1992	20	0	0	No	0	Yes	No	No	No
10/4/1990	21	0	0	No	0	Yes	Yes	Yes	No
9/9/1989	23	0	2	No	0	Yes	No	Yes	No
6/4/1967	45	0	0	No	0	Yes	No	Yes	No
8/25/1971	40	1	0	No	0	Yes	No	Yes	No
2/14/1991	21	0	2	No	0	Yes	Yes	No	No
7/24/1950	61	0	0	Yes	0	Yes	No	No	No
5/20/1987	25	0	0	No	1	Yes	No	No	No
1/12/1972	39	0	0	No	0	Yes	No	No	No
4/8/1992	20	0	0	No	0	Yes	No	No	No
12/21/1987	23	0	3	No	0	Yes	No	No	No

11/4/1990	21	0	0	Yes	0	Yes	No	No	No
4/7/1987	24	0	0	No	0	Yes	No	Yes	No
6/4/1967	45	0	0	No	1	Yes	Yes	Yes	No
8/25/1971	40	1	0	No	2	Yes	Yes	No	No
2/14/1991	21	0	2	No	1	No	No	Yes	No
7/24/1950	61	0	0	No	0	Yes	No	Yes	No
5/20/1987	25	0	0	No	1	No	No	Yes	No
1/12/1972	39	0	0	Yes	0	Yes	No	No	No
4/8/1992	20	0	0	Yes	1	Yes	No	No	Yes
12/21/1987	23	0	3	No	0	Yes	No	No	No
11/4/1990	21	0	0	Yes	0	Yes	No	Yes	No
4/7/1987	24	0	0	No	1	Yes	No	No	No
5/9/1991	21	0	2	Yes	1	Yes	No	Yes	No
5/11/1984	27	0	0	No	0	Yes	No	Yes	No
2/18/1991	21	0	0	No	1	Yes	No	No	No
5/7/1987	25	0	2	No	0	Yes	No	No	No
4/21/1988	24	0	3	No	0	Yes	No	Yes	No
10/4/1985	26	0	0	No	1	Yes	No	No	No
10/26/1964	48	0	2	Yes	0	No	No	Yes	No
7/24/1991	21	0	0	No	1	Yes	No	No	No
6/20/1977	34	0	0	No	0	Yes	No	No	No
1/27/1989	23	0	2	No	2	Yes	No	No	No
9/11/1967	45	0	0	No	1	Yes	No	Yes	No
11/20/1979	32	0	3	No	0	Yes	No	No	No
9/1/1972	39	0	0	No	0	Yes	No	Yes	No
6/7/1989	23	0	2	Yes	1	Yes	No	No	No
6/3/1973	38	0	3	Yes	2	Yes	No	No	No
4/6/1986	26	0	2	No	2	Yes	No	Yes	No

VITA

STEPHEN L. MCQUEEN

Personal Data:	Date of Birth: February 25, 1985
	Place of Birth: Maryville, TN
	Marital Status: Single
Education:	Greenback High School, Greenback, TN
	Maryville College, Maryville, TN
	B.A, Biology, 2007
	East Tennessee State University, Johnson City, TN
	M.S.E.H, Environmental Health, 2012