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The Girasoles (Sunflower) Study: Exploring the Physiologic Heat Stress Response

Linda McCauley, RN, PhD, FAAN, FAAOHN
Dean and Professor
Nell Hodgson Woodruff School of Nursing
Emory University

Friday, October 26, 2018

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The Girasoles (Sunflower) Study

Center for Disease Control and Prevention | National Institute for Occupational Safety and Health

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Occupational Heat Stress

Farmworker, 24, dies after collapsing in field

By Alan Mauldin Jun 25, 2018

MOULTRIE — A farmworker who had been in the country less than a week died from an apparent heat stroke after he collapsed on Thursday.

The Moultrie Observer

Farmworker dies after complaining of heat exhaustion on bus ride back to Immokalee

Maria Perez, Naples Daily News Published 12:00 a.m. ET May 19, 2016

Naples Daily News

Pregnant Farmworker Dies After Being Denied Shade, Water; Family Calls for Action

Thursday, June 05, 2008
Associated Press

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June 2: Josefina Flores, right, carries a photograph of Maria Isabel Vasques Jimenez, an undocumented farm worker who collapsed and died in a vineyard last month because her conditions on thousands of vineyards and orchards.

LODI, California — The death of a pregnant teenager pruning grape vines in scorching heat has outraged California's farmworking community and sparked calls for safety reforms as laborers prepare for the long summer harvest.

Authorities in California — the only state with a heat-illness standard — suspect Maria Isabel Vasquez Jimenez, a 17-year-old undocumented Mexican immigrant, collapsed last month because her farm labor contractor denied employees proper access to shade and water.

On Wednesday, 500 farmworkers and their advocates capped a poignant, four-day march to the statehouse demanding safer

Governor Arnold Schwarzenegger and the Mexican government have called the girl's death preventable. State officials say they have revoked the company's license.

Advocates for farm workers, many of whom are immigrants from Mexico and other parts of Latin America, say California's safety rules are routinely violated. Authorities have investigated nearly two dozen suspected heat-related deaths since 2005.

Regulations require farms and contractors to give workers water and breaks, have shade available and have an emergency plan in place to help those suffering from heat exhaustion. The rules are intended to protect 450,000 seasonal workers who pick and sort much of the nation's plums, peaches and other crops during summer's peak.

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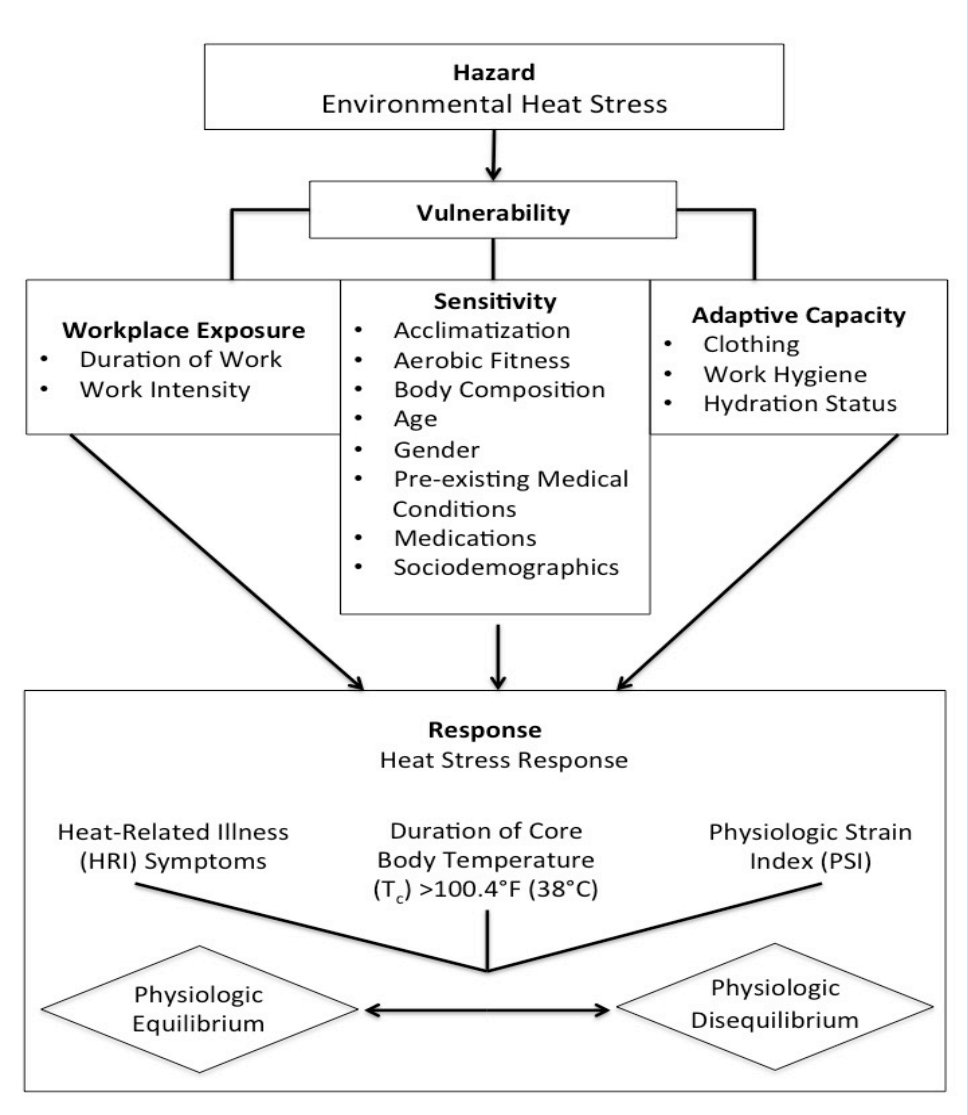
Farmworker Vulnerability to Heat Hazards Framework

1. Hazard
2. Vulnerability factors:
   - Workplace exposure
   - Sensitivity (non-modifiable)
   - Adaptive capacity (modifiable)
3. Heat Stress Response



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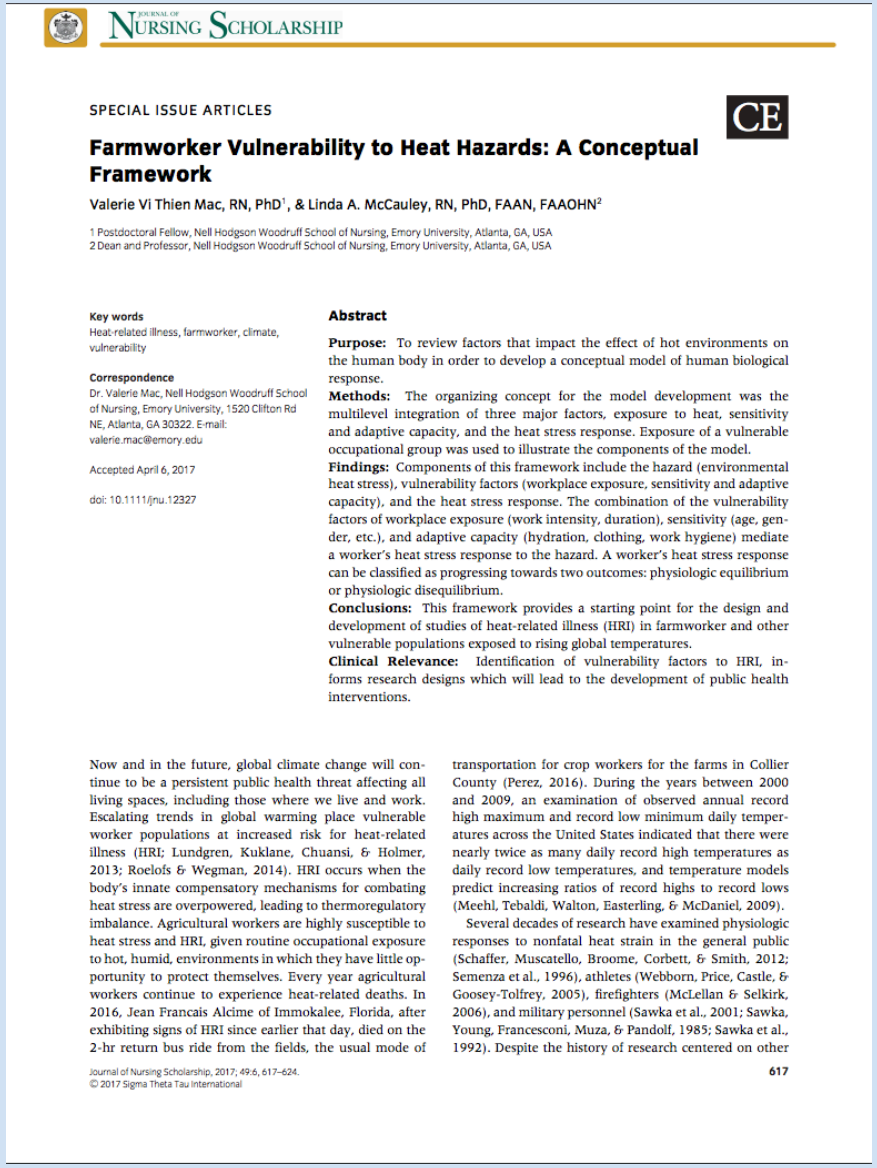

JOURNAL OF NURSING SCHOLARSHIP

SPECIAL ISSUE ARTICLES

CE

Farmworker Vulnerability to Heat Hazards: A Conceptual Framework

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Key words
Heat-related illness, farmworker, climate, vulnerability

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Abstract

Purpose: To review factors that impact the effect of hot environments on the human body in order to develop a conceptual model of human biological response.

Methods: The organizing concept for the model development was the multilevel integration of three major factors, exposure to heat, sensitivity and adaptive capacity, and the heat stress response. Exposure of a vulnerable occupational group was used to illustrate the components of the model.

Findings: Components of this framework include the hazard (environmental heat stress), vulnerability factors (workplace exposure, sensitivity and adaptive capacity), and the heat stress response. The combination of the vulnerability factors of workplace exposure (work intensity, duration), sensitivity (age, gender, etc.), and adaptive capacity (hydration, clothing, work hygiene) mediate a worker's heat stress response to the hazard. A worker's heat stress response can be classified as progressing towards two outcomes: physiologic equilibrium or physiologic disequilibrium.

Conclusions: This framework provides a starting point for the design and development of studies of heat-related illness (HRI) in farmworker and other vulnerable populations exposed to rising global temperatures.

Clinical Relevance: Identification of vulnerability factors to HRI, informs research designs which will lead to the development of public health interventions.

Now and in the future, global climate change will continue to be a persistent public health threat affecting all living spaces, including those where we live and work. Escalating trends in global warming place vulnerable worker populations at increased risk for heat-related illness (HRI; Lundgren, Kuklane, Chuansi, & Holmer, 2013; Roelofs & Wegman, 2014). HRI occurs when the body's innate compensatory mechanisms for combating heat stress are overpowered, leading to thermoregulatory imbalance. Agricultural workers are highly susceptible to heat stress and HRI, given routine occupational exposure to hot, humid, environments in which they have little opportunity to protect themselves. Every year agricultural workers continue to experience heat-related deaths. In 2016, Jean Francais Alcime of Immokalee, Florida, after exhibiting signs of HRI since earlier that day, died on the 2-hr return bus ride from the fields, the usual mode of transportation for crop workers for the farms in Collier County (Perez, 2016). During the years between 2000 and 2009, an examination of observed annual record high maximum and record low minimum daily temperatures across the United States indicated that there were nearly twice as many daily record high temperatures as daily record low temperatures, and temperature models predict increasing ratios of record highs to record lows (Meehl, Tebaldi, Walton, Easterling, & McDaniel, 2009).

Several decades of research have examined physiologic responses to nonfatal heat strain in the general public (Schaffer, Muscatello, Broome, Corbett, & Smith, 2012; Semenza et al., 1996), athletes (Webborn, Price, Castle, & Goosey-Tolfrey, 2005), firefighters (McLellan & Selkirk, 2006), and military personnel (Sawka et al., 2001; Sawka, Young, Francesconi, Muza, & Pandolf, 1985; Sawka et al., 1992). Despite the history of research centered on other

Mac, Valerie Vi Thien, and Linda A. McCauley. "Farmworker vulnerability to heat hazards: a conceptual framework." *Journal of nursing scholarship* 49.6 (2017): 617-624.

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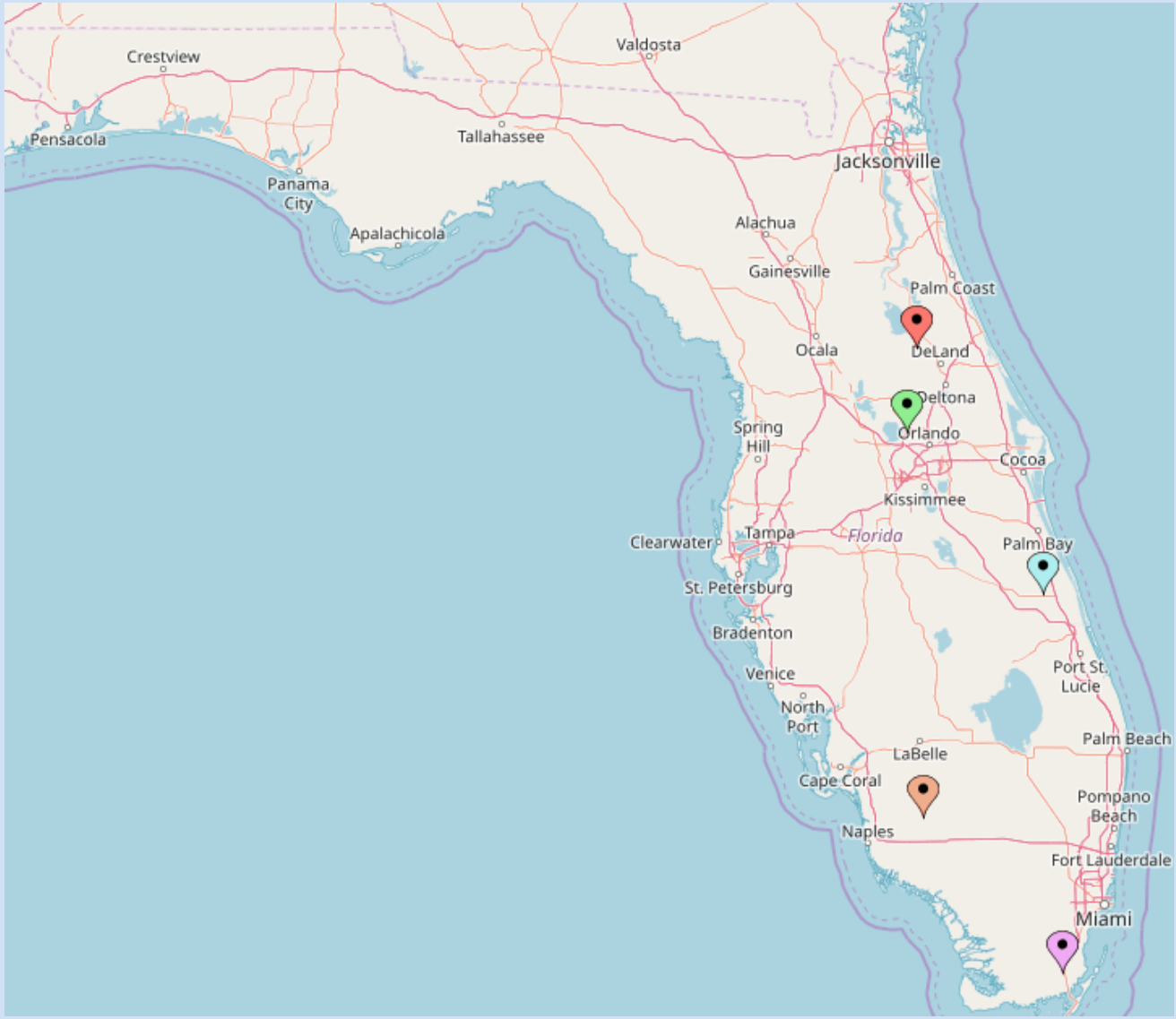
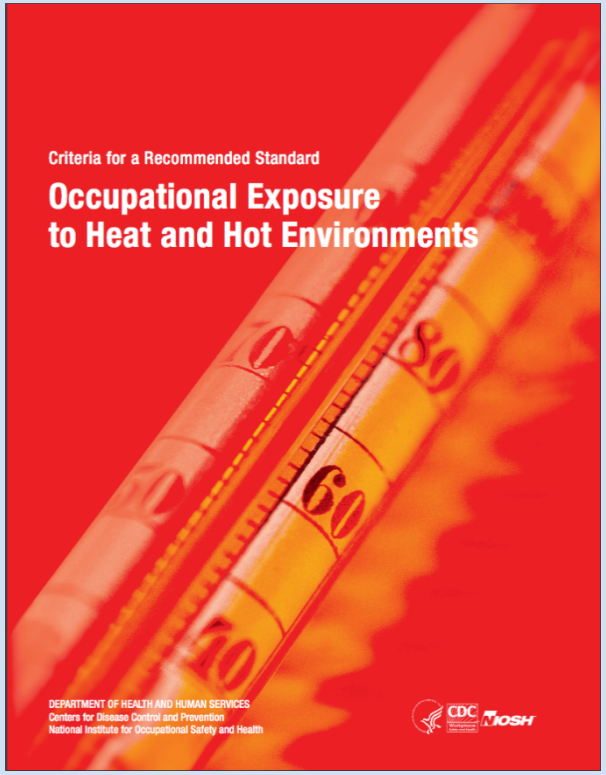
5 Girasoles Study Recruitment Locations in Florida

- Pierson
- Apopka
- Fellsmere
- Immokalee
- Homestead



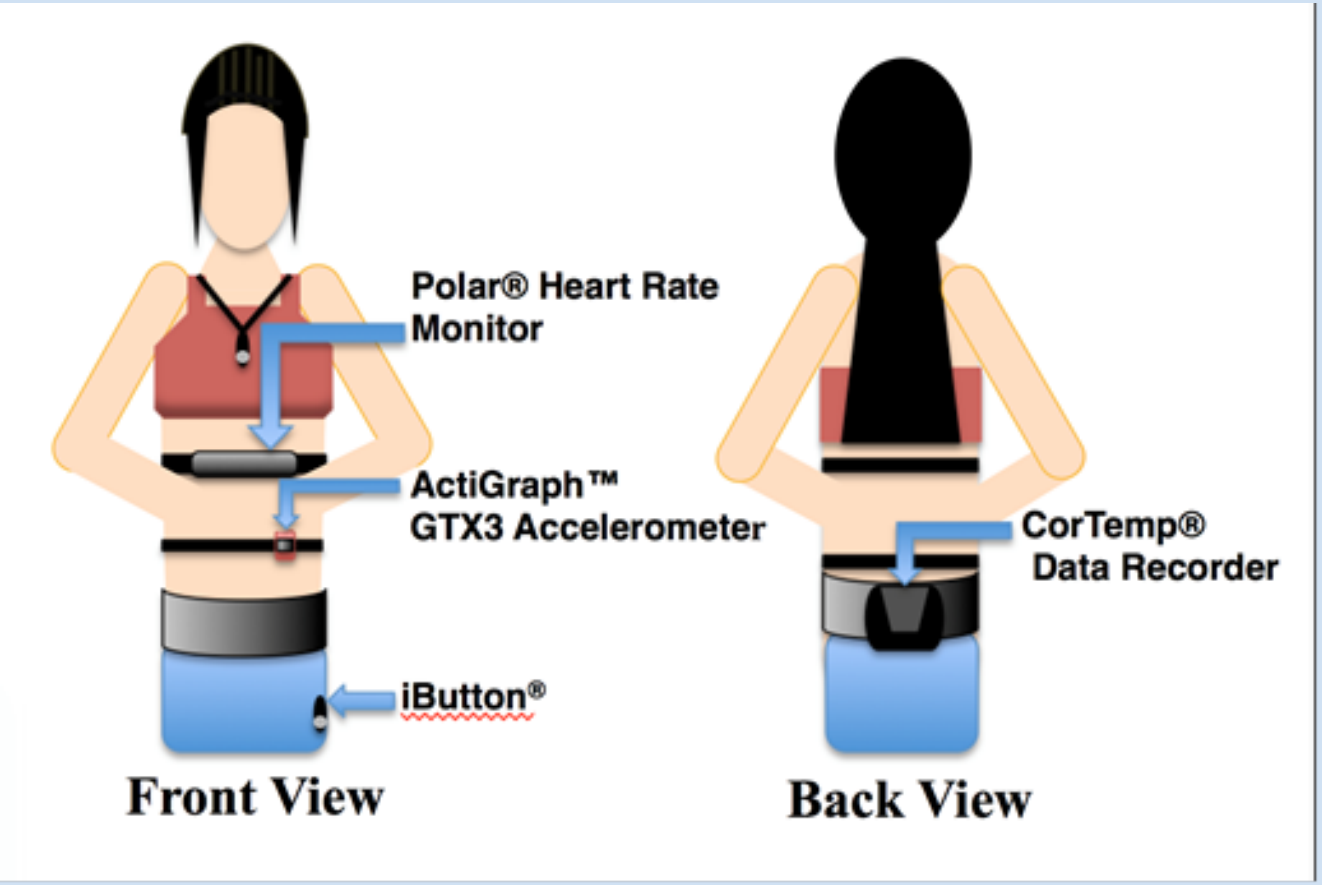
Recommended Core Body Temperature Limits



38.0°C (100.4°F) – For workers not acclimatized or medically cleared.

38.5°C (101.3°F) – For workers acclimatized, medically screened and monitored. Worker core body temperature should never exceed this level.

3 Workdays of Biomonitoring + Surveys



Baseline, Pre-Workday and Post-Workday

<u>Biological Samples:</u>

- Urine Specific Gravity
- Blood osmolality/Blood chemistry

<u>Survey:</u>

- Heat-related Illness Symptoms
- Demographics

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Comprehensive Heat Stress Monitoring

Actigraph Accelerometer records physical activity

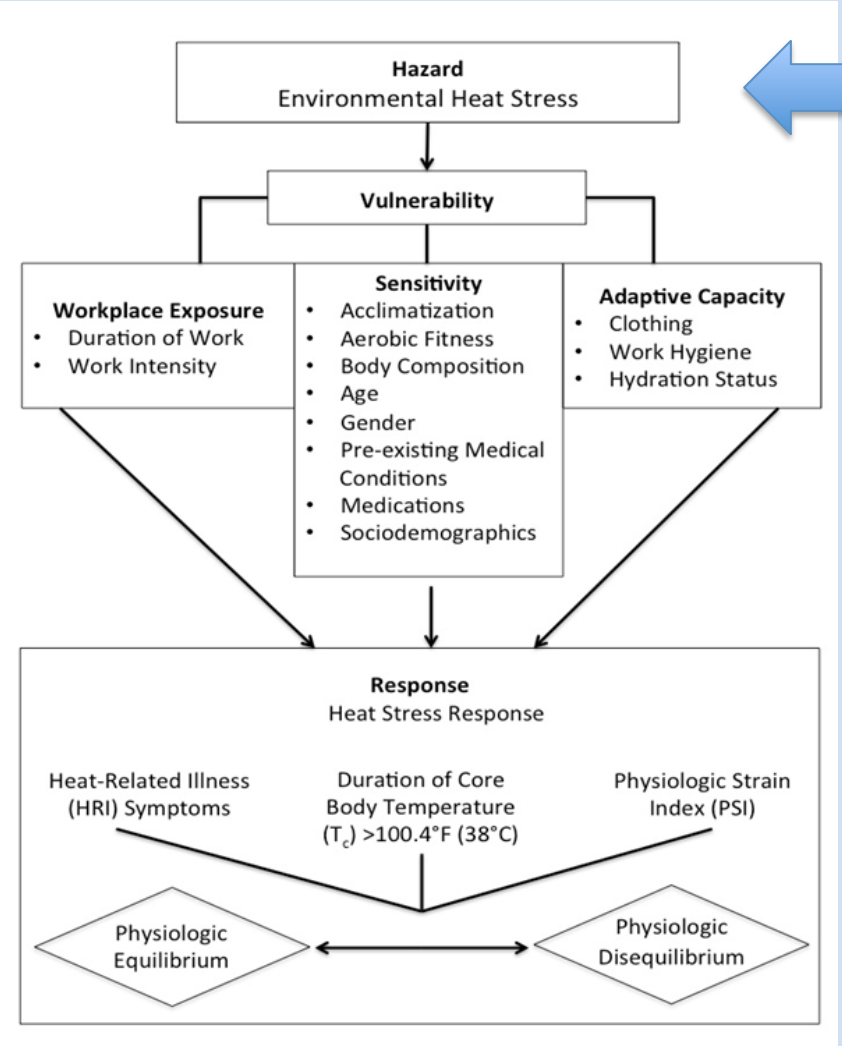
CorTemp® monitor records core body temperature

Heart rate monitor measures heart rate at work

Home monitor records the overnight home temperatures

iButton records the temperature and humidity at your workplace

Hazard: Environmental Heat Stress



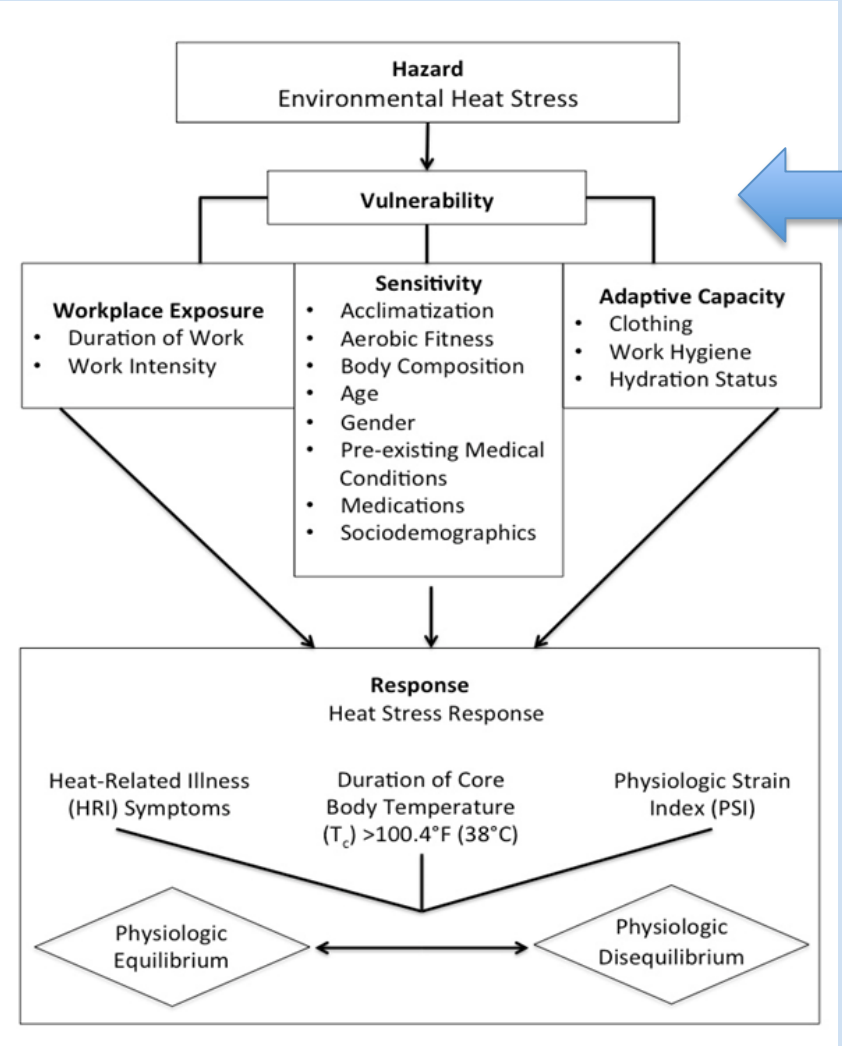
Environmental Heat

- FAWN Data:
  - Regional Weather Network Data every 15 minutes
  - Mean Heat Index: 90°F ±6

- iButton Data
  - Immokalee (n=66) and Apopka (n=39)
  - 284 Observation days
  - Worksite-based data every 15 minutes = 10,000 readings
  - Mean Heat Index: 105°F ± 9.2

Mac VV, Hertzberg V, McCauley LA. Examining Agricultural Workplace Micro and Macroclimate Data Using Decision Tree Analysis to Determine Heat Illness Risk. Journal of Occupational and Environmental Medicine, in press, October 2018 .

Vulnerability



Study Participant Characteristics n = 248

- Mean Age: 38 years (SD± 9)
- Female: 62%
- Years in U.S. Agriculture: 12 years (SD± 8)
- Country of Origin: Mexico (66%), Guatemala (15%), Haiti (10%), Other (7%) , U.S. (2%)
- Work Type: Crops (31%), Fernery (26%) and Nursery (41%)

Measured Work Activity: Accelerometer

- Accelerometer was placed at the worker's right iliac crest and recorded acceleration counts on three planes of motion (vertical, antero-posterior, and medio-lateral) every 30 seconds during the workday
- Vector magnitude (VM3): a composite activity count measure incorporating all three planes of motion
- Time spent in moderate to vigorous activity (MV): calculated by summing the minutes reaching a VM3 count of ≥ 2690[1]

[1]Sasaki JE, John D, Freedson PS. Validation and comparison of ActiGraph activity monitors. J Sci Med Sport. 2011;14(5):411-6. doi: 10.1016/j.jsams.2011.04.003. PubMed PMID: 21616714.

Activity Measures from Accelerometer Data

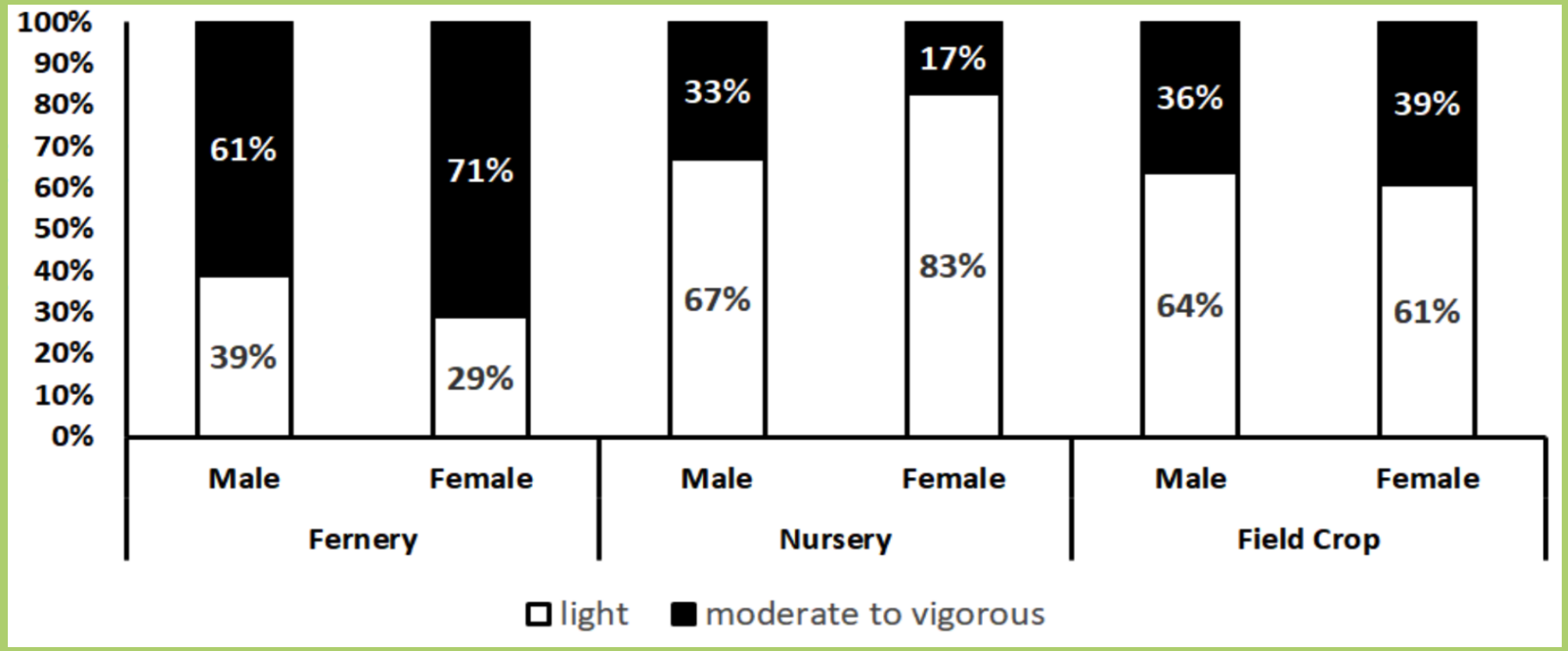
Work Activity Measure	Agricultural Work Type							
	Overall (n = 244)		Fernery (n = 65)		Nursery (n = 102)		Crop (n = 77)	
	M	(IQR)	M	(IQR)	M	(IQR)	M	(IQR)
Counts per minute	1,988	(1,215 – 2,896)	3,759	(2,727 – 5,081)	1,249	(915 – 1,818)	2,056	(1,482 – 2,596)
Activity Level (min/day)[1]								
Sedentary	52	(31 – 86)	24	(14 – 45)	69	(42 – 102)	58	(40 – 88)
Light	243	(141 – 343)	75	(46 – 145)	332	(262 – 389)	235	(170 – 290)
Moderate-Vigorous	146	(71 – 219)	220	(167 – 283)	91	(40 – 143)	158	(97 – 211)
Moderate-Vigorous[2]	96	(14 – 204)	231	(165 – 289)	29	(0 – 83)	121	(46 – 185)

[1]Activity levels are defined as the following vector magnitude cutoffs: Sedentary: 0 to <200; Light: 200 to <2690; Moderate to Vigorous: ≥2690

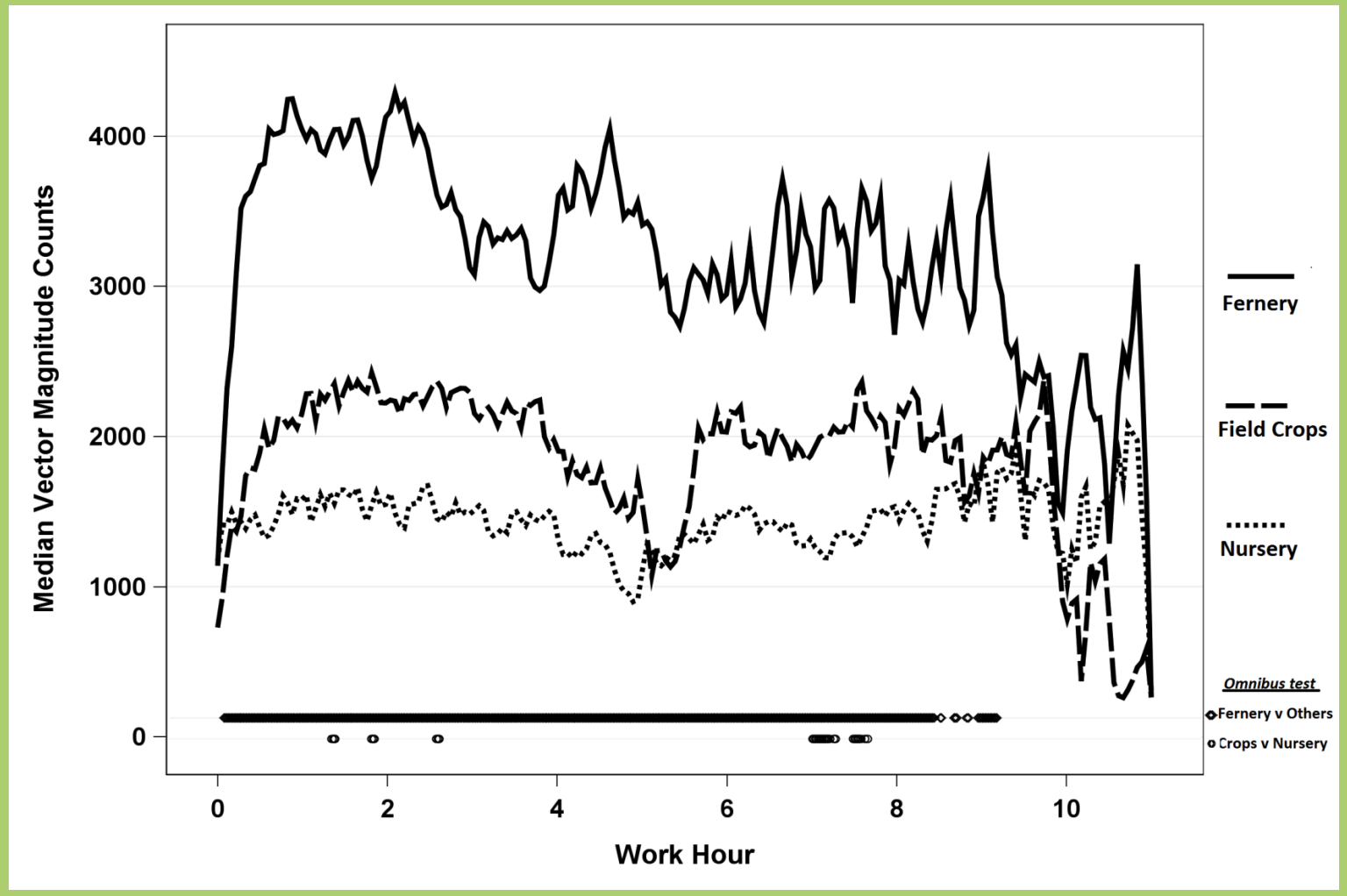
[2]Sustained bouts of activity of 10 consecutive minutes or more, allowing for up to a 2-minute interruption

[3] Significant p value <.0001 results shown

Proportion of Day Spent in Activity Levels



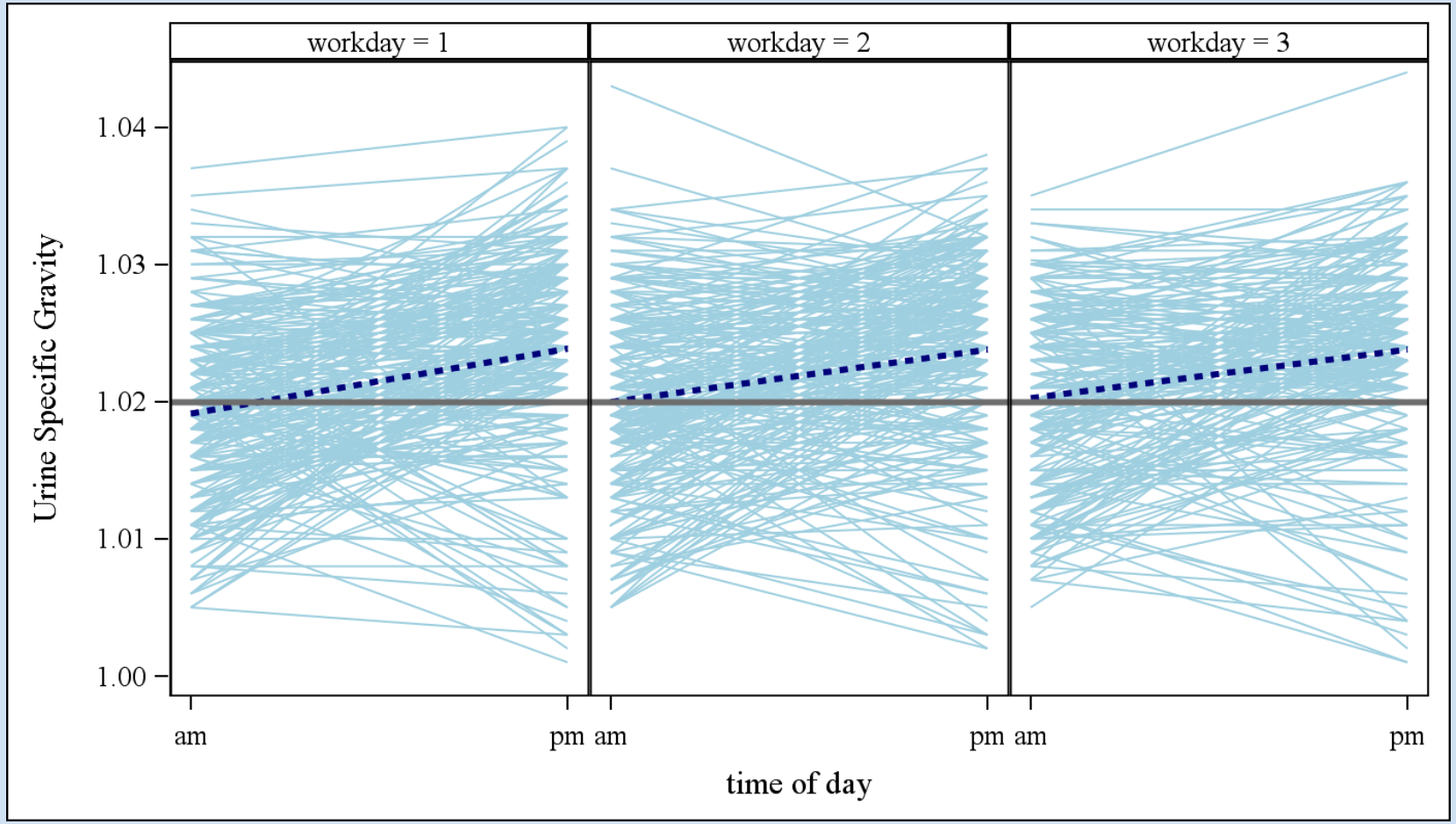
Activity Pattern Over the Workday



Hydration Status

- Urine samples collected before work and after work from each participant
- **Urine Specific Gravity (USG):** measurement widely used to measure hydration status in the field setting
  - Values range from 1.000 (pure water) to 1.050 (maximum concentration capacity of renal system
- USG was categorized into
  - USG ≥ 1.020: hypohydration threshold
  - USG ≥ 1.030: clinical indicator for severe dehydration

USG measures before and after work



Plots display USG measures for n = 248 workers, over 549 workdays

Hydration Status (n =248, 549 workdays)

Biomarker	Before Work[1]	After Work[1]	p value[2]
USG, mean ± SE	1.020 ± 0.0004	1.024 ± 0.0004	<.0001
USG ≥ 1.020	53%	81%	<.0001
USG > 1.030	3%	13%	<.0001

[1]n participants for day 1 was n = 248 , day 2 was n = 243, and day 3 was n = 228
[2]adjusted for random effects due to multiple participants in households and multiple days per participant

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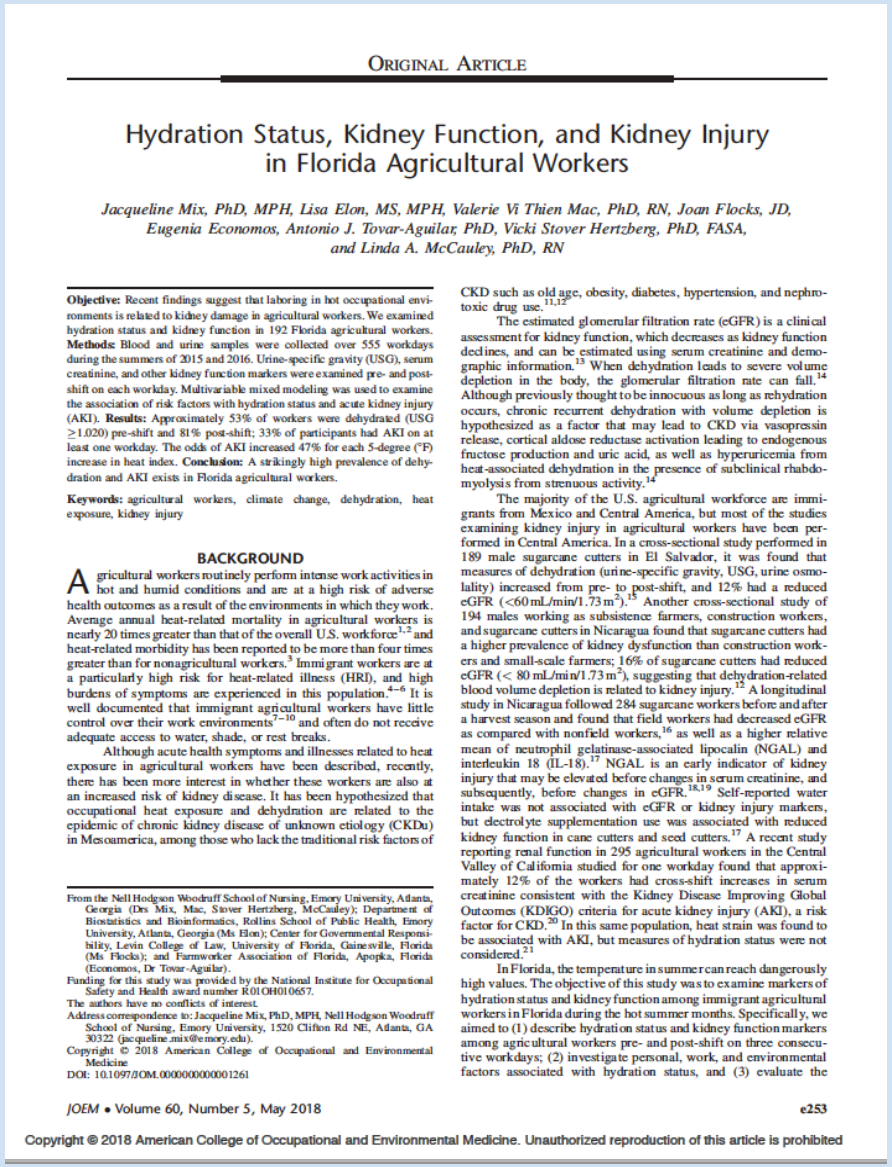

ORIGINAL ARTICLE

Hydration Status, Kidney Function, and Kidney Injury in Florida Agricultural Workers

Jacqueline Mix, PhD, MPH, Lisa Elon, MS, MPH, Valerie Vi Thien Mac, PhD, RN, Joan Flocks, JD, Eugenia Economos, Antonio J. Tovar-Aguilar, PhD, Vicki Stover Hertzberg, PhD, FASA, and Linda A. McCauley, PhD, RN

Objective: Recent findings suggest that laboring in hot occupational environments is related to kidney damage in agricultural workers. We examined hydration status and kidney function in 192 Florida agricultural workers. **Methods:** Blood and urine samples were collected over 555 workdays during the summers of 2015 and 2016. Urine-specific gravity (USG), serum creatinine, and other kidney function markers were examined pre- and post-shift on each workday. Multivariable mixed modeling was used to examine the association of risk factors with hydration status and acute kidney injury (AKI). **Results:** Approximately 53% of workers were dehydrated (USG ≥1.020) pre-shift and 81% post-shift; 33% of participants had AKI on at least one workday. The odds of AKI increased 47% for each 5-degree (°F) increase in heat index. **Conclusion:** A strikingly high prevalence of dehydration and AKI exists in Florida agricultural workers.

Keywords: agricultural workers, climate change, dehydration, heat exposure, kidney injury

BACKGROUND

Agricultural workers routinely perform intense work activities in hot and humid conditions and are at a high risk of adverse health outcomes as a result of the environments in which they work. Average annual heat-related mortality in agricultural workers is nearly 20 times greater than that of the overall U.S. workforce[1,2] and heat-related morbidity has been reported to be more than four times greater than for nonagricultural workers.[3] Immigrant workers are at a particularly high risk for heat-related illness (HRI), and high burdens of symptoms are experienced in this population.[4–6] It is well documented that immigrant agricultural workers have little control over their work environments[7–10] and often do not receive adequate access to water, shade, or rest breaks.

Although acute health symptoms and illnesses related to heat exposure in agricultural workers have been described, recently, there has been more interest in whether these workers are also at an increased risk of kidney disease. It has been hypothesized that occupational heat exposure and dehydration are related to the epidemic of chronic kidney disease of unknown etiology (CKDu) in Mesoamerica, among those who lack the traditional risk factors of CKD such as old age, obesity, diabetes, hypertension, and nephrotoxic drug use.[11,12]

The estimated glomerular filtration rate (eGFR) is a clinical assessment for kidney function, which decreases as kidney function declines, and can be estimated using serum creatinine and demographic information.[13] When dehydration leads to severe volume depletion in the body, the glomerular filtration rate can fall.[14] Although previously thought to be innocuous as long as rehydration occurs, chronic recurrent dehydration with volume depletion is hypothesized as a factor that may lead to CKD via vasopressin release, cortical aldose reductase activation leading to endogenous fructose production and uric acid, as well as hyperuricemia from heat-associated dehydration in the presence of subclinical rhabdomyolysis from strenuous activity.[14]

The majority of the U.S. agricultural workforce are immigrants from Mexico and Central America, but most of the studies examining kidney injury in agricultural workers have been performed in Central America. In a cross-sectional study performed in 189 male sugarcane cutters in El Salvador, it was found that measures of dehydration (urine-specific gravity, USG, urine osmolality) increased from pre- to post-shift, and 12% had a reduced eGFR (<60 mL/min/1.73 m^2).[15] Another cross-sectional study of 194 males working as subsistence farmers, construction workers, and sugarcane cutters in Nicaragua found that sugarcane cutters had a higher prevalence of kidney dysfunction than construction workers and small-scale farmers; 16% of sugarcane cutters had reduced eGFR (< 80 mL/min/1.73 m^2), suggesting that dehydration-related blood volume depletion is related to kidney injury.[12] A longitudinal study in Nicaragua followed 284 sugarcane workers before and after a harvest season and found that field workers had decreased eGFR as compared with nonfield workers,[16] as well as a higher relative mean of neutrophil gelatinase-associated lipocalin (NGAL) and interleukin 18 (IL-18).[17] NGAL is an early indicator of kidney injury that may be elevated before changes in serum creatinine, and subsequently, before changes in eGFR.[18,19] Self-reported water intake was not associated with eGFR or kidney injury markers, but electrolyte supplementation use was associated with reduced kidney function in cane cutters and seed cutters.[17] A recent study reporting renal function in 295 agricultural workers in the Central Valley of California studied for one workday found that approximately 12% of the workers had cross-shift increases in serum creatinine consistent with the Kidney Disease Improving Global Outcomes (KDIGO) criteria for acute kidney injury (AKI), a risk factor for CKD.[20] In this same population, heat strain was found to be associated with AKI, but measures of hydration status were not considered.[21]

In Florida, the temperature in summer can reach dangerously high values. The objective of this study was to examine markers of hydration status and kidney function among immigrant agricultural workers in Florida during the hot summer months. Specifically, we aimed to (1) describe hydration status and kidney function markers among agricultural workers pre- and post-shift on three consecutive workdays; (2) investigate personal, work, and environmental factors associated with hydration status, and (3) evaluate the

From the Nell Hodgson Woodruff School of Nursing, Emory University, Atlanta, Georgia (Drs Mix, Mac, Stover Hertzberg, McCauley); Department of Biostatistics and Bioinformatics, Rollins School of Public Health, Emory University, Atlanta, Georgia (Ms Elon); Center for Governmental Responsibility, Levin College of Law, University of Florida, Gainesville, Florida (Ms Flocks); and Farmworker Association of Florida, Apopka, Florida (Economos, Dr Tovar-Aguilar).

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The authors have no conflicts of interest.

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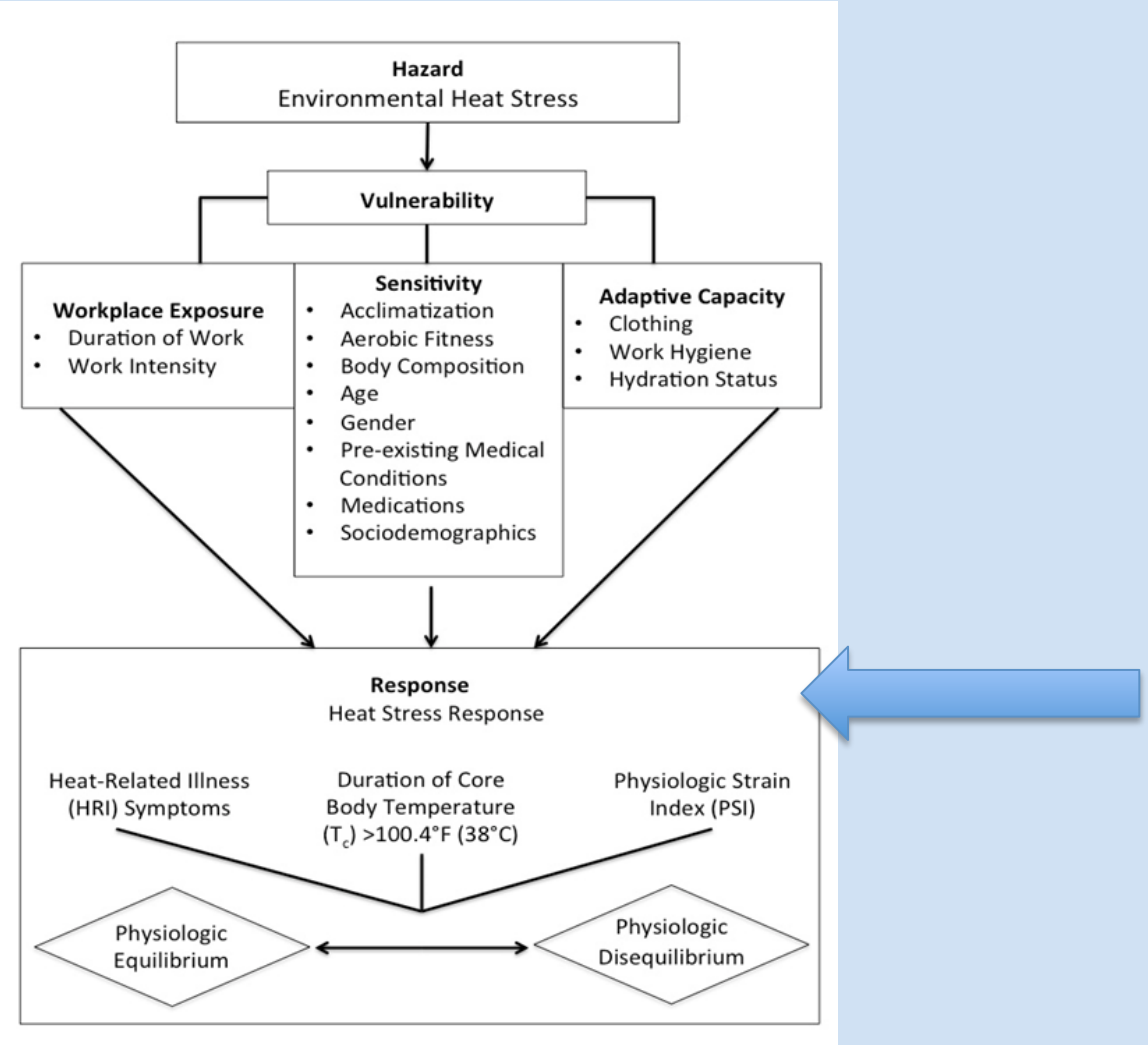
Response


Hazard
Environmental Heat Stress
Vulnerability
Workplace Exposure
• Duration of Work
• Work Intensity
Sensitivity
• Acclimatization
• Aerobic Fitness
• Body Composition
• Age
• Gender
• Pre-existing Medical Conditions
• Medications
• Sociodemographics
Adaptive Capacity
• Clothing
• Work Hygiene
• Hydration Status
Response
Heat Stress Response
Heat-Related Illness (HRI) Symptoms
Duration of Core Body Temperature (T_c) >100.4°F (38°C)
Physiologic Strain Index (PSI)
Physiologic Equilibrium
Physiologic Disequilibrium

Heat Related Illness Symptoms

- On the post-work survey, workers reported HRI symptoms experienced during their workday:
  - Excessive sweating
  - Headache
  - Dizziness
  - Nausea/Vomiting
  - Muscle Cramps
  - Confusion
  - Fainting
- **84.3%** of workers reported at least one symptom, **42.3%** reported two or more symptoms, and **18.6%** reported three or more

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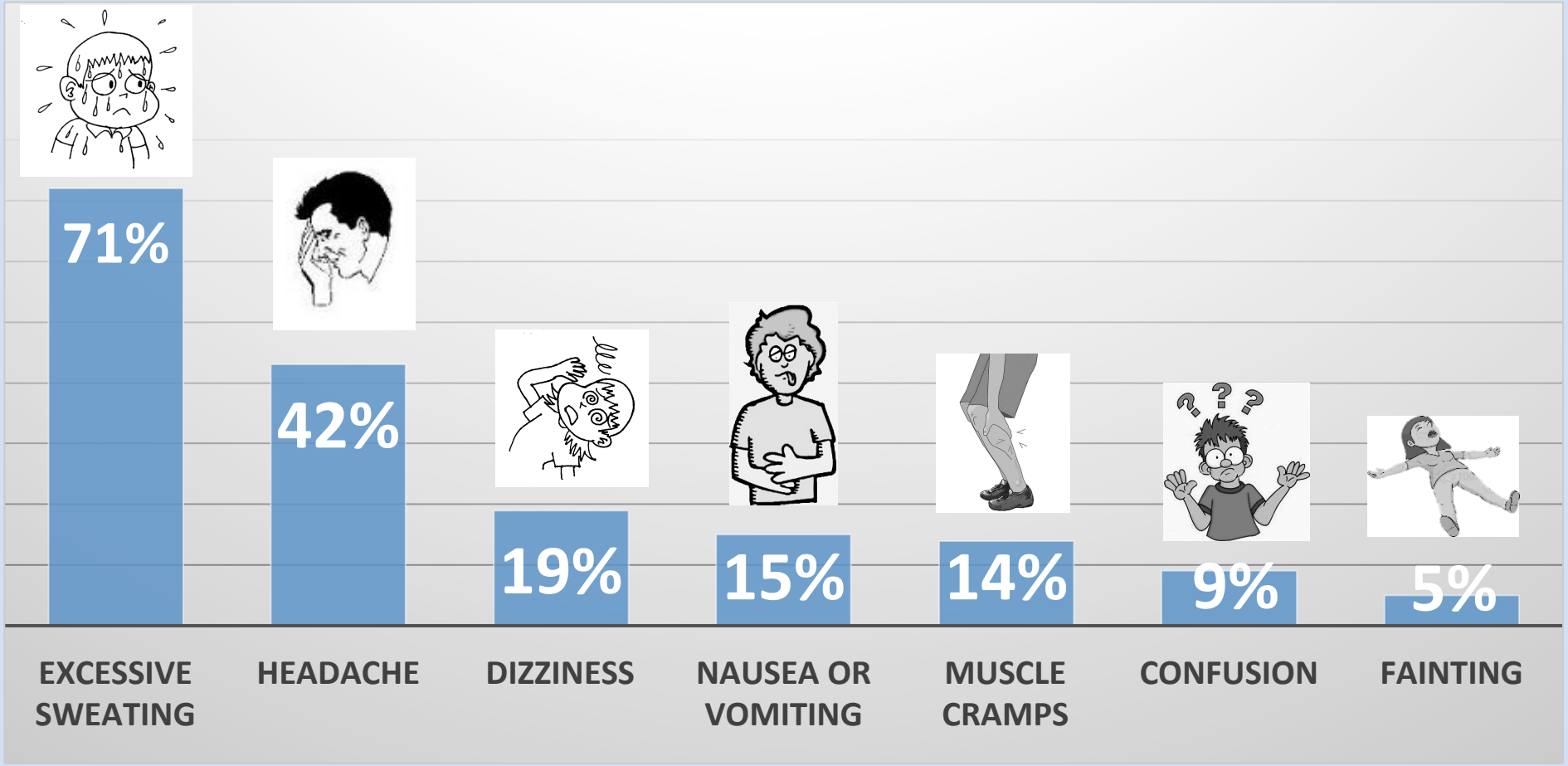
Heat-Related Illness Symptoms During Work



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JOURNAL OF NURSING SCHOLARSHIP

CLINICAL SCHOLARSHIP

Classification of Heat-Related Illness Symptoms Among Florida Farmworkers

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Key words
Adult health/adult care, community/public health/environmental health, environmental health, health disparities, work environment/working conditions

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Abstract

Background: Farmworkers working in hot and humid environments have an increased risk for heat-related illness (HRI) if their thermoregulatory capabilities are overwhelmed. The manifestation of heat-related symptoms can escalate into life-threatening events. Increasing ambient air temperatures resulting from climate change will only exacerbate HRI in vulnerable populations. We characterize HRI symptoms experienced by farmworkers in three Florida communities.

Methods: A total of 198 farmworkers enrolled in 2015–2016 were asked to recall if they experienced seven HRI symptoms during the previous work week. Multivariable logistic regression was used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) for the association between selected sociodemographic characteristics and reporting three or more symptoms. Latent class analysis was used to identify classes of symptoms representing the HRI severity range. We examined sociodemographic characteristics of the farmworkers across the latent classes.

Results: The mean age (±*SD*) of farmworkers was 38.0 (±8) years; the majority were female (60%) and Hispanic (86%). Most frequently reported symptoms were heavy sweating (66%), headache (58%), dizziness (32%), and muscle cramps (30%). Females had three times the odds of experiencing three or more symptoms (OR = 2.86, 95% CI 1.18–6.89). Symptoms fell into three latent classes, which included mild (heavy sweating; class probability = 54%), moderate (heavy sweating, headache, nausea, and dizziness; class probability = 24%), and severe (heavy sweating, headache, nausea, dizziness, muscle cramps; class probability = 22%).

Conclusions: Farmworkers reported a high burden of HRI symptoms that appear to cluster in physiologic patterns. Unrecognized accumulation of symptoms can escalate into life-threatening situations if untreated. Our research can inform interventions to promote early recognition of HRI, on-site care, and appropriate occupational health policy. Administrative or engineering workplace controls may also reduce the manifestation of HRI.

Mutic, A.D., Mix, J.M., Elon, L., Mutic, N.J., Economos, J., Flocks, J., Tovar-Aguilar, A.J. and McCauley, L.A., 2018. Classification of Heat-Related Illness Symptoms Among Florida Farmworkers. *Journal of nursing scholarship*, *50*(1), pp.74-82.

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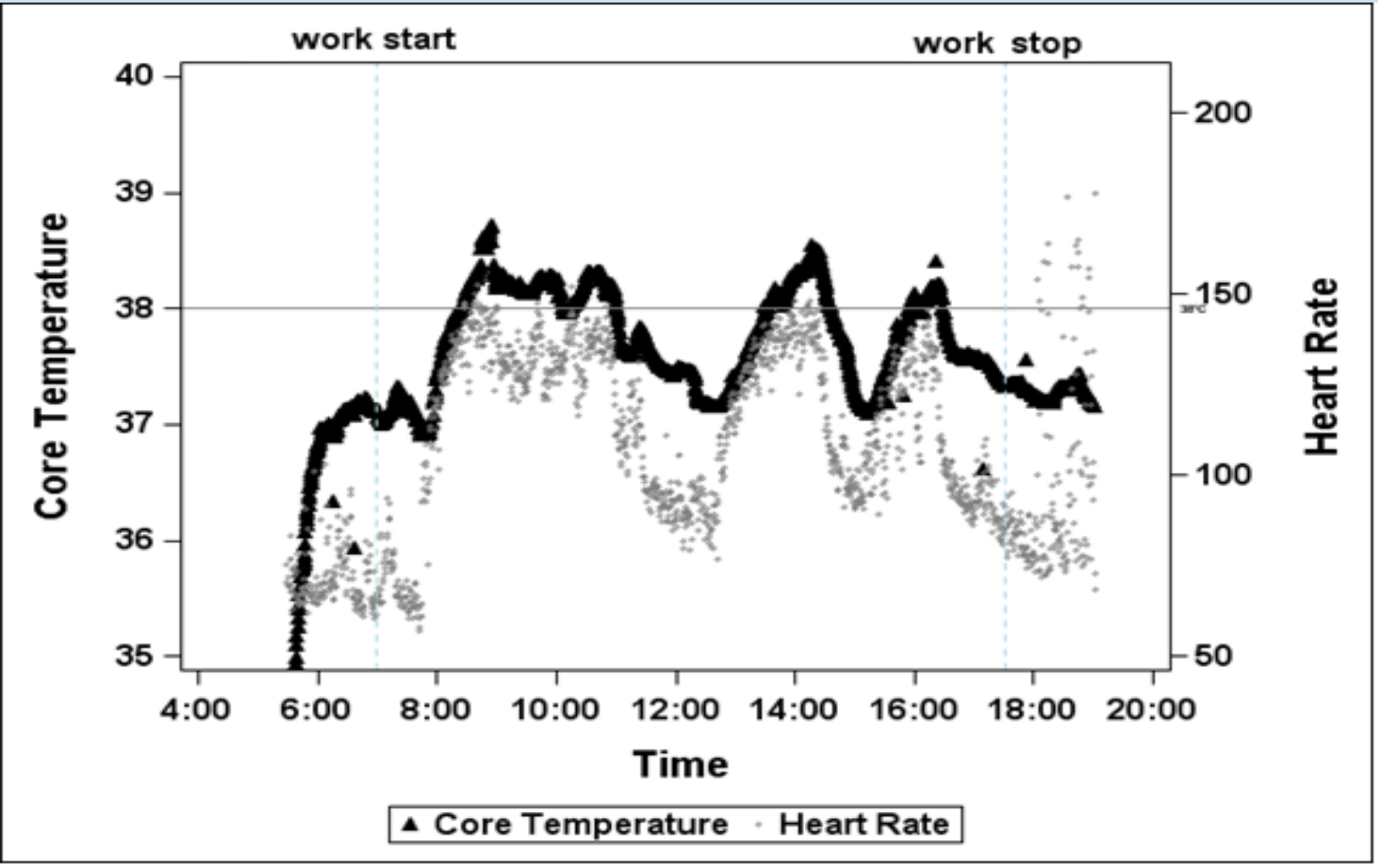
Body Temperature & Heart Rate in One Worker



- Recorded every 30 seconds
- 2 consecutive readings over 38.0C or 38.5C considered exceeding physiologic limit threshold
- Temperature or Heart Rate file removed if >20% of data points missing

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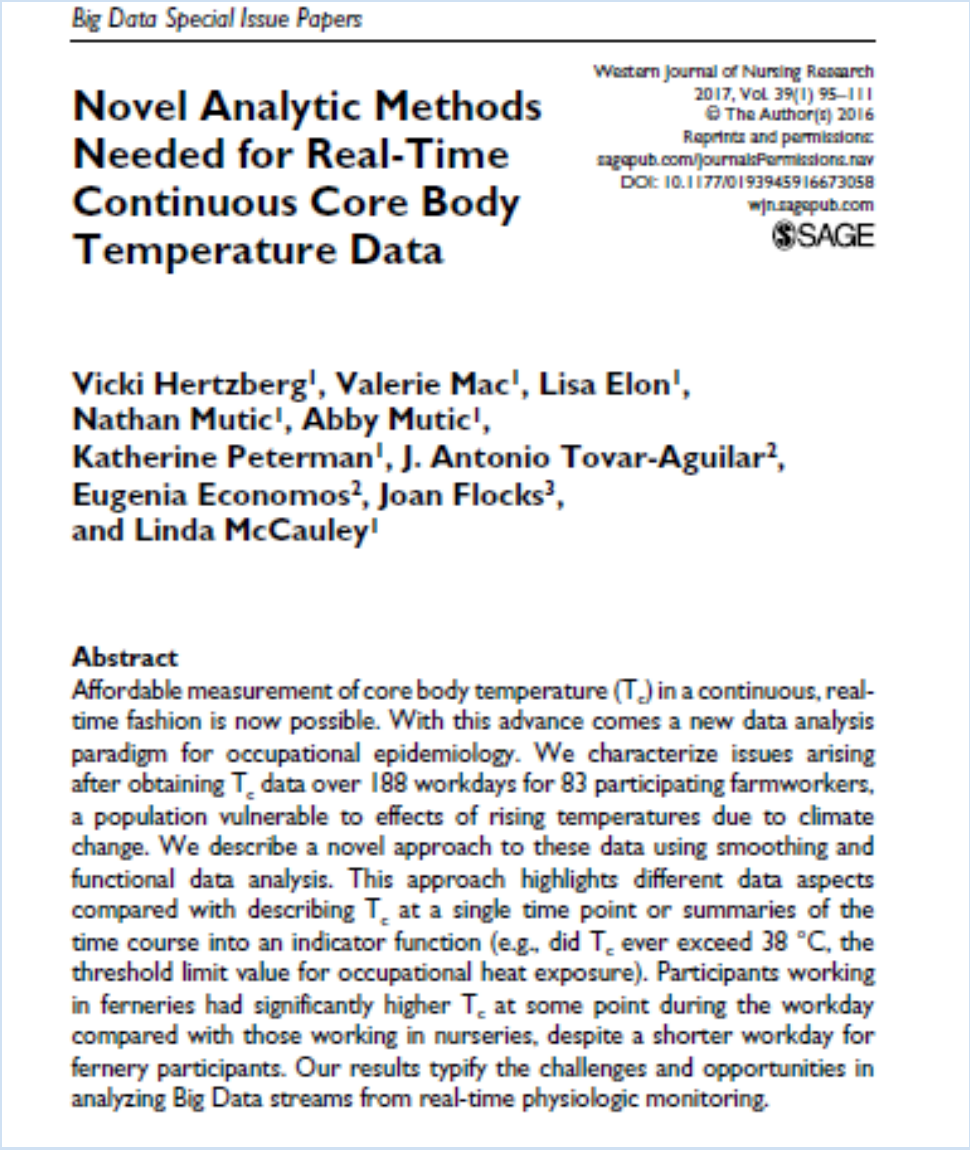
Methods for Analyzing Real-Time Data



Big Data Special Issue Papers

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Novel Analytic Methods Needed for Real-Time Continuous Core Body Temperature Data

Vicki Hertzberg[1], Valerie Mac[1], Lisa Elon[1], Nathan Mutic[1], Abby Mutic[1], Katherine Peterman[1], J. Antonio Tovar-Aguilar[2], Eugenia Economos[2], Joan Flocks[3], and Linda McCauley[1]

Abstract

Affordable measurement of core body temperature (T_c) in a continuous, real-time fashion is now possible. With this advance comes a new data analysis paradigm for occupational epidemiology. We characterize issues arising after obtaining T_c data over 188 workdays for 83 participating farmworkers, a population vulnerable to effects of rising temperatures due to climate change. We describe a novel approach to these data using smoothing and functional data analysis. This approach highlights different data aspects compared with describing T_c at a single time point or summaries of the time course into an indicator function (e.g., did T_c ever exceed 38 °C, the threshold limit value for occupational heat exposure). Participants working in ferneries had significantly higher T_c at some point during the workday compared with those working in nurseries, despite a shorter workday for fernery participants. Our results typify the challenges and opportunities in analyzing Big Data streams from real-time physiologic monitoring.

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Core Temperatures 2015-2017

<u>82% reached 38.0°C</u>

Length of time over 38.0°C

Median= 69 minutes

Range = 1-555 minutes

<u>24% reached 38.5°C</u>

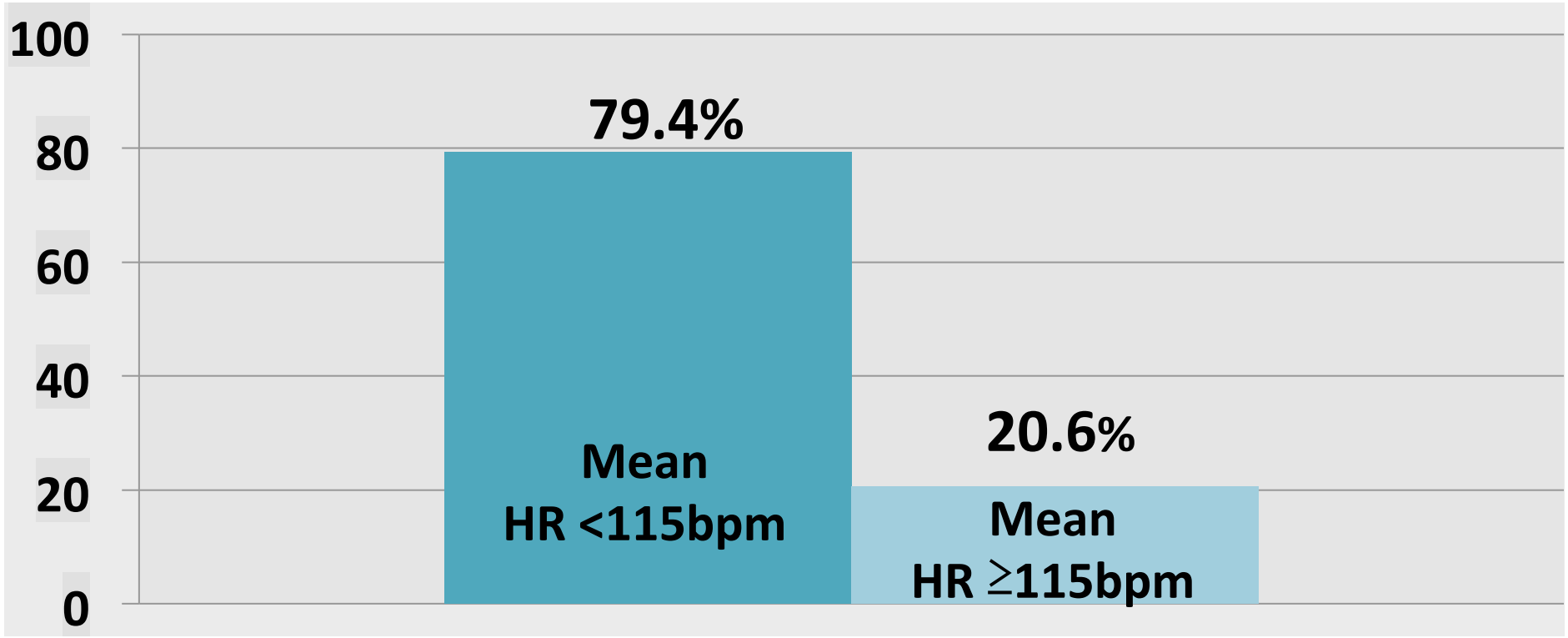
Length of time over 38.5°C

Median= 22 minutes

Range = 1-318 minutes

Heart Rate 2015-2017

% Workers with a Mean Workday Heart Rate (HR) >115 bpm (35% of Maximum Aerobic Capacity) on ≥1 Study Day



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What Vulnerability Factors Predict the Heat Response?

- Hydration Status
- Work Intensity
- Gender, Age, BMI
- Medical Conditions
- Breaks and Shade

Physiologic Response to Heat: Core Temperature >=38°C

Significant Risk Factors:

	Change in odds of T≥38	95% CI
Model considered Work Intensity		
Per 10 Minutes Mod/Vig Activity	5% increase	2% - 8%
Per 1 unit BMI	7% increase	1% - 13%
Per 5°F Mean Heat Index	27% increase	4% - 56%
Model considered Dehydration		
Per .010 Urine Specific Gravity in pm	47% increase	8% - 101%
Per 1 unit BMI	6% increase	1% - 12%
Per 5°F Mean Heat Index	26% increase	3% - 54%

Physiologic Response to Heat: Core Temperature >=38.5°C

Significant Risk Factors:

	Change in odds of T≥38.5	95% CI
Model considered Work Intensity		
Per 10 Minutes Mod/Vig Activity	4% increase	0% - 7%
Per 1 year Working in Agriculture	8% decrease	(-13)% - (-3)%
Per 1 unit BMI	17% increase	7% - 27%
Per 5°F Mean Heat Index	39% increase	2% - 89%
Male (compared to Female)	142% increase	20% - 386%
Model considered Dehydration		
Dehydration was not a significant predictor of T≥38.5; other results similar		

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Heat Exposure and Kidney Function

Kidney Function: 2015-2016

Biomarker	Before Work[1]	After Work[1]	p value[2]
Serum Creatinine, mean	0.70 ± 0.13	0.80 ± 0.013	<.0001
eGFR, mean	115.2 ± 0.94	104.7 ± 0.94	<.0001
eGFR <90	3%	20%	<.0001
BUN, mean	14.4 ± 0.29	15.8 ± 0.29	<.0001
Serum Potassium, mean	4.4 ± 0.02	4.2 ± 0.02	<.0001
Serum Sodium, mean	141.0 ± 0.11	141.2 ± 0.11	.01

[1]n participants for day 1 was n = 248 , day 2 was n = 243, and day 3 was n = 228
[2]adjusted for random effects due to multiple participants in households and multiple days per participant

Chronic Kidney Disease of Unknown Etiology (CKDu)

- Affecting agricultural workers around the globe
- Mainly sugar cane industry
- Primarily young men in seemingly good health
- Need for dialysis in 30's and 40's
- > 20,000 premature deaths in Central America alone

- California Heat Illness Prevention Study (CHIPS) (n=295)
  - 12% with acute kidney injury over the course of one day at work

AKI in Girasoles

Presence of AKI:

- 36% of participants had the criteria indicating AKI on at least one workday

Stages of AKI:

- 32% had **stage 1 AKI** on at least one workday
- 3% had **stage 2 AKI** on at least one workday
- 0.4% had **stage 3 AKI** on at least one workday

- The odds of AKI increased 22% for each 5 bpm increase in mean heart rate and 37% for each 5 degree (°F) increase in mean heat index

(KIDIGO Criteria: Increase of post-shift serum creatinine by at least 0.3 mg/dL OR ≥ 1.5 times the pre-shift creatinine)

Analyses/Papers in Progress

- Predictors for Heat Stress Symptoms and Core Body Temperatures
- Overall Health Status and Work Behaviors as Predictors of Heat Response
- Quantifying Occupational Work Intensity and Heat Stress Response
- Seasonal Differences in Work Intensity and Heat Stress Response

****Community Translation of Research Findings*****

Next Steps

- Pilot testing interventions to reduce heat related illness
- Metabolomic analysis of workers with heat exposure
- Heat exposure and the microbiome

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Thank you!