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Examining the efficacy and feasibility of implementing an electrolyte hydration intervention among agricultural workers

By

Liris Stephanie Berra
Master of Public Health

Hubert Department of Global Health

Dr. Amy Webb Girard
Committee Chair

Dr. Roxana Chicas
Committee Member

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Liris Stephanie Berra

B.S.
University of Miami
2018

Thesis Committee Chair: Dr. Amy Webb Girard, PhD

An abstract of
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Rollins School of Public Health of Emory University
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Abstract

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Background: Farmworkers are amongst one of the most vulnerable populations in the United States; a myriad of structural, social, and occupational conditions expose significant health disparities. Of these, occupational heat exposure is particularly concerning due to rising global environmental temperatures. These hot environmental temperatures place farmworkers at a significant risk for experiencing dehydration and consequently heat-related illness (HRI).
Objective: To estimate the prevalence of dehydration/HRI and current hydration practices among agricultural workers in central Florida. To determine the efficacy and feasibility of an electrolyte intervention to prevent dehydration and HRI.
Methods: Prevalence estimates were calculated from parent study sample (n=88). Pilot participants were randomized to a water group (n=16) or an electrolyte group (n=14) who received 169oz (5L) of the respective beverage. A logistical regression model was utilized to calculate odds ratios and a thematic analysis was conducted from post shift interviews to identify barriers/facilitators to beverage consumption.
Results: At post shift, 46% of the study sample was dehydrated or severely dehydrated and 42% experienced at least one HRI symptom (n=88). Among electrolyte group participants, the odds of dehydration were 13.4 (95% CI =(1.17,152.95) times higher and the odds of experiencing heat related illness was 0.72 (95% CI =(0.07, 7.27) times 9lower. Taste, feelings of wellness/energy, and the beverage container were identified as facilitators to beverage consumption. Factors identified as barriers were taste, increased urination, and beverage temperature.
Discussion: Regional variations exist; however, prevalence estimates confirm that findings confirm that the prevalence of HRI and dehydration is high. Hydration practices were consistent with other study findings, consumption of sugar sweetened beverages during work is a significant concern. Findings surrounding hydration status and consumption of electrolyte beverages is inconsistent with other studies that have found electrolytes to maintain adequate hydration status in outdoor workers. Failure of randomization to control and water group, differences in explanatory variables, and the electrolyte solution formula could be contributing factors to the discrepancy. Findings suggest that electrolytes may be protective against experiencing HRI. Further research with a larger sample size should be conducted to identify the optimal rehydration formula for agricultural workers laboring in hot conditions.

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Table of Contents

Glossary of Acronyms

AKI	Acute Kidney Injury
ANPRM	Advance Notice of Proposed Rulemaking
CKDu	Chronic Kidney Disease of Uknown Etiology
eGFR	Estimated Glomerular Filtration Rate
FWAF	Farmworker Association of Florida
HI	Heat Index
HRI	Heat Related Illness
NAWS	National Agricultural Worker Survey
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety & Health Administration
RM	Rhabdomyolysis
USG	Urine Specific Gravity

Chapter 1: Introduction

Rationale

Farmworkers are amongst one of the most vulnerable populations in the United States (U.S.); a myriad of structural, social, and occupational conditions expose significant health disparities (National Center for Farmworker Health, 2020). Of these, occupational heat exposure is particularly concerning due to rising global environmental temperatures (Fenske & Pinkerton, 2021; Pal et al., 2021). These hot environmental temperatures place farmworkers at a significant risk for experiencing heat-related illness (HRIs) (Quandt & Arcury, 2009). In addition to HRIs, kidney disease has become a growing concern, with the rise in cases of chronic kidney disease of unknown etiology (CKDu) that has presented itself in agricultural communities across several countries (Gifford et al., 2017). Recently it has been suggested that the United States might be a growing hot spot for CKDu due to the incidence of acute kidney injury (AKI) in farmworkers (Aguilar & Madero, 2019). A complex relationship between HRIs, CKDu, and AKI exists which will be further explored in the literature review, integral to this relationship is dehydration. Recommendations set forth by regulation regulating bodies such as National Institute for Occupational Safety and Health (NIOSH) and Occupational Safety & Health Administration (OSHA) recommend drinking water and electrolyte beverages to remain hydrated (National Institute for Occupational Safety and Health, 2016; Occupational Safety & Health Administration, n.d.). However, there are no specific recommendations on the type and quantity of electrolyte beverages that should be consumed. To date, few studies have evaluated the impact of consuming electrolyte beverages and health outcomes with farmworkers working under hot climatic conditions (Butler-Dawson et al., 2019; Krisher et al., 2020) There is a need to understand the effects of drinking an electrolyte beverage on hydration status and health outcomes, and the feasibility of implementing an intervention promoting the consumption of beverages among farmworkers.

Purpose Statement

The purpose of this study is to evaluate the feasibility and impact of implementing an electrolyte intervention to prevent dehydration and heat-related illness among agricultural workers.

Research Questions & Aims

The following research questions (RQ) and aims (A) guide this study:

RQ1: What are current hydration practices, the hydration status, and the prevalence of heat-related illnesses among agricultural workers in Central Florida?

A1.1: Characterize the hydration practices of agricultural workers in Central Florida.

A1.2: Estimate the hydration status of a sample of agricultural workers in Central Florida.

A1.3: Estimate the prevalence of self-reported heat related illness symptoms of agricultural workers in Central Florida.

RQ2: What is the effect of an electrolyte intervention on hydration status and self-reported heat-related illness symptoms?

A2.1: Determine if hydration status differed between those randomized to an electrolyte vs water beverage .

A2.2: Determine if the number of self-reported heat related illness symptoms differed between those randomized to an electrolyte vs water beverage.

RQ3: What is the feasibility of implementing an electrolyte hydration intervention amongst agricultural workers?

A3.1: Identify perceived barriers and facilitators to implementing an electrolyte intervention amongst agricultural workers.

Significance Statement

The findings of this study could contribute to the evidence base used by regulating bodies to develop recommendations for the prevention of heat related illness among agricultural workers.

Definition of Terms

Acute Kidney Injury: An abrupt and rapid decrease in kidney function which encompasses injuries involving both structural damage and loss of function. (National Kidney Foundation, 2015)

Agricultural Worker: Hired workers who are employed for labor in agricultural settings. In this study, participants are agricultural workers who are employed in either a ferneries, nurseries, or crop and hence agricultural worker will be utilized when discussing the study in Chapter 3. (U.S. Department of Agriculture, 2021)

Chronic Kidney Disease of Unknown Etiology: A type of chronic kidney disease that presents itself suddenly in primarily young male agricultural workers who perform strenuous labor in extreme conditions of heat. This disease has also been termed Meso-American Nephropathy. (Gifford et al., 2017)

Electrolytes: Minerals existing in the body, such as sodium, calcium, potassium, chloride, phosphate, and magnesium, that are ingested from consumption of foods and beverages. (American College of Sports Medicine et al., 2007)

Farmworker: The USDA defines farmworkers as hired workers who encompass a variety of occupations such as crop workers, nursery workers, livestock workers, graders and sorters. In the literature review, information, data, statistics, and epidemiological findings will be presented surrounding farmworkers as much of the data is reported as per the USDA's definition of farmworker. (U.S. Department of Agriculture, 2021)

Heat-Related Illness: A continuum of diseases that are due to exposure to heat that range from mild symptoms to death from heat stroke. Types of Heat Related Illnesses (HRIs) include heat exhaustion, heat syncope, heat cramps, and heat rash, heat exhaustion, and heat stroke. (Centers for Disease Control and Prevention, 2020)

Hydration Status: The state of hydration that a person is experiencing. Dehydration is the state of the body experiencing excess water loss. One of the mechanisms used to measure hydration status is urine specific gravity. (Lacey et al., 2019)

Heat Index: A measurement that delineates what the environmental temperature feels like to the human body when relative humidity is combined with the air temperature. (National Oceanic and Atmospheric Administration, n.d.)

Estimated Glomerular Filtration Rate: A measure of the kidney's filtration rate that is used to estimate kidney function. (National Kidney Foundation, 2017)

Serum Creatinine: A waste product that is filtered through the kidneys and excreted in urine. Serum creatinine levels above 1.2 typically indicate kidney issues. (National Kidney Foundation, 2017)

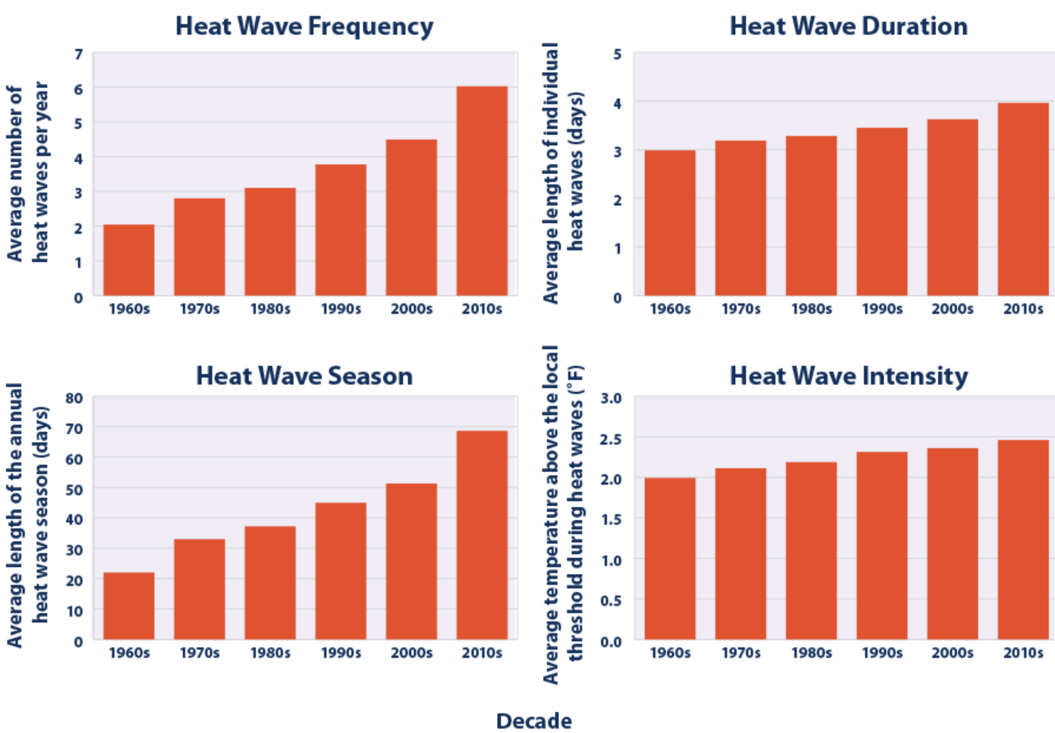
Urine Specific Gravity: A test compares that works by comparing the density of urine to the density of water. This test can be utilized to measure hydration status as well as optimal kidney function. (Lacey et al., 2019)

Chapter 2: Review of the Literature

Introduction

From June to July of 2021, record breaking temperatures resulting from an incredibly strong heat wave were observed across the Pacific Northwest (Templeton & Samayoa, 2021). A study conducted by scientists across the United States, Canada, the United Kingdom, Netherlands, France, Germany and Switzerland found that this heat wave is a testament to human-induced climate change and they predict that these extreme heat events will continue if global warming continues (World Weather Attribution, 2021). As can be seen from Figure 1, the number of heat waves and duration of the heat wave season has increased significantly, similarly the duration and intensity have moderately increased since 1961(Environmental Protection Agency, 2021).

Figure 1. Heat wave characteristics in the United States by Decade, 1961-2019



The most recent heatwave resulted in more than 1,400 deaths across the United States and Canada, including at least one known farmworker who died of heat stroke while working at a nursery in Oregon (Selsky, 2021; Templeton & Samayoa, 2021). In response to the event, both

Oregon and Washington state issued emergency heat protection rules that mandated cooldown breaks for workers working in extreme heat conditions (Bernton, 2021; Selsky, 2021). Climate change poses an incredible risk to this already vulnerable population. In this review, the unique social and occupational context of farmworkers will be explored through a situational analysis, the relationship between various biological mechanism that result from heat stress will be explained, a summary of existing efforts to mitigate the effects of working in the heat will be presented, and a view of the unique local context of farmworkers in Florida.

Agricultural & Farmworker Situational Analysis

Overview

The National Center for Farmworker Health estimates that there are approximately 2.5 to 3 million hired farmworkers in the United States (National Center for Farmworker Health, 2020). While farmworkers are critical to the trillion dollar agricultural industry, they encompass less than 1% of all wage and salary workers in the U.S. (National Center for Farmworker Health, 2020; U.S. Department of Agriculture, 2021). Despite the critical role they play in the United States food system they are subject to a series of structural, social, and occupational conditions that contribute to significant health disparities. In this section a demographic profile of farmworkers will be presented followed by a discussion of these factors and their role in the health outcomes of the population.

Demographic Profile

Most farmworkers are Latino/Hispanic immigrants from Mexico and Central America. While determining legal status is challenging, it is estimated that nearly half of these workers are not authorized to work in the United States. (U.S. Department of Agriculture, 2021) Findings from the National Agricultural Workers Survey (NAWS), indicate that the age of farmworkers has gradually increased over time with the current average age of 41 (U.S. Department of Labor, 2021). While an estimated 69% of farmworkers are male, there has been a steady increase of female workers since 2006 (U.S. Department of Agriculture, 2021; U.S. Department of Labor, 2021).

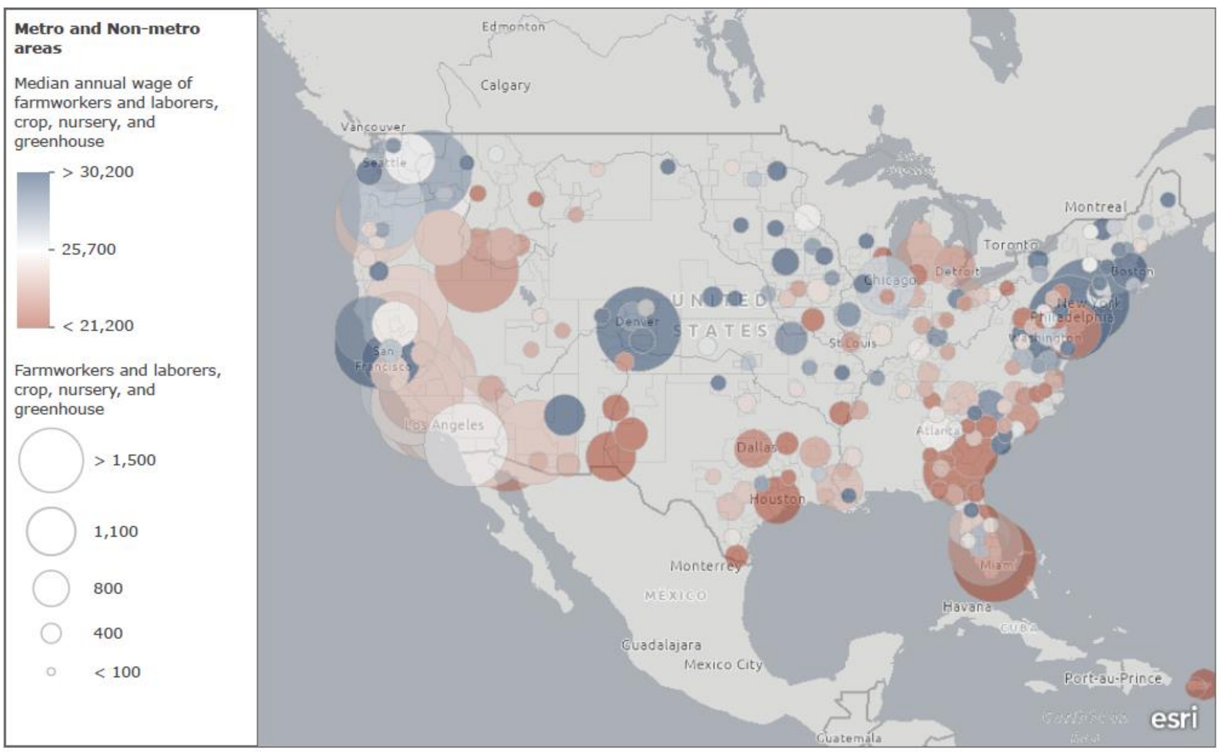
Estimates from the NAWS indicated that about half of workers are married (57%) and are parents (50%). Most adults did not complete higher than a 12^{th} grade education (86%) and over three-quarters of the population does not speak English. Among the population, literacy levels in Spanish are high with 78% indicating they read Spanish well and lower English literacy with 35% indicating they read English well. (U.S. Department of Labor, 2021)

The 2019 American Community Survey indicated that most farmworkers reside in the Pacific region of the United States which includes Washington, Oregon, and California. The second largest concentration of workers is in the South Atlantic region consisting of states such as North Carolina, South Carolina, Georgia, and Florida (U.S. Department of Agriculture, 2021). Historically, farmworkers in the United States have followed crop productions through regional migrant streams (Western, Midwestern, and Eastern regional streams). However, increasingly they have become settled with an estimated 87% of workers residing in one location as of 2018 (U.S. Department of Labor, 2021).

Structural, Social, and Occupational Conditions

Farmworkers are among one of the most vulnerable populations in the United States. Several structural and social conditions coupled with occupational hazards and exposures contribute to the vulnerability of this population.

Figure 2. The number of farmworkers employed across the United States layered with average annual wages based on data from the Labor of Bureau Statistics



As a whole, farmworkers are the lowest compensated workers in the industry making an average hourly wage of $14.64 – across the nation this wage seldom exceeds minimum wage and at times falls below minimum wage (Quandt & Arcury, 2009; U.S. Department of Agriculture, 2021). As can be seen in Figure 2, large populations of farmworkers exist across the United

States with annual salaries under $21,200 (Berry, 2019). These low income levels have led to a poverty rate of 21 % which is nearly double the current national poverty rate of 11.4% (US Census Bureau, 2021; U.S. Department of Labor, 2021). High poverty rates among farmworkers contribute to overcrowding in households with an estimated 26 % of individuals living in a crowded home (Marsh et al., 2015; U.S. Department of Labor, 2021). While there is large variability in the state and type of dwellings that farmworkers reside in, the physical conditions are often inadequate with many consisting of faulty electrical and plumbing systems, lacking facilities for food storage and preparation, and containing biological and chemical toxins such as molds and lead (Quandt & Arcury, 2009). Poor housing quality in combination with overcrowding has profound negative effects on both physical and mental health (Quandt et al., 2015).

Beyond the household level, farmworker communities are exposed to racism that leads several systematic issues such as over policing and lack of adequate infrastructure like sidewalks. The communities are often near farming industries which produce noisy, dirty, and toxic living environments all which contribute to an unhealthy environment. (Marsh et al., 2015) As many neighborhoods are isolated, access to essentials such as grocery stores and parks is another significant issue (Quandt et al., 2015). Isolation promotes issues of food security and ability to seek medical care in these populations further negatively impacting health and well-being of farmworkers and their families (Arcury & Quandt, 2007; Quandt et al., 2004).

Coupled with the lack of access to health facilities, agricultural and farmworkers are largely uninsured further acting as a barrier to seek healthcare. According to the NAWS of those whom visited a health clinic in the last two years, over half were uninsured. (U.S. Department of Labor, 2021) In addition to cost, language barriers, fear of the medical system, a complex healthcare systems, and transportation have also been identified as barriers to seeking medical care among farmworkers (Arcury & Quandt, 2007). High poverty rates, low wages, inadequate housing, and barriers to medical care all contribute to elevated stress among agricultural and farmworkers. Other identified stressors include difficult physical nature of work, long hours with no days off and few to no rest breaks, exploitation from employer, lack of supervision for children, undocumented immigration status, and lack of familiar foods and media. (Hovey & Seligman, 2006)

Aside from these structural and social conditions, this occupational sector is vulnerable to a host of other exposures that contribute to adverse health outcomes. Occupational hazards have been well-documented amongst agricultural workers and include increased rates of musculoskeletal injuries, exposures to pesticides contributing to chronic respiratory diseases, and exposure to extreme heat that contributes to poor health. (National Center for Farmworker Health, 2018).

Musculoskeletal injuries are one of the most common occupational hazards affecting this population (Quandt & Arcury, 2009). A study conducted among farmworkers in California found that chronic musculoskeletal pain is associated with common work positions such as kneeling and bending (Xiao et al., 2013). While the recommended treatment for musculoskeletal injuries is rest and recovery, workers are subject to both internal and external pressures to continue working and utilize home remedies or over the counter anti-inflammatory agents to treat injuries (Quandt & Arcury, 2009). Exposure to pesticides is a significant occupational hazard that contributes to several adverse health outcomes that agricultural workers experience. Among these are reduced lung function, chronic bronchitis, and chronic obstructive pulmonary disease (Nordgren & Charavaryamath, 2018). Further exacerbating pesticide exposure is the lack of enforcement of pesticide safety trainings and the lack of personal protective equipment available when working with pesticides (Quandt & Arcury, 2009).

Of particular concern is the extreme heat exposure that farmworkers experience. Agricultural workers are 35 times more at risk of experiencing heat-related death compared to workers in other industries (Gubernot et al., 2015). The effects of heat exposure on health outcomes of workers will further be explored in later sections.

Heat Stress & Kidney Disease

Overview

Heat exposure as a risk factor interweaves heat stress, heat-related illness (HRIs), chronic kidney disease of unknown etiology (CKDu), and acute kidney injury (AKI). In this section, the biological mechanisms of these diseases and the interrelation of dehydration is described. The epidemiological findings among agricultural and farmworkers of these diseases is also presented.

Biological Mechanisms

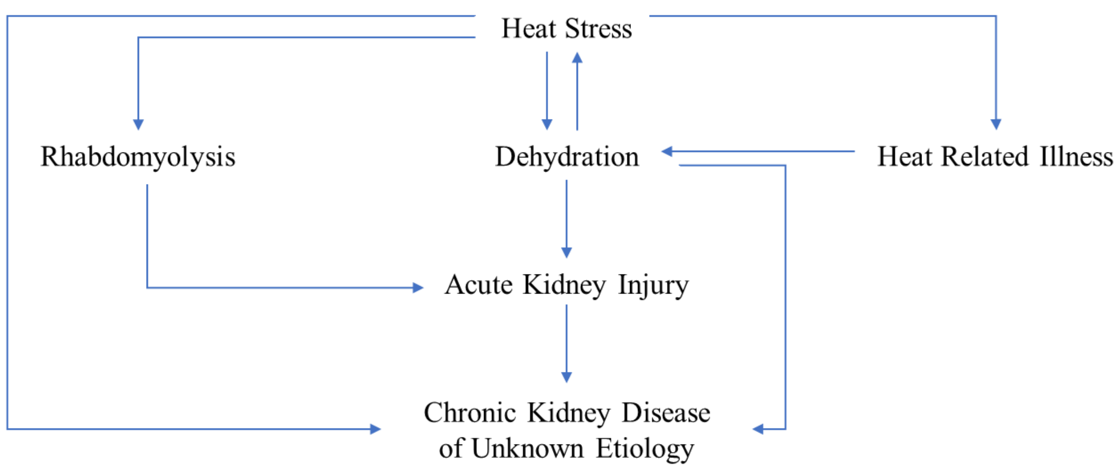
HRI exist along a continuum that ranges from mild symptoms to death from heat stroke. HRI can include symptoms such as heat cramps, heat rash, heat exhaustion, heat syncope, and heat stroke. Some of the common symptoms associated with HRIs include elevated body temperature, headache, nausea, dizziness, heavy sweating, muscle cramps, and abnormally dark urine, and/or decreased urine output. (Centers for Disease Control and Prevention, 2020) Aside from HRIs, prolonged exposure to heat can exacerbate pre-existing chronic conditions such as existing respiratory and cardiovascular diseases (National Institute of Environmental Health Sciences, n.d.).

Exposure to hot temperatures and strenuous work environments has also been theorized to lead to the development of a specific type of kidney disease called chronic kidney disease of unknown etiology (CKDu). A particular concern surrounding CKDu is that it presents itself in young adults who are otherwise seemingly healthy. The nature of the disease onset additionally presents concerns as it begins subtly with symptoms not manifesting until the disease is advanced. (Anupama et al., 2020) While the exact etiology is not known, increased core body temperature and dehydration as a result of heat exposure and physically demanding work are notable possible mechanisms for the development of the CKDu. Studies have also examined the role that AKI might play in contributing to CKDu (Johnson et al., 2019). Studies suggest that AKI and kidney disease are very interconnected (Chawla et al., 2014).

AKI is an abrupt and rapid decrease in kidney function which encompasses both injuries involving structural damage and loss of function (Makris & Spanou, 2016). It can be brought on by a variety of reasons including decreased blood flow, direct damage to the kidney, and blockage of the urinary tract (National Kidney Foundation, 2015). Recently the role that dehydration plays in AKI has been discussed with the emergence of CKDu among agricultural and farmworkers (Roncal-Jimenez et al., 2015). Serum creatinine is a waste product that the kidneys normally remove from the body and when kidney function is impaired then creatine levels rise which can indicate AKI or other diseases of the kidney. Development of AKI over the work shift can be defined using the Kidney Disease Improving Global Outcomes (KDIGO) criteria, where incident AKI over the workday is considered to be present if serum creatinine values after the work shift increased at least 0.3 mg/dL from values before work or the ratio of post- to pre-shift values was ≥ 1.5 (Kellum et al., 2013). From the serum creatine values, the Glomerular Filtration Rate (GFR) can be estimated which measures kidney function by using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation (National Kidney Foundation, 2017). Normal kidney function is an estimated glomerular filtration rate (eGFR) of ≥ 90 mL/min/1.73 m^2. An eGFR of ≤ 90 mL/min/1.73 m^2 indicates reduced kidney function.

Furthermore, resulting from the effects of heat stress is rhabdomyolysis (RM). RM is a clinical syndrome with many causes including heat stress that results in rapid breakdown, rupture, and death of muscle. These damaged muscles then release proteins and electrolytes into the blood that can cause damage to the kidneys. (National Institute for Occupational Safety and Health, 2021) Evidence suggests that AKI can also be induced by RM (Petejova & Martinek, 2014). A simplified relationship between the forementioned diseases is illustrated in Figure 3. As can be seen these key mechanisms are interrelated - core to the relationship between them is dehydration.

Figure 3. A simplified relationship between key biological mechanisms and dehydration leading to acute kidney injury and chronic kidney disease of unknown etiology.



The state of the body experiencing excess water loss is termed dehydration, one becomes dehydrated when water leaves the body through routes such as sweating or urinating (Kavouras, 2002). Prolonged physical activity in the heat increases sweating where loss of water and electrolytes such as sodium, chloride, and potassium can be substantial (Maughan & Shirreffs, 1997). Depletion of water and electrolytes from dehydration can impair the kidneys' ability to function which could lead to diseases such as AKI and CKDu (Feehally & Khosravi, 2015). Dehydration can be measured by assessing hydration status. Some methods for measuring hydration status include changes in body weight and urinary indices. Urinary indices include urine color, urine osmolality and urine specific gravity (USG) (Kavouras, 2002).

Epidemiology of HRI, CKDu, and AKI Among Agricultural and Farmworkers

Farmworkers are at high risk for experiencing heat stress and HRI (Quandt & Arcury, 2009). There have been several studies examining the prevalence of HRI in farmworkers in the United States. One such study conducted with workers in Florida found that 84% of workers reported experiencing one or more symptoms of HRI during a work week (Mutic et al., 2018). A study conducted among Oregon farmworkers found that nearly 30% of participants reported two or more HRI symptoms during the past work week (Bethel & Harger, 2014). A study conducted in North Carolina assessed lifetime history of experiencing HRI symptoms while working in extreme heat, this prevalence was found to be closer to 40% (Mirabelli et al., 2010). Furthermore, elevated core body temperature a pre-cursor to experiencing HRI, has been documented among farmworkers in California. (Moyce et al., 2020) In Florida, 59% of workers were found to have core temperatures greater than NIOSH-recommended core temperature (Tc) thresholds, 38.0 °C [Tc38.5] (Mac et al., 2021). While there appears to be variation across regions, there is consensus among various studies that the prevalence of HRI is high among this population.

Contrary to studies that examine HRI in this population, studies examining CKDu in farmworkers have been predominately outside of the United States. CKDu has been found to exist among workers in many countries including El Salvador, Nicaragua, Costa Rica, Egypt, Sri Lanka, and India (Gifford et al., 2017). In 2013, the Pan American Health Organization (PAHO) called attention to the rising epidemic and entities have continued to raise attention to the rise in CKDu cases (Gifford et al., 2017; Pan American Health Organization, 2013). Of notable concern is the disease among Nicaragua, El Salvador, Costa Rica, and Guatemala and most recently a region of Mexico where the most affected population is young male workers (Aguilar-Ramirez et al., 2021; Gifford et al., 2017). Recently it has been suggested that the United States might be a growing hot spot for CKDu due to the incidence of AKI in farmworkers (Aguilar & Madero, 2019).

However, to date there have been very few studies examining incidence of AKI among farmworkers in the United States (Smith et al., 2021). Findings from these studies indicated that 33% of farmworkers (n=192) in Florida experienced AKI on at least one of the three study days and 12.3% of farmworkers (n=283) in California experienced AKI during the workday (Mix et al., 2018; Moyce et al., 2017). The presence of AKI among this population has also been documented in other regions such as Brazil and Guatemala where respectively, 18.5% (n=28) and 50% (n=517) of the study population experienced AKI over the course of a workday (Butler-Dawson et al., 2019; Paula Santos et al., 2015).

Existing Efforts

Overview

Drinking enough water and remaining hydrated is a key recommended protective factor against HRI (National Institute for Occupational Safety and Health, 2016). In this section, NIOSH's and OSHA's recommendations and regulations surrounding hydration are presented. While limited studies examining hydration among farmworkers exist, those that detail hydration status of other occupational groups exposed to heat are described and one study examining the role of electrolyte beverages among farmworkers is presented.

Recommendations & Regulations

To remain hydrated the National Institute for Occupational Health and Safety (NIOSH) recommends drinking 8 ounces of water every 15-20 minutes. For workers engaging in prolonged sweating that last several hours, NIOSH also recommends drinking sports drinks with balanced electrolytes (Centers for Disease Control and Prevention, 2018). In 2011, OSHA launched the WATER. REST. SHADE. campaign to educate both employers and workers on the dangers of working in the heat. Hydration was one of the principle key safety messages and workers were encouraged to drink water in order to prevent HRI. (Occupational Safety & Health Administration, n.d.)

Despite the NIOSH recommendation, OSHA's campaign did not include messaging on the consumption of beverages containing electrolytes. In the NIOSH's most recent Criteria for a Recommended Standard Occupational Exposure to Heat and Hot Environments, they indicated that "it is advisable to consume a sports drink that contains balanced electrolytes to replace those lost during sweating, as long as the concentration of electrolytes/carbohydrates does not exceed 8% by volume" (National Institute for Occupational Safety and Health, 2016). However, there are no specific recommendations for workers on which electrolytes to consume nor information on which beverages meet those recommendations.

The current regulations surrounding hydration for the agricultural sector are threefold: (1) Potable water shall be provided and placed in locations readily accessible to all employees; (2) the water shall be suitably cool and in sufficient amounts, taking into account the air temperature, humidity and the nature of the work performed, to meet the needs of all employees; (3) the water shall be dispensed in single-use drinking cups or by fountains. (OSHA, n.d.)

Existing Hydration Studies

A very limited body of literature surrounding the effectiveness of hydration interventions in protecting against dehydration and HRI among occupational groups exists (Table 1). Of those studies that were conducted with workers exposed to hot environments, the aims of the studies varied. Some studies aimed to assess the overall hydration status of workers such as a study conducted with construction workers which found that workers exposed to the sun experienced a high level of dehydration (Montazer et al., 2013). Another study examined underground miners who worked under hot environmental conditions and those who did not. The study found that those who experienced thermal stress were dehydrated at the end of their shift. (Brake & Bates, 2003) A similar study conducted with factory workers utilized different environmental temperatures to examine the hydration status of workers when provided with an electrolyte beverage. The study found that workers exposed to hot temperatures who drank an electrolyte beverage had laboratory measurements indicating optimal hydration status. (Ilyas et al., 2018)

While there have been studies that have examined other elements of hydration among farmworkers, to date there are few that examined the role of electrolytes in promoting hydration and protecting against the effects of heat stress. One study conducted with Guatemalan farmworkers across three weeks, consisting of a six-day work week (Krisher et al., 2020). In each workday of the week, farmworkers were provided with an electrolyte solution and at the end of each work week pre and post shift measures were collected. Point-of-care creatinine and weight were collected both pre and post shift, and serum electrolytes, serum and urine osmolality, and serum creatine kinase were collected post shift. The study found that across all study weeks on average workers remained hydrated, reported fewer HRI symptoms as concentration of electrolyte solution increased, and experienced less muscle damage. While the study found that the increase in electrolytes did not have an overall effect on renal function, creatine kinase levels declined significantly each week as the amount of electrolyte consumption increased. (Krisher et al., 2020)

Table 1. Summary of existing hydration studies with non-agricultural outdoor workers

Author & Year	Aim	Study Design	Findings
Montazer, et al. 2013	Assess hydration status by measuring USG	• Exposed vs. Control	• Average USG values were significantly

	among construction workers in Iran	• Exposed group worked in sun, Control group in shade • Both groups provided hydration schedule and followed water consumption schedule	different between control (1.0213, sd=0.0054) and exposed (1.026, sd=0.005) groups ($p < 0.05$)
Ilyas et al. 2018	Evaluate the effects of two different type of fluid intake at the workplace in preventing dehydration among male workers working in a hot and cool environment among factory workers in Indonesia	• Crossover, randomized, double blinded placebo-controlled trial • Controlled hot (36–38°C) and cool (20–22 °C) environments • Both groups received water and electrolyte beverages	• In the hot environment, median electrolyte USG values were significantly higher among those who drank the electrolyte beverage (1.006, min=1.001, max=1.032) compared to those who drank water (1.004, min=1.001, max=1.022) ($p < 0.05$)
Brake & Bates 2003	Examine the hydration status and fluid replacement in industrial shift workers in Australia	• 39 workers USG values were collected pre-shift, mid-shift, and post-shift • 64 workers USG values were collected pre-shift for a comparison group	• There were no differences between USG values at start (1.0251, sd=0.0053), mid, (1.0248, sd=0.0053) and end of shift (1.0254, sd=0.0069)

Local Context

Introduction

The perception many hold of Florida is one of beaches lined with tourist soaking up the sun. However, the reality is that most of inland Florida is largely agricultural land producing the second largest proportion of fruits and vegetables in the United States. To farmworkers across the state, the sun is not a commodity and they describe having to carry the "weight of the sun" on their backs when working in the fields. (La Isla Network, 2018)

Florida Heat

A recent study conducted by John Hopkins, found that across the United States, Florida is the most vulnerable state to the effects of climate change. These effects have already been observed in Florida as temperatures have risen more than 2°F since the beginning of the 20th century (Kunkel, 2022). Many reports show trends of measures of temperature that don't include humidity, a significant contributing factor to the Heat Index (HI) (Kunkel, 2022). However, a novel model that includes humidity as a factor estimates that the number of days where the HI will exceed 100°F will quadruple to 105 days by midcentury (Kunkel, 2022; Staletovich, 2019). These projections have serious implications for a state which already experiences very high rates of HRI (Centers for Disease Control and Prevention, 2014). From 2010 to 2020, 36 outdoor workers died from HRI in the state of Florida (Gorucu et al., 2021). A study analyzing the HRI related morbidity and mortality from 2005 to 2012 across the state of Florida found that the highest rates and counts of HRI were observed among males and those who live in rural counties (Harduar Morano et al., 2016). It is evident that patterns in heat related morbidity and mortality elicit cause for concern for outdoor workers across the state.

Farmworkers in Florida

The Farmworker Association of Florida (FWAF) is the oldest and largest community-based non-profit that works for social and environmental justice with farmworkers across the state (Zheng & Berra, 2022). Their mission is to "build power among farmworker and rural low-income communities, to respond to and gain control over the social, political, economic, workplace, health, and environmental justice issues that impact their lives." With offices in Apopka, Fellsmere, Homestead, Immokalee, and Pierson cities the organization has a strong relationship with farmworkers across the state. (Farmworker Association of Florida, 2022) Estimates from the National Center for Farmworker Health, state that there are approximately 2,978 farmworkers in Volusia county, which is where the Pierson office is located and 3,064 in Orange county, where the Apopka office located (National Center for Farmworker Health, 2017). Despite the large proportion of farmworkers living across the state, very little is known about the living and working conditions at the localized levels.

Discussion

Farmworkers workers are a particularly vulnerable population due to several conditions. The population experiences significant health disparities that are further exacerbated by occupational exposures. With rising global temperatures, exposure to heat is of particular concern, specifically in areas such as Florida where heat related morbidity and mortality is already high. A relationship exists between dehydration, HRI and kidney diseases such as AKI and CKDu. There is evidence that agricultural workers experienced increased rates of HRI, AKI, and CKDu. Hydration is shown to be a protective factor against these and regulating bodies such as OSHA encourage hydration. Recommendations from the NIOSH also propose that workers exposed to heat consume electrolyte beverages to protect against HRI.

While research has been conducted examining the role of hydration among occupational groups exposed to heat, limited studies have been done with farmworkers. Even fewer studies have been conducted examining health outcomes associated with electrolyte beverages. To date, only one study has examined the role of electrolytes and heat-related illness among farmworkers. There exists a gap in the literature that examine the effects of electrolyte beverages have on protecting workers from HRI and AKI. More studies are needed to examine the effectiveness of electrolyte beverages as a protective factor against key health outcomes such as dehydration and HRI.

Chapter 3: Manuscript

Abstract

Objective: To estimate the prevalence of heat-related illnesses (HRI) and dehydration among agricultural workers in Florida and determine the impact/feasibility of an electrolyte intervention to prevent dehydration and HRI.

Methods: Workers were randomized to a water group (n=16) or an electrolyte group (n=14) who received 169oz (5L) of the respective beverage. A logistical regression model was utilized to calculate odds ratios and a thematic analysis was conducted to identify barriers/facilitators to beverage consumption.

Results: The odds of dehydration were 13.4 (95% CI =(1.17,152.95) times higher and the odds of experiencing heat related illness was 0.72 (95% CI =(0.07, 7.27) lower among electrolyte group participants. Taste can act as a barrier/facilitator and highlighting benefits such as increased energy can act as a facilitator to increase uptake of an electrolyte beverage.

Conclusions: The recommended WHO solution was not found to protect workers against dehydration but may be protective against HRI, however, implementing an electrolyte intervention to protect against other health outcomes is feasible.

Introduction

The National Center for Farmworker Health estimates that there are approximately 2.5 to 3 million hired agricultural workers in the United States. [1] Despite the critical role they play in contributing to the $134.7 billion food industry, they are among one of the most vulnerable populations in the country. [1,2] A myriad of social, structural, and occupational conditions contribute to inequitable health outcomes. [3,4] Of the many occupational hazards that agricultural workers face, heat exposure is particularly concerning due to rising global environmental temperatures from climate change. With the increasing number of high heat days, agricultural workers face an increased risk for heat-related illness (HRI). [5,6]

There have been several studies examining the prevalence of HRI in farmworkers across the United States. A study conducted among Oregon farmworkers found that nearly 30% of participants reported experiencing two or more HRI symptoms in one work week. [7] In North Carolina, the prevalence of experiencing two or more HRI symptoms during agricultural work was found to be closer to 40% [8]. One study conducted with agricultural workers in Florida found that 84% of workers reported experiencing one or more symptoms of HRI across one work week [9]. Furthermore, a study examining fatalities reported by the Bureau of Labor Statistics found that the agricultural industry has more than 35 times the risk of experiencing heat-related death compared to other industries [10].While there appears to be variation across regions, there is consensus among various sources that the prevalence of HRI is high among this population.

HRI exists along a continuum, ranging from mild symptoms to death from heat stroke. Common symptoms associated with HRI include elevated body temperature, headache, nausea, dizziness, heavy sweating, muscle cramps, and abnormally dark urine, and/or decreased urine output. [11] To remain hydrated and prevent HRI the National Institute for Occupational Health and Safety (NIOSH) recommends drinking 8 ounces of water every 15-20 minutes. For workers engaging in prolonged sweating that last several hours, the NIOSH also recommends drinking sports drinks with balanced electrolytes. [12] However, there is no guidance on which electrolytes to consume, nor information on which beverages meet those thresholds. [13]

To date, only a single study has explored the relationship between electrolyte beverages and agricultural workers health outcomes. This three-week efficacy trial conducted in Guatemala provided farmworkers with a daily electrolyte solution and collected pre and post shift urine and blood samples. The study found that as the concentration of electrolyte solution increased, farmworkers experienced less dehydration and less muscle damage and reported fewer HRI symptoms. [14] To our knowledge, no such studies have been conducted in the United States.

This study aimed to (1) characterize hydration practices and estimate the hydration status and prevalence of heat-related illnesses among agricultural workers in Florida; (2) determine the effectiveness of electrolytes in preventing dehydration and reducing the number of heat-related illness symptoms; and (3) determine the feasibility of implementing an electrolyte intervention among agricultural workers in Florida.

Methods

Population and Design

The sample for this hydration pilot study comprises 30 agricultural workers participating in a larger longitudinal parent study (CDC/NIOSH R01OH01178201). Briefly, the longitudinal parent study aimed to examine kidney function among agricultural workers over the course of two harvest seasons in Apopka and Pierson, Florida. Inclusion criteria for the parent study included being between the age of 18 to 49 and working in the agricultural sector for at least the last 4 weeks at the time of enrollment. Those that reported being pregnant, had type I or 2 diabetes mellitus, were under treatment for hypertension, or reported a history of glomerulonephritis, pyelonephritis, renal calculi, or a snake bite were excluded.

A convenience sample of agricultural workers who planned to work on the scheduled workday were recruited for this pilot study after they completed data collection activities for the parent study. Those who consented were scheduled to return on another workday at which time they were randomized to control (water group) or intervention (electrolyte group). A computer-generated randomization schedule was generated *a priori*, both research staff and participants were blinded to this schedule. Workers were randomized to one of two groups for the trial: a water group (n=16) who received 169oz (5L) of plain water or an electrolyte group (n=14) who received 169oz (5L) of water with an electrolyte solution based on the World Health Organization (WHO) recommended oral rehydration formula (glucose 13.5 grams [g], trisodium citrate dihydrate 2.9g, sodium chloride 2.6g, potassium chloride 1.5g) [15]. At the start of the workday, each participant was provided two 84.5oz (2.5L) water bottles filled with their assigned beverage. The Institutional Review Board at Emory University provided approval for the study and all participants provided oral informed consent. Participants in the pilot hydration study received a $70 gift card at the end of the pilot study workday as remuneration for their time and contributions.

Data Collection and Analysis

At the beginning of the pilot study workday, FWAF Community Health Workers (CHWs) administered a baseline survey in the language of the participant's choosing (Spanish or English) that captured socio-demographic characteristics, work history, general fluid intake and activities during work. At the end of the pilot study workday, the remaining amount of beverage in each bottle was recorded to determine the amount of liquid drank by each participant. FWAF – CHWs administered a post workday survey capturing heat related illness symptoms and a 15-minute electrolyte exit interview. Participants also provided a urine sample. Urine specific gravity (USG) was measured using a digital refractometer (Atago PAL-10S digital refractometer, Bellevue, Washington). USG values were categorized based on guidelines of the American College of Sports Medicine into normal ≤ 1.020, dehydrated > 1.020, and severely dehydrated > 1.030 [16–18].

SAS version 9.4 (SAS Institute Inc., Cary, NC) was used to conduct all statistical analyses and MAXQDA version 10 (Verbi Software, Berlin, Germany) was utilized to conduct all qualitative analyses. To characterize hydration practices, estimate the hydration status, and estimate prevalence of heat-related illnesses, data from *all* participants of the parent longitudinal study (n =88) were utilized, representing the control day. Comparisons between those included in the pilot study and those not included assessed comparability of the two samples. To determine the effect of the electrolyte beverage on hydration status and total number of HRI symptoms, a logistic regression model was utilized controlling for the amount of the beverage drunk and the number of hours worked.

To determine the feasibility of implementing an electrolyte intervention, a mixed methods approach was utilized. Quantitative data was analyzed from the Electrolyte Exit Survey. The interview transcripts were de-identified and transcribed verbatim by FWAF CHWs. A thematic analysis was first conducted by examining patterns across all the transcripts. A list of key themes was generated to construct a codebook that consisted of barriers and facilitators. The codes were then applied to participants in the hydration intervention study. A thematic analysis was conducted comparing the electrolyte group to the control group.

Results

The parent sample included a total of 88 participants of which 30 participated in the pilot study. Those participating in the pilot study did not differ significantly from those in the parent study for any sociodemographic characteristics. As can be seen in Table 1, the average age of participants was 40 years (sd=7) and 69% were female. The sample consisted of mostly coupled individuals (72%) who identified as Hispanic (98%). Most participants indicated they were Spanish speakers (86%), however some participants indicated that they spoke English (6%) and/or a Dialect (5%). Participants had varying levels of education, with most having between 6 to 9 years or more than 10 years of education. The average number of years worked in U.S. agriculture was 12 (sd=8), and the average number of years worked specifically in southern U.S. agriculture as 11 (sd=8). Participants reported working an average of eight hours a day (sd=2).

As can be seen in Table 2, post-shift USG values across all participants indicated that 47% were dehydrated and 1% were severely dehydrated. At post shift, 52% of participants indicated that they experienced no HRI symptoms during their shift, 34% reported one symptom, 8% reported two symptoms, and 6% reported more than three symptoms. Of those who experienced HRI symptoms, the most common symptom reported was heavy sweating (38%). Participants also reported experiencing headaches (14%), dizziness (7%), nausea (5%), muscle cramps (5%), and dysuria (2%). Other symptoms included dryness of mouth, general weakness, back and leg pains, and shivers. All participants reported drinking water during work. The next most common beverages were soda (64%), sports drinks (47%), coffee (38%), juice (19%), tea (13%), energy drinks (6%), diet soda (5%), and alcohol (2%). Most participants reported that they had not received some sort of HRI training within the past year (62%) and have never visited the emergency room for an HRI event (99%).

On the control day, 79% participants randomized in the electrolyte group had at least one HRI symptom compared to only 50% of the water group participants. Similarly, electrolyte participants on the control day (64%) were more dehydrated than the water group (37%). Differences from control day values indicate that although the groups were randomized, on average the electrolyte group was more dehydrated and experienced more HRI symptoms than the water group, suggesting randomization did not occur.

On the pilot day, participants randomized to the water group (114 oz, sd=47) drank more water compared to the electrolyte group (108 oz, sd=34). The water group participants worked on average more hours and reported a higher number of breaks then the electrolyte group. They also experienced more urination and were exposed to a higher max Heat Index. The prevalence of both HRI and dehydration was lower on the pilot day compared to the control day in both the electrolyte and water groups.

On the pilot day, the odds of dehydration were 13.4 times higher among those randomized to the electrolyte group compared to the water group after controlling for the amount of beverage consumed and the number of hours worked (95% CI =(1.17,152.95). However, the odds of reporting heat related illness symptoms, were lower among those randomized to the electrolyte group relative to the water group (0.72, (95% CI =(0.07, 7.27).

Several barriers and facilitators from the electrolyte group arose from the interview process, these are summarized in Table 5. The most salient theme was taste. Perceptions on the palpability of the beverage varied across participants. About half reported enjoying the taste and the other half disliking the taste. Of those that reported not liking the taste, all stated that the beverage was salty. Participants recommended offering a variety of flavoring options to increase uptake of the beverage. Feeling energized was another prominent theme that arose across participants. Some expressed that they felt less tired and more active. Others expressed that they felt that the beverage gave them strength to continue working. Many of the participants mentioned HRI Symptoms when discussing their experiences drinking the beverage. Several reported that they did not feel *"soleado/a"* or overheated while drinking the beverage. The symptoms of HRI that were mentioned across participants included dry mouth, nausea, thirst, sweat, pain, headache, and rapid breathing. Thirst and nausea were among the most frequently mentioned symptoms. Most participants expressed that the electrolyte beverage made them less thirsty and nauseous than what they generally experience on other workdays. However, one participant stated that the salt from the beverage made them feel thirstier than normal and one reported the salty flavor made them feel nauseous. Urination was a barrier that was mentioned by some participants that felt that it made them have to go more frequently during work. Finally, the temperature and beverage container were perceived as both barriers and facilitators. Participants largely reported they would not drink the beverage if it were not chilled. One participant also discussed that the liter jug was a facilitator to drinking the beverage as it provided a visualization for seeing how much they have drunk.

The most prominent theme in the water group was feeling energized or less fatigued. One participant noted a difference from the sugary drinks they typically drink and water. "*I felt better, well, I wasn't as fatigued; with the drinks, that I drink with sugar, I don't feel great and with water I felt better*." Participants also reported feeling less dehydrated. One participated stated: "*I liked the flavor of the water, I felt very hydrated, I felt good, I didn't have… well with other types of water sometimes I have nausea, but with this one I felt good.*" Many participants in the water group mentioned using the bathroom more, however, perceptions on this varied. Some participants viewed it as a sign that they were keeping hydrated, but some viewed it as a barrier and reported that they didn't like that it made them have to urinate more during work. Taste was also prominent in this group with all participants who mentioned the taste stated that they liked it or that it tasted like natural water, though one participant recommended flavoring the water to make it palatable. Symptoms of HRI were less frequently mentioned in the water group compared to the electrolyte group, and one participant reported that they started work with a headache and after drinking the beverage their headache went away.

Discussion

Studies examining the hydration status and prevalence of HRI in agricultural workers in the United States are limited. Estimating the prevalence of both of these outcomes among agricultural workers is critical to understanding trends among the population. Our findings indicate that more than half of participants in the parent study were dehydrated or severely dehydrated at the end of their shift (n=86) and approximately half experienced 1 or more HRI symptoms across the study sample (n=88). These estimates are lower than findings from another study which collected data from migrant farmworkers in the summers of 2015 and 2016. In this study approximately 81% of workers were dehydrated post-shift (USG 1.020, n=192) and 84% experienced at least one symptom of HRI (n=198). [19] Discrepancies in these findings could be due to several factors including variation in types of work conducted, heat conditions, and types and amounts of beverages consumed. In comparison to studies estimating the prevalence in Oregon and North Carolina, the prevalence of experiencing HRI symptoms during work was found to be higher in Central Florida [7,8]. Despite these variations, our findings confirm that the prevalence of HRI and dehydration is high for this population.

A significant contributing to factor to these high rates is the lack of protective measures in place for agricultural workers laboring in hot conditions. Studies have shown that protective factors against HRI include resting in shaded areas, taking extra breaks, increased fluid consumption, and having access to medical attention [20,21]. However, currently none of these are mandated to be provided and enforced by employers.

OSHA's current standards for protecting workers from heat is covered under the General Duty Clause, Section 5(a)(1) of the Occupational Health Act of 1970. The clause implies that an "an employer has a legal obligation to provide a workplace free of conditions or activities that either the employer or industry recognizes as hazardous and that cause, or are likely to cause, death or serious physical harm to employees when there is a feasible method to abate the hazard," including heat related hazards. [22] However, this general clause is ambiguous, widely open to interpretation, and not enforced at the federal level. The NIOSH does have published criteria for recommended standards including practices such as setting workplace limits for working in the heat, medical monitoring, and an HRI prevention and response training program. However, these are solely recommendations and are similarly not enforced. [13] The only enforceable regulations exists under OSHAs Occupational Safety and Health Standards for Agriculture under Field Sanitation and are solely focused on supplying water to employees. [23] Consequently, a conundrum exists where evidenced based recommendations and regulations exist yet are not enforceable nor implemented.

Currently, California, Minesota, and Washington all have enacted an OSHA approved state plan that addresses hazards not addressed at the federal level. [22] Most notably of these is California's heat standard which requires employers to provide water, shade, and HRI training. In the statute, the standard is enforceable by Division of Occupational Safety and Health and requires employers integrate measures into a written Injury and Illness Program. [24] We can see the direct effects of this mandate through prevalence estimates of HRI prevention training programs among workers. In California, 91% of workers reported receiving training where our estimates indicate that most participants in central Florida have not received any sort of training within the past year (63%, n=55). [25] This low prevalence of HRI training is incredibly concerning given the estimates on hydrations status and HRI among the population.

Hydration practices among the population were consistent with other study findings. [26] All of participants were drinking water, as per recommendations. However, workers also reported consuming sodas (64%) and (47%) sports beverages. Both sodas and sports drinks contain high amounts of sugar, with sodas on average containing 40.2 grams and sports beverages nearly half of that content. [27] Given that sugar-sweetened sodas don't have the added benefits of electrolytes, this further adds to cause for concern given their association with heat related acute kidney injury, kidney stones, chronic kidney disease, obesity and type 2 diabetes [28–32]. While studies have shown that drinking electrolyte beverages is a protective against kidney disease, the added sugar content of readily available sports drink is concerning [33–36]. Furthermore, the exact formula of electrolyte beverages varies across brands. Interview participants in the pilot study most frequently mentioned Suero and Gatorade as electrolyte beverages. Comparisons of these electrolyte formulas show that Suero contains more than double the amount of sodium than Gatorade and nearly six times more potassium (Table 6). [37,38] The NIOSHs broad recommendation on consuming electrolyte beverages, leaves the type of beverage, frequency, and amount up to interpretation. [13]

The findings of this study indicated that drinking electrolytes might be protective against HRI. However, the results were not significant. This could have been to a number of factors including the small sample size. In this study those randomized to the electrolyte beverage had significantly higher prevalence of dehydration post-shift based on USG compared to those randomized to water. However, control day data indicates that randomization did not distribute groups equally as the electrolyte group was significantly more dehydrated compared to the water group. This suggests that the electrolyte group could have been more dehydrated on the pilot day and consequently could have been more likely to suffer HRI. Furthermore, since the electrolyte group consumed less water and had less breaks than the water group this could have further contributed to the findings.

Another possible explanation for these results could be that the water group consumed more of the beverage on average compared to the electrolyte group. While the electrolyte group worked less hours on average than the water group, they worked in higher temperatures compared to the water group. These higher temperatures could have led to increased sweating, which includes both water and electrolyte loss. In the water group, participants only replaced water, affecting the concentration of their urine and making it appear as they were more hydrated. However, in the electrolyte group, participants had a higher concentration of electrolytes in their urine, making the urine thicker which could explain the increased USG values. Since hydration status was measured by USG, a measure of the density of urine, then the increased concentration of electrolytes could have contributed to the electrolyte group being more dehydrated.

Furthermore, regarding the electrolyte concentration, the WHO formula utilized in this study is recommended for the purposes of rehydration due to diarrheal loss not sweat loss. [15] Since electrolyte loss occurs at a different rate compared to sweat loss, this formula might have created a situation of hyperkalemia and hyponatremia with excessive amount of K+ and Na+. However, a study conducted in Guatemala utilizing the same formula found the solution to maintain adequate hydration and average electrolyte levels among the workers with only mild indications of hyponatremia. [14] A study conducted with sugar cane workers in El Salvador utilized a different electrolyte solution containing 7 grams of sugar per dl, 50 mg of sodium chloride and 20 mg of potassium phosphate, and found the solutions to be protective against kidney injury. [36] Ultimately, the findings of this electrolyte pilot are inconsistent with other field-based studies in the role of electrolytes in maintaining hydration status. [33,39]

The identified barriers and facilitators provide valuable insight to inform future interventions. While the findings of this study provide foundational information, extensive market research is further needed. The CDC recognizes the importance of market research in public health and defines it as an opportunity to "enhance understanding of the target audience's characteristics, attitudes, beliefs, values, behaviors, determinants, benefits and barriers to behavior change in order to create a strategy." [40] However, very little literature exists on market research conducted with agricultural workers. A common practice in consumer research involves examining intrinsic (things that are physically related to the product) and extrinsic (things that are product-related but are not part of the physical product) cues that are related to the product. [41] Findings of this study found that the most notable intrinsic cue for electrolyte group participants was the taste of the beverage. Feelings of wellness and feeling energized were intrinsic cues for both the water and electrolyte groups. Extrinsic cues identified included the temperature of the beverage and the container. In particular, findings about the container align with the Health Belief's Model's (HBM) cues to action theory, that suggest certain cues can elicit behaviors to occur. [42] The beverage containing times to drink the beverage with indication of how much was drunk was found to act as a cue to action for hydration.

Given the identified prevalence estimates, we believe that our findings affirm the need for an enforceable National Heat Standard that includes mandated areas for shade, rest breaks, and

HRI training, among other preventions to mitigate dehydration and HRI. Furthermore, findings from the pilot study suggest that the NIOSHs recommendations surrounding electrolyte consumption should be informed form evidence-based research for the optimal hydration formula and recommend types/brands of beverages that meet this formula, provide guidance on amounts and frequencies of consumptions. Finally, findings surrounding the feasibility suggest the need for an update on messaging strategies that emphasize electrolytes over sodas and make use of intrinsic and extrinsic cues to increase optimal hydration practices.

A strength of this study was the interview process which was conducted by CHWs at FWAF that have a relationship with agricultural workers, which likely increased the accuracy of the data. Additionally, the prevalence estimates for the control day are taken from the larger sample across two locations which more accurately reflects the larger population of agricultural workers in Florida. Sample size is a considerable limitation to this study, with only thirty participants, the power to detect a significant difference between the two groups is very small. Given our small sample size, other explanatory variables such as the rigor of work and number of breaks were not included in the regression model, ultimately, limiting our understanding of the true effect. The discrepancy between electrolyte and water group participants that were dehydrated on the control day indicated that randomization did not occur which could have significantly affected the outcomes of the pilot results. The measures that we utilized for the outcomes, USG and self-reported HRI, could be considered limitations as well given the reliability of both measures and inability to detect electrolyte imbalances.

Further research should be conducted with a larger sample size utilizing more specific measures such as a basic metabolic panel that has the power to detect electrolyte imbalances and utilizing more reliable proxies of HRI such as core body temperature. Most notably, research is needed to understand the optimal formula for rehydration for agricultural workers laboring in hot conditions.

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Appendix

Table 1. Sociodemographic and agricultural work characteristics across all study participants and pilot water/electrolyte group participants

	Overall Sample (Parent + Pilot) (n=88)	**Pilot: Water Group** (n = 16)	**Pilot: Electrolyte Group** (n = 14)
Sociodemographic Characteristics			
Age, *mean (sd)*	40 (7)	40 (7)	41 (6)
Sex, *n (%)*			
Male	19 (22)	6 (37.5)	6 (43)
Female	69 (78)	10 (62.5)	8 (57)
Marital status, *n (%)*			
Coupled	63 (72)	12 (75)	11 (79)
Single	25 (28)	4 (25)	3 (21)
Race/Ethnicity, *n (%)* [a]			
Black	1 (1)	0 (0)	0 (0)
Hispanic	86 (98)	16 (100)	14 (100)
Other	1 (1)	0 (0)	0 (0)
Languages spoken, *n (%)* [b]			
English	6 (6)	1 (6)	0 (0)
Spanish	84 (86)	15 (88)	14 (93)
Dialect	5 (5)	1 (6)	1 (7)
Other	3 (3)	0 (0)	0 (0)
Years of education, *n (%)*			
0-5	15 (18)	4 (25)	1 (7)
6-9	51 (58)	9 (56)	11 (79)
10+	21 (24)	3 (19)	2 (14)
Agricultural Work Characteristics			
Work location, *n (%)*			
Pierson	36 (41)	4 (25)	3 (21)
Apopka	52 (59)	12 (75)	11 (79)
Agriculture work type, *n (%)* [c]			
Fernery	30 (34)	5 (31)	7 (50)
Nursery	45 (51)	8 (50)	6 (43)
Yardwork	8 (9)	3 (19)	1 (7)
Other	5 (6)	0 (0)	0 (0)
Years worked in U.S. agriculture, *mean (sd)*	12 (8)	14 (9)	14 (7)
Years worked in southern U.S. agriculture, *mean (sd)*	11 (8)	13 (10)	14 (8)
Average number of hours worked per day, *mean (sd)*	8 (2)	8 (2)	8 (2)

[a] The other category encompasses Asian, White, and Multi-Racial identities.
[b] Participants selected multiple languages, percentages reported do not sum to 100.
[c] The other category encompasses the occupations housecleaning, construction, and painting.

Table 2. Prevalence of general hydration practices, hydration status, and heat-related illness characteristics across all study participants and pilot water/electrolyte group participants on control day

	Overall Sample (n=88)	**No Intervention** (n=58)	**Water Group** (n = 16)	**Electrolyte Group** (n = 14)
Hydration Practices				
General Beverages During Work, *n(%)*				
Water	88 (100)	58 (100)	16 (100)	14 (100)
Coffee	33 (38)	21 (36)	6 (38)	6 (43)
Tea	11 (13)	7 (12)	3 (19)	1 (7)
Juice	17 (19)	11 (19)	4 (25)	2 (14)
Soda	56 (64)	35 (60)	11 (69)	10 (71)
Diet Soda	4 (5)	3 (5)	0 (0)	1 (7)
Sports Drinks	41 (47)	25 (43)	8 (50)	8 (57)
Energy Drinks	5 (6)	3 (5)	1 (6)	1 (7)
Alcohol	2 (2)	2 (3)	0 (0)	0 (0)
Hydration Status				
Urine specific gravity, *n (%)* [a b]				
Normal (< 1.0199)	40 (47)	25 (45)	10 (63)	5 (36)
Dehydrated (>1.0200)	40 (47)	26 (46)	6 (37)	8 (57)
Severe dehydration (>1.0300)	6 (1)	5 (9)	0 (0)	1 (7)
Heat Related Illness				
Types of symptoms reported, *n (%)* [b c]				
Heavy Sweating	33 (38)	16 (28)	7 (44)	10 (71)
Headache	12 (14)	5 (9)	3 (19)	4 (29)
Nausea	4 (5)	2 (3)	0 (0)	2 (14)
Confusion	0 (0)	0 (0)	0 (0)	0 (0)
Dizziness	6 (7)	3 (5)	1 (6)	1 (7)
Fainting	0 (0)	0 (0)	0 (0)	0 (0)
Muscle Cramps	4 (5)	3 (5)	0 (0)	1 (7)
Dysuria	2 (2)	2 (3)	0 (0)	0 (0)
Other	7 (8)	6 (10)	0 (0)	1 (7)
Number of symptoms reported, *n(%)*				
Reporting 0 symptoms	46 (52)	35 (60)	8 (50)	3 (21)
Reporting 1 symptoms	30 (34)	18 (31)	6 (38)	6 (43)
Reporting 2 symptoms	7 (8)	3 (5)	1 (6)	3 (21)
Reporting ≥3 symptoms	5 (6)	2 (3)	1 (6)	2 (14)
HRI training in past year, *n (%)*				
Yes	33 (38)	19 (33)	7 (44)	7 (50)
Visited ER for HRI in lifetime, *n (%)*				
Yes	1 (1)	0 (0)	0 (0)	0 (0)

[a] n=86 for overall sample, and n=56 for no intervention group, 2 participants had no USG values reported.
[b] USG values and HRI symptoms are at post-shift.
[c] Other HRI symptoms reported included dryness of mouth, general weakness, back and leg pain, and shivers.

Table 3. Comparison of key explanatory variables and unadjusted health outcomes between the water and electrolyte groups on the pilot day

	Water Group (n = 16)		Electrolyte Group (n = 14)				
	mean(sd)	n(%)	mean(sd)	n(%)	t	x^2	p
Explanatory Variables							
Total oz of beverage drunk	114 (47)		108 (34)		0.41		0.69
Number of hours worked	9 (2)		8 (2)		1.47		0.15
Number of breaks reported	3 (1)		2 (1)		1.24		0.23
Number times urinated [a]	5 (1)		4 (2)		1.61		0.12
Max Heat Index	102 (4)		101 (3)		0.59		0.56
Health Outcomes							
Number of HRIs reported							
0 symptoms		9 (56)		6 (43)		0.54	0.46
≥1 symptoms		7 (44)		8 (57)			
Dehydrated based on USG							
No		15 (94)		7 (50)		7.31	< 0.01
Yes		1 (6)		7 (50)			

[a] Control n=12, electrolyte n=13

Table 4. Adjusted estimates for the association between post-shift hydration status and experiencing heat related illness symptoms by water and control groups on the pilot day

	n(%)	n(%)	Odds Ratio (95% CI)
Urine Specific Gravity	**Not Dehydrated**	**Dehydrated**	
Water	15 (68)	1 (12.5)	Ref
Electrolyte	7 (32)	7 (87.5)	13.4 (1.17,152.95)
Heat Related Illness Symptoms	**No symptoms**	**≥ 1 symptom**	
Water	9 (60)	7 (47)	Ref
Electrolyte	6 (40)	8 (53)	0.72 (0.07, 7.27)

[a] Logistical model adjusted for number of hours worked and amount of beverage drunk.

Table 5. Perceived barriers and facilitators of adopting the electrolyte beverage among electrolyte group pilot participants

	Barriers	Facilitators
Taste	*"Truthfully, I did not like the flavor very much, it had a salty taste."*	*"Very good, I felt good, comfortable with the drink, it had a good taste and it's easy to digest."*
Energy	----	*"Well, I felt… right now I feel more energized, I feel good."*
Urination	*"I didn't like that it made me want to use the bathroom all the time at work."*	----
HRI Symptoms Thirst Nausea Heavy Sweating Dry Mouth Pain Rapid breathing	----	*"I had a headache and my back hurt; I don't know what the water has but it took away the back pain"* *"In the morning I had nausea and during the day I was drinking it, it seems like it took it away."* *"When I drink water normally I sweat a lot, when I drank the beverage, I sweat, but less than normal."*
Beverage Temperature	*"Room temperature it tastes different, it tastes better cold."*	----
Beverage Container	----	*"It helps you see, visualize how much you have drunk, it has the measurement and time, it is a good tip."*

Table 6. Comparison of most consumed electrolyte beverages

	Carbohydrates	Calories	Sugar	Sodium	Potassium	Zinc	Chloride
Suero	9g	35	9g	414 mg	282 mg	2.8 mg	511 mg
Gatorade	21 g	80	21 g	160 mg	45 mg		

Chapter 4: Conclusion and Recommendations

Introduction

From the culmination of this thesis research, there are four primary recommendations that if implemented have the potential to significantly impact public health outcomes: (1) regulating bodies need to move from guidance to requirements (2) employers should be held accountable to follow these requirements (3) messaging needs to be updated to reflect the population it intends to reach (4) data surrounding agricultural workers needs to be more readily available.

Mandates Not Guidance

OSHA's current standards for protecting workers from heat is covered under the General Duty Clause, Section 5(a)(1) of the Occupational Health Act of 1970. The clause implies that an "an employer has a legal obligation to provide a workplace free of conditions or activities that either the employer or industry recognizes as hazardous and that cause, or are likely to cause, death or serious physical harm to employees when there is a feasible method to abate the hazard," including heat related hazards. (OSHA, n.d.) However, this general clause is ambiguous, widely open to interpretation, and not enforced at the federal level. The NIOSH does have published criteria for recommended standards including practices such as setting workplace limits for working in the heat, medical monitoring, and an HRI prevention and response training program. However, these are solely recommendations and are similarly not enforced. (National Institute for Occupational Safety and Health, 2016) The only enforceable regulations exists under OSHAs Occupational Safety and Health Standards for Agriculture under the Field Sanitation section and are solely focused on supplying water to employees. (Occupational Safety and Health Standards for Agriculture, 1987)

Currently, California, Minesota, and Washington all have enacted an OSHA approved state plan that addresses hazards not addressed at the federal level. (OSHA, n.d.) Most notably of these is California's heat standard which requires employers to provide water, shade, and HRI training. In the statute, the standard is enforceable by Division of Occupational Safety and Health and requires employers integrate measures into a written Injury and Illness Program. (California Heat Standard, n.d.)

We can see the direct effects of this mandate through prevalence estimates of HRI prevention training programs among workers. In California, 91% of workers reported receiving training where our estimates indicate that most participants in Central Florida have not received any sort of training within the past year (63%, n=55). (Stoecklin-Marois et al., 2013) This low prevalence of HRI training is incredibly concerning given HRI prevalence estimates across several states (Bethel & Harger, 2014; Mac et al., 2021; Mirabelli et al., 2010; Moyce et al., 2020; Mutic et al., 2018)

In 2021, OSHA published an Advance Notice of Proposed Rulemaking (ANPRM) for Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings in the Federal Register, which would initiate the rule making process to establish a heat-specific workplace standard that would clearly lay out employer obligations to protect employees from heat. OSHA invited comments in order to understand issues that should be "considered in developing the standard, including the scope of the standard and the types of controls that might be required." During a three-month period from October 2021 to January 2022, 1,078 public comments were received which are currently under review. (OSHA, 2021)

There are several things that should be mandated under the new rule. First and foremost, HRI prevention and response training should be required at several time points, including refresher trainings, for all workers and include information on how to mitigate HRI, knowing the symptoms and how to respond, and include emergency response training if workers do experience HRI.

To prevent HRI, employers should be mandated to create physical and working environments that allow for the necessary preventative actions to occur. Mandated rest breaks should be implemented for workers by employers beyond a standard lunch break. These breaks should not penalize workers in any way, such as workers who are being paid piece rate losing time to harvest produce. These breaks should be taking place in a shaded environment that is provided by the employer such as field tents, enough shade should be available for all workers. Several water stations with cooled water should be placed in easily accessible areas for workers to maintain hydrated. Based on research findings, these stations should also include electrolyte beverages that include multiple flavoring options. Workers should also have easy access to emergency response materials such as ice and cooling towels in the event of someone experiences a serious HRI.

Employer Accountability

Once OSHA establishes the standard proposed in the ANPRM, it is critical that employers are held accountable for following these requirements and that failure to do so results in severe consequence. Agricultural employers are already notorious for the exploitation of farmworkers. Over 70% of federal labor standards investigations of farms conducted by the Wage and Hour Division (WHD) of the U.S. Department of Labor detect violations of laws that are set in place to protect agricultural workers (Costa et al., 2020). One of the key recommendations for enforcement agencies to increase compliance is to examine whether the "severity of sanctions is sufficient; increasing the value of civil money penalties should be considered in order to shift penalties from a cost of doing business to an incentive for compliance" (Costa et al., 2020). With a demonstrated track record of agricultural employers ignoring federal requirements, then the need for OSHA to consider enforcement and mechanisms that will hold employers accountable is crucial to the effective implementation of the federal heat standard.

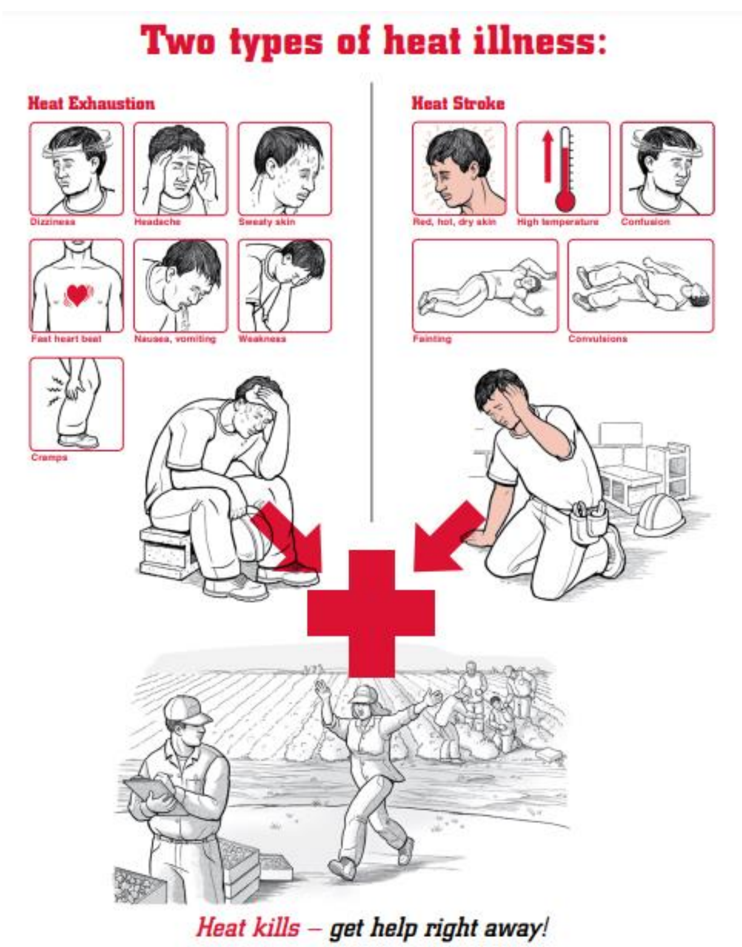
Tailored Messaging

As discussed in Chapter 2, OSHA's HRI prevention campaign WATER. REST. SHADE was created over 10 years ago, yet in the past ten years, the agricultural workforce has changed significantly. Particularly there has been a rise in the number of female agricultural workers (U.S. Department of Agriculture, 2021). This is also reflected in our findings, where over three quarters of the sample population were women. To communicate with this changing demographic, formative research needs to be conducted that aims to understand this target audience better. While no information is readily available on what, if any at all, formative research was utilized or conducted prior to developing the WATER.REST.SHADE campaign, it is plausible that the shifting population might elicit reason for necessary changes to the key messages. In order to understand the target populations preferred method of communication, communication channels, and enablers of behavior change, and develop tailored messages that speak to workers, extensive market research is needed.

Based on our research, there is also significant opportunity to tailor messaging that elicit behavior changes specifically around beverage consumption. Understanding the current hydration practices of agricultural workers was a key part of this study, while we did find that all workers reported drinking water regularly, many participants reported drinking other non-recommended beverages such as soda (64%) and sports drinks (47%) regularly during work. Future messaging materials should consider framing the impacts of drinking sodas during work and promote the benefits of drinking electrolytes. Furthermore, dependent on research findings, messaging should include frequency and amount of electrolyte beverages that should be consumed and which beverages meet the optimal formula for hydration.

There are also opportunities for improvement of OSHAs current marketing materials. For instance, text based infographics on recognizing symptoms of HRI and response strategies are available in both English and Spanish, however, as per the NAWS approximately a quarter of workers reported that they do not read Spanish well and three quarters reported not reading English well (Occupational Safety & Health Administration, n.d.; U.S. Department of Labor, 2021). With a significant portion of the population reporting not reading well, messaging should include multiple modalities such as video, audio, and pictorial content. Among the materials available for download, only one of the materials was developed for low-literacy populations (Figure 4). While providing this type of material is a good start, market research can identify the best means and methods of communication that speaks to workers.

Figure 4. Image of OSHA's heat safety illustrated low-literacy fact sheet for agricultural and construction workers. (OSHA, 2021)



Readily Available Data

As discussed in Chapter 2, there is a limited body of evidence surrounding the health outcomes of agricultural workers in the United States related to occupational heat exposure. To our knowledge, there exists no open access data sets that explore health outcomes besides data collected by OSHA on injuries and mortalities. In general, localized data that explores the other conditions that workers are exposed to, is also scarce.

According to the National Center for Farmworker Health, there is only a few open access data sets with data about agricultural workers readily available (National Center for Farmworker Health, n.d.). The most established is the NAWS, which collects demographic, employment, and health data. The codebook for fiscal year 1989 to 2018 contains only one item related to hydration and none related to HRI. The item asks, "Does your employer provide clean drinking water and disposable drinking cups?" (U.S. Department of Labor, 2020) While this question begins to explore issues of access that affect hydration practices, one item is not enough to understand trends among the population.

Nezahualcoyotl Xiuhtecutli, General Coordinator of FWAF alludes to the need for readily available data, that prompted the research partnership between the organization and Emory to explore the impacts of heat on kidney function. He states "regulators and lawmakers, anybody that was in those positions to make the rules, would go ' I hear you but show us the data." (Zheng & Berra, 2022) The importance of data that allows us to detect trends surrounding HRI is critical for agencies such as FWAF to translate research findings into action. Furthermore, readily accessible data promotes transparency in organizations. With OSHA moving forward with the national federal heat standard, data collection surrounding not only the violation of standards, but outcomes tied with the requirements should be considered a critical part to understanding if this policy is affecting short- and long-term outcomes.

Conclusion

While advances with OSHAs ANPRM has ignited optimism for movement towards protecting workers from occupational heat exposure, there is a need for continued attention, research, and advocacy. As the ANPRM progresses, we should remain vigilant for opportunities to contribute our voice in commenting periods from the public, continue to support research that aims to understand the health outcomes that effects workers, and we should act as allies by advocating on behalf of agricultural workers.

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