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IMPACTS OF CLIMATE CHANGE AND HEAT STRESS ON FARMWORKERS' HEALTH: A SCOPING REVIEW

by
MOUSSA ISSA EL KHAYAT

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by
MOUSSA ISSA EL KHAYAT

Approved by:

Dr. Rima Habib, Professor Advisor
Department of Environmental Health

Dr. Ibrahim Alameddine, Assistant Professor
Department of Civil and Environmental Engineering Member of Committee

M.Haidar

Dr. Mustapha Haidar, Professor Member of Committee
Department of Agriculture

Date of thesis defense: July 29, 2021

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ABSTRACT
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Due to the continuous rise in global temperatures and heat waves as a result of climate change, concerns for the health and safety of agricultural workers have increased globally. Agricultural workers are at an increased risk of heat stress due to the strenuous nature of their work which is performed primarily outdoors. Therefore, a scoping review was undertaken to summarize the existing knowledge regarding the impact of climate change particularly extreme heat exposure on farmworkers' health and the available prevention strategies to alleviate these impacts on farmworkers. A systematic search of 5 electronic databases (Embase, Medline, Scopus, CINAHL and Web of Science) and grey literature websites was conducted to identify relevant literature published until August 24, 2020. Six thousand nine hundred and eight (6908) records were retrieved from the searches and 77 articles were included for the final review. The majority of the reviewed articles focused on (1) heat related illness (HRI), which is a continuum of diseases ranging from mild conditions including heat rash, heat syncope and heat cramps to more severe outcomes heat exhaustion and heat stroke (n=47) as well as kidney disease (n=24). In addition, the majority of the reviewed studies assessing HRI symptoms were conducted in the US, while most studies assessing kidney disease outcomes focused on the Central America region. Risk factors associated with heat-related health outcomes were identified in the reviewed studies, including gender, workload, piece-rate payment, job decision latitude and hot environmental conditions. On the other hand, various protective factors for HRI were identified including reducing soda consumption, taking breaks in the shade, increasing access to regular breaks and changing work hours and activities, while the protective factors for kidney disease included increasing electrolyte consumption. In addition, the most common identified preventive measures include drinking more water, wearing appropriate clothing, taking breaks in shaded areas, going to air-conditioned places during or after work, changing work hours and activities and taking extra breaks. The findings of this review identified several research gaps. Although HRI and kidney disease have been adequately explored in the literature, evidence regarding the effect of heat exposure on other health outcomes such as occupational injuries and mental health was limited in the reviewed studies. Various associations between certain physiological, behavioral and sociodemographic factors (such as acclimatization, hydration, training,

migrant status, and poor socioeconomic conditions) and both HRI and kidney disease were understudied in the reviewed literature. The findings of this review also identified a focus on countries in the North and Central America region, while revealing a gap in studies quantifying the burden of heat related health outcomes among agricultural workers in hot regions such as Sub-Saharan Africa, Middle East and North Africa and Southeast Asia, which host millions of vulnerable agricultural workers. Moreover, findings from this review highlighting the high prevalence of HRI among the agricultural workforce coupled with a lack of accessibility to heat preventative measures reflects the need to establish heat safety standards requiring employers to provide heat prevention programs which are suitable to local environmental conditions and physical requirements instead of employee's self-reliance for prevention and safety. The review has revealed that there is an urgent need to expand future research to cover vulnerable agricultural communities especially in tropical developing countries, including the MENA region, and to investigate the effect of all potential and understudied risk factors and preventive measures so that effective policies and programs can be developed.

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ABBREVIATIONS

HRI	Heat related illness
CKD	Chronic Kidney disease
CKDu	Chronic Kidney disease of unknown etiology
GFR	Glomerular filtration rate
CBT	Core body temperature
WRS	Water, Rest, Shade
AKI	Acute kidney injury
IKI	Incident kidney injury

CHAPTER I

INTRODUCTION

A. Climate change

Climate change, defined as the change in the state of the climate, is mainly driven by greenhouse gas emissions released from human activities (UNFCCC, 2011). Global atmospheric concentrations of greenhouse gases such as carbon dioxide, methane and nitrous oxide have increased since 1750 and now far exceed pre-industrial values leading to a warming of the Earth’s surface (IPCC, 2014). In recent decades, climate change has caused various impacts on natural and human systems in all regions of the world (IPCC, 2014). These impacts include rising global temperature and increase in the frequency and intensity of extreme weather events such as heat waves, droughts, floods, and cyclones (IPCC, 2018). It is expected that the continued emissions of greenhouse gases will cause further warming and changes in the climate system (IPCC, 2014).

As a result of climate change, global average temperatures have increased by about 1.0°C over the last 115 years (from 1901 to 2016) (IPCC, 2018). Since the 1980s, the average temperatures have exceeded the last century's average every year (USGCRP, 2017). Moreover, the number of cold days and nights has decreased, while the number of warm days and nights has increased globally (IPCC, 2014). Nineteen of the warmest years on record have occurred since 2000 (NASA, 2021). In addition, 2020 was tied with 2016 as the warmest year on record (NASA, 2021). In addition, the intensity, frequency and duration of heatwaves has increased around the globe (Perkins, 2015). A majority of the world's regions experienced at least one extra heatwave day per decade from 1950 to 2017, which was as high as 3 to 5 days per decade in low-latitude areas (Perkins-Kirkpatrick et al., 2020).

Global average temperatures are projected to further increase to 1.8 – 4 °C by 2100 above pre-industrial times (IPCC, 2014, 2018). In addition, more frequent, longer, and more intense extreme heat events are expected to occur in the twenty-first century in most land regions (IPCC, 2019). In addition, future projections estimate that the number of countries exposed to heat stress will increase to 129 and 135 under 1.5 °C and 2.0 °C warming scenarios, respectively, compared to 109 heat-stressed countries in the baseline period of 1981 to 2000 (Sun et al., 2019).

B. Heat exposure

Exposure to high temperatures due to climate change results in a range of negative health impacts, ranging from acute health effects such as nausea, headache, sweating and vomiting to more severe and chronic conditions including heat-related illnesses and heat strokes and in extreme circumstances death (WHO, 2015). Moreover, heat exposure can exacerbate chronic health conditions, including cardiovascular and respiratory diseases (De Blois et al., 2015), diabetes (Vallianou et al., 2020), kidney disease (Borg et al., 2017), and mental health problems (Thompson et al., 2018). As expected, certain groups within a population are at a higher risk of experiencing heat stress such as older adults, children, women, those with chronic diseases, and people taking certain medications (IPCC, 2018).

Currently, about 30% of the world’s population experience at least 20 days per year of extreme heat exposure that could potentially be fatal (Mora et al., 2017). In addition, the number of people exposed to heatwaves was 157 million in 2017, with the average person experiencing an additional 1.4 days of heatwaves per year from 2000 to 2017 (Watts et al., 2018). Heat stress is expected to affect 1.2 billion people under the 3°C warming scenario, which is projected to occur by 2100 if current greenhouse gas emissions continue. This projection is four times the number of people that are currently affected by extreme heat (Li et al., 2020).

The extent to which heat-related morbidity and mortality are projected to increase varies by region due to various differences such as acclimatization status, population vulnerability, the built environment, access to air conditioning and other factors (IPCC, 2018). Figure 1 shows the projected global distribution of heat-related mortality expressed in death-equivalents per 100,000 due to climate change in 2100. As shown in Figure 1, the changes in heat related mortality are disproportionately distributed with a greater increase in heat related mortality in low-income countries as compared to high-income countries (Carleton et al., 2018). For example, the tropical city of Accra in Ghana is estimated to have an additional 160 deaths per 100,000 annually due to increasing temperatures. In contrast, in the northern city of Oslo in Norway, an additional 230 lives per 100,000 are saved annually due to fewer cold days and greater ability to adapt to higher temperatures (Carleton et al., 2018). Moreover, the global average heat-related death for people who are over 65 has increased by 53.7% between the period 2000–2004 and 2014–2018, with a total of 296 000 recorded deaths from heat exposure in 2018 alone (Watts et al., 2021).

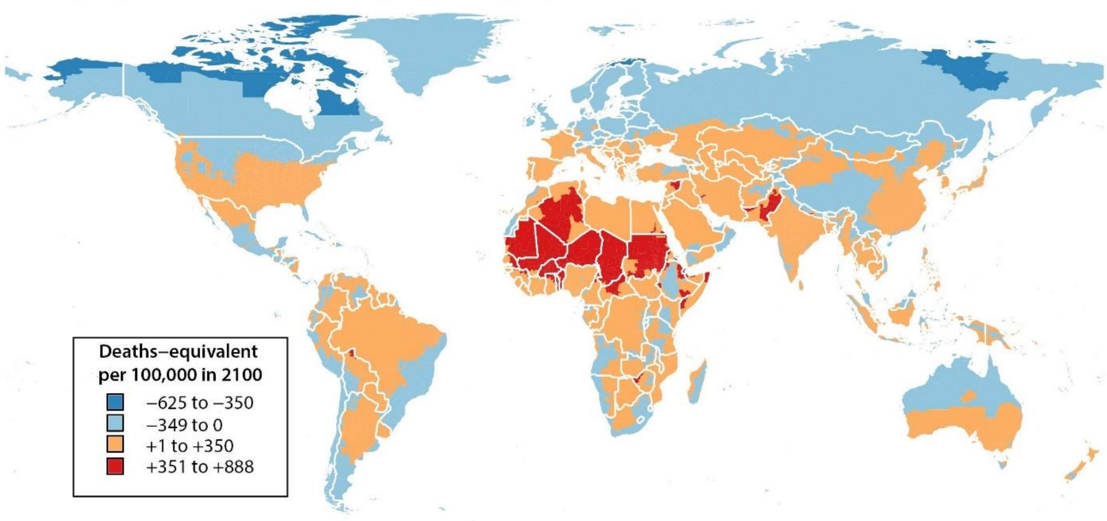

Figure 1: Projected heat related mortality due to climate change in 2100 (The Hamilton Project et al., 2019)

C. Occupational heat exposure

In addition to the adverse effects of heat exposure on the general population, the health and safety of working populations can also be affected. Workers engaged in heavy manual labour in various occupations such as the agriculture, mining, and construction at temperatures greater than 35°C are likely to experience heat stress (Parsons, 2014). A global meta-analysis of workers from various occupations showed that individuals working under conditions of heat stress are 4 times more likely to experience occupational heat strain than individuals working in thermoneutral conditions after a single work shift (Flouris et al., 2018). Outdoor workers engaged in agriculture, construction, landscaping, and oil and gas well operations are vulnerable to heat stress due to prolonged exposure to solar radiation during the workday (OSHA, 2020; Xiang et al., 2014). Furthermore, workers in indoor workplaces such as manufacturing, foundries, bakeries, kitchens, laundries, and furnaces are also at risk of experiencing heat stress due to heat generated from work processes or equipment and the absence of air conditioning (OSHA, 2020; Xiang et al., 2014). Between 2000 and 2010, 359 occupational heat-related deaths were reported in the U.S. with an annual mean mortality rate of 0.22 per 1 million workers (Gubernot et al., 2015)

Workers are expected to experience substantial increases in exposure to extreme temperature due to global climate change. The projected numbers of additional occupational heat stress fatalities due to climate change may reach up to 22,000 in 2030 and 43,000 in 2050 as compared to 1975 (Kjellstrom et al., 2014). In addition, 55,000 cases of additional non-fatal occupational heat stroke are projected to occur in 2030 and 61,000 in 2050 as compared to 1975 (Kjellstrom et al., 2014).

Figure 2 shows the global distribution of occupational heat exposure. It presents the monthly average Wet Bulb Globe Temperature (WBGT) which is a standard heat exposure index that combines temperature, humidity, wind speed, and heat radiation for the period 1980–2009 (Kjellstrom et al., 2014). As shown in Figure 2, excessive workplace heat exposure is already present in many tropical and subtropical areas (Lucas et al., 2014). These areas are home to more than four billion people who may be affected by workplace heat exposure (UNDP, 2016). Workers in these countries are vulnerable to excessive heat exposure due to large population densities, limited resources or absence of cooling methods such as air conditioning, greater economic incentives to maintain productivity, the presence of a large informal workforce, and weak safety regulations (Kjellstrom et al., 2009; Lucas et al., 2014).

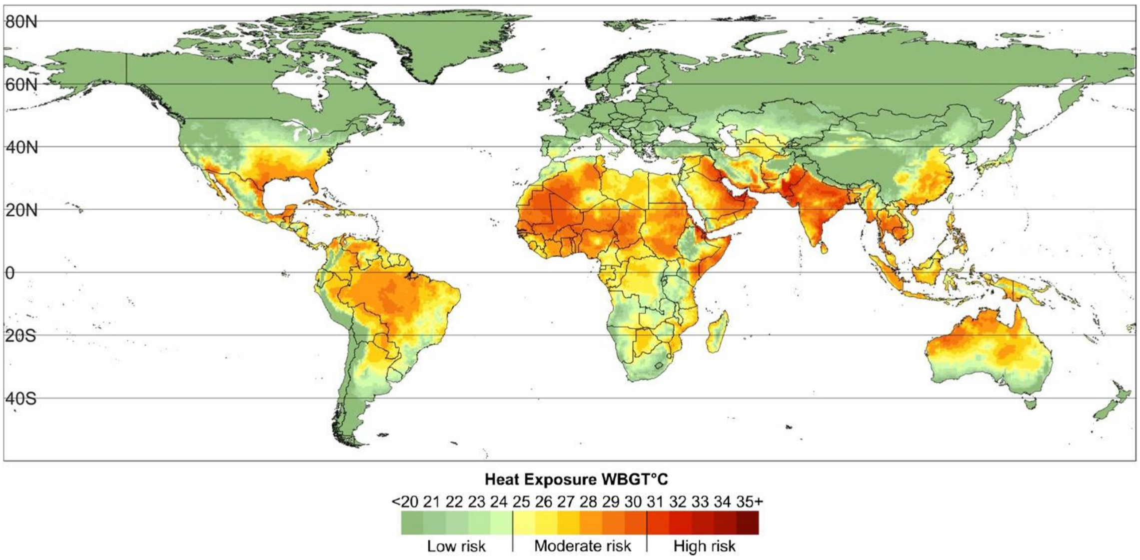

Figure 2: Monthly average WBGT for 1980–2009 (Kjellstrom et al., 2014)

D. Heat exposure and vulnerabilities of farmworkers

There are various factors that render farmworkers vulnerable to the effects of heat exposure. Studies show that the agricultural workforce globally are exposed to heat stress in the U.S. (Bethel et al., 2014; Fleischer et al., 2013; Mirabelli et al., 2010), India (Sahu et al., 2013), Central America (Crowe et al., 2013; Delgado Cortez, 2009), and Africa (Frimpong et al., 2017; Sadiq et al., 2019). Farmworkers also perform physically demanding tasks under high temperature conditions, which increases their risk of heat stress (Mitchell et al., 2018; Mix et al., 2019). Furthermore, most agricultural work is performed outdoors, where workers are continuously exposed to sunlight and the use of cooling is not feasible (Staal Wästerlund, 2018). Farmworkers often lack access to adequate preventative methods such as shade, air conditioning, hydration, and rest breaks (Fleischer et al., 2013; Hansen et al., 2020). In addition, farmworkers lack access to sanitation facilities, which discourages them from drinking water while working in hot environments (Lam et al., 2013; Spector et al., 2015).

Furthermore, studies have shown that the use of Personal Protective Equipment (PPE) to reduce chemical exposure among agricultural workers in the field may also increase the risk of heat exposure and heat-related illnesses by preventing the dissipation of heat (Lam et al., 2013; Riccò, 2018; Riccò et al., 2020). Climate change is expected to cause a further increase in heat exposure among farmworkers. The number of days that are too hot to work outside is expected to double by 2050 and triple by the year 2100 for U.S. agricultural workers due to climate change (Tigchelaar et al., 2020).

Farmworkers face poor working conditions that can exacerbate their vulnerability to adverse health outcomes. Agricultural workers receive low wages and are forced to work long hours (UN, 2018). Moreover, farmworkers who are paid by piece-rate which is based on the amount of product harvested often work beyond their physical limits and avoid taking breaks to rest or hydrate in order maximize their income (CIDIN, 2014; Verité, 2016). In addition, health and safety regulations are usually absent in the agricultural sector even though it is a dangerous occupation with at least 170,000 death per year (FAO, 2016). Furthermore, the presence of a large informal workforce which is estimated to be 94% of the agricultural sector globally also contributes to precarious working conditions (ILO, 2018b)

Various forms of labour exploitation are common in the agricultural sector. The hiring of agricultural workers through labor contractors increases their vulnerability to exploitation as they can be deceived about working or living conditions or charged with additional fees (Verité, 2013, 2016). In addition, agricultural workers are likely to fall into debt bondage to cover their living expenses such as food or housing (The Freedom Fund, 2016; Verité, 2017). One form of labour exploitation is forced labor, which is found in different agricultural sectors around the world (DOL, 2020). It is estimated that around 3.5 million people globally work as forced labour in agriculture (FAO, 2015). Moreover, human trafficking is also widespread in the agricultural sector and is found in all parts of the world involving both males and females as well as adults and children (UNODC, 2020).

In addition to the harsh working conditions, the living conditions that agricultural workers face can have a detrimental effect on their health. Agricultural communities lack access to basic social and health services, clean drinking water, infrastructure and adequate housing (Habib et al., 2016; Öztaş et al., 2018). They lack access to health care services due to long distances to healthcare facilities, low income and inability to pay medical expenses, and lack of insurance (Arcury et al., 2007; Hoerster et al., 2011). Furthermore, the majority of farmworkers live in low socioeconomic conditions, with the levels of extreme poverty more than four times higher among agricultural workers compared to non-agricultural workers (Castañeda et al., 2018).

Moreover, the agricultural sector includes vulnerable working populations such as children, women and migrants. Child labor is commonly found in various agricultural communities due to widespread poverty in rural areas, which forces families to rely on children’s income to survive (ILO, 2017a). The agricultural sector accounts for 71% of child labor worldwide, which is equivalent to 108 million out of 152 million child laborers. The number of child laborers in agriculture has increased from 98 million to 108 million since 2012 (ILO, 2017b). Exposure to agricultural hazards can affect children’s health and development, especially since children are more susceptible than adults due to physiological differences (FAO/ILO, 2017). Children are extremely vulnerable to the effects of hot temperatures, ergonomic hazards, and pesticide exposure (FAO/ILO, 2017).

In addition, women account for 43% of the agricultural labour force in developing countries (FAO, 2016). Women working in the agricultural sector face exploitation and discrimination including longer working hours, lower wages and fewer labour rights and protections (FAO, 2010). Furthermore, females face sexual harassment and violence in various agricultural sectors around the world (ILO, 2018a). Female farmworkers are unlikely to report incidents of sexual abuse or violence due to fear of losing their work or retaliation by the perpetrator (ILO, 2018a). Moreover, they lack access to adequate sanitation facilities which forces many women to refrain from drinking water during the day in order to limit their trips to the toilet (Venugopal et al., 2019).

Moreover, migrants account for an increasing share of the agricultural labour workforce, with 16.7 million migrants engaged in agriculture worldwide (ILO, 2015). Migrant agricultural workers are not covered by labour regulations, face language and cultural barriers, lack formal education and access to social security, and are not present in labour unions (Svensson et al., 2013). Moreover, migrant farmworkers are often victims of human trafficking and forced labor (Izcara Palacios et al., 2017). Furthermore, language and cultural barriers prevent them from understanding health and safety training guidelines and from accessing health care or social security services (Svensson et al., 2013).

E. Heat-related health outcomes

1. Heat stress

Heat stress occurs when the body receives heat in excess of what it can tolerate leading to physiological impairment. There are several factors that affect heat stress, which include (1) climatic environmental conditions, (2) metabolism, and (3) clothing (ACGIH, 2019). Environmental factors that affect heat exposure include air temperature, radiant temperature, humidity, and air movement (ACGIH, 2019). Under conditions of high air temperature, the human body gains heat from the surrounding environment (Cramer et al., 2016; Kenny et al., 2014). Furthermore, conditions of high humidity and low air movement can block evaporative cooling, which is a major mechanism of heat loss from the body (Kenny & Flouris, 2014; Pryor et al., 2015). In addition, metabolism is a major internal source of heat, which increases with higher levels of physical activity (Parsons, 2014). Furthermore, the amount of clothing can also affect transfer of heat from the body to the surrounding environment and sweat evaporation (ACGIH, 2019). Protective clothing can inhibit sweat evaporation and normal heat dissipation due to low moisture permeability and high insulating properties (Holmér, 2006). In addition, protective clothing can cause movement restriction that increases the metabolic demands of manual work, which leads to a more rapid rise in body temperature (Dorman et al., 2009). On the other hand, wearing loose-fitting and lightweight clothing can enhance cooling by allowing for better evaporative heat loss (Howe et al., 2007)

2. Heat-related illnesses

Heat-related Illnesses (HRI) occurs when the body is unable to dissipate heat adequately, leading to a steady increase in core body temperature which should be maintained at around 37°C (NIOSH, 2016). If heat-related symptoms are not properly treated, HRI can develop into a continuum of diseases ranging from mild to severe conditions, including heat rash, heat syncope, heat cramps, heat edema, heat exhaustion and heat stroke. Heat rash is the most common HRI in hot work environments. It is a skin irritation from clogged sweat glands which appears as red cluster of pimples or small blisters (NIOSH, 2018; OSHA, n.d.-b). Heat syncope is another type of HRI and is a temporary loss of consciousness due to insufficient blood and oxygen to the brain leading to dizziness and fainting (Jackson et al., 2010). Workers can also suffer from heat cramps, which are painful muscle contractions generally induced by an electrolyte imbalance after intense sweating (NIOSH, 2018; OSHA, n.d.-a). Moreover, heat exhaustion, another HRI, and may present as muscle weakness, fatigue, and a host of other symptoms caused by dehydration, which reduces blood volume and circulation (Jackson & Rosenberg, 2010). Additionally, the most serious HRI caused by extreme heat exposure is heat stroke, which is a potentially life threatening condition and requires emergency treatment (NIOSH, 2018; OSHA, n.d.-b). It is caused by a complete breakdown of the body’s thermoregulation ability leading to dry skin or excessive sweating, very high body temperature, confusion, seizures, and fainting (NIOSH, 2018; OSHA, n.d.-b). While heat stokes could be fatal, non-fatal cases may require extended recovery periods and can result in permanent organ damage (Jackson & Rosenberg, 2010). In severe cases, extreme heat exposure has been associated with heat-related deaths among agricultural workers (Petitti et al., 2013). Heat-related fatalities among agricultural workers accounted for 22% of occupational deaths between 2000 and 2010 in the U.S. with a mortality rate of over 35 times higher when compared to workers from other populations (Gubernot et al., 2015).

Farmworkers can have different tolerance to heat depending on various individual factors. Gender is a common factor that affects heat tolerance with women having increased risk of heat stress due to lower aerobic capacity and sweating rate compared to men (NIOSH, 2016). In addition, age lowers heat tolerance of workers because the thermoregulatory processes of older workers slow down including reduced sweat capacity, cutaneous blood flow and reduced function of heat shock proteins (Hanna et al., 2015). In addition, some therapeutic medications taken by workers can reduce thermoregulatory responses by impairing sweating, impeding normal cardiovascular adjustments to heat stress, depleting fluid and electrolytes and increasing metabolic heat production (Hanna & Tait, 2015; Leon et al., 2015). Workers having preexisting health conditions, such as diabetes mellitus, cardiovascular, neurologic, mental, chronic kidney, and respiratory diseases are at increased risk of adverse health outcomes when exposed to extreme temperatures (Kravchenko et al., 2013). Obese individuals have higher HRI risk since they have higher metabolic heat production and reduced ability of the body to dissipate heat from the skin (NIOSH, 2016). While acclimatization can be an important protective factor that increases tolerance to heat stress and reduces the risk of developing HRI, it is a temporary adaptation that improves heat dissipation through physiological changes such as changes in sweat composition, improved regulation of blood pressure and increased sweat production rate at lower electrolyte concentrations (AIOH, 2013).

3. Chronic kidney disease

An epidemic of chronic kidney disease of unknown etiology (CKDu) has been observed among agricultural workers since the 1970s (Ordunez et al., 2018; Wesseling et al., 2015). The main victims of this disease are young males between the ages of 20 and 50 (Johnson et al., 2019). CKDu is mainly concentrated in Central America, where it has been named Mesoamerican nephropathy (MeN) (Correa-Rotter et al., 2014). The etiology of this CKDu epidemic is unknown and is not explained by common risk factors such as diabetes or hypertension (Johnson et al., 2019). In addition, increased rates of CKDu among agricultural workers have been reported in Sri Lanka and India (Abraham et al., 2019; Jayasumana, 2019). However, heat stress and recurrent dehydration is believed to be a key causal factor in the pathophysiology of CKDu especially in Central America (Glaser et al., 2016; Wesseling et al., 2020). However, in India and Sri Lanka, the evidence regarding the association between heat stress/dehydration and CKDu has been conflicting (Glaser et al., 2016; Herath et al., 2017).

CKDu is usually fatal due to the lack of renal replacement therapy (RRT) such as dialysis or kidney transplantation in poor countries (Correa-Rotter et al., 2014; Weiner et al., 2013). A global meta-analysis of workers from various occupations showed that 15% of those working under conditions of heat stress experienced kidney disease or acute kidney injury (Flouris et al., 2018). The Pan American Health Organization (PAHO) reported that 47,885 deaths from CKDu were recorded in Mesoamerica between 1997 and 2013, which made CKDu the seventh leading cause of death from noncommunicable diseases (PAHO, 2019). Furthermore, the mortality rate of CKDu in some Central American countries represent four times the global CKDu mortality rate (Jayasumana et al., 2017). The incidence of CKDu is expected to increase globally due to rising temperatures and greater number of heatwaves caused by climate change (Glaser et al., 2016).

Studies have shown that the disease is common among agricultural communities working in extremely hot conditions especially sugarcane workers (García-Trabanino et al., 2015; PAHO/WHO, 2019; Sorensen et al., 2019; Wesseling et al., 2016b). The sugarcane industry has poor working conditions, which increase workers' vulnerability to CKDu. Sugarcane cutting requires high physical activity characterized by the performance of vigorous, fast, and repetitive movements with a machete and the loading of the sugarcane bundles (Leite et al., 2018). Furthermore, sugarcane work is concentrated in regions with high temperature and humidity, which increases the risk of heat stress and dehydration (Crowe et al., 2013; Delgado Cortez, 2009). They also have insufficient access to breaks, shade and drinking water throughout the workday (International, 2014). CKDu in also common in other plantation agriculture such as cotton (Peraza et al., 2012) and banana (Torres et al., 2010) as well as rice (Sanoff et al., 2010) and corn farmworkers (PAHO/WHO, 2019; Peraza et al., 2012; Sanoff et al., 2010; Wesseling et al., 2016a). However, coffee farmers have lower prevalence of kidney disease since coffee plantations are primarily located in cooler regions (Laux et al., 2012). In addition, subsistence farmers have lower prevalence of kidney diseases since they have greater control over their working conditions compared to agricultural workers employed on plantations (Peraza et al., 2012; Wesseling et al., 2016b).

4. Other heat related health outcomes

Agricultural workers working in hot conditions are also at an increased risk for workplace injuries due to increased fatigue, reduced alertness, deterioration in psychomotor abilities, and loss of concentration (Riccò, 2018; Spector et al., 2016). Other heat related health outcomes include cardiovascular strain and respiratory diseases. The effect of heat exposure on the cardiovascular and respiratory systems is due to over-loading of these systems with the physiological reactions to heat exposure including increased core body temperature, increased heart rate, shift of blood flow from central organs to skin, increased sweating, and associated dehydration if sufficient replacement liquid is not taken in (Kjellstrom et al., 2010).

F. Preventative Measures

1. Heat safety standards and guidelines

International agencies responsible for preventing the health risk of occupational heat stress have established heat stress standards and guidelines that specify upper limits of safe heat exposure expressed as WBGT. The ISO standard provides reference values for acclimatized and unacclimatized workers according to work/rest ratio and workload with the aim of preventing core body temperature from exceeding 38°C (Parsons, 2006). Workload is classified into metabolic rate categories ranging from light to very heavy. ISO 7243 assumes that workers are healthy, physically fit for the required activity level, and normal work clothing (Parsons, 2006).

The American Conference of Governmental Industrial Hygienists (ACGIH) also provides maximum allowable heat exposure limits for acclimatized (Threshold Limit Values (TLV)) and unacclimatized workers (Action Limits (AL)) to maintain core body temperature within 37 °C. TLV and AL vary according to different work/rest schedules and workload. As the workload increases the TLV and AL values decrease to ensure that most workers maintain core body temperature around 37 °C. Both upper limits are designed for workers who are healthy, adequately hydrated, without any medications, and wearing only a single clothing layer. When WBGT exceeds TLV or AL, preventative measures are required including engineering, administrative controls and physiological monitoring of workers (ACGIH, 2019)

These international standards have been designed and developed in accordance with data from Europe and the USA (McNeill et al., 1999). Differences in physiology, anthropometrics and culture prevents their application in work settings in developing countries (McNeill & Parsons, 1999). In addition, the existing guidelines have adopted a generalized "one size fits all" approach to manage heat stress at the workplace without considering any interindividual (age, sex, disease, others) or intra-individual (medication use, fitness, hydration, others) factors that cause extensive variability in physiological tolerance to a given heat stress (Notley et al., 2019). The consideration of personal risk factors when addressing health and safety issues at the workplace is necessary so that work is not unnecessarily limited, while concurrently minimizing the risk of HRI (Notley et al., 2019).

2. Preventative measures

Because of the farmworkers' vulnerabilities, the US Occupational Safety and Health Administration has recommended a series of administrative and engineering measures to protect farmworkers from heat exposure. The administrative measures include rescheduling tasks to cooler parts of the day and providing workers with extra breaks, adding extra personnel to physically demanding tasks and rotating workers to job tasks that are less strenuous (Luque et al., 2020; Mirabelli et al., 2010; OSHA, n.d.-b). In addition, OSHA recommends drinking water every 15 to 20 minutes when working in the heat to replace fluids lost through sweating. Another important administrative measure is acclimatization, which is the gradual increase in workloads and work hours that allows the body to build tolerance to working in the heat (Luque et al., 2020; OSHA, n.d.-b). Acclimatization usually takes about 5 to 7 days, during which time the body will undergo physiological changes that will make the body more tolerant to heat exposure. Acclimatization is necessary for new workers, workers who were on sick leave or on vacation, and all workers during a heat wave (OSHA, n.d.-b). Another important measure is training which is required to help workers recognize the signs and symptoms of HRI, learn simple measures that can help prevent it and the necessary actions to take in case he/she experiences any of the symptoms. Other measures commonly used by farmworkers include the use of head protection and sunscreen for protection from direct sun exposure (Kearney et al., 2016; OSHA, n.d.-b). In addition, some engineering controls that have been recommended to reduce heat exposure is the use of fans that facilitates cooling of the body by increasing heat exchange between the skin surface and the surrounding air and the rate of evaporation (Bethel et al., 2017; OSHA, n.d.-b). In addition, the provision of rest stations or air-conditioned facilities allows workers to take breaks during or after work and reduce prolonged exposure to heat (Arcury et al., 2015; Bethel et al., 2017).

G. Research Objectives

With the continuous increase in global temperatures and the severity of its impact on the health and safety of the agricultural workforce globally, a scoping review is needed to summarize the existing knowledge regarding the impact of climate change particularly extreme heat exposure on farmworkers' health and the available prevention strategies to alleviate these impacts on farmworkers. To the best of our knowledge, no review has been carried out to study the effects of climate change and heat stress on the health and safety of farmworkers. This work will also inform policymakers to develop more effective policies and programs to protect vulnerable farming communities from climate change.

The objectives of this review are to:

1. Summarize the available evidence on the effects of climate change on farmworkers' health with a focus on heat-related illnesses
2. Identify the risk factors for heat-related illnesses among farmworkers
3. Review the preventive measures that are used to minimize heat stress exposure among farmworkers
4. Recommend appropriate and evidence-based interventions to reduce workplace heat exposure and protect the health and safety of farmworkers

CHAPTER II

METHODS

A. Study design and Protocol

To meet the objectives of the present study, a scoping review was conducted. The protocol was developed following the PRISMA extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018). Scoping reviews can be conducted to meet various objectives including summarizing the existing evidence on a specific topic, summarizing findings from a body of knowledge that is heterogeneous in methods or discipline, determining the value of undertaking a systematic review and providing recommendations for future research (Tricco et al., 2016).

B. Search Strategy

We conducted a comprehensive search in 5 electronic databases: Medline, Embase, Scopus, CINAHL, and Web of Science. A medical librarian (Ms. Layal Hneiny) developed a search strategy using a combination of controlled vocabulary such as MeSH and keywords for each database. The search strategy was not restricted to a particular region in order to capture all published studies globally. In addition, specific health outcomes were not included in the search strategy in order to capture all heat-related health effects covered in the medical and public health literature published in the selected databases. The search strategies are detailed in Appendix A. Two concepts were used in our search strategy: (1) heat exposure and (2) agricultural setting:

- Keywords used for heat exposure included: extreme temperature, thermal comfort, thermal sensation, global warming, heatwave, climate variability.

- Keywords used for agricultural setting included: farmworker, farmer, harvester, grower, sugarcane cutter, agriculturalist, agricultural worker.

In addition, the websites of international agencies and agricultural databases were manually searched to identify relevant articles. The reference lists were also checked in the grey literature to find additional studies for the review. The database and grey literature searches were conducted on August 24, 2020.

C. Eligibility criteria

Articles that addressed symptoms and outcomes related to heat exposure, risk and protective factors associated with heat-related health outcome and preventive measures used to protect workers from heat exposure were included based on a series of pre-established eligibility criteria (Table 1). No restrictions were applied on (1) heat related health outcome, (2) year of publication, and (3) language, in order to capture the maximum number of articles that have addressed the topic in the literature. The screening guide can be found in Appendix B.

Table 1: Inclusion and exclusion criteria

Category	**Inclusion criteria**	**Exclusion criteria**
Population	Farmworkers of all age groups	Not farmworkers
Outcome of interest	Studies assessing: (1) Symptoms and outcomes related to heat exposure; (2) Risk and protective factors associated with health outcomes; and (3) Preventive measures	Studies assessing outcomes not related to heat related outcomes and symptoms and studies that calculate the effects with simulations or models instead of actual measurements in humans
Context of interest	Studies assessing the impact of occupational heat exposure on workers' health and safety	Studies not related to the context of the study such as those on the impact of heat exposure on the general

		population, plants, animals, and crops
Study design	Primary studies including quantitative and qualitative methods	Editorials, commentaries, letter to the editors, reviews, reports and conference abstracts

D. Selection Process

Two stages for the screening and selection of articles were carried out independently and in duplicates by 2 reviewers (1. Moussa El Khayat: Author of this thesis; and 2. Dana Halwani: member of Dr. Rima Habib's research team, and with previous experience in screening protocols/scoping reviews). The screening phase was guided by the pre-established eligibility criteria. Calibration exercises were conducted by the 2 reviewers to assess and refine, if necessary, the screening questions and ensure the validity of the selection process in coordination with Dr. Rima Habib (the advisor on this thesis). The records that were deemed eligible for inclusion by the two reviewers during the title and abstract screening phase were screened at the full-text stage. Disagreements about inclusion in the full text screening were resolved through discussion until consensus was reached between both reviewers. If consensus could not be reached, a third reviewer (Dr. Rima Habib: Advisor on this thesis) was consulted to resolve the disagreement. Google translate was used for the translation of non-English publications in order to conduct full text screening of these publications.

E. Data abstraction and analysis

Data were extracted from the included articles by one of the reviewers using a pre-established data abstraction form. This form was developed and reviewed by the authors of this review. A calibration exercise was conducted by the 2 reviewers before the beginning of the data abstraction phase in order to assess and refine, if necessary, the fields/data items in the form and to ensure the validity of the data abstraction process (i.e. the same information is extracted by both reviewers). Information relating to study characteristics and the findings were extracted from each selected study: (1) First author and year of publication, (2) study location and region, (3) study design, (4) study population and sample size, (5) heat exposure metric, (6) period of heat exposure and study duration, (7) methods of data collection (8) data analysis, (9) heat related health outcome, (10) risk factors, (11) protective factors, and (12) preventative measures.

Data on health outcomes, risk and protective factors and preventative measures were descriptively summarized and analyzed. Furthermore, statistically significant risk and protective factors from quantitative studies and all factors from qualitative studies were classified into superordinate categories.

CHAPTER III

RESULTS

The selection process of the articles is presented in Figure 3 using the PRISMA flow diagram. Five thousand five hundred and eighty five (5585) records were identified from the database search while an additional 1323 records were identified through searching the grey literature (any research that has not gone through peer review for publication). In addition, 5 records were identified through manual searching. Four thousand eight hundred and twenty one (4821) records remained for tittle and abstract screening after the removal of duplicates. After completing title and abstract screening of the identified records, 170 articles remained for full-text screening. Ninety-three records were excluded for various reasons as listed in the flow diagram and 77 records were included for the final review.

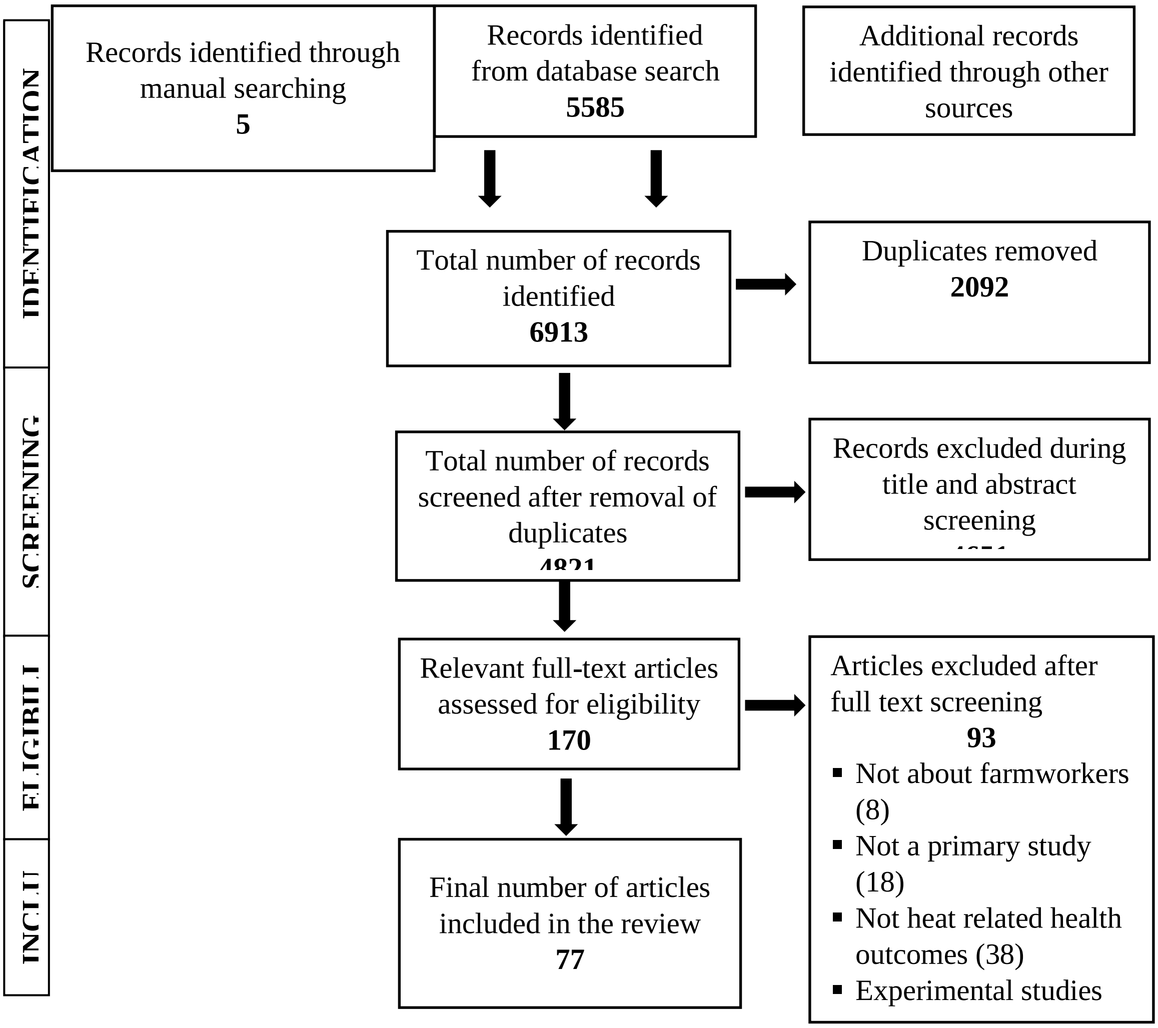

Figure 3: Flow chart of selection process for included studies

A. Descriptive characteristics of included studies

Please refer to Appendix C for the full data abstraction tables. Table 2 presents the descriptive characteristics of the studies included in this review. The majority of reviewed articles were quantitative studies, which included cross sectional (n=52; 68%) and longitudinal studies (n=13; 17%). While the other reviewed articles employed qualitative (n=5; 7%) and mixed methods designs (n=2; 3%). The remaining articles were case reports (n=3; 4%), comparative studies (n=1; 1%) and case studies (n=1; 1%).

In addition, the majority of the reviewed articles used questionnaires (n=58; 75%), followed by physiological measurements (N=29; 38%) and biological sampling (n=31; 40%) as data collection tools. In addition, some studies used interview/focus groups (n=7; 10%), while the rest used observations (n=3; 4%).

As presented in Table 2, the majority of the included articles focused on agricultural workers/farmworkers (n=45; 58%) and sugarcane cutters (n=19; 25%). While the remaining articles studied pesticide applicators (n=1;1%), nursery workers (n=1;1%), sheep shearers (n=1;1%), forestry (n=2; 3%), harvesters (n=2; 3%), crop workers (n=1;1%), horticulture workers (n=1;1%) and paddy farmers (n=1;1%).

The majority of the reviewed studies were conducted on farmworkers in the United States (n=33; 43%), followed by Nicaragua (n=10; 13%), India (n=6; 8%), and El Salvador (n=4; 5%) (Table 2). Figure 4 presents the number of articles by study location using a color-coded map.

Table 2: Descriptive characteristics of the included articles

Characteristics	**N**	**%**
Study design		
Quantitative studies		
Cross sectional	52	68
Longitudinal	13	17
Case report	3	4
Case study	1	1
Comparative	1	1
Qualitative	5	7
Mixed methods	2	3
Data collection methods		
Questionnaire	58	75
Biological sampling	31	40
Physiological measurements	29	38
Interview/Focus group	7	9
Observation	3	4

Study population		
Forestry workers	2	3
Farmworkers/Agricultural workers	44	57
Fernery workers	3	4
Tractor driver	1	1
Nursery workers	1	1
Horticulture	1	1
Harvesters	3	3
Crop workers	1	1
Pesticide applicators	1	1
Sheep shearers	1	1
Sugarcane workers	19	25
Paddy farmers	1	1
Country		
USA	33	43
Australia	2	3
Costa Rica	2	3
Sri Lanka	2	2
India	6	8
Guatemala	3	4
Nicaragua	10	13
El Salvador	4	5
Ghana	2	3
Canada	1	1
Italy	1	1
South Africa	1	1
South Korea	1	1
Slovenia	1	1
Finland	1	1
Nigeria	1	1
Brazil	1	1
Poland	1	1
Mexico	1	1
Nepal	1	1
Indonesia	1	1
Cameron	1	1

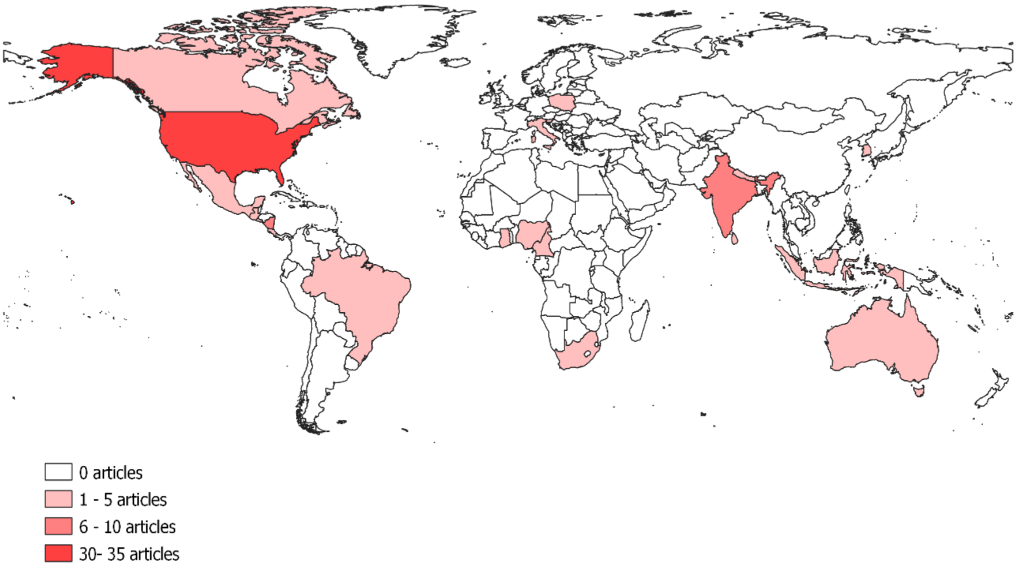

Figure 4: Number of studies on heat related health outcomes by study location

In addition, as shown in Figure 5, there has been an increase in the number of articles published on this topic in the last couple of years, reaching its peak in 2019 and 2020. The highest number of publications was in 2019, with 16 articles published that year.

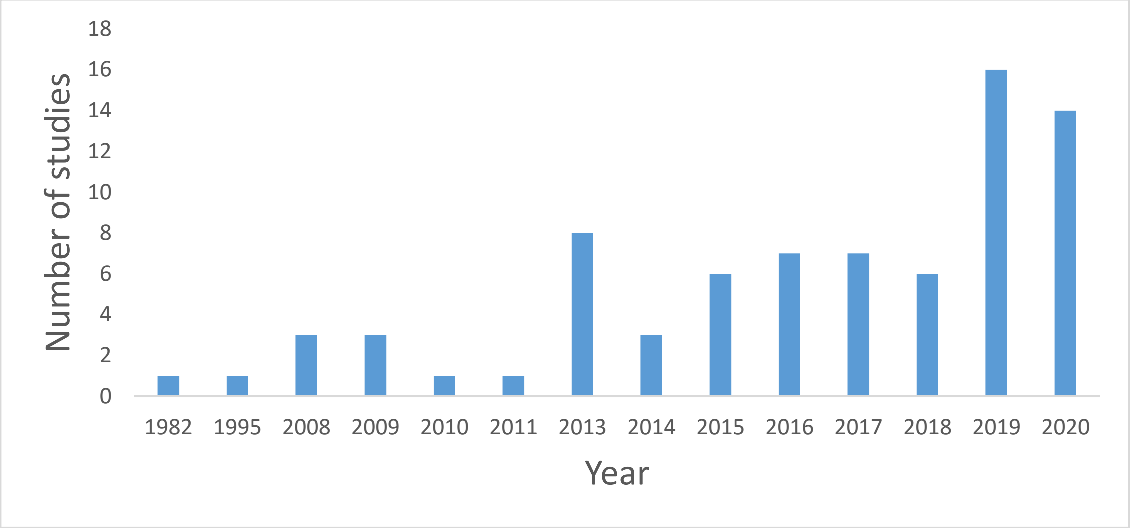

Figure 5: Number of studies on heat related health outcomes by year of publication

B. Heat related health outcomes

The type of heat related health outcomes assessed in the included studies are presented in Table 3. The most common heat-related health outcomes assessed were heat-related illnesses (HRI), dehydration (n=47; 61%) and kidney diseases (n=24; 31%). While the remaining articles assessed cardiovascular diseases (n=1; 1%), respiratory diseases (n=2; 3%), injuries (n=1; 1%), skin disorders (n=1; 1%), diabetes and hypertension (n=1; 1%).

Table 3: Heat related health outcomes of included studies

Heat related outcomes	**N**	**%**
HRI and dehydration	47	61
Kidney diseases	24	31
Cardiovascular diseases	1	1
Respiratory diseases	2	3
Injuries	1	1
Skin disorders	1	1
Diabetes and Hypertension	1	1

C. Characteristics of reviewed studies assessing heat related illnesses

Forty nine articles out of 77 reviewed articles assessed the prevalence of HRI symptoms among their study population, out of which, 22 studies collected data on self-reported HRI symptoms using questionnaire surveys (Arcury et al., 2019; Arcury et al., 2020; Arcury et al., 2015; Arnold et al., 2020; Bethel & Harger, 2014; Bodin et al., 2016; Budhathoki et al., 2019; Crowe et al., 2015; Culp et al., 2019; Fleischer et al., 2013; Frimpong et al., 2014; Kearney et al., 2016; Luque et al., 2020; Mirabelli et al., 2010; Mutic et al., 2018; Pogacar et al., 2017; Riccò et al., 2020; Sadiq et al., 2019; Sahu et al., 2013; Sen et al., 2019; Smith et al., 2021; Spector et al., 2015) while 15 studies assessed HRI by measuring physiological parameters (Biggs et al., 2011; CDC, 2008; Culp & Tonelli, 2019; Das et al., 2013a, 2013b; Gun et al., 1995; Lumingu et al., 2009; Lundgren et al., 2014; Mac, 2016; Mac et al., 2019; Miller, 1982; Mitchell et al., 2017; Stoklosa et al., 2020; Vega-Arroyo et al., 2019; Wagoner et al., 2020). In addition, 11 studies assessed working conditions and preventative measures without assessing HRI (Bethel et al., 2017; Crowe et al., 2009; Delgado Cortez, 2009; Flocks et al., 2013; Frimpong et al., 2020; Hansen et al., 2020; Kwon et al., 2015; Lam et al., 2013; Luque et al., 2019; Stoecklin-Marois et al., 2013; Wilmsen et al., 2019).

The most commonly used physiological parameters to assess HRI among participants included core body temperature, blood pressure and heart rate. Three studies measured core body temperature using an ingestible temperature pill (Mac et al., 2019; Mitchell et al., 2017; Wagoner et al., 2020). Moreover, 5 studies measured heart rate (Culp & Tonelli, 2019; Das et al., 2013a, 2013b; Lumingu & Dessureault, 2009; Sahu et al., 2013), 2 studies measured blood pressure (Das et al., 2013a, 2013b) and 3 studies measured dehydration using changes in body weight and urine specific gravity (Biggs et al., 2011; Vega-Arroyo et al., 2019; Wagoner et al., 2020).

Out of the 49 articles assessing HRI prevalence, 22 articles examined HRI and dehydration among vulnerable populations including migrant workers, children and females. Seventeen studies focused on migrant farmworkers in the U.S. (Arcury et al., 2015; Bethel & Harger, 2014; Bethel et al., 2017; CDC, 2008; Culp et al., 2011; Fleischer et al., 2013; Flocks et al., 2013; Kearney et al., 2016; Luque et al., 2020; Luque et al., 2019; Mirabelli et al., 2010; Mitchell et al., 2017; Mutic et al., 2018; Smith et al., 2021; Stoecklin-Marois et al., 2013; Stoklosa et al., 2020; Wilmsen et al., 2019) and one conducted in Australia (Hansen et al., 2020). One of these studies presented a case report on heat exhaustion in a migrant agricultural worker in the U.S. involved in labor trafficking (Stoklosa et al., 2020). In addition, child farmworkers were the target population in 4 studies which examined the experiences, risk factors and preventive measures for HRI (Arcury et al., 2019; Arcury et al., 2020; Arcury et al., 2015; Arnold et al., 2020). Moreover, one study focused on female farmworkers to examine women’s perceptions of HRI and pregnancy (Flocks et al., 2013). Males represented the majority of those sampled in most included studies while 4 studies recruited only male farmworkers as study participants (Arcury et al., 2015; Culp & Tonelli, 2019; Gun & Budd, 1995; Sahu et al., 2013). Furthermore, only one of the included studies compared HRI symptoms between men and women (Pogacar et al., 2017) while one study compared heat related knowledge and task distribution between males and females (Stoecklin-Marois et al., 2013).

D. Characteristics of reviewed studies assessing Kidney disease

Twenty four of the included studies were focused on kidney disease, out of which, 15 were conducted in Central America, where an increased incidence and prevalence of CKDu has been observed since the early 2000s, including Guatemala (Butler-Dawson et al., 2018; Butler-Dawson et al., 2019; Sorensen et al., 2019), El Salvador (García-Trabanino et al., 2015; Hansson et al., 2020; Wegman et al., 2018), and Nicaragua (Glaser et al., 2020; Hansson et al., 2020; Hansson et al., 2019; Kupferman et al., 2018; Laws et al., 2015, 2016; Raines et al., 2014; Wesseling et al., 2016a; Wesseling et al., 2016b). Three studies were conducted in South Asia, which is another endemic region for CKDu including Sri Lanka (Jayasekara et al., 2019; Nanayakkara et al., 2020) and India (Raju et al., 2014). In addition, 7 studies were conducted in nonendemic regions including the US (Mix et al., 2018; Moyce et al., 2020a; Moyce et al., 2016; Moyce et al., 2017; Moyce et al., 2020b), Cameroon (Ekiti et al., 2018), and Indonesia (Fitria et al., 2020).

All included studies relied on blood and urine samples to determine the prevalence of kidney diseases. Moreover, surveys/interviews were administered in some studies alongside the collection of biological samples to examine correlations between the occurrence of kidney diseases and lifestyle factors such as tobacco, NSAID, alcohol use, diet, and employment history. In addition, 2 studies measured core body temperature (Moyce et al., 2020a; Moyce et al., 2020b) while another study assessed heat strain using the Physiological Strain Index (PSI) (Moyce et al., 2017).

Eleven studies assessed changes in kidney function over an entire working day (cross-shift) (Butler-Dawson et al., 2019; García-Trabanino et al., 2015; Mix et al., 2018; Moyce et al., 2020a; Moyce et al., 2016; Moyce et al., 2017; Moyce et al., 2020b;

Nanayakkara et al., 2020; Sorensen et al., 2019; Wegman et al., 2018; Wesseling et al., 2016a), while 10 studies examined changes in kidney function over the harvest season (cross-harvest) (Butler-Dawson et al., 2018; Butler-Dawson et al., 2019; Glaser et al., 2020; Hansson et al., 2020; Hansson et al., 2019; Kupferman et al., 2018; Laws et al., 2015, 2016; Wegman et al., 2018; Wesseling et al., 2016a). The remaining studies assessed changes in kidney function at a single point in time (Ekiti et al., 2018; Fitria et al., 2020; Jayasekara et al., 2019; Raines et al., 2014; Raju et al., 2014; Wesseling et al., 2016b)

Studies have relied on clinical definitions to specify cases of CKD (Ekiti et al., 2018; Fitria et al., 2020; Raju et al., 2014) and acute kidney injury (AKI) (Butler-Dawson et al., 2019; Kupferman et al., 2018; Mix et al., 2018; Moyce et al., 2020a; Moyce et al., 2016; Moyce et al., 2017; Moyce et al., 2020b). Other studies assessed incident kidney injury (IKI) which is a reduction in kidney function over the harvest season (Glaser et al., 2020; Hansson et al., 2020; Hansson et al., 2019).

Twelve studies focused specifically on kidney disease among sugarcane workers (Butler-Dawson et al., 2018; Butler-Dawson et al., 2019; Ekiti et al., 2018; Glaser et al., 2020; Hansson et al., 2020; Hansson et al., 2019; Kupferman et al., 2018; Laws et al., 2015, 2016; Sorensen et al., 2019; Wegman et al., 2018; Wesseling et al., 2016a), while 9 studies focused on various types of farmworkers including agricultural workers (Jayasekara et al., 2019; Mix et al., 2018; Moyce et al., 2020a; Moyce et al., 2016; Moyce et al., 2017; Moyce et al., 2020b; Raines et al., 2014), rice harvesters (Fitria et al., 2020), paddy farmers (Nanayakkara et al., 2020). In addition, one study recruited construction workers, sugarcane workers and farmers (Wesseling et al., 2016b). While another study selected CKD patients as their target population (Raju et al., 2014).

Furthermore, males represented the majority of those sampled in most included studies. In addition, a few studies recruited only male farmworkers (Butler-Dawson et al., 2018; Butler-Dawson et al., 2019; Fitria et al., 2020; Nanayakkara et al., 2020; Wesseling et al., 2016a; Wesseling et al., 2016b). Three studies used gender stratification to compare risk factors between males and females (Moyce et al., 2020a; Moyce et al., 2017; Moyce et al., 2020b).

E. Climatic measurements and Heat Indices

A variety of heat exposure metrics were used to measure heat stress in the included studies. Overall, 35 articles employed some form of heat exposure metric. Some of these studies used simple weather metrics including temperature (n=7; 10%) and relative humidity (n=4; 6%). In addition, composite indices accounting for temperature and other weather parameters were used including WBGT (n=27; 35%) and heat index (n=6; 9%).

F. Statistical Analyses adopted in the included Studies

The statistical models used to assess association between risk factors and HRI include logistic regression analysis (n=5), chi-square tests (n=1), linear regression (n=2), mixed-effects logistic regression (n=1), population intervention models (n=1), and log-binomial regression models (n=2).

Statistical models used to assess association of risk factors with kidney disease include mixed effects logistic regression (n=3), multiple logistic regression (n=2), multivariate logistic regression (n=1), multinomial logistic regression (n=1), logistic regression models (n=6), linear mixed effects models (n=3), linear regression models (n=3) and regression model (n=1).

G. HRI symptoms

HRI symptoms could not be compared between different agricultural populations or study regions due to the use of different reporting periods and the absence of case definitions[1] in the majority of the reviewed studies. The most common self-reported symptoms in the included studies include muscle cramps, nausea or vomiting, hot and dry skin, confusion, dizziness, weakness or fatigue, fainting, headache, and heavy sweating (Arcury et al., 2019; Arcury et al., 2015; Arnold et al., 2020; Bethel & Harger, 2014; Budhathoki & Zander, 2019; Crowe et al., 2015; Fleischer et al., 2013; Kearney et al., 2016; Luque et al., 2020; Mutic et al., 2018; Sadiq et al., 2019; Smith et al., 2021). Other HRI symptoms reported include fever, tachycardia, dysuria, difficulty breathing, skin rash or bumps, blurred vision, pain in different body parts (Crowe et al., 2015; Kearney et al., 2016; Luque et al., 2020; Riccò et al., 2020; Sahu et al., 2013).

H. Significant Factors associated with HRI

Fifteen articles reported risk or protective factors for HRI, 12 of which reported statistical measures of association, while 3 reported potential factors without a statistical analysis to determine their association or relationship with HRI. Of these 15 studies, 11 were conducted in the US while the remaining studies were conducted in Australia

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[1] Case definitions specify the number or type of reported symptoms used to determine HRI status

(n=2), Italy (n=1), and Costa Rica (n=1). Risk estimates include odds ratio (OR), regression coefficient (β), prevalence ratios (PR), population intervention parameter with 95% confidence intervals (CI) were reported from studies using statistical models. Table 4 summarizes the studies that identified significant risk and protective factors associated with HRI.

1. Work organization and management

Workload: Three studies assessed the association between HRI and workload measured using an accelerometer among U.S. farmworkers. Two of these studies found that there was a 12% increase in the odds of the Core Body Temperature (CBT) reaching or exceeding 38°C for every 100 kilocalories of energy expended among fernery workers (OR: 1.12, 95% CI: 1.03- 1.21) (Mac, 2016; Mac et al., 2019). Similarly, Vega-Arroyo et al. (2019) found that an increase in mean work rate of 1000 counts per minute (cpm) was associated with an increase of CBT by 0.6°C (95% CI: 0.4-0.9). Overall, evidence suggests that workload is an important risk factor for HRI among agricultural workers.

Work tasks: One study found that pesticide applicators in Italy performing specific agricultural tasks such as handling pesticides had greater odds of reporting HRI (OR: 2.975, 95% CI: 1.185-42.035) compared to other tasks such as seeding, harvesting/picking, machine operation, irrigation, mechanized hoeing/weeding and pruning (Riccò et al., 2020). In addition, HRI status was also associated with performing manual hoeing/weeding (OR: 8.847, 95% CI: 1.882-41.579)

Payment method: Another work factor associated with increased risk of HRI is type of payment. Two studies identified that piece-rate work can increase the risk of

HRI. In an observational study, Crowe et al. (2009) found that sugarcane workers in Costa Rica paid by piece-rate are often reluctant to take breaks. Another qualitative study using focus group discussion identified that migrant Latino farmworkers in the US paid by piece-rate worked for long hours and were less likely to take sufficient breaks, which can increase their risk of HRI (Luque et al., 2019). Similarly, Spector et al. (2015) also reported that U.S. farmworkers paid by piece-rate are 6.2 times more likely to have higher HRI compared to hourly pay (OR: 6.20; 95% CI: 1.11-34.54). However, another study found no significant association between piece-rate work and HRI among Latino child farmworkers even though one third of the workers reported being paid by piece-rate (Arcury et al., 2020). Overall, evidence from the three studies suggests that piece-rate work is a risk factor for HRI.

Job decision latitude: Two qualitative studies identified that lack of control over workplace conditions can increase the risk of HRI among farmworkers. Hansen et al. (2020) reported, through a case study, that due to power inequality at the workplace, horticulture workers are unable to make decisions about their health and safety and to determine safe work rate, take rest breaks and drink water, which can lead to an increased risk of HRI. Similarly, Lam et al. (2013) reported that Latino farmworkers lack the ability to exert control over certain HRI preventative measures such as access to clean drink water, shade availability and proximity to bathroom facilities.

2. Physiological and behavioral factors

Rest in shaded area: Two studies assessed the effect of resting in shaded areas on the development of HRI. Fleischer et al. (2013) showed that increasing breaks in the shade can reduce the prevalence of HRI symptoms by 9.2% among migrant farmworkers in the U.S. However, another study identified paradoxically that rest in shady but not air-conditioned areas is associated with higher HRI (OR: 5.491, 95% CI: 1.372-21.971) among farmworkers in Italy (Riccò et al., 2020).

Sun safety behavior: Kearney et al. (2016) assessed the effect of various sun safety behavior on the prevalence of HRI symptoms among migrant farmworkers. The study was not able to establish meaningful and significant associations between specific sun safety behaviors including wearing sunscreen, wearing a hat, wearing a shirt with collar and protection over face and the prevalence of HRI. Other sun safety behaviors including wearing long-sleeved shirts, limiting time in sun, wearing sunglasses and wearing long pants showed a protective association with HRI symptoms; however, these findings did not reach significance.

Changing work hours and work activities: Mirabelli et al. (2010) assessed the associations between 5 adaptive strategies including changing work hours, changing work activities, drinking more water, resting in shaded areas, and going to air-conditioned places during or after work and prevalence of HRI symptoms among migrant Latino agricultural workers having H-2A visas (temporary agricultural worker visa) and those without an H-2A visa (non–H-2A visa) in the U.S. The study found that changes in work hours and work activities as adaptive strategies for HRI symptoms were associated with a lower prevalence of HRI symptoms among H-2A farmworkers (PR: 0.44, 95% CI: 0.22-0.89) but not among non–H-2A farmworkers. This is probably due to better working conditions and more safety behaviors among H-2A workers compared to non–H-2A workers (Mirabelli et al., 2010).

Going to air conditioned places: An unexpected finding from 1 study is that child farmworkers going to air conditioned places during rest breaks or after work reported significantly higher HRI levels (59.6% vs. 41.7 %, p= 0.0279) (Arnold et al., 2020).

Extra breaks: Two studies found that access to regular breaks is protective for HRI. One study found that increasing access to regular breaks can reduce HRI symptoms by 6% (Fleischer et al., 2013). Similarly, Arnold et al. (2020) showed that child farmworkers taking extra breaks are more likely to have lower HRI

Soda consumption: One study found that reducing soda consumption is protective for HRI with a reduction in HRI symptoms by 6.7% (Fleischer et al., 2013). Research indicates that soda is inferior to water and sports drinks for hydration and that drinks containing sugar and caffeine should be avoided due to its diuretic properties (Fleischer et al., 2013).

Clothing practices: A qualitative study by Lam et al. (2013) identified various clothing practices that can increase the risk of HRI among Latino farmworkers in the U.S. Female participants reported wearing darker clothing and sweatshirts layered on top of short-sleeved shirts to induce sweating in order to lose weight which can increase the risk of developing HRI. Furthermore, male participants reported wearing back support belts to prevent back injury which can trap heat and prevent evaporative cooling.

However, other factors such as drinking more water and HRI training were not found to be significantly associated with HRI (Mirabelli et al., 2010; Riccò et al., 2020; Spector et al., 2015).

3. Accessibility to heat prevention and treatment

Cultural and language barriers: Hansen et al. (2020) reported, through a case study, that cultural and language barriers is a risk factor for HRI that prevents workers from understanding proper safety training requirements. Furthermore, a qualitative study focused on Latino farmworkers in the U.S. reported that some participants believed exposure to cold immediately after heat can cause health problems such as headache, fainting, arthritis, and oral blisters indicating that cultural beliefs could lead to less effective HRI treatment (Lam et al., 2013).

Access to toilet facilities: Spector et al. (2015) found that walking for more than 3 minutes to get to the toilet is associated with 4.86 times higher odds of HRI among crop workers compared to less than 3 minutes (OR: 4.86; 95% CI: 1.18–20.06).

Access to medical medication: Fleischer et al. (2013) identified that increasing access to medical attention reduces HRI symptoms by 7.3% among migrant farmworkers.

Health and safety training: One study found that child farmworkers receiving pesticide safety training had a greater odds of reporting HRI symptoms (OR: 3.26, 95% CI: 1.39-7.65) (Arcury et al., 2020).

4. Medication and lifestyle factors

One study identified alcohol consumption as a risk factor for HRI. Gun and Budd (1995) assessed the effect of alcohol consumption on rectal temperature, sweat loss and thermal comfort among sheep shearers in Australia. They found that alcohol explained 5% of the variation in rectal temperature while no association was found between alcohol and thermal comfort and sweat loss. In addition, heavier alcohol drinkers had 0.16°C lower (p=0.02) rectal temperature compared to lighter drinkers, indicating a lower HRI prevalence. In contrast, 2 studies conducted in the U.S. found that alcohol use is not a significant factor for HRI among farmworkers (Fleischer et al., 2013; Mutic et al., 2018)

5. Sociodemographic factors

Age: Two studies identified increasing age as a risk factor for HRI among Latino child farmworkers in the US. Arcury et al. (2019) found that increasing age is associated with higher odds of HRI (OR: 1.41, 95% CI: 1.18-1.69). Similarly, another study reported that older children aged 16-17 years are more likely to experience HRI compared to younger children aged 10-13 years (OR: 4.52, 95% CI: 1.93-10.57) (Arcury et al., 2020). Furthermore, a study also found that older children were more likely to report HRI symptoms (p=0.0011) (Arnold et al., 2020).

Overall, evidence regarding the effect of age on HRI among adult farmworkers is inconsistent. A study in the U.S. reported that increasing age is associated with 0.92 times lower odds of HRI among crop workers (OR: 0.92; 95% CI: 0.87–0.98) (Spector et al., 2015). In contrast, some studies found no significant association between age and HRI including three studies from the U.S. (Mac et al., 2019; Mutic et al., 2018; Vega-Arroyo et al., 2019) and another from Italy (Riccò et al., 2020)

Gender: Three studies in the U.S. identified female gender to be associated with increasing HRI. Two studies found that female fernery workers were 5.38 times more likely to have core body temperature reaching or exceeding 38°C compared to males after adjusting for energy expenditure (OR: 5.38, 95% CI: 1.03-18.30) (Mac, 2016; Mac et al., 2019). Similarly, Mutic et al. (2018) found that female migrant and seasonal farmworkers had three times the odds of experiencing three or more HRI symptoms compared to their male counterparts (OR: 2.86, 95% CI: 1.18-6.89). However, other studies found no significant association between female gender and HRI among pesticide applicators in Italy (Riccò et al., 2020) and farmworkers in the U.S. (Vega-Arroyo et al., 2019). Overall, evidence suggests that females are more likely to experience HRI compared to male counterparts.

Migrant status: Several studies found no association between migrant status or nationality and increased risk of HRI (Arcury et al., 2019; Arcury et al., 2020; Mutic et al., 2018).

6. Environmental conditions

Two studies identified hot environmental conditions as a risk factor for HRI. Vega-Arroyo et al. (2019) reported that WBGT is associated with higher core body temperature (β: 0.03, 95% CI: 0.017-0.05) among migrant farmworkers. In addition, Gun and Budd (1995) assessed the relationship between WBGT, radiant heat and vapor pressure with rectal temperature, thermal comfort and sweat loss among sheep shearers in Australia. The study found that WBGT explained 27% of the variation in rectal temperature, 14% of thermal comfort and 61% of sweat loss. Vapor pressure explained 16% of variation in rectal temperature while radiant heat explained 6% of thermal comfort. However, Mac et al. (2019) found that average WBGT was not found to be a significant predictor of elevated CBT among fernery workers.

Table 4: Studies that found risk and protective factors associated with HRI

Factors	**Risk Factor**	**Protective factor**
Work organization and management		
Workload	Mac (2016) Mac et al. (2019) Vega-Arroyo et al. (2019)	
Work tasks	Riccò et al. (2020)	
Payment method	Crowe et al. (2009) Spector et al. (2015) Luque et al. (2019)	
Job decision latitude	Hansen et al. (2020)	
Physiological and Behavioral		
Go to air-conditioned areas	Arnold et al. (2020)	
Rest in shaded area	Riccò et al. (2020)	Fleischer et al. (2013)
Extra breaks		Fleischer et al. (2013) Arnold et al. (2020)
Change work hours and activities		Mirabelli et al. (2010)
Reduce soda consumption		Fleischer et al. (2013)
Accessibility to heat prevention and treatment		
Culture and language	Hansen et al. (2020)	
Access to toilet	Spector et al. (2015)	
Access to medical attention		Fleischer et al. (2013)
Health and Safety Training		Arcury et al. (2020)
Medications and lifestyle factors		
Alcohol consumption		Gun and Budd (1995)
Sociodemographic		
Increasing age	Quandt et al. (2019)	Spector et al. (2015)

	Arcury et al. (2020) Arnold et al. (2020)	
Female gender	Mac (2016) Mac et al. (2019) Mutic et al. (2018)	
Environmental conditions		
Hot environmental conditions	Vega-Arroyo et al. (2019)	

I. Significant Factors associated with kidney disease

Twenty out of 24 studies identified and reported on factors that are associated with kidney diseases. Risk and protective values were extracted from multivariate analysis. Risk estimates include odds ratio (OR), incidence ratio (IR), regression coefficient (β), relative mean, mean difference, exponentiated β coefficients were reported. Table 5 summarizes the studies that identified the significant risk and protective factors associated with kidney disease.

1. Work organization and management

Workload: Three studies have identified workload as a risk factor for kidney disease. Hansson et al. (2019) compared cross-harvest incident kidney injury (IKI) and GFR among sugarcane workers in Nicaragua which included field support staff (low workload group), drip irrigation workers (moderate workload), seed cutters (high workload) and burned sugarcane cutters (very high workload). The study found that cross-harvest GFR was significantly lower in the burned cane cutters and seed cutters (GFR -5 and -9 ml/min/1.73m2, respectively) compared to the other workload groups. In addition, cases of IKI also developed more frequently among groups with the highest physical workload with 27% in burned sugarcane cutters compared to 2% in both field support staff and irrigation workers. Furthermore, 2 other studies conducted in the US showed an association between workload measured using an accelerometer and higher odds of cross-shift AKI among agricultural workers with odds ratios ranging from 1.01 (95% CI: 1.01–1.02) to 1.92 (95% CI, 1.05-3.51) (Moyce et al., 2020a; Moyce et al., 2020b). Overall, evidence from the three studies suggests that workload is a risk factor for kidney disease.

Job categories or work tasks: Various studies have assessed the association between specific job categories and kidney disease in different agricultural populations (Kupferman et al., 2018; Laws et al., 2016). Overall, evidence suggests that cane cutting is strongly associated with reduced kidney function. In fact, studies show that sugarcane cutters experience the greatest decline in kidney function during the harvest season. Laws et al. (2016) assessed changes in biomarkers of kidney injury (NGAL, NAG and IL-18) between job categories with the highest increase over the harvest occurring among cane cutters. Similarly, Kupferman et al. (2018) found cane cutters had a 20% higher serum creatinine level as compared to other workers (e^{β}: 1.20, 95% CI: 1.13-1.27). Cane cutters also had a 16% higher serum creatinine levels at end of harvest after the addition of a pre-harvest baseline value indicating that the worse kidney function of cane cutters cannot be explained by pre-harvest kidney damage (e^{β}: 1.16, 95% CI: 1.10-1.22).

Furthermore, in a cross-sectional study on agricultural workers in the U.S., picking was associated with higher odds of AKI (OR: 2.51, 95% CI: 1.39–4.54) which increased among males (OR: 4.12, 95% CI: 1.87–9.08) among males (Moyce et al., 2020b). In contrast, other studies did not find a significant association between picking and cross-shift AKI among agricultural workers in the U.S. (Moyce et al., 2020a; Moyce et al., 2017).

Payment method: Four studies conducted in the US identified piece-rate work as a risk factor for cross-shift AKI among agricultural workers. Moyce et al. (2017) identified that piece-rate work is associated with 4.24 (95% CI: 1.56-11.52) times higher odds of AKI which increased to 102.81 odds of AKI (95% CI: 7.32-1443.20) among females. Similarly, both Moyce et al. (2020a) and (Moyce et al., 2016) found that piece-rate work is associated with 3.02 (95% CI: 1.44-6.34) and 4.52 (95% CI: 1.61-12.70) higher odds of AKI respectively. Overall, evidence from the four studies suggests that piece-rate work is associated with kidney disease.

Duration of employment: Two studies found a relationship between duration of employment in the agricultural sector and decline in kidney function. Moyce et al. (2017) identified an association between years in agricultural work and cross-shift AKI among female agricultural workers in the U.S. (OR: 1.12, 95% CI: 1.01 to 1.24). Similarly, Laws et al. (2015) found that an increase in the number of years employed in the sugarcane industry was associated with a 0.3 ml/min/1.73 m2 decline in pre-harvest eGFR (95% CI: 20.6, 20.04)

2. Physiological and behavioral factors

Dehydration: Three studies conducted in Central America assessed the effect of dehydration on the decline in kidney function among sugarcane workers. Overall, the studies show conflicting evidence regarding the role of dehydration on the development of kidney disease among agricultural workers. Butler-Dawson et al. (2019) showed that dehydration indicated by higher post-shift specific gravity is a risk factor for cross-shift AKI measured at three different time points among sugarcane workers despite providing workers with an enhanced hydration intervention (OR: 1.24, 95% CI: 1.02–1.52). However, other studies did not find an association between dehydration and kidney disease. Moyce et al. (2017) did not find a significant association between volume depletion based on changes in body mass and AKI among agricultural workers in the U.S. Similarly, Sorensen et al. (2019) found that indicators of dehydration such as increasing post-shift urine specific gravity, BUN, and serum osmolality were not associated with cross-shift declines in eGFR.

Fluid consumption: Three studies assessed the association between fluid consumption and kidney disease among agricultural workers. Overall, the studies show conflicting evidence regarding the effect of fluid consumption on kidney disease. Moyce et al. (2020b) identified that increase in fluid consumption was associated with increased odds of cross shift AKI measured over a single working day among US agricultural workers (OR: 1.47, 95% CI: 1.09-1.99). However, García-Trabanino et al. (2015) reported an increase in post-shift body weight and reduced serum creatinine with greater fluid consumption among sugarcane cutters in El Salvador indicating an improvement in kidney function and hydration status respectively. On the other hand, Wesseling et al. (2016b) found that low water intake was not associated with reduced kidney function

Electrolyte consumption: Five studies conducted in Central America identified an association between electrolyte intake and improved kidney function. Overall, evidence from the three studies suggest that electrolyte consumption is protective for kidney disease. Butler-Dawson et al. (2019) showed that lower electrolyte intake is associated with higher odds of AKI among sugarcane workers in Guatemala (OR: 0.94, 95% CI: 0.89-0.99). Similarly, Hansson et al. (2020) showed that electrolyte consumption is associated with lower IKI (IR: 0.5, 95% CI: 0.2-0.9). In addition, Laws et al. (2016) showed that each electrolyte solution packet consumed by cane cutters during the workday was associated with a decrease in kidney injury biomarkers (NGAL and NAG). In addition, seed cutters had a decrease in kidney injury biomarkers (IL-18 and NAG) with each additional electrolyte solution packet consumed. However, there was no overall effect of electrolyte consumption among all workers. Similarly, Laws et al. (2015) found that for each additional electrolyte solution packet consumed by cane cutters during the workday the mean late-harvest eGFR increased by 6.1 ml/min/1.73 m2 (95% CI: 20.06-12.2) and cross-harvest eGFR increased by a mean of 7.0 ml/min/1.73 m2 (95% CI: 1.9-12.1). Furthermore, Wesseling et al. (2016b) found that intake of electrolyte solutions tended to be associated with improved GFR among sugarcane cutters (β: 8.1, 95% CI: −1.2-17.5).

Sugar consumption: Two studies conducted in Central America show that sugar consumption is a risk factor for kidney diseases (Hansson et al., 2020; Raines et al., 2014). One of these studies identified that sugary drink intake greater than 1 L is associated with increased risk of IKI (IR: 4.4, 95% CI: 1.0–19) (Hansson et al., 2020). Raines et al. (2014) identified that overall fructose intake is not associated with reduced GFR among a group of current or former agricultural workers in a community with high prevalence of CKDu. However, agricultural workers with a history of sugarcane chewing which is a source of sugar were 3.12 times more likely to have reduced GFR (OR: 3.12, 95% CI: 1.21–8.04). Similarly, daily bolis consumption which is a sugary rehydration packet was also associated with reduced GFR (OR: 1.48, 95% CI: 1.02–2.14) (Raines et al., 2014). On the other hand, two studies found no association between intake of sugary beverages and kidney disease (Butler-Dawson et al., 2018; Butler-Dawson et al., 2019; Moyce et al., 2020b). Overall, evidence regarding the effect of sugar consumption on the decline in kidney function is inconsistent.

3. Medical history

Diabetes: Two studies have identified diabetes as a risk factor for kidney disease. Moyce et al. (2020b) showed that male agricultural workers in the U.S. with diabetes have 6.76 times higher odds of cross-shift AKI (OR: 6.76, 95% CI: 1.49–30.77). Similarly, Sorensen et al. (2019) showed that with each 1% increase in HbA1c which is an indicator of diabetes, there was a 7.35 % decline in cross-shift GFR among sugarcane workers in Guatemala.

However, several studies conducted in different regions showed that there is no association between diabetes and kidney disease including Central America (Raines et al., 2014) and other nonendemic regions (Ekiti et al., 2018; Mix et al., 2018; Moyce et al., 2020a; Raines et al., 2014).

Obesity: Two studies from nonendemic countries assessed the obesity as a risk factor for kidney disease including the US (Moyce et al., 2017) and Cameroon (Ekiti et al., 2018). Moyce et al. (2017) identified that obesity is associated with lower odds of cross-shift AKI among agricultural workers (OR: 0.29, 95% CI: 0.10-0.82). In addition, overweight or obese men have 0.29 (95% CI: 0.08-0.97) and 0.25 (95% CI: 0.07-0.94) times lower odds of AKI respectively. However, Ekiti et al. (2018) did not find a significant association between obesity and CKD among sugarcane workers.

4. Medications and lifestyle factors

NSAID use: Two studies have identified NSAID use as a risk factor for kidney disease among sugarcane workers with both studies conducted in Central America (Butler-Dawson et al., 2019; Hansson et al., 2020). One of these studies conducted in Nicaragua and El Salvador showed an association between NSAID use and increased incidence of IKI (IR: 2.1, 95% CI: 1.2-3.8) (Hansson et al., 2020). While the second study in Guatemala found that increasing dehydration in combination with NSAID use was associated with higher AKI (OR: 8.38, 95% CI: 1.67–42.16) (Butler-Dawson et al., 2019). However, three studies found that NSAID use is not significantly associated with kidney dysfunction among sugarcane workers in Central America (Hansson et al., 2019; Sorensen et al., 2019; Wesseling et al., 2016b). Overall, the evidence regarding the effect of NSAID on the development of kidney disease is conflicting or inconsistent.

Smoking: Butler-Dawson et al. (2018) found that current smokers working in the sugarcane industry are more likely to experience a decline in kidney function compared with former and never smokers. Current smokers have greater odds of having a decline in kidney function less than 0%GFR (OR: 2.33, 95% CI: 1.17-4.63). In addition, being a current smoker was significantly associated with a severe decline in kidney function across the harvest (OR: 5.27, 95% CI: 1.54-17.99).

5. Sociodemographic factors

Age: Four studies have identified increasing age as a risk factor for kidney disease including three studies conducted in Central America (García-Trabanino et al., 2015; Wesseling et al., 2016b) and one in Cameroon (Ekiti et al., 2018). García-Trabanino et al. (2015) found that a 1-year increase in age is associated with reduced GFR among sugarcane workers in El Salvador (OR: 1.09, 95% CI: 1.02-1.16). Similarly, Wesseling et al. (2016b) showed that age is associated with reduced GFR among workers in three different occupations including construction workers, subsistence farmers and sugarcane workers compared to workers with normal kidney function (β: −1.3, 95% CI: −1.8- −0.8) and in analysis restricted to sugarcane workers (β: −1.9, 95% CI: −2.7- −1.1). Furthermore, Ekiti et al. (2018) showed a significant association between age greater or equal to 40 and higher CKD among sugarcane workers in Cameron (OR: 18.7, 95% CI: 1.5-236.4).

In contrast, several studies show no significant association between age and kidney damage in Central America (Butler-Dawson et al., 2019) and the U.S. (Mix et al., 2018; Moyce et al., 2020a; Moyce et al., 2017; Moyce et al., 2020b).

Socioeconomic status: Jayasekara et al. (2019) assessed the association between socioeconomic status and heat stress-dehydration symptom score among agricultural workers in India. Willingness to give up 5% of annual income for a 10% reduction in CKDu was used as a proxy for socioeconomic status. People unwilling to give up income for a lower risk of disease reported a greater heat stress-dehydration symptom score (9.4 vs. 7.6, p=.07). This indicates that lower income is associated with a potentially greater risk of CKDu. In addition, a significant correlation was found between higher income and lower heat stress-dehydration symptom score with 2.1 fewer points.

Gender: Moyce et al. (2017) found that female agricultural workers paid by piece-rate have greatly increased odds of developing cross shift AKI (OR: 102.81, 95% CI: 7.32-1443.20). In addition, Jayasekara et al. (2019) found that females are associated with a higher heat stress dehydration index with 3.1 additional points on the index indicating greater vulnerability to CKDu.

6. Environmental conditions

Hot environmental conditions: Five studies identified hot environmental conditions as a risk factor for reduced kidney function. Three of these studies were conducted in Central America including among sugarcane workers. García-Trabanino et al. (2015) has identified that the coastal region where temperature and humidity is higher has 3.5 times higher odds of reduced GFR compared to high and medium altitude regions (OR: 3.5, 95% CI: 1.3–9.4). In addition, the study determined an association between WBGT and reduced kidney function indicated by post-shift serum creatinine with a 2% increase in serum creatinine per degree of WBGT (p=0.001). Similarly, Raines et al. (2014) identified that increased lifetime days cutting sugarcane during the dry season was associated with reduced GFR (OR: 4.07, 95% CI: 1.32-12.58). Furthermore, Sorensen et al. (2019) identified that an increase in average WBGT by 1°C is associated with a 1.6% decline in cross-shift GFR.

In addition, 2 other studies were conducted in the U.S. focusing on the association between hot environmental conditions and cross shift AKI among agricultural workers (Mix et al., 2018; Moyce et al., 2017). Moyce et al. (2017) found an association between heat strain based on changes in core body temperature and heart rate and higher odds of AKI (OR: 1.34, 95% CI: 1.04-1.74). Similarly, Mix et al. (2018) found that each 5°F increase in mean heat index was associated with a 47% increase in the likelihood of AKI among migrant agricultural workers (OR:1.47, 95% CI: 1.14-1.90).

However, rice harvesters at a high altitude/low WBGT farm had 2 times higher risk of developing CKDu compared with rice harvesters at a low altitude/high WBGT farm (POR 2.0, 95% CI: 1.2–3.5) (Fitria et al., 2020). Overall, the evidence suggests that hot environmental conditions increases the risk of developing kidney disease among agricultural communities.

Agrochemical exposure: Two studies conducted in Central America found a signification association between agrochemical exposure and decline in GFR. Raines et al. (2014) identified that accidental pesticide exposure is a risk factor for reduced GFR among a subset of current or former agricultural workers in a community with high prevalence of CKDu (OR: 3.14, 95% CI: 1.12-8.78). However, other indicators of pesticide exposure such as lifetime days mixing pesticides, lifetime days applying pesticides, and lifetime days working in fields with pesticide use were not significant. García-Trabanino et al. (2015) found that “any use of pesticide ever” was not associated with low eGFR, however the “use of carbamate pesticides ever” was found to have a significant association.

In contrast, other studies conducted in Central America did not find a significant association between pesticide use and kidney disease. Laws et al. (2016) found that pesticide applicators did not have a significant decrease in eGFR during harvest period and had the lowest decline in GFR compared to the workers in other job categories in the field. A study in Nicaragua among small-scale farmers, construction workers, and sugarcane cutters did not observe an association between pesticides and biomarkers of kidney function (Wesseling et al., 2016b).

Studies in other regions which are nonendemic for CKDu found no significant association between pesticide use and kidney disease. One study found that the risk of CKDu increased with the longer and more frequent use of insecticides among rice harvesters in Indonesia but the association was not significant (Fitria et al., 2020).

Similarly, another study conducted in Cameron also reported no association between agrochemical exposure and CKDu among sugarcane workers (Ekiti et al., 2018).

Table 5: Studies that identified risk and protective factors associated with kidney diseases

Factors	**Risk factor**	**Protective Factor**
Work organization and management		
Workload	Hansson et al. (2019) Moyce et al. (2020a) Moyce et al. (2020b)	
Job category or work tasks	Laws et al. (2016) Kupferman et al. (2018) Moyce et al. (2020b)	
Duration of employment	Moyce et al. (2017) Laws et al. (2015)	
Payment method	Moyce et al. (2017) Moyce et al. (2020a) Moyce et al. (2016)	
Physiological and Behavioral factors		
Hydration status		
Dehydration	Butler-Dawson et al. (2019)	
Hydration practices		
Fluid consumption	Moyce et al. (2020b)	García-Trabanino et al. (2015)
Electrolyte intake		Butler-Dawson et al. (2019) Hansson et al. (2020) Laws et al. (2016) Laws et al. (2015) Wesseling et al. (2016b)
Sugary beverage intake	Hansson et al. (2020) Raines et al. (2014)	
Medical history		
Pre-existing health conditions	Sorensen et al. (2019) Moyce et al. (2020b)	

	Moyce et al. (2017)	
Medications and lifestyle factors		
NSAID use	Butler-Dawson et al. (2019) Hansson et al. (2020)	
Smoking	Butler-Dawson et al. (2018)	
Obesity/ High BMI		Moyce et al. (2017)
Sociodemographic factors		
Increasing age	García-Trabanino et al. (2015) Wesseling et al. (2016b) Ekiti et al. (2018) Sorensen et al. (2019)	Hansson et al. (2019) Wesseling et al. (2016b)
Female gender	Moyce et al. (2017) Jayasekara et al. (2019)	
Socioeconomic status	Jayasekara et al. (2019)	
Environmental conditions		
Pesticide exposure	Raines et al. (2014) García-Trabanino et al. (2015)	
Hot environmental conditions	García-Trabanino et al. (2015) Raines et al. (2014) Sorensen et al. (2019) Moyce et al. (2017) Mix et al. (2018)	

J. Factors affecting other heat related health outcomes

Quandt et al. (2008) assessed risk factors for skin related quality of life (QOL) which was measured using the Dermatology Life Quality Index (DLQI) among Latino farmworkers in the U.S. Specific work tasks including planting, cultivating, tobacco topping and harvesting are associated with elevated DLQI with odds ratios ranging from 2.20 to 4.16. In addition, the study identified that working in high temperature is associated with higher DLQI with odds ratios of 2.29 and 3.33. Näyhä et al. (2017) reported that working in agriculture compared to industry is associated with 2.27 times higher odds of cardiopulmonary symptoms among a working population in Finland. Spector et al. (2018) found no significant association between heat exposure and impaired vigilance or balance which are considered potential mediators of the relationship between heat exposure and traumatic injuries among agricultural workers.

K. Preventive measures

The most common preventive measures identified in the included studies were drinking more water, taking breaks in shaded areas, going to air-conditioned places during or after work, changing work hours and activities and taking extra breaks (Arcury et al., 2015; Arnold et al., 2020; Bethel & Harger, 2014; Bethel et al., 2017; Mirabelli et al., 2010; Pogacar et al., 2017; Riccò et al., 2020). Several studies reported that agricultural workers also wear head protection such as baseball caps, hats, bandannas and hood from sweatshirt (Bethel & Harger, 2014; Kearney et al., 2016; Luque et al., 2020; Riccò et al., 2020). In addition, different types of clothing are used including long sleeved shirts, long pants and light colored or lightweight shirt (Bethel & Harger, 2014; Bethel et al., 2017; Kearney et al., 2016; Luque et al., 2020; Luque et al., 2019; Pogacar et al., 2017). Water is the most commonly consumed beverage in addition to sports drinks, energy drinks, soda, fruit juice and coffee (Bethel et al., 2017; Culp & Tonelli, 2019; Luque et al., 2020; Mix et al., 2018). Some studies also reported the consumption of electrolyte solutions among agricultural workers (Glaser et al., 2020; Luque et al., 2019) Other commonly used preventive measures include acclimatization (Bethel & Harger, 2014; Bethel et al., 2017), HRI training (Bethel et al., 2017; Riccò et al., 2020; Stoecklin-Marois et al., 2013), wearing sunglasses and sunscreen (Kearney et al., 2016; Riccò et al., 2020) and the use of rest stations and fans (Bethel et al., 2017; Luque et al., 2020). Preventative measures that were less common include eating traditional diet (Frimpong et al., 2020) and bathing in cold water (Bethel et al., 2017; Budhathoki & Zander, 2019).

L. Intervention studies

Several studies assessed the effectiveness of intervention programs in improving kidney function or reducing HRI symptoms. Bodin et al. (2016) examined the effectiveness of a Water, Rest, Shade (WRS) intervention during sugarcane cutting in El Salvador. The intervention included providing water supplies in individual backpacks, mobile shaded rest areas and scheduled rest periods. Data were collected pre-harvest, pre-intervention, mid-intervention and at the end of harvest. Self-reported water consumption increased 25% after the intervention was introduced. Symptoms associated with heat stress and with dehydration decreased post-intervention compared to pre-intervention including reduced exhaustion, nausea, cramps, dry mouth, low/dark urine, fever, dizziness, disorientation, fainting, stomachache, headache.

Butler-Dawson et al. (2019) studied the effect of enhanced hydration intervention among a large number of sugarcane workers in Guatemala to evaluate the effect of improved hydration on cumulative incidence of AKI. 81% of sugarcane workers had at least one AKI during the study period despite appropriate hydration in the field. The prevalence of dehydration post-shift (> 1.020 specific gravity) was 11% in February 9% in March, and 6% in April. Cumulative incidence of AKI was 53% in February 54% in March, and 51% in April. Despite appropriate hydration in the field, increasing post-shift specific gravity was observed to be a risk factor for AKI while higher electrolyte solution intake was found to be protective.

Wegman et al. (2018) assessed the potential of a WRS and efficiency intervention program to reduce kidney damage among sugarcane workers in El Salvador. One of the two groups of workers studied was provided with portable water reservoirs, mobile shaded tents, and scheduled rest periods. Cross-shift and cross-harvest GFR was determined at baseline and at three subsequent times over the course of the harvest. After the introduction of the intervention the decline of cross-shift GFR was lower (6.1%) and smaller increase in uric acid (-7.3%) was recorded in the intervention group. The decrease in cross-harvest GFR was lower in the intervention group -3.4 mL/min/1.73m2 (95% CI: -5.5- -1.3) than the non-intervention group -5.3 (95% CI: -7.9- -2.7).

Glaser et al. (2020) compared cross-harvest changes in (eGFR) and cases of incident kidney injury (IKI) between harvest 2017-2018 and harvest 2018-2019 among sugarcane harvest workers in Nicaragua. During harvest 2018-2019 an intervention was introduced that included enhanced rest schedules and improved access to hydration and shade. Three jobs with different physical workloads were included burned cane cutters, seed cutters and irrigation repair workers and field support staff. Among burned cane cutters, mean cross-harvest eGFR decreased by 9/min/1.73 m2 during the first harvest, but the decline was lower in harvest 2 (4 ml/min/1.73 m2). IKI was 70% (95% CI: 90%- 50%) lower in harvest 2 as compared with harvest 1 among burned cane cutters. Seed cutters did not improve nor worsen significantly from harvest 1 to harvest 2. Seed cutter groups with the worst compliance had the most cases of IKI whereas the groups with the best compliance had only one case.

CHAPTER V

DISCUSSION

A. Factors associated with HRI

1. Work organization and management factors

Several work organization and management factors have been found to be associated with increased risk of HRI among agricultural populations. Findings from the reviewed studies suggest that workload is associated with an increased risk of HRI among agricultural workers (Mac, 2016; Mac et al., 2019; Vega-Arroyo et al., 2019). This is due to greater metabolic heat generation, which leads to an increase in CBT and a risk of developing HRI (Parsons, 2014). In fact, several studies have shown that agricultural workers frequently perform strenuous physical activities (Mix et al., 2018; Toupin et al., 2007).

Furthermore, the reviewed studies found that piece-rate payment, which based on the amount of product harvested, is significantly associated with HRI. Piece-rate work incentives agricultural workers to work at a faster pace to increase productivity in order to maximize their earnings (Mitchell et al., 2018; Quandt et al., 2019; Toupin et al., 2007). One study in the U.S. found that farmworkers paid by piece have higher physical activity levels compared to those who were paid hourly or by salary (Mitchell et al., 2018). Similarly, another study showed that brushcutters in Canada who are paid by piece-rate had a physical workload, measured by heart rate, that was twice the maximum acceptable level for an eight-hour work day (Toupin et al., 2007). In addition, research shows that farmworkers paid by piece-rate work longer hours and are unwilling to take breaks to rest or drink water (Lam et al., 2013; Luque et al., 2019).

Another risk factor related to work organization and management is the lack of job decision latitude in agricultural workplaces. This results in a lack of control over certain HRI risk factors such as shade availability and proximity to bathroom and water facilities at work. In fact, agricultural workers commonly report a lack of access to cooling measures such as shade, rest breaks and drinking water (Bethel et al., 2017; Fleischer et al., 2013). The lack of control over workplace conditions is due to the presence of a power imbalance between employers and agricultural workers, which prevents workers from making decisions about their health and safety or complaining about poor working conditions. In addition, migrant farmworkers often strive to keep their jobs at any cost, particularly since their legal status is tied to their employment (Caxaj et al., 2019). Furthermore, agricultural workers are unable to form trade unions to bargain for better working conditions due to legal restrictions and the geographical isolation and the informal nature of the agricultural workforce (FAO, 2016). However, as the evidence is based on qualitative studies including focus group discussion, cross-sectional surveys or longitudinal studies are needed to measure the association between job decision latitude and HRI.

In addition, limited evidence indicates that agricultural workers performing pesticide application are at greater risk of HRI. Pesticide applicators are likely to wear protective clothing which can inhibit sweat evaporation and normal heat dissipation due to their low moisture permeability and high insulating properties (Holmér, 2006). In addition, protective clothing can cause movement restriction that increases the metabolic demands of manual work, which leads to a more rapid rise in body temperature (Dorman & Havenith, 2009). In fact, OSHA has recommended that workers wearing heavy or non-breathable clothing or impermeable chemical protective clothing require additional precautions such as rescheduling activities to cooler parts of the day and physiological monitoring (OSHA, n.d.-a).

2. Physiological and behavioral factors

Limited evidence from the reviewed studies shows that various behavioral factors are protective for HRI, such as taking breaks in the shade, increasing access to regular breaks, and changing work hours and activities. These preventive practices have been previously reported by several occupational health agencies to reduce heat exposure (NIOSH, 2016; OSHA, n.d.-a). In fact, OSHA recommends a proper work/rest schedule to reduce heat exposure and to allow workers to recover from HRI (OSHA, n.d.-a). As rest can reduce metabolism from heavy physical workload which allows the body to release excess heat (Jackson & Rosenberg, 2010). Furthermore, OSHA has established how much rest a worker needs per hour during hard physical work in hot climates based on WBGT to reduce the risk of HRI (OSHA, 1999). According to OSHA guidelines, workers should rest 15 minutes each hour when WBGT exceeds 26°C, 30 minutes of rest each hour when WBGT reaches 28°C and 45 minutes of rest each hour when WBGT reaches 30°C (OSHA, 1999).

In addition, limited evidence from the reviewed studies suggests that reducing soda consumption can be protective for HRI among farmworkers. In fact, soda consumption is common among agricultural workers to increase alertness and productivity (Bethel et al., 2017; Culp & Tonelli, 2019; Lam et al., 2013; Luque et al., 2020; Mix et al., 2018). This is consistent with the literature which shows that caffeine consumption can increase core body temperature (Ely et al., 2011; McHill et al., 2014). According to OSHA guidelines, workers should be encouraged to choose water over soda and other drinks containing caffeine and high sugar content since they can lead to dehydration (OSHA, n.d.-a). Evidence on the effect of other types of beverages such as coffee and tea on the prevalence of HRI is lacking in the reviewed studies even though agricultural are consuming these beverages (Bethel et al., 2017; Luque et al., 2020).

Few studies assessed the effect of behavioral factors on the prevalence of HRI symptoms on agricultural populations. Furthermore, evidence regarding the effect of various physiological and behavioral factors such as HRI training, clothing, hydration status and acclimatization status on the development of HRI among farmworkers is limited or absent. In addition, a few studies identified that several behavioral factors that are considered as preventive in the literature such as resting in shaded areas and going to air conditioned places had a positive association with HRI. Because these studies were cross-sectional, this may be a case of reverse causation. As workers who were experiencing more symptoms may have taken preventative measures to alleviate their symptoms.

3. Accessibility to heat prevention and treatment

Furthermore, several risk factors related to accessibility to heat prevention measures and treatment have been identified. One of these risk factors is cultural and language barriers that can affect prevention and treatment of HRI among farmworkers. This is consistent with findings from the international literature, which shows that language and cultural barriers prevent migrant farmworkers from understanding health and safety information (Arcury et al., 2010; Farquhar et al., 2009; Viveros-Guzmán et al., 2015). Furthermore, language and cultural barriers is also one of the key factors that prevent migrant farmworkers from accessing health care services (Viveros-Guzmán & Gertler, 2015). Another risk factor identified in the reviewed studies is the lack of access to bathroom facilities. Similarly, previous reports have identified inaccessibility to toilets as a barrier to adequate hydration, which increases the risk of HRI (Lam et al., 2013; Culp et al., 2011).

4. Sociodemographic factors

Findings from the reviewed studies indicate female agricultural workers were more likely to experience HRI compared to their male counterparts. This may be due to several behavioral factors that increase risk of HRI among females. One factor is the lack of sanitation facilities at agricultural workplaces that leads women to limit their water consumption (Oxfam, 2020). Moreover, female agriculture workers are less comfortable taking breaks to drink water as they have lower stature while men have greater autonomy and job security (Stoecklin-Marois et al., 2013). Furthermore, female farmworkers are often less knowledgeable about heat safety compared to males due to less experience in farm work or less training (Luque et al., 2020; Stoecklin-Marois et al., 2013). In addition to behavioral factors, physiological differences due to gender can also lead to increased vulnerability to HRI among females. Women usually have lower sweating rates and lower aerobic capacity than men due to smaller body size and lower metabolic rates which increases their risk of HRI (Sawka et al., 2007). Due to lower aerobic capacity, females have a greater metabolic heat production rate leading to a greater increase in core body temperature (Adams et al., 2020). Other differences in biological factors such as body surface to mass ratio and adipose distribution can also affect tolerance to heat among males and females (Hanna & Tait, 2015).

The effect of other demographic variables such as age and migrant status were either inconclusive or limited. Findings suggest that older child farmworkers are more likely to experience HRI compared to their younger counterparts. This may be due to the fact that older children work at a pace similar to their adult counterparts, work for longer hours and can better recognize HRI symptoms than younger children (Arnold et al., 2020). However, the reviewed articles show conflicting evidence concerning the association between age and HRI among adult farmworkers. Similarly, there is inconsistent evidence from the literature regarding the relationship between age and HRI. While some studies show an increased risk of exertional heat illness with increasing age due to the loss of sweat capacity, which is a major mechanism for heat dissipation (Larose et al., 2013; McGinn et al., 2017); other studies show an independent association between age and exertional heat illness, as thermoregulatory response is maintained among aerobically fit individuals (Best et al., 2012).

Interestingly, other sociodemographic factors such as migrant status which have been documented in the literature to be associated with HRI were not identified as risk factors in this review (Arcury et al., 2015; Bethel & Harger, 2014; Fleischer et al., 2013).

5. Environmental conditions

Another risk factor for HRI identified in the reviewed studies was hot environmental conditions. This is due to limited heat transfer from the body to the surrounding environment at hot ambient conditions leading to an increased risk of developing HRI (Adams & Jardine, 2020). Furthermore, hot and humid environmental conditions block sweat evaporation which is a major mechanism of heat dissipation (Adams & Jardine, 2020). Therefore, occupational health agencies have recommended various preventative measures that can be implemented to reduce heat exposure while working in hot conditions. OSHA has established four risk categories based on heat index values which include low, moderate, high and very high/extreme (OSHA, n.d.-a). OSHA recommends that preventative measures increase depending on the risk category. While ACGIH and NIOSH have determined maximum heat exposure levels based on workload, work/rest cycle and whether or not workers are acclimatized to the heat in order to prevent core body temperature from exceeding 38°C (ACGIH, 2019; NIOSH, 2016)

B. Factors associated with kidney disease

1. Work organization and management

Various factors related to work organization and management have been identified as risk factors. Evidence from the studies reported in this current review suggests that heavy workload is significantly associated with kidney diseases. In addition, the reviewed studies show that sugarcane cutters have a higher prevalence of reduced kidney function. Sugarcane cutters require unusually high physical exertion comparable to the first 12 hours of adventure racing and above that of military personnel during multiday operations (Lucas et al., 2015).

In addition, the findings of the current review suggest that piece-rate work is significantly associated with kidney diseases among agricultural workers. This payment method can cause agricultural workers to push themselves beyond their physical limits to earn as much as they can and to take fewer breaks to rest or drink water (UN, 2018) leading to a higher risk of heat stress and dehydration and consequently to the development of kidney disease.

2. Physiological and behavioral factors

There is a general consensus in the literature that dehydration is involved in the development of CKDu. Research suggests that recurrent dehydration can stimulate the release of vasopressin and increase uric acid levels leading to kidney damage (Roncal-Jimenez et al., 2015). However, findings from the reviewed studies show inconsistent evidence on the role of dehydration in CKDu.

Another factor that can affect the development of kidney among agricultural workers is hydration practices. Evidence from the reviewed studies suggests that electrolyte solution can be protective for kidney disease. Prolonged physical activity in hot and humid conditions can lead to the loss of electrolytes such as sodium, chloride, and potassium through sweating (Maughan et al., 1997). According to NIOSH, electrolyte replacement should be provided to workers in the form of sports drinks containing balanced electrolytes if excessive sweating occurs for 4 or more hours in hot conditions (NIOSH, 2016). On the other hand, OSHA guidelines recommends water consumption but does not comment on electrolyte replacement (OSHA, n.d.-a). However, various studies show that agricultural workers consume low amounts of electrolyte solutions (Butler-Dawson et al., 2019; Laws et al., 2016).

Although the evidence is less consistent, findings suggest that sugar consumption is a risk factor for kidney disease among agricultural workers. Similarly, rehydration with sugary beverages has been reported in the literature as a risk factor for CKDu. A recent clinical study also reported that rehydration with soft drinks can increase markers of kidney damage in healthy subjects following exercise in high temperatures (Chapman et al., 2019). Furthermore, several animal studies also show that rehydration with soft drinks containing fructose exacerbates dehydration and associated renal damage (García-Arroyo et al., 2016; Milagres et al., 2018).

Overall the evidence for an association between fluid consumption and kidney disease is contradictory across the reviewed studies. Similarly, the international literature has also provided inconsistent evidence regarding this association. A systematic review reported a positive association between high water intake and CKDu probably due to a case of reverse causation since workers with kidney damage have a reduced urine concentrating ability (González-Quiroz et al., 2018). However, another review article found that increased fluid intake can have a beneficial effect on renal function in patients with all forms of CKD and in those at risk of CKD due to reduced vasopressin secretion (Clark et al., 2016).

In addition, the literature suggests that other physiological or behavioral factors such as acclimatization status and clothing practices can affect the development of kidney disease (Nerbass et al., 2017; Omassoli et al., 2019). However, evidence from the reviewed studies on the effect of these factors on the prevalence of kidney disease among agricultural workers is lacking.

3. Medication and lifestyle factors

Overall, the evidence regarding the effect of NSAID use on kidney disease in agricultural populations is contradictory. The majority of studies assessing the association between NSAIDs use and kidney disease have focused on sugarcane workers in Central America. NSAIDs are widely used and sold over the counter in Central America, which can contribute to CKD development due to their nephrotoxicity (Ramirez-Rubio et al., 2013). Sugarcane workers report using prescription painkillers such as opioids in order to work long hours under extremely physically demanding conditions (Verité, 2017). The literature indicates that recurrent dehydration or volume depletion can be exacerbated by NSAIDs use (Correa-Rotter et al., 2014; Weiner et al., 2013). In addition, a systematic review indicated that NSAIDS were found to be significantly associated with CKDu in Mesoamerica (González-Quiroz et al., 2018).

4. Sociodemographic factors

Findings from the reviewed studies suggest that female agricultural workers are at a greater risk of kidney disease compared to their male counterparts. However, this is inconsistent with previous reports, which indicate that CKDu is more common among males in both Central America and South Asia (Johnson et al., 2019; Venugopal et al., 2020). In addition, two systematic reviews show a positive association between males and CKDu (González-Quiroz et al., 2018; Lunyera et al., 2016).

One study identified that piece rate payment and years working in agriculture are significant risk factors for AKI among females (Moyce et al., 2017). According to the study’s interpretation, female agricultural workers avoid taking trips to the bathroom due to lack of adequate sanitation facilities and to avoid sexual harassment or assault which usually occurs around bathroom facilities. Therefore, women who are paid by piece rate will have an additional incentive to avoid visiting the bathroom during their work shift which leads them to limit their water consumption thus increasing their risk of kidney disease (Moyce et al., 2017). In addition, women working longer in the agricultural sector may experience frequent chronic delayed urination which increases their risk of developing kidney diseases (Moyce et al., 2017).

In addition, limited evidence indicates that low socioeconomic status is associated with an increased risk of kidney disease. This is consistent with the literature, which indicates that CKDu is mainly concentrated in poor agricultural communities characterized by indiscriminate use of agrochemicals, hot and humid environments and harsh working conditions at agricultural workplaces (Orantes-Navarro et al., 2017).

5. Environmental conditions

Many studies suggest that hot environmental conditions is significantly associated with kidney diseases. This is consistent with findings reported in the literature that indicate that occupational heat stress is a primary factor in the development of CKDu (Correa-Rotter et al., 2019; Glaser et al., 2016; Wesseling et al., 2020). In fact, various studies indicate that CKDu is primarily diagnosed among farmworkers who work in lower altitude which have higher temperatures. (Ekiti et al., 2018; Peraza et al., 2012). Furthermore, the majority of studies, which found an association between hot environmental conditions and kidney disease, have focused on sugarcane workers in Central America. Sugarcane workers in Central America are exposed to high levels of heat exposure. One study in El Salvador that measured the heat index during harvest in three different sugarcane plantations found that mean HI was 110–125 °F that is classified as very high to extremely high-risk category according to the OSHA Heat Index requiring aggressive protective measures (García-Trabanino et al., 2015). In addition, sugarcane workers are particularly vulnerable to heat stress due to the heavy physical workload, lack of shade, infrequent breaks, long work hours, and lack of access to clean drinking water (CIDIN, 2014; CNV International, 2016; Verité, 2017).

Another environmental factor related to kidney disease is agrochemical exposure. The majority of studies suggest a lack of association between pesticides and kidney disease among agricultural populations. Similarly, a systematic review found no significant association between pesticides and CKDu in agricultural workers in Mesoamerica (González-Quiroz et al., 2018). Furthermore, another systematic review recommended that better exposure assessment is needed before ruling out pesticides as a cause of CKDu since studies have not examined biomarkers of agrochemical exposure and have relied only on self-reports of work practices and history (Valcke et al., 2017).

C. Preventive measures

Various heat preventive measures practiced by agricultural workers have been identified in the reviewed studies. The most common administrative preventive measures include drinking more water, taking breaks in shaded areas, going to air-conditioned places during or after work, changing work hours and activities and taking extra breaks. In addition, a few studies showed that agricultural workers are practicing acclimatization by gradually increasing the number of work hours at the start of the season, which is an important protective measure for HRI. OSHA has recommended ‘‘Water- Rest-Shade.’’ guidelines to reduce heat stress in hot working environments (OSHA, n.d.-b). Furthermore, a systematic review have also identified similar preventative measures practiced by outdoor workers (Habibi et al., 2021).

In the case of hydration practices, water was the most commonly consumed beverage among agricultural workers with other types of beverages including sports drinks, energy drinks, soda, fruit juice and coffee. However, various studies reported that agricultural workers had low water consumption (Mix et al., 2018; Moyce et al., 2020b; Stoecklin-Marois et al., 2013). NIOSH recommends that workers drink 1 cup of water every 15 to 20 min to replace the loss of body water as working under hot conditions can result in the loss of body water via sweating which can reach between 6 and 8 L during a work shift (NIOSH, 2016). In addition, OSHA recommends that workers consume 1 quart of potable water per hour and to avoid soda and other drinks containing caffeine and sugar as they can lead to dehydration (OSHA, n.d.-a).

In addition, several studies identified various sun safety behavior commonly used by agricultural workers including clothing practices such as wearing long sleeved and light colored shirts and long pants. Furthermore, several studies reported that agricultural workers also use sunscreen and sunglasses as well as head protection such as baseball caps, hats, bandannas and hoods. NIOSH recommends that workers should wear breathable, light-colored, and loose-fitting clothing when working in hot environmental conditions (NIOSH, 2018). While OSHA encourages workers to use sunscreen and using other protections from direct sunlight such as wearing hats (OSHA, n.d.-a).

A few studies also indicate that farmworkers also utilize engineering control measures including fans or misters. The use of fans or misters can reduce heat exposure among agricultural workers by increasing convective and evaporative cooling particularly in dry climates but are not effective at reducing heat stress in hot and humid environments (Jackson & Rosenberg, 2010).

On the other hand, several reviewed studies showed that agricultural workers lack access to adequate cooling measures such as shade, water, sanitation facilities, HRI training and rest breaks (Bethel et al., 2017; Fleischer et al., 2013; Kearney et al., 2016). Furthermore, workplace culture can also prevent the implementation of preventive measures such as lack of control over workplace conditions (Hansen et al., 2020; Lam et al., 2013).

D. Reviewed research limitations, literature gaps, and implications for future research

The findings of this review demonstrate that there is limited information on health outcomes related to occupational heat stress among agricultural workers globally. The US represents the country with the highest number of HRI studies. In addition, the majority of studies assessing the prevalence of kidney disease have been concentrated in Central America. However, various hot regions such as Sub-Saharan Africa, Middle east and North Africa and Southeast Asia host millions of vulnerable agricultural workers and thus the need for studies assessing the impacts of hot temperatures on health outcomes in these populations is imperative (ILO, 2014; Kjellstrom et al., 2016). Therefore, more studies are required globally to quantify the burden of heat related health effects as regional information is important because the conditions of farm work vary by location and type of crops produced.

Few studies have assessed heat related health effects among vulnerable populations including children and women who constitute a large percentage of the agricultural workforce globally. In addition, most studies that focused on migrant farmworkers were conducted in the U.S. Further research is needed to determine the prevalence of heat-related health effects as well as risk and protective factors among these vulnerable workers in order to design more effective preventative measures tailored to these populations. In addition, paying greater attention to poor working conditions and high poverty levels facing these farmworkers is key to understanding their vulnerability to heat-related health effects.

In addition, most studies examining the role of heat stress and dehydration on the development of kidney disease have been concentrated mainly on sugarcane workers in

Central America. Since the adverse impacts of heat stress on kidney function is expected to increase due to rising global temperatures, future studies should focus on other agricultural communities exposed to hot environmental conditions to gain a better understanding of the relationship between occupational heat stress and kidney health and its interaction with other possible etiologic factors.

Since only one study has examined cultural beliefs among farmworkers, more studies are needed to understand cultural beliefs that may interfere with accepted scientific principles related to HRI treatment or prevent the adoption of preventative measures. In addition, more intervention studies are needed to assess the effects of various work/ rest schedules, training and provision of shade and hydration on core body temperature, HRI symptoms, and hydration status for various agricultural jobs, as only 4 intervention studies have been identified in the review. Additional research in these areas will better inform employers, workers, and occupational health agencies to design and implement more effective preventative measures and regulations.

Furthermore, other than HRI and kidney diseases, evidence regarding the effect of high temperatures on various health outcomes such as occupational injuries and mental health is limited in the reviewed studies. Therefore, these heat related health outcomes require greater attention as they are expected to become more prevalent with rising global temperatures (Cianconi et al., 2020; Kjellstrom et al., 2010; Varghese et al., 2018).

1. Preventative measures

Agricultural workers face various adverse health effects while working in hot and humid environments such as HRI which remains prevalent in agricultural communities according to the reviewed studies (Arcury et al., 2015; Kearney et al., 2016; Mirabelli et al., 2010; Näyhä et al., 2017; Riccò, 2018). In addition, there is a growing concern about the possible role of prolonged exposure to heat stress and chronic dehydration on the development of an epidemic of kidney disease among agricultural communities in several hot regions including Central America and Southeast Asia (Glaser et al., 2016; Johnson et al., 2019). Furthermore, climate change is projected to intensify the duration and magnitude of occupational heat stress leading to a further rise in heat related health outcomes among various working populations (Kjellstrom et al., 2016; Lundgren et al., 2013). Therefore, it has become imperative to develop proper heat safety standards suitable to local environmental conditions and the physical requirements of agricultural tasks to protect vulnerable agricultural communities. Thus, farm managers or supervisors should be required to implement appropriate administrative and engineering measures such as the provision of water, shade and rest breaks as well as provide better education and training instead of relying on workers to implement these heat preventative measures.

In addition, future studies should assess the use of a broader range of preventative measures such as job rotation, self-pacing, increasing the number of workers for each task or the use of self-monitoring which can be important in reducing occupational heat strain according to the literature (NIOSH, 2016; OSHA, n.d.-a). Furthermore, future studies should examine the accessibility or availability of preventative measures in agricultural workplaces and the barriers that can affect their implementation.

However, commonly recommended administrative or engineering measures are sometimes ineffective in reducing the risk of heat stress among agricultural workers especially as global temperatures continue to rise as a result of climate change. Hence, various technological and engineering solutions should be developed to protect vulnerable agricultural communities from the effects of heat stress. Recent technological advancements have led to rapid growth in the development of personal or microclimate cooling systems such as personal cooling garments and cooling vests which can provide a convenient and flexible method to reduce heat stress and improve thermal comfort among working populations including agricultural workers (Chan et al., 2015; Chan et al., 2016; Choi et al., 2008). Other measures include various engineering controls including the use of mechanical aids to reduce the levels of physical activity or the use of portable shade structures (Ioannou et al., 2021; Lundgren et al., 2013). Furthermore, the use of a proper ventilation systems can be effective in reducing heat exposure in agricultural settings such as the poultry industry (Al Assaad et al., 2021). However, these technical solutions may not be applicable in developing countries and marginalized communities due to their lack of affordability but could be easily implemented in developed countries such as the U.S. Therefore, occupational health agencies such as OSHA should develop cost-effective and affordable technologies that can be implemented to protect vulnerable and marginalized agricultural workers from heat related health effects. In addition, field-based research is needed to examine the effectiveness and practicality of these measures in different work settings and in different regions.

2. Risk and protective factors

Limited evidence was found in the current review on the effect of various risk factors on the development of HRI. Physiological and behavioral factors such as acclimatization, hydration practices and training are identified in the literature as protective for HRI. However, none of the reviewed studies have investigated and identified the effect of these factors on HRI among agricultural populations. In addition, few studies have assessed the effect of sociodemographic factors on HRI prevalence including migrant status and poor socioeconomic conditions. Therefore, future studies on occupational heat stress in the agricultural workforce should consider investigating the effect of all potential risk factors. This will provide a better understanding of the role of these factors in the development of HRI among farmworkers so that effective policies and programs can be developed.

Other challenges include the use of cross-sectional design to assess association between potential risk factors and HRI. Various behavioral factors, which are protective for HRI such as taking breaks in the shade, increasing access to regular breaks and changing work hours and activities, have been identified as risk factors in the current reviewed studies. Therefore, longitudinal studies would be better equipped to assess workers' risk of occupational heat stress and address reverse causality. Furthermore, most studies assessing the risk factors of HRI have recruited diverse groups of farmers, which prevented any comparability of risk factors between different agricultural populations. Future research should concentrate on more homogenous groups of farmers to explore specific HRI risk factors and to allow greater comparability.

Overall, the evidence regarding the effect of several physiological and behavioral factors including dehydration status, sugary beverage intake and fluid consumption on the development of kidney disease in agricultural populations has been contradictory across the reviewed studies. In addition, evidence regarding the effect of acclimatization status and clothing practices on kidney disease was limited. Therefore, more longitudinal studies are required to gain a greater insight into the association between these risk factors and kidney disease. Furthermore, only one study assessed the effect of socioeconomic conditions on the development of kidney disease. Therefore, more studies are required to provide a critical social lens for the analysis of CKDu prevalence in vulnerable farmworker populations using both quantitative and qualitative study designs.

Furthermore, the reviewed studies have not thoroughly investigated the differences in risk factors between male and female farmworkers. Few studies have utilized gender stratification to examine differences in risk factors between male and female farmworkers. However, various physiological and behavioral factors can lead to gender differences in heat related health outcomes. In addition, it has been well established that men and women perform distinct agricultural tasks even when given a similar job classification in studies of farmworkers (Habib et al., 2020; Mix et al., 2019; Stoecklin-Marois et al., 2013). In a systematic review of the literature on gender in occupational health research of farmworkers, Habib et al. (2014) recommended the use of a gender sensitive approach in research to identify specific risk factors for men and for women farmworkers who perform different tasks and have different exposures.

3. Improved methods of exposure assessment

Greater consistency in assessment tools used to examine heat related health outcomes among farmers may be beneficial for future research. The identification of risk or protective factors associated with heat stress or kidney disease requires the design of consistent and comparative multisite studies in high-risk populations. Most studies assessing the prevalence of HRI relied mainly on self-reported HRI symptoms using questionnaires that have not been validated. Comparison of HRI symptoms between studies is difficult due to differing reporting periods, number of symptoms and case definitions of HRI. Instead, heat exposure can be assessed using validated questionnaires that can be modified and validated for local conditions such as the HOTHAPS (The High Occupational Temperature, Health, and Productivity Suppression) questionnaire that has been used in some of the included studies (Pogacar et al., 2017; Sahu et al., 2013). In addition, objective measures of HRI is needed to provide more valid estimates of the prevalence of heat stress and dehydration among agricultural populations such as core body temperature, which can be determined using an ingestible temperature pill that has been used in some of the included studies (Mac, 2016; Mitchell et al., 2017; Moyce et al., 2020a; Vega-Arroyo et al., 2019). Future research efforts should also incorporate an objective measure of hydration status. Change in body weight is considered an inexpensive and reliable measure of dehydration status (Wegman et al., 2016). Other measures of hydration status include urinary specific gravity or urine and serum osmolality (Wegman et al., 2016). Future research should also obtain objective measures of physical activity using accelerometers which are inexpensive and reliable devices (Hills et al., 2014) or heart rate monitors (Wegman et al., 2016) to measure the heat load generated by the performance of specific agricultural jobs.

E. Strengths and limitations of the current review

To the authors' current knowledge, this is the first scoping review that aims to describe the prevalence, risk factors and preventative measures of occupational heat stress among agricultural populations. All health outcomes related to occupational heat stress among agricultural workers were included. A wide range of literature formed the basis for this review as both peer-reviewed studies and grey literature published in various languages were included with no restriction on publication date. This scoping review can provide an overview of current research in the field and as a starting point to guide future research to assess heat related health outcomes among farmworkers.

However, similar to other scoping reviews, a limitation to this current scoping review is the lack of quality assessment of the included studies. Furthermore, the comparability of risk factors and prevalence of heat related health effects between various regions and agricultural populations was difficult to perform due to the use of different measurement instruments and the lack of inclusion of specific groups of farmworkers in most studies.

CHAPTER V

CONCLUSION

Given the projected increase in global temperatures and extreme heat events due to climate change, the adverse health impacts of occupational heat stress on agricultural communities are likely to increase in the future. This scoping review provides a comprehensive overview of heat related health effects among agricultural populations as well as risk factors and preventative measures used to minimize heat stress exposure among farmworkers. Knowledge of risk factors and preventative measures is essential for reducing the burden of heat stress among agricultural workers. Thus, this scoping review is an important step in synthesizing the knowledge base and outlining possible suggestions for prevention, as well as highlighting areas for future research. Although HRI and kidney disease have been adequately explored in the literature, evidence regarding the effect of heat exposure on other health outcomes such as occupational injuries and mental health was limited in the reviewed studies. The findings of this review also identified a focus on countries in the North and Central America region, while revealing a gap in studies quantifying the burden of heat related health outcomes among agricultural workers in hot regions such as Sub-Saharan Africa, Middle East and North Africa and Southeast Asia, which host millions of vulnerable agricultural workers. The main risk factors identified for both kidney disease and HRI include gender, workload, piece-rate work, job decision latitude and hot environmental conditions. On the other hand, various protective factors for HRI were identified including reducing soda consumption, taking breaks in the shade, increasing access to regular breaks and changing work hours and activities while increasing electrolyte consumption is protective factors for kidney disease. Furthermore, the most common preventive measures practiced by agricultural workers include drinking more water, taking breaks in shaded areas, going to air-conditioned places during or after work, changing work hours and activities, taking extra breaks and wearing appropriate clothing and head protection. However, limited evidence was found regarding the effect of physiological and behavioral factors as well as sociodemographic factors (such as acclimatization, hydration, training, migrant status, and poor socioeconomic conditions) on the prevalence of both HRI and kidney disease. Furthermore, few studies have assessed accessibility to preventative measures in agricultural workplaces as well as the barriers that can affect their implementation. Therefore, more studies are required globally to quantify the burden of heat stress and to identify understudied risk and protective factors as well as preventative measures among vulnerable agricultural communities in different geographical regions. In addition, further research will be required to evaluate and understand the effectiveness of heat preventative measures through intervention studies, farmworkers' cultural beliefs and prevalence of heat related health effects among vulnerable populations including children, women and migrant farmworkers.

APPENDIX

A. Search strategies

Date of Searches: 24 August 2020

Databases	**Strategy**	**Results**
Medline- 1879 to August 2020	#1 Farmers/ OR (farmworker? or farm-worker? or cattlem?n or cowboy? or cowgirl? or cowhand? or cowpoke? or gaucho or shepherd? or backwoodsm?n or backwoodswom?n or boor? or bumpkin or clodhopper? or cornfed or (country adj (boy? or girl? or cousin?)) or countrym?n or countrywom?n or farmer? or hayseed or yokel or rustic or hick or ((farm* or agricultur*) adj3 (hand or worker? or lab?or?r?)) or grower? or peasant? or gleaner? or rancher? or breeder? or agriculturalist? or agriculturist? or agronomist? or cob or cropper? or plower? or planter? or harvester? or homesteader? or villein? or grazer? or (country adj person?) or horticulturist? or plower? or (sugarcane adj2 (cutter* or worker*))).mp. #2 exp Heat Stress Disorders/ OR (((heat or heat-related) adj3 (stress or exposure or symptom? or strain or illness* or disorder? or syndrome? or collapse? or prostration or cramp? or exhaustion? or stroke?)) or heatstroke?).mp. OR ((sun adj stroke?) or sunstroke?).mp. OR ((extreme adj (heat or temperature*)) or (thermal adj (comfort or sensation))).mp. OR exp Climate Change/ OR (climate adj2 (chang* or effect? or warmer or variability)).mp. OR Global warming/ OR (global adj3 warming).mp. OR Hot Temperature/ OR (heatwave* or (heat adj wave*) or ((hot or high or warm) adj2 (environment? or weather or temperature?)) or WBGT or "' wet bulb globe temperature").mp. #1 AND #2	1632

Scopus –1788 to August 2020	#1 (TITLE ((farmworker* OR farm-worker* OR cattlem*n OR cowboy* OR cowgirl* OR cowhand* OR cowpoke* OR gaucho OR shepherd* OR backwoodsm*n OR backwoodswom*n OR boor* OR pumpkin OR clodhopper* OR corned OR (country PRE/1 (boy* OR girl* OR cousin*)) OR countrym*n OR countrywom*n OR farmer* OR mayweed OR yokel OR rustic OR hick OR ((farm* OR agricultur*) W/3 (hand OR worker* OR lab*or*r*)) OR grower* OR peasant* OR gleaner* OR rancher* OR breeder* OR agriculturalist* OR agriculturist* OR agronomist* OR cob OR cropper* OR plower* OR planter* OR harvester* OR homesteader* OR villein* OR grazer* OR (country PRE/1 person*) OR horticulturist* OR plower*)) OR harvester* OR (sugarcane W/1 (cutter* OR worker*))) # 2(TITLE (((heat OR heat-related) W/3 (stress OR exposure OR strain OR symptom* OR illness* OR disorder* OR syndrome* OR collapse* OR prostration OR cramp* OR exhaustion* OR stroke*)) OR heatstroke* OR (sun PRE/1 stroke*) OR sunstroke* OR (climate W/3 (effect* OR warmer OR variability OR chang*)) OR (global W/3 warming) OR (extreme W/1 (heat OR temperature*)) OR (thermal W/1 (comfort OR sensation)) OR heatwave* OR (heat PRE/1 wave*) OR ((hot OR high OR warm) W/2 (environment* OR weather OR temperature*)) OR wbgt OR "wet bulb globe temperature")) #1 AND #2	1251
Web of Science-1900- August 2020	#1TI=(farmwORker$ OR farm-worker$ OR cattlem$n OR cowboy$ OR cowgirl$ OR cowhand$ OR cowpoke$ OR gaucho OR shepherd$ OR backwoodsm$n OR backwoodswom$n OR boOR$ OR bumpkin OR clodhopper$ OR cORnfed OR “country boy” OR “country girl” OR “country cousin” OR “country boys” OR “country girls” OR “country cousins” OR countrym$n OR countrywom$n OR farmer$ OR hayseed OR	

	yokel OR rustic OR hick OR ((farm* OR agricultur*) NEAR/3 (hand OR wORker$ OR lab*OR*r$)) OR grower$ OR peasant$ OR gleaner$ OR rancher$ OR breeder$ OR agriculturalist$ OR agriculturist$ OR agronomist$ OR cob OR cropper$ OR plower$ OR planter$ OR harvester$ OR homesteader$ OR villein$ OR grazer$ OR “country person” OR “country persons” OR hORticulturist$ OR plower$ OR (sugarcane NEAR/2 (cutter$ OR wORker$))) #2TI=(((heat OR heat-related) NEAR/3 (stress OR exposure OR symptom$ OR strain OR illness* OR disORder$ OR syndrome$ OR collapse$ OR prostration OR cramp$ OR exhaustion$ OR stroke$)) OR heatstroke$ OR “sun stroke” OR “sun strokes” OR sunstroke$ OR “extreme heat” OR “extreme temperature” OR “extreme temperatures” OR “thermal comfORt” OR “thermal sensation” OR (climate NEAR/2 (chang* OR effect$ OR warmer OR variability)) OR (global NEAR/3 warming) OR heatwave$ OR “heat wave” OR “heat waves” OR ((hot OR high OR warm) NEAR/2 (environment$ OR weather OR temperature$)) OR WBGT OR "wet bulb globe temperature") #1 AND #2	733
CINAHL –1937 to August 2020	#1 (MH "Farmworkers") OR TI (cattlem#n OR cowboy# OR cowgirl# OR cowhand# OR cowpoke# OR gaucho OR shepherd# OR backwoodsm#n OR backwoodswom#n OR boor# OR bumpkin OR clodhopper# OR cornfed OR (country W0 (boy# OR girl# OR cousin#)) OR countrym#n OR countrywom#n OR farmer# OR hayseed OR yokel OR rustic OR hick OR ((farm* OR agricultur*) N3 (hand OR worker# OR lab#or#r#)) OR grower# OR peasant# OR gleaner# OR rancher# OR breeder# OR agriculturalist# OR agriculturist# OR agronomist# OR cob OR cropper# OR plower# OR planter# OR harvester# OR homesteader# OR villein# OR grazer# OR (country W0 person#) OR horticulturist# OR plower# OR farmworker# OR farm-worker# OR (sugarcane W0 (cutter* OR Worker*))) OR AB (cattlem#n OR cowboy# OR cowgirl# OR cowhand# OR cowpoke# OR gaucho OR shepherd# OR backwoodsm#n OR backwoodswom#n OR boor# OR bumpkin OR clodhopper# OR cornfed OR (country W0 (boy# OR girl# OR cousin#)) OR countrym#n OR countrywom#n OR farmer# OR hayseed OR	

	yokel OR rustic OR hick OR ((farm* OR agricultur*) N3 (hand OR worker# OR lab#or#r#)) OR grower# OR peasant# OR gleaner# OR rancher# OR breeder# OR agriculturalist# OR agriculturist# OR agronomist# OR cob OR cropper# OR plower# OR planter# OR harvester# OR homesteader# OR villein# OR grazer# OR (country W0 person#) OR horticulturist# OR plower# OR farmworker# OR farm-worker# OR (sugarcane W0 (cutter* OR Worker*))) OR MW (cattlem#n OR cowboy# OR cowgirl# OR cowhand# OR cowpoke# OR gaucho OR shepherd# OR backwoodsm#n OR backwoodswom#n OR boor# OR bumpkin OR clodhopper# OR cornfed OR (country W0 (boy# OR girl# OR cousin#)) OR countrym#n OR countrywom#n OR farmer# OR hayseed OR yokel OR rustic OR hick OR ((farm* OR agricultur*) N3 (hand OR worker# OR lab#or#r#)) OR grower# OR peasant# OR gleaner# OR rancher# OR breeder# OR agriculturalist# OR agriculturist# OR agronomist# OR cob OR cropper# OR plower# OR planter# OR harvester# OR homesteader# OR villein# OR grazer# OR (country W0 person#) OR horticulturist# OR plower# OR farmworker# OR farm-worker# OR (sugarcane W0 (cutter* OR Worker*))) # 2(MH "Heat Stress Disorders+") OR TI ((((heat OR heat-related) N2 (stress OR exposure OR strain OR symptom# OR illness* OR disorder# OR syndrome# OR collapse# OR prostration OR cramp# OR exhaustion# OR stroke#)) OR heatstroke#)) OR AB ((((heat OR heat-related) N2 (stress OR exposure OR strain OR symptom# OR illness* OR disorder# OR syndrome# OR collapse# OR prostration OR cramp# OR exhaustion# OR stroke#)) OR heatstroke#)) OR MW ((((heat OR heat-related) N2 (stress OR exposure OR strain OR symptom# OR illness* OR disorder# OR syndrome# OR collapse# OR prostration OR cramp# OR exhaustion# OR stroke#)) OR heatstroke#)) OR TI (((sun W0 stroke#) OR sunstroke# OR ((extreme W0 (heat OR temperature#)) OR (thermal W0 (comfort OR sensation)))) OR AB (((sun W0 stroke#) OR sunstroke# OR ((extreme W0 (heat OR temperature#)) OR (thermal W0 (comfort OR sensation)))) OR MW (((sun W0 stroke#) OR sunstroke# OR ((extreme W0 (heat OR temperature#)) OR (thermal W0 (comfort OR sensation))) OR TI (climate N2 (chang# OR effect# OR warmer OR variability)) OR AB (climate N2 (chang# OR effect# OR warmer OR variability)) OR MW (climate N2 (chang# OR effect# OR warmer OR variability))	

	OR TI (global N2 warming) OR AB (global N2 warming) OR MW (global N2 warming) OR TI ((heatwave# OR (heat W0 wave#) OR ((hot OR high OR warm) N2 (environment# OR weather OR temperature#)) OR WBGT OR “wet bulb globe temperature”)) OR AB (((heatwave# OR (heat W0 wave#) OR ((hot OR high OR warm) N2 (environment# OR weather OR temperature#)) OR WBGT OR ”wet bulb globe temperature”))) OR MW ((heatwave# OR (heat W0 wave#) OR ((hot OR high OR warm) N2 (environment# OR weather OR temperature#)) OR WBGT OR ”wet bulb globe temperature”)) OR (MH "Climate Change") #1 AND #2	165
EMBASE-1947 to August 2020	#1'heat stress'/de OR 'high temperature'/de OR 'heat stroke'/de OR 'climate change'/exp OR (((heat OR 'heat related') NEAR/3 (stress OR exposure OR symptom$ OR strain OR illness* OR disorder$ OR syndrome$ OR collapse$ OR prostration OR cramp$ OR exhaustion$ OR stroke$)):ti,ab,kw) OR heatstroke$:ti,ab,kw OR ((sun NEXT/1 stroke$):ti,ab,kw) OR sunstroke$:ti,ab,kw OR ((extreme NEXT/1 (heat OR temperature$)):ti,ab,kw) OR ((thermal NEXT/1 (comfort OR sensation)):ti,ab,kw) OR (climate NEAR/2 (chang$ OR effect$ OR warmer OR variability)):ti,ab,kw OR (global NEAR/3 warming):ti,ab,kw OR heatwave$:ti,ab,kw OR ((heat NEXT/1 wave$):ti,ab,kw) OR (((hot OR high OR warm) NEAR/2 (environment$ OR weather OR temperature$)):ti,ab,kw) OR wbgt:ti,ab,kw OR 'wet bulb globe temperature':ti,ab,kw #2 'agricultural worker'/exp OR farmworker$:ti,ab,kw OR 'farm worker':ti,ab,kw OR 'farm workers':ti,ab,kw OR cattlem$n:ti,ab,kw OR cowboy$:ti,ab,kw OR cowgirl$:ti,ab,kw OR cowhand$:ti,ab,kw OR cowpoke$:ti,ab,kw OR gaucho:ti,ab,kw OR shepherd$:ti,ab,kw OR backwoodsm$n:ti,ab,kw OR backwoodswom$n:ti,ab,kw OR boor$:ti,ab,kw OR bumpkin:ti,ab,kw OR clodhopper$:ti,ab,kw OR cornfed:ti,ab,kw OR ((country NEXT/1 (boy$ OR girl$ OR cousin$)):ti,ab,kw) OR countrym$n:ti,ab,kw OR countrywom$n:ti,ab,kw OR farmer$:ti,ab,kw OR hayseed:ti,ab,kw OR yokel:ti,ab,kw OR rustic:ti,ab,kw OR hick:ti,ab,kw OR (((farm* OR agricultur*) NEAR/3 (hand OR worker$ OR laborr$)):ti,ab,kw) OR	

	grower$:ti,ab,kw OR peasant$:ti,ab,kw OR gleaner$:ti,ab,kw OR rancher$:ti,ab,kw OR breeder$:ti,ab,kw OR agriculturalist$:ti,ab,kw OR agriculturist$:ti,ab,kw OR agronomist$:ti,ab,kw OR cob:ti,ab,kw OR cropper$:ti,ab,kw OR planter$:ti,ab,kw OR harvester$:ti,ab,kw OR homesteader$:ti,ab,kw OR villein$:ti,ab,kw OR grazer$:ti,ab,kw OR ((country NEXT/1 person$):ti,ab,kw) OR horticulturist$:ti,ab,kw OR plower$:ti,ab,kw OR ((sugarcane NEAR/2 (cutter$ OR worker$)):ti,ab,kw) #1 AND #2	1804
Total Results		5585

B. Eligibility criteria sheet in the screening process

Inclusion reasons involved the following:

- **Population of interest:** Farmworkers of all age groups
- **Outcome of interest:** Studies assessing: (1) Heat-related symptoms and illnesses; (2) Risk factors of heat-related symptoms; and (3) Preventive measures
- **Context of interest:** Studies on the impact of occupational heat exposure on workers' health and safety
- **Types of study design:** Primary studies including quantitative and qualitative methods

Exclusion reasons involved the following:

- **Not population of interest:** Not farmworkers
- **Not outcome of interest:** Studies assessing outcomes not related to heat illnesses and symptoms and studies that calculate the effects with simulations or models instead of actual measurements in humans
- **Not context of interest:** Studies not related to the context of the study such as those on the impact of heat exposure on the general population, plants, animals, and crops
- **Not primary study:** Studies such as editorials, commentaries, letter to the editors, reviews, reports and conference abstracts

Flowchart of decision:

1. Is the study population farmworkers?

☐ NO → Exclude

☐ Yes or uncertain → Go to the next question

2. Does the study assess heat-related outcomes?
(outcomes such as heat-related symptoms and illnesses; risk factors of heat-related symptoms; and preventive measures.)

☐ NO → Exclude

☐ Yes or uncertain → Go to the next question

3. Is the study assessing the impact of occupational heat exposure on workers' health and safety?

☐ NO → Exclude

☐ Yes or uncertain → go to the next question

4. Does the study use primary data to assess or measures study outcomes?
(qualitative, quantitative, and mixed methods)

☐ NO → Exclude

☐ Yes or uncertain → Get full text

C. Data Abstraction table

Reference	Study Location	Study region	Study design	Heat exposure metric	Period of heat exposure	Study duration	Methods of data collection	Outcome assessed	Data analysis
Acrury et al. 2019	North Carolina, USA	Americas	Cross-sectional	-	May to November 2017	6 months	Questionnaire	Health outcome Risk factors	Logistic regression analysis
Acrury et al. 2020	North Carolina, USA	Americas	Cross-sectional	-	April to November 2017	7 months	Questionnaire	Health outcome Risk factors	logistic regression model
Arcury et al. 2015	North Carolina, USA	Americas	Cross-sectional	Heat index	August 2013	1 month	Questionnaire	Health outcome Risk factors Preventative measures	Chi-square tests
Arnold et al. 2020	North Carolina, USA	Americas	Mixed methods	-	-	-	Questionnaire In-depth interviews	Health outcome Risk factors Preventative measures	Thematic analysis Descriptive statistics
Bethel et al. 2014	Oregon, USA	Americas	Cross-sectional	-	July and August 2013	2 months	Questionnaire	Health outcome Preventative measures	Log-binomial models Descriptive statistics
Bethel et al. 2017	Oregon/Washington, USA	Americas	Cross-sectional	-	July and August 2013	2 months	Questionnaire	Preventative measures	Descriptive statistics
Biggs et al. 2011	South Africa	Africa	Cross-sectional	-	-	-	Biological sampling	Health outcome Risk factors Preventative measures	Descriptive statistics
Bodin et al. 2016	El Salvador	Americas	Longitudinal	WBGT	-	-	Questionnaire Blood sampling	Health outcome	Descriptive statistics
Budhathoki et al. 2019	Nepal	Southeast Asia	Cross-sectional	-	November 2017 to January 2018	3 months	Questionnaire	Health outcome Preventative measures	Descriptive statistics
Butler-Dawson et al. 2017	Guatemala	Americas	Longitudinal	-	Pre-harvest: August - November 2015 End-harvest: May 2016		Questionnaire Physiological measurements Biological sampling		Multiple logistic regression model Multinomial logistic regression
Butler-Dawson et al. 2019	Guatemala	Americas	Prospective longitudinal cohort	WBGT	February, March and April 2017	3 months	Questionnaire Biological sampling	Health outcome Risk factors	Mixed effects logistic regression analysis
CDC, 2008	North Carolina, USA	Americas	Case report	High temperature Relative humidity	July 2005	1 month	-	Health outcome	-
Cortez et al. 2009	Nicaragua	Americas	Cross- sectional	WBGT	15th April to 30th April 2008	15 days	Data collection sheet	Health outcome Preventative measures	Descriptive statistics
Crowe et al. 2009	Costa Rica	Americas	Qualitative	Average maximum and minimum temperature	November 2008 and March 2009	2 months	Observation Exploratory interviews	Risk factors Preventative measures	-
Crowe et al. 2015	Costa Rica	Americas	Cross- sectional	-	February 2011	1 months	Questionnaire	Health outcome	Chi-square tests and Fisher’s exact test

									Gamma statistic
Culp et al. 2019	Iowa, USA	Americas	Mixed methods	WBGT	June and July	2 months	Questionnaire Physiological measurements	Health outcome Risk factors	Descriptive statistics Fisher's test Fisher's exact test and Odds Ratio
Das et al. 2013	India	Asia	Cross- sectional	WBGT	-	-	Physiological measurements	Health outcome	Descriptive statistics
Das et al. 2013	India	Asia	Cross- sectional	WBGT			Physiological measurements	Health outcome	Descriptive statistics
Ekiti et al. 2018	Cameron	Africa	Cross- sectional		November 2015 to May 2016	7 months	Questionnaire Biological sampling Physiological measurements	Health outcome Risk factors	Multivariate logistic regression model
Fitria et al. 2020	Indonesia	Americas	Cross-sectional	WBGT	-	-	Questionnaire Physiological measurements Biological sampling	Health outcome Risk factors	Multivariate Logistic Regression
Fleischer et al. 2013	Georgia, USA	Americas	Cross- sectional		2011–2012	2 years	Questionnaire	Health outcome Risk factors	Population intervention models
Flocks et al. 2013	Florida, USA	Americas	Qualitative	-	-		Focus group discussion	Health outcome Preventive measures	Thematic analysis
Frimpomg et al. 2013	Ghana	Africa	Cross- sectional	-	January to May 2013	5 months	Questionnaire	Health outcome	Descriptive statistics
Frimpomg et al. 2020	Ghana	Africa	Cross- sectional	-	January to June 2013	6 months	Questionnaire	Preventive measures	Descriptive statistics
García-Trabanino et al. 2015	El Salvador	Americas	Cross- sectional	Temperature Heat index WBGT	March-April 2014	2 months	Questionnaire Biological sampling Physiological measurements	Health outcome Risk factors	Multiple linear regression logistic regression models
Glaser et al. 2020	Nicaragua	Americas	Cohort		November 2018–April 2019	6 months	Questionnaire Biological sampling	Health outcome	Regression modelling
Gun, 1995	Australia	Western Pacific	Cross- sectional	WBGT	-	-	Physiological measurements	Health outcome Risk factors	Multiple regression analysis
Hansen et al. 2020	Australia	Western Pacific	Qualitative	-	-	-	Interview	Risk factors Preventive measures	Thematic analysis
Hansson et al. 2019	Nicaragua	Americas	Cohort	WBGT	November 2017-April 2018	6 months	Questionnaire Biological sampling	Health outcome Risk factors	mixed-effects linear regression Poisson regression
Hansson et al. 2020	Nicaragua El Salvador	Americas	Longitudinal study	-	2014–2016 2017–2019	-	Questionnaire Biological sampling		mixed-effects logistic regression
How et al.	Malaysia	Western	Cross-sectional	WBGT	January to	2 months	Questionnaire	Health outcome	Descriptive statistics

2020		Pacific		Physiological Strain Index (PSI) Heat Stress Index (HIS)	February 2019		Biological sampling		
Jayasekara et al., 2019	Sri Lanka	Southeast Asia	Cross-sectional				Questionnaire Biological sampling	Health outcome Risk factors	
Kearney et al. 2016	North Carolina, USA	Americas	Cross- sectional	-	August to September 2013	3 months	Questionnaire	Health outcome Preventative measures	Logistic and log-binominal regression models
Kupferman et al. 2018	Nicaragua	Americas	Cross-sectional	-	Late harvest enrollment: March-May 2015		Questionnaire Physiological measurements Biological sampling	Health outcome Risk factors	Linear regression models
Kwon et al. 2015	South Korea	Western Pacific	Cross- sectional	WBGT	July 2012 to September 2012		Questionnaire Observation	Preventative measures	Spearman’s correlation analysis Correlation of Kendall’s τc
Lam et al. 2013	Washington, USA	Americas	Qualitative	-	-	-	Focus group discussion	Preventative measures	Thematic analysis
Laws et al. 2016	Nicaragua	Africa	Longitudinal study	-	October 2010–December 2010 March 2011–May 2011	6 months	Biological sampling	Health outcome	Linear mixed effects models
Laws et al., 2015	Nicaragua	Americas	Longitudinal	-	Pre-harvest: October - December 2010 Late-harvest: March–May 2011		Questionnaire Biological sampling	Health outcome Risk factors	multiple linear regression models
Lumingu et al. 2009	Canada	Americas	Cross- sectional	WBGT	Summers of 2004,2005, and2006	-	Physiological measurements	Health outcome	Descriptive statistics
Lundgren et al. 2014	India	Southeast Asia	Comparative	WBGT	January-February and April-May	4 months	Physiological measurements	Health outcome Risk factors	Descriptive statistics
Luque et al. 2019	South Carolina, USA	Americas	Qualitative	-	October and December 2017	2 months	Focus group discussion	Risk factors Preventive measures	Thematic analysis
Luque et al. 2020	Florida and Georgia, USA	Americas	Cross- sectional	-	Between August and October 2018	3 months	Questionnaire	Health outcome Preventive measures	Descriptive analysis Multiple regression analysis
Mac et al. 2016	Florida, USA	Americas	Cross- sectional	WBGT	Summers of 2012 and 2013	-	Questionnaire Physiological measurements	Health outcome Risk factors	Logistic regression analysis utilizing a generalized estimating equations (GEE) approach
Mac et al.	Florida, USA	Americas	Cross- sectional	WBGT	Summers of 2012	-	Questionnaire	Health outcome	Logistic regression

2019					and 2013		Physiological measurements	Risk factors	analysis utilizing a generalized estimating equations (GEE) approach
Miller, 1982	USA	Americas	Cross- sectional				Physiological measurements		
Mirabelli et al. 2010	North Carolina, USA	Americas	Cross- sectional	-	June and September 2009	2 months	Questionnaire	Health outcome	Log-binomial regression
Mitchell et al. 2017	California, USA	Americas	Cross- sectional	WBGT	June to October of 2014 and 2015	8 months	Questionnaire Physiological measurements Biological sampling	Health outcome	Descriptive analysis
Mix et al. 2018	Florida, USA	Americas	Cross- sectional	-	summers of 2015 and 2016	-	Questionnaire Biological sampling	Health outcome Risk factors	Multivariable mixed modeling
Moyce et al. 2016	USA	Americas	Cross-sectional	-	Summer 2014		Questionnaire Physiological measurements Biological sampling	Health outcome Risk factors	
Moyce et al. 2017	California, USA	Americas	Cross- sectional	Physiological strain index (PSI)	Summer of 2014	-	Questionnaire Physiological measurements Biological sampling	Health outcome Risk factors	Logistic regression models
Moyce et al. 2019	California, USA	Americas	Cross- sectional	WBGT	-	-	Questionnaire Physiological measurements Biological sampling	Health outcome Risk factors	Logistic regression
Moyce et al. 2020	California, USA	Americas	Cross- sectional	WBGT	Summers of 2014 and 2015	-	Questionnaire Physiological measurements Biological sampling	Health outcome Risk factors Preventive measures	Logistic regression models
Mutic et al. 2018	Florida, USA	Americas	Cross- sectional	Ambient temperature and relative humidity	summer months of 2015 to 2016	-	Questionnaire	Health outcome Risk factors	Multivariable logistic regression
Nanayakkara et al. 2020	Sri Lanka	South east Asia	Cross-sectional				Questionnaire Biological sampling		
Nayha et al. 2017	Finland	Europe	Cross- sectional	-	January–March 2007	3 months	Questionnaire	Health outcome	Logistic regression
Pogačar et al. 2017	Slovenia	Europe	Cross- sectional	-	September 2016 to April 2017	8 months	Questionnaire	Health outcome Preventive measures	Descriptive analysis
Quandt et al. 2008	North Carolina, USA	Americas	Longitudinal	Average temperature	May to October 2005	6 months	Questionnaire	Health outcome Risk factors	Descriptive analysis Multivariate logistic

									regression
Raines et al. 2014	Nicaragua	Americas	Cross- sectional design with nested case control Analysis	-	Weekends in July–August 2012	8 days	Questionnaire Physiological measurements Biological sampling	Health outcome Risk factors	chi square, and univariate and multiple logistic regression
Rajewski et al. 2008	Poland	Europe	Case report	-	-	-	Biological sampling Physiological measurements	Health outcome	-
Raju et al. 2014	India	Southeast Asia	Cross- sectional	-	January 2011 to December 2012	24 months	Biological sampling	Health outcome	Descriptive analysis
Ricco et al. 2017	Italy	Europe	Cross- sectional	-	March 2017	1 month	Questionnaire	Health outcome Preventive measures	Binary logistic regression analysis
Sadiq et al. 2019	Nigeria	Africa	Cross- sectional	WBGT	July to September, 2016	3 months	Questionnaire	Health outcome	Descriptive statistics
Sahu et al. 2013	India	South east Asia	Cross- sectional	WBGT	April to June 2011	3 months	Questionnaire Physiological measurements	Health outcome	Descriptive statistics
Sen et al. 2019	India	South east Asia	Cross- sectional	WBGT, HI, Humidex, UTCI, SET, PMV	November to April 2015 to 2017	18 months	Questionnaire Physiological measurements	Health outcome	Descriptive statistics
Smith et al. 2020	Georgia, USA	Americas	Cross- sectional	Maximum daily heat index Relative humidity	-	-	Questionnaire	Health outcome Preventive measures	Descriptive statistics
Sorensen et al. 2019	Guatemala	Americas	Longitudinal	WBGT	February, March, and April, 2017	3 months	Questionnaire Biological sampling	Health outcome Risk factors	Linear mixed-effects univariate and multivariable models
Spector et al. 2015	Washington state, USA	Americas	Cross- sectional	Mean maximum daily heat indices over the past week (HImax)	July to September 2013	3 months	Questionnaire	Health outcome Risk factors Preventive measures	Mixed-effects logistic regression
Spector et al. 2018	Washington state, USA	Americas	Cross- sectional	WBGT	August and September 2015	2 months	Questionnaire Physiological measurements Biological sampling	Health outcome Risk factors	Linear mixed models
Stoecklin-Marois et al. 2013	California, USA	Americas	Cross- sectional	-	November 2008-Febrruary 2010	14 months	Questionnaire	Preventive measures	Multivariate logistic regression
Stoklosa et al. 2020	USA	Americas	Case report				Physiological measurements Biological sampling	Health outcome	
Trevisan et al.	Brazil	Americas	Longitudinal study	Temperature and	March-April 2014	6 months	Questionnaire	Health outcome	Generalized linear

2019				relative humidity	July-October 2014		Biological sampling		models
Vega-Arroyo	California, USA	Americas	Cross- sectional	temperature, WBGT, and the heat index	June- September 2015	4 months	Questionnaire Physiological measurements	Health outcome Risk factors	Multivariate regression model
Wagoner et al. 2020	Mexico	Americas	Cross- sectional	WBGT	March, June, and August 2016	3 months	Questionnaire	Health outcome	Descriptive statistics
Wegman et al.	El Salvador	Americas	Longitudinal	WBGT	Inland group (January 7, February 18 and April 8) Coastland group (January 9 and April 10)		Questionnaire Physiological measurements Biological sampling	Health outcome	Multivariate linear regression models
Wesseling et al. 2016a	Nicaragua	Americas	Longitudinal	-	November 2012-January 2013	4 months	Questionnaire Physiological measurements Biological sampling	Health outcome	Mixed effects model Descriptive statistics
Wesseling et al. 2016b	Nicaragua	Americas	Cross- sectional	-	January–February 2013	2 months	Questionnaire Physiological measurements Biological sampling	Health outcome Risk factors Preventive measures	Multivariate linear regression models
Wilmsen et al. 2019	Oregon, USA	Americas	Case studies	-	-	-	Interview	Health outcome Preventive measures	Thematic analysis

WBGT: wet bulb globe temperature; HSI: heat stress index; UTCI: Universal Thermal Climate Index; STI: Subjective Temperature Index; PSI: Physiological Strain Index; PMV: Predicted mean vote; SET: Standard Effective Temperature: HI: heat index

Reference	**Study population (sample size)**	**Gender/Age**	**Heat-related outcomes (only statistically significant in quantitative studies and all outcomes in qualitative studies)**	**Protective factor (only statistically significant in quantitative studies and all risk factors in qualitative studies)**	**Risk factor (only statistically significant in quantitative studies and all risk factors in qualitative studies)**	**Non-significant association**	**Prevalence of preventive measures**
Acrury et al. 2015	Farmworkers (101) Worked outside in extremely hot weather conditions: 68 Worked inside in extremely	101 males Age range: 30-70	• 35.6% of the of the total sample reported heat illness • 52.9% of the sample that worked outside in extremely hot weather conditions had at least one heat illness symptom *HRI symptoms:* • Sudden muscle cramps (outside extremely hot weather conditions 25% vs inside in				• Drinking more water (58.4% of total sample vs 86.8% working outside in extremely hot conditions) • Taking breaks in shaded areas (59.4% vs 88.2%) • Going to air-conditioned places (19.8% vs 29.4%) • Changing work hours (16.8 %

	hot weather conditions: 18		extremely hot weather conditions 27.8%) • Nausea or vomiting (10.3% vs 22.2%) • Hot, dry skin (32.4% vs 61.1%) • Confusion (13.2% vs 22.2%) • Dizziness (16.2% vs 27.8%)				vs 25%) • Changing work activities (13.9% vs 20.6%) • Changing hours or activities (19.8% vs 29.4%) • Changing hours and activities (10.9% vs 16.2%)
Acrury et al. 2019	Latinx child farmworkers (202)	35 males 50 females Age range: 10-17	• 45.5% heat-related illness in the past year *HRI symptoms reported:* • 25.7% dizziness • 21.8% sudden muscle cramps • 17.3% hot, dry skin • 7.4% nausea or vomiting • 5.0% confusion • 1.5% fainting		*Association with greater odds of HRI:* • Increased age (OR 1.41, 95% CI 1.18, 1.69)	• Gender • Migrant status • Work with adult relative • Amount of work in last three months	
Acrury et al. 2020	Latinx child farmworkers (202)	76 females 126 males Age range: 10-17	• 45.5% of participants reported HRI		*Association with greater odds of HRI in bivariate models:* • Pesticide safety training (OR 2.03, 95% CI 1.08, 3.84) *Association with greater odds of HRI in multivariate models:* • Oldest farmworkers aged 16-17 years (OR 4.52, 95% CI 1.93, 10.57) compared to youngest aged 10-13 years • Pesticide safety training (OR 3.26, 95% CI 1.39, 7.65)	*Bivariate models:* • Appropriate work clothing • Safety training—tool use • Safety training—machinery • Work piece-rate • Field sanitation services • Safety/risk attitudes • Vulnerability • Work safety climate scale • Supervisor interested in doing the job fast and cheaply versus as much as possible • Supervisor doing as much as possible to do the job safety versus as much as possible *Multivariate models:* • Age (14–15 years versus 10–13 years) • Gender • Migrant worker • Work with adult relative • Amount of Work in Last Three Months Clothing • Safety training—tool use • Safety training—machinery • Safety/risk attitudes • Vulnerability • Work safety climate scale • Supervisor interested in doing the	

						job fast and cheaply versus as much as possible • Supervisor doing as much as possible to do the job safety versus as much as possible	
Arnold et al. 2020	Latinx child farmworkers (165)	106 males 59 females Age range: 10-17	• 47.8% of participants reported at least one HRI symptom • 22% experienced at least two symptoms *HRI symptoms reported:* • 29.1% dizziness • 21.8% sudden muscle cramps • 17.6% hot, dry skin • 8.5% nausea or vomiting • 6.1% confusion • 1.8% fainting	*Association with lower HRI:* • Take extra breaks (62.0% vs. 39.7%, p= .0045)	*Association with higher HRI:* • Older participants compared to younger (10-13, 60.8%; 14-15, 44.2%; 16-17, 23.5%, p= 0011) • Go to air-conditioned places during breaks or after work (59.6 % vs. 41.7 %,p= .0279)	• Gender • Farmworker status • Years of farm work experience • Work with older relative • Pay structure • Recipient of pay • Extra water • Breaks in shade • Hours changed • Tasks changed	• 90.9% drank extra water • 87.9 % took breaks in shaded areas • 55.8 % took extra breaks • 43% changed work hours • 34.6 % gone to air-conditioned places during breaks or after work • 10.9 % changed tasks • Some reported leaving work early
Bethel et al. 2014	Farmworkers (100)	60 males 40 females Age range: 18-62	• 30% of participants reported experiencing 2 or more HRI symptoms *HRI symptoms reported:* • 10% skin rash/skin bumps • 9% painful muscle cramps/spasms • 7% dizziness/light-headedness • 1% fainting • 24% headache • 50% heavy sweating • 14% extreme weakness/fatigue • 2% nausea/vomiting • 3% confusion • 36% none			•	• 48.3% gradually increased work hours at start of season • 73% drank water at least once per hour past week • 40% had no cooling measure at work *Head protection usually worn at work:* • Baseball cap (94%) • Wide brimmed hat (21.0%) • Other hat (2.0%) • Bandana (75.0%) • Hood from hooded sweatshirt (63.0%) *Clothing usually worn at work* • Light-colored short-sleeved shirt (9.0%) • Dark-colored short-sleeved shirt (2.0%) • Light-colored long-sleeved shirt (90.0%) • Dark-colored long-sleeved shirt (23.0%) • Shorts (4.0%) • Pants (97.0%) • Jacket (72.0%)
Bethel et al. 2017	Farmworkers (197) Oregon state:	 60 males					*Types of beverages consumed:* • 98.5% water • 46.2% sports drink

	100 Washington state: 97	40 females Mean age:31.8 51 males 46 females Mean age:40.4					• 8.6% energy drink • 24.9% juice • 4.6% iced coffee or tea • 10.7% hot coffee or tea • 48.2% soda • 2% other drink • Shade structures (Oregon 26% vs. Washington 6%) • Rest stations (19% vs. 6%) • Trees (47% vs 91.8) • Fans (4% vs 2.1%) • Building with air conditioning (1% vs 0%) • Cars with air conditioning (14% vs. 3%) • Mister (3 % vs 0%) • Wet clothes (40% vs. 2.1%) • Hose (14% vs. 2%) • Jump in river or canal (1% vs 0%) • HRI training (54% vs 34%) • Gradual increase of work hours at start of season (48.3% vs 34.4%) *Headwear usually worn at work:* • Baseball cap (94% vs 76.3%) • Wide-brimmed hat (21% vs 22.7%) • Other hat (2% vs 0%) • Bandana (75% vs 25.8%) • Hood from hooded sweatshirt (63% vs 15.5%)
Biggs et al. 2011	Forestry workers (182) Autumn: 103 Winter:79	64 males 39 females Mean range: 37 68 males 11 females Mean range:26	• Preshift dehydration was 43% in autumn and 47% in winter (USG > 1.020 g ml) • Significant increase (P= 0.001) in the post-shift dehydration as 64% (P = 0.001) in autumn and 63% (P=0.043) in winter • 21% in autumn and 23% in winter lost >2% of their body weight across the shift • 44% of all workers were dehydrated pre-				

			shift(USG>1.021) • 63% of all workers were dehydrated post-shift (USG >1.020)				
Bodin et al. 2016	Sugarcane workers (116) Intervention group (Inland): 56 Nonintervention group (Coastland): 60	Intervention group: 55 males 1 female Nonintervention group: 46 males 14 females Age range: 18-63	Compared to pre-intervention, in post-intervention workers reported reduction of: • Exhaustion • Nausea • Cramps • Dry mouth • Low/dark urine • Fever • Dizziness • Disorientation • Fainting • Stomachache • Headache				
Budhathoki et al. 2019	Farmworkers (350)	220 males 130 females Age range: 38.72; 12.9	• 37% experienced heat related health problems *HRI symptoms reported:* • 73% fatigue • 63% dizziness • 41% headache • 28% nausea • 24% confusion • 12% heat rash • 8.3% fainting • 8% loss of concentration • 2.3% heat strokes			•	• 96% wore broad brimmed hats or used umbrellas • 65% rescheduled their work shifts • 61% stopped their outdoor farm activities • 93% rested in the shade and slowed down their work pace • 54% drank more cold water, stayed in sheds, stayed inside the house, and used wet clothing • Bathed in cold water
Butler-Dawson et al. 2017	Sugarcane workers (330)	Male: 330 Median age: 28	• 14% at baseline had eGFR between 60 and 89 ml/min/1.73m2 and 1% < 60ml/min/1.73m2 • Cross-harvest decline in eGFR in 37% of sugarcane cutters, 31% with a decline in eGFR 1-20% and 6% with a decline in eGFR > 20% • 3% of cutters had eGFR< 60 ml/min/1.73m2 *Decline in 0%ΔGFR:* • Workers at Mill A had 12.03% decline in eGFR compared		*Decline in kidney function (less than 0%ΔGFR):* • Mill A (OR 2.60, 95% CI=1.39,4.80) • Local worker (OR: 2.15, 95% CI: 1.28,3.60) • Current smoker (OR: 2.33, 95% CI: 1.17,4.63) *Severe decline (more than 20% decline) in %ΔGFR:* • Pre-employment eGFR less than 90 (OR: 4.23, 95% CI: 1.12,15.99) • Local worker (OR: 4.37, 95% CI: 1.41,13.52)		

			with workers at Mill B. • Local workers had 6.30% decline in eGFR compared to highland workers • Current smokers had 5.80% decline in eGFR compared to Never/Former smokers • Workers with pre-employment eGFR <90 had 7.31% improvement in eGFR compared with workers with an eGFR ≥ 90		• Current smoker (OR: 5.27, 95% CI: 1.54,17.99) *Mild decline (0% to 20% decline) in %ΔGFR:* • Local worker (OR: 1.92, 95% CI: 1.12:3.30) • Working at Mill A (OR: 2.48, 95% CI: 1.30:4.72)		
Butler-Dawson et al. 2019	Sugarcane workers (517)	517 males Age range: >18	• 81% of sugarcane workers had at least one AKI (indicated by increase in serum creatinine of 26.5 μmol/L or 50% or more from the pre-shift value) during the study period • AKI cumulative incidence over a work shift was 47% in February, 51% in March and 45% in April	*Association with lower AKI (univariate analysis):* • Average WBGT (per 1 °C) (OR 0.90,95% CI 0.82, 0.98) • Maximum WBGT (per 1 °C) (OR 0.89 95% CI 0.82, 0.96) • More work shift hours (OR 0.89 95% CI 0.83, 0.95) *Association with lower AKI (multivariate analysis):* • Higher baseline eGFR (OR 0.98, 95% CI 0.97–0.99) • Higher electrolyte solution intake were associated (OR 0.94, 95% CI 0.89–0.99)	*Association with higher AKI (univariate analysis):* • Age (OR 1.01, 95% CI 1.00–1.03) • Baseline eGFR (OR 0.98, 95% CI 0.98–0.99) • Pre-shift urinary-specific gravity (OR 1.41, 95% CI 1.19–1.67) • Post-shift specific gravity (OR 1.48; 95% CI 1.27–1.72) • Electrolyte solution intake (OR 0.89, 95% CI 0.85–0.93) • Rest breaks (OR 0.83, 95% CI 0.75–0.93) • Work shift hours (OR 0.89, 95% CI 0.83–0.95) • Job type (OR 3.10, 95% CI 2.29–4.19) • Average WBGT (OR 0.90, 95% CI 0.82–0.98 • Maximum WBGT (OR 0.89, 95% CI 0.82–0.96) *Association with higher AKI (multivariate analysis):* • Dehydration indicated by higher post-shift specific gravity (OR 1.24, 95% CI 1.02–1.52) • NSAIDs and increasing post shift specific gravity (OR 8.38, 95% CI 1.67–42.16)	*Univariate analysis:* • Local home residence • Hypertension • BMI • Previous harvests • Body weight change • Specific gravity, percent change • Sugary beverage intake • Smoked cigarette • NSAID use • Alcohol intake *Multivariate analysis:* • Age • Hypertension • Work shift hours • Rest breaks • Pre-shift specific gravity • Average WBGT	

CDC, 2008	A Hispanic worker	Male Age: 56	• Death due to heat stroke • Core body temperature was 42°C at time of death • The man developed confusion before death			•	• The worker had not received HRI training
Cortez et al. 2009	Sugarcane workers (22)	Age not specified Gender not specified				•	• Seven workers drank from 7 to 8 L as temperature increased • Although temperature increased to maximum values many workers did not follow the rehydration measures and drank less than 6 L which is considered low
Crowe et al. 2009	Sugarcane field workers (sample size not specified)				• Temporary workers are reluctant to take breaks since they are paid by piece	•	• Most field workers take between 2 and 10 liters of water into the field with them • Most workers reported drinking either coffee or 'fresco' (fruit juice mixed with water and sugar) • Workers use long sleeves, long pants and neck covering
Crowe et al. 2015	Sugarcane cutters (169) Harvesters: 106 Median age: 34 Non-harvesters: 63 Median age: 37	(gender not specified) Median age: 34 Median age: 37	• Heat and dehydration symptoms experienced at least once per week were significantly different between harvesters and non-harvesters (P<0.05) with the exception of vomiting and dry mouth *HRI symptoms at least once per week:* • Headache (harvesters 50.9% vs non-harvesters 25.4%) • Tachycardia (34.9% vs 4.8%) • Muscle cramps (24.5% vs 11.1%) • Fever (17.9% vs 3.2%) • Nausea (17% vs 0%) • Difficulty breathing (13.2% vs 0%) • Dizziness (11.3% vs 1.6%) • Swelling of hands/feet (7.5% vs 0%)				

			- Vomiting (3.8% vs 0%) - Dry mouth (32.1% vs 22.2%) - Dysuria (28.3% vs 3.2%) - Heat and dehydration symptoms increased as heat exposure categories increased (office and various workers, field and plant workers and harvesters)				
Culp et al. 2019	Farmworkers (168) Cross sectional (CS) group: 148 Intensive Surveillance (IS) Group: 20	168 males Age range: 18-65	*CS group:* - Extreme thirst (21.9% among participants between the ages of 18-34 years 21.9% vs. 16.5% among participants equal or older than 35 years 16.5%) - Muscle cramps (7.8% vs 7.1%) - Confusion (4.7% vs 7.1%) - Light-headed or dizzy (4.7% vs 5.9%) - Nausea (4.7% vs 3.6%) - Chest pounding (3.1% vs 1.2%) *Association with uncomfortable Physiological intensity (PI) score (0-5) PI among IS group:* - Higher body temperature (F ratio = 16.41, p < .001) - Kilocalories per hour (F ratio=8.41, p=0.001) *Association with uncomfortable WBGT among IS group:* - Higher heart rate (F ratio: 4.59, p = 0.014) - Higher breathing rates (F ratio: 6.48, p = 0.003) - Higher PI scores (F ratio: 5.11, p = 0.003)				*CS group:* *Types of beverages consumed:* - 68.9% water - 19.6% soda - 4.7% sports drinks
Das et al. 2013a	Control and experimental group (170) Experimental:	Gender not	*Rate at work vs. just after work* - Heart rate:74.4 vs. 121.5 beats/min - Systolic blood pressure: 110.2 vs. 132.2				

	Groundnut farmers (85) Control: Office workers (85)	specified Mean age: 31.9;6.82 Gender not specified Mean age: 27.2;5.4	• Diastolic blood pressure: 71.9 vs. 80.1 *Rate among farmers vs. office workers* • Maximum heart rate: 188.1 vs. 192.8 • Heart Rate Reserve: 113.8 vs. 117.7 • Net Cardiac Cost: 47.1 vs. 31.8 • Relative Cardiac Cost: 63.45 vs. 42.6				
Das et al. 2013b	Control and experimental group (240) Experimental: Child agricultural workers (120) Control (120)	63 males 57 females Age range: 10-16	• Change of heart rate (workers 81.5 beat/min vs control 32.8 beat/min) • Change of systolic blood pressure (35 mmHg vs 19.3 mmHg) • Change of diastolic blood pressure (7 mmHg vs 4.3 mmHg)				
Ekiti et al. 2018	Sugarcane workers (204) Office: 23 Factory:57 Field:124	153 males 51 females Mean age: 38.8;9.8	• 3.4% of participants had CKD (indicated by proteinuria and/or GFR< 60 ml/min/1.73 m2 persistent after 3 months) • CKD prevalence was 7% in factory workers compared to 0% and 2.4% in office and field workers • 2.9% had persistent proteinuria which was mild • 0.5% had GFR < 60 ml/min/1.73 m2		*Association with higher CKD:* • Age ≥ 40 years (OR = 18.7, 95% CI = 1.5–236.4, p = 0.024)	• Sex • Contract type • Duration of employment • Socio-economic status • Exposure to agrochemicals, heavy metals and heat • Alcohol use • Chronic use of herbal medicines • Family history of CKD • Obesity and overweight • NSAID use • Tobacco use • Hypertension • Diabetes	
Fitria et al. 2020	Rice harvesters (354)	Male: 354 Age: 20-65	• The overall prevalence of CKD was 24.9% while CKDu was 18.6%.		*Association with CKDu:* • Farm location (high altitude versus low altitude location) (Prevalence Odds Ratio (POR): 2.0; 95% CI: 1.2–3.5)		
Fleischer et al.	Farmworkers (405)	326 males 79 females	• 1/3 reported experienced three or more symptoms in the past	*Association with a reduction in prevalence of*		• Go cool down • Sports drinks	*Drink more of beverage during hot conditions:*

2013		Age range: >18	week • 71% experienced at least one symptom in the past week *HRI symptoms:* • 50.8% headache • 44.9% hot, dry skin • 33.7% sudden muscle cramps • 24.6% dizziness • 16.7% nausea or vomiting • 15.5% confusion • 4.4% fainting	*three or more HRI symptoms:* • Increasing breaks in the shade reduces (9.2%) • Increasing access to medical attention (7.3%) • Reducing soda intake by (6.7%) • Increasing access to regular breaks (6.0%)		• Water • Time in Georgia this year • Education • Access to shade • Load/pack outside • Alcohol • Change work duties • Work days/week • Juice • Wear sunscreen • Work hours/day	• 95.3% water • 83.8% sports drinks • 62.6% juice • 53.5% soda • 21.6% energy drinks • 6.8% coffee or tea • 6.5% alcohol
Flocks et al. 2013	Fernery and nursery workers (35)	35 females Age range: 18-55	• Prevalence of general health effects include headaches, dizziness/fainting, respiratory problems, vomiting, and exacerbated high or low blood pressure				
Frimpong et al. 2013	Farmworkers (308)	Gender not specified Age not specified	• Prickly heat (17% male vs 17% female) • Heat cramp (29% vs 17%) • Heat exhaustion (40% vs 23%) • Malaria (77% vs 54%) • Cerebro-spinal meningitis (23% vs 10%)				
Frimpong et al. 2020	Farmworkers (308)	Males: 186 Females: 122 Age not specified				•	• 26.6% got away to a shade for a while • 4.2% removed clothing for free air • 19.8% drank water regularly • 16.9% wore a hat • 32.5% wore of airy dress • 3.2% covered head with traditional scarf • 10.4% wore traditional cloth which is airy • 46.1% ate traditional food which induces regular intake of water • 40.3% didn't eat traditional food
García-Trabanino et al. 2015	Sugarcane cutters (189)	168 males 21 females Age range: 18-49	• 20% of the men had a pre-shift serum creatinine level above 1.2 mg/dL • 27% of the men had a serum uric acid level above 7.0 mg/dL.	*Association with increased GFR linear regression models:* • Liquid intake (0.06 mg/dl decrease in serum creatinine for each dL per	*Association with reduced GFR among* logistic regression model: • Age (OR 1.09 per year, 95% CI 1.02–1.16, P=0.008)	*Logistic regression model:* • BMI • Smoking • Kidney stones • Hypertension • NSAIDS use	• The mean liquid intake was 0.3 L at breakfast and 3.3 L during work (mean 0.8 L per hour) • 90% was water

			- 14% had a pre-shift GFR less than60 mL/min/1.73 m^2 - 3 workers had severely reduced eGFR (<30 mL/min) - 10% increase in serum creatinine, urea nitrogen, and uric acid during post-shift as compared to pre-shift - Mean urine specific gravity was 1.016 pre-shift and 1.020 post-shift - Increase of mean urinary creatinine from 1.1 to 1.9 g/L - 1/3 of workers lost >0.5 kg of body weight	hour of liquid intake, P=0.07) *Association with increase post shift body weight* - One extra liter of fluid increased post-shift body weight with about 0.5 kg (P=0.008)	- Region – coastal region (where temperature and humidity is higher) versus the other two regions combined (OR 3.5, 95% CI 1.3–9.4, P=0.01) - Association with ever use of carbamate insecticide when replacing any use of pesticides *Association with increased post-shift serum creatinine in multiple linear regression models:* - WBGT (about 2% increase in serum creatinine per degree of WBGT, P=0.001)	- Diuretics - Number of previous harvests - Any use of pesticides *Multiple linear regression:* - Work time - Region	
Glaser et al. 2020	Sugarcane workers Harvest 1 (525) Harvest 2 (567)	Mean age Harvest 2: Field support staff (FS) 31 (7) Irrigation repair workers (IR) 29 (7) Seed cutters (SC): 28 (7) Burned cane workers (BCC): 31 (8)	*After intervention is introduced:* - Lower decline in cross harvest eGFR among BCC (6, 95% CI 2 to 9) - Lower decline in cross harvest eGFR among SC (2 −1, 4) - IKI (indicated by increase in serum creatinine by ≥0.30 mg/dL or ≥1.5 times increase from baseline to end-harvest) was 70% (95% CI 90% to 50%) lower among BCC - Seed cutter groups with the worst compliance had the most cases of IKI whereas the groups with the best compliance had only one case				- Workers reported larger water and boli (300 mL electrolyte solution bags) intake after intervention is introduced

Gun, 1995	Sheep Shearers (43)	43 males Age range: 18-59	• Daily average sweat loss was 6.1 Kg • Average dehydration was 2·8% of body mas • Drink was 72% of sweat loss • Average rectal temperature was 37.7°C • Afternoon mean values of rectal temperature exceeded 38·0°C in 4 of the l5 observations made when WBGT > TLV	*Association with decreased rectal temperature:* • Heavier alcohol consumption was associated with 0·16°C lower (p = 0·02) rectal temperature	*Association with increased rectal temperature:* • WBGT (Percentage of variation explained 27%, partial regression Coefficients 0·029) • Vapor pressure (16%, 0.054) • Fat free mass (4%, 0.008) • Alcohol (5%, -0.001) *Association with sweat loss:* • WBGT (61%, 508) • Fat free mass (16%, 116)	• Added radiant heat • Thermal environment • Body fat content	• Drinking water
Hansen et al. 2020	Case study of seasonal migrant workers				• Cultural and language barriers to understanding safety training and instructions • Lack of ability to make autonomous decisions about their health and safety • Piece rate work encourages workers to continue working		
Hansson et al. 2019	Sugarcane workers (525) Field support (low workload): 52 Irrigation workers (moderate):128 Seed cutters (high):188 Cane cutters: (very high):157	394 males 131 females Age range: 18-60	*IKI prevalence:* • 27% in burned sugarcane cutters • 9% in seed cutters • 2% in both field support staff and irrigation workers • eGFR decreased by 4.6 (95% CI 3.2 to 6.0) mL/ min/1.73 m2 during harvest • Of the 427 workers examined at baseline and end-harvest, 32 (7%) had IKI	*Association with lower eGFR and IKI:* • 1-year age increase associated with a 0.96 (95% CI 0.92 to 0.99) IR decrease	*High-moderate workload groups had higher IKI:* • Burned cane cutters (Incidence ratio 9.3, 95% CI 3.2 to 28.3) • Seed cutters (3.3, 95% CI 1.1 to 9.9) *Association between workload and cross harvest GFR:* • Irrigation repair and field support (mean 0; 95% CI -2,1) • Seed cutters (-5, -7, -3) • Cane cutters (-9, -13, -6)	• Sex • Pesticide use • NSAID use • Smoking • Change in 24-hour liquid intake over harvest • Sugary beverage intake per 24 hours at end of harvest • Diabetes • Hypertension	
Hansson et al. 2020	Male Sugarcane cutters (>800)	Age range: >18		*Association with reduced risk of IKI (indicated by ≥0.3 mg/dL or ≥50%*	*Association with increased risk of IKI:*	• Age	

				increase in serum creatinine since baseline): • Morning boli intake (300 mL electrolyte sachets) (Incidence Ratio IR 0.5, 95% CI 0.2–0.9)	• Sugary drink intake greater than 1L (IR 4.4, 95% CI 1.0–19) • NSAID use at least once per week (IR 2.1, 95% CI 1.2–3.8)		
How et al. 2020	Farmworkers (58) Agroecology (no pesticide use): 33 Conventional rice farmers (pesticide users): 25	58 males Age range: 20-60	• Significant difference in blood pressure and blood glucose (p < 0.05) among organic and conventional farmers • Significantly higher HSI among conventional rice farmers (p < 0.001) *Compared to agroecology farmers, conventional farmers have higher odds of:* • Prehypertension (OR: 3.89, CI: 0.904-16.72) • Hypertension (OR: 15.0, CI: 3.153-71.367) • Prediabetes (OR: 13.75, CI: 2.86-66.03) • Diabetes (OR: 5.56, CI: 1.37–22.56)				
Jayasekara et al. 2019	Agricultural workers (257) No CKD or diabetes (DM) group: 216 CKD or DM group: 41 Mean age: 53.73 ± 11.20	Mean age: 46.59;13.02 Mean age: 53.73;11.20	*Workers reporting CKD or DM had:* • Higher heat stress and dehydration symptom index (10.78 vs. 8.03, p < .01) • Higher (Urine albumin-creatinine ratio) ACR > 30 (85.4% vs. 69.4%, p < .05) *Among workers with no CKD or DM group:* • ACR > 30 (high-prevalence CKD region 72.2% vs low prevalence region 55.6%, p < .05) • Higher index (8.4 vs. 6.1, p < .001)	*Association with lower index:* • Higher income (2.1 fewer points on the index, p < .05)	*Association with higher index:* • Female status (3.1 additional points on the index, p=.001)	• Age • Average water intake (l) • BMI • ACR > 30	
Kearney et al. 2016	158 farmworkers	154 males 1 female Age range: > 18	• 72% of farmworkers experienced at least one HRI symptom • 27% of farmworkers had three or more HRI symptoms *HRI symptoms reported:* • 43.6% headache	*Associated with reduced HRI (≥3 Symptoms):* • Wearing long-sleeved shirts (Prevalence ratio (PR) 0.89, 95% CI: 0.32, 2.51), • Limiting time in sun (PR	*Associated with increased HRI (≥3 Symptoms):* • Wearing sunscreen (PR 3.08, 95% CI: 0.87, 10.92) • Wearing a hat (PR 1.39, 95% CI:0.16, 11.87) • Wearing a shirt with collar	• Gloves	*Sun safety behavior used often or always:* • 98.1% wore long pants • 92.9% wore head protection (baseball hat, cap, or visor) • 27.5% wore a wide-brim hat • 85.8% wore a long-sleeved

			• 37.6% heavy sweating • 35.7% muscle cramps or spasms • 17.9% weakness or fatigue • 13.5% dizziness or light headedness • 12.1% rash/bumps • 8.5% nausea or vomiting • 4.3% fainting • 1.4% confusion • 5.0% other symptoms or illness during a hot day at work	0.97 95% CI: 0.46, 2.07) • Wearing sunglasses (PR 0.84, 95% CI:0.33, 2.16) • Wearing long pants (PR 0.35, 95% CI: 0.02, 7.67)	(PR 1.30, 95% CI: 0.46, 3.62) • Protection over face (PR 1.24, 95% CI: 0.59, 2.60)		shirt or blouse • 79.4% wore a shirt with a collar • 56.3% wore gloves • 15.6% wore any protective gear over face • 11.2% wore sunglasses • 9.1% wore sunscreen
Kupferman et al. 2018	Sugarcane workers (326) Cane cutters: 153 Seeders/ seed cutters: 59 Weeders: 35 Pesticide applicators:25 Irrigators:54 First follow-up: 29	Male: 326 Age 18-60	• 34 participants (10.4%) had AKI • 19.0% of cane cutters had AKI compared with 2.9% performing other job tasks (P < 0.001) • Median serum creatinine (SCr) of the 34 AKI workers was 1.64 vs non-AKI workers 0.88 mg/dL • AKI workers had an increase in median SCr to 1.25 and 1.27 after 6 and 12-month follow-up respectively • 10 participants (34.5%) with AKI developed eGFR < 60 and 11 (37.9%) had >30% decrease in eGFR at 12-month follow-up		*Association with higher serum creatinine levels:* • Job as cane-cutter vs other (e^{β} 1.20, 95% CI 1.13-1.27) Addition of pre-harvest Scr level to the model: • Job as cane-cutter vs other 1.16 e^{β}, 95% 1.10-1.22)		
Kwon et al. 2015	Farmers (120)	49 males 71 females Age: 61;11.6					*Farmworkers wear less clothing with higher WBGT:* • Clothing insulation (χ2 = 390.923, df = 344, p = 0.041) and had a correlation with WBGT (τ = −.191) • Number of layers for Upper clothing (χ2 =27.880, df = 16, p = 0.033) and had a correlation (τ = −.257) • Footwear (χ2 = 67.726, df = 40, p =0.004) and had correlation (τ = −.123)

Lam et al. 2013	Latino farmworkers (35)	21 males 14 females Age range: > 18				•	• In addition to water participants also reported drinking energy drinks to increase alertness and productivity • Workers identified removal of clothing layers as an HRI preventive measure • Female participants also reported wearing darker clothing and layered clothes to sweat to lose weight
Laws et al. 2016	Sugarcane workers (284)	251 males 33 females Age range: 18-63	• eGFR was 113 mL/min/1.73 m2 • <5% of workers had albuminuria • Men had NGAL and IL-18 levels that were about one-third those of women at both the pre- and late harvest • Increase in NGAL levels among cane cutters (preharvest 7.6 ug/g, late harvest 19.3) • Decrease in NAG levels in factory workers (preharvest 2.23, late harvest 0.60)	*Consumption of electrolyte packet among cane cutters:* • 23% decrease in mean NGAL (RM, 0.77; 95% CI, 0.61-0.98) • 16% decrease in mean NAG (RM 0.84 95% CI 0.70-1.01) *Consumption of electrolyte packet among seed cutters:* • 31% decrease in mean IL-18 (RM 0.69 95% CI, 0.46-1.04) • 33% decrease in mean NAG (RM 0.67 95% CI 0.44-1.02)	*Association with higher NGAL among all workers:* • Cane cutters (RM, 2.57; 95% CI, 1.54-4.27) • Irrigators (RM, 2.07; 95% CI, 1.24-3.47) • Field workers (RM, 1.49; 95% CI, 1.06-2.09) compared to non-field workers *Association with higher IL-18 among all workers:* • Field workers (RM 1.61; 95% CI, 1.12-2.31) compared to non-field workers • Cane cutters (RM, 1.89 95% CI 1.08-3.29) • Seeders (RM, 2.11; 95% CI 1.14-3.92)	• Agrichemical applicators did not have increases in kidney injury biomarkers compared to other field workers • No overall association between self-reported daily intake of water or electrolyte solution and NGAL, IL-18, or NAG	
Laws et al., 2015	Sugarcane workers (284) Cane cutters (51) Seeders (36) Seed cutters (19) Agrochemical applicators (29) Irrigators (49) Drivers (41) Factory workers (59)	Male: 251 Female: 33 Age: 18-63	*Cross harvest eGFR (ml/min/1.73):* • Decline in cross harvest eGFR among field workers (-6.9 ml/min) compared to non-field workers • Decline in cross harvest eGFR among seed cutters (-8.6), irrigators (-7.4), cane cutters (-5.0) compared to factory workers • Fewer than 5% of workers had albumin-to-creatinine ratio (ACR) >30 mg/g	*Late harvest eGFR:* • Consumption of electrolyte packet among cane cutters (6.1 ml/min/1.73 m2; 95% CI: 20.06, 12.2) *Cross harvest eGFR:* • Consumption of electrolyte packet among cane cutters (7.0 ml/min/1.73 m2; 95% CI: 1.9, 12.1)	*Decline in pre-harvest eGFR:* • Number of years employed at the company (0.3 ml/min/1.73 m2 95% CI: 20.6, 20.04)		

Lumingu et al. 2009	Young farmworkers (18)	Age range: 12-35	• All the final sublingual temperatures were under 38°C • Only 4 cases showed sweating that reached 5% of body weight • Mean heart rate was below threshold when WBGT was <28 °C and exceeded threshold when WBGT was >43 °C				
Lundgren et al. 2014	Agricultural workers (4)	1 Male 3 Female Age range: not specified	• Predicted time to reach a core temperature of 38°C was 240 minute in agriculture for females • Average metabolic rate was 190 while doing the following work tasks: Preparation of land for cultivation, sowing, watering, weeding, pest control, fertilization, crop maintenance and harvesting, bending, walking speed 2.45.5 km/h				
Luque et al. 2019	Hispanic farmworkers (29)	15 males 14 females Age range: >19			• Farmworkers working under contractual arrangements were less likely to take sufficient breaks and worked for long hours • Focus groups agreed that inexperienced or new workers in the fields are at higher risk for HRIs since they had not had time to acclimatize to the weather conditions	•	• Used a variety of PPE including protective clothing, such as caps, gloves, long sleeve shirts and pants • Brought their own water since they did not like the odor or taste of the tap water at the worksite • Drank electrolyte solutions or Gatorade • Rested in the shade • Used wet cool cloths
Luque et al. 2020	Hispanic farmworkers (101)	61 males 40 females Age range: 19-66	• 19% of participants reported HRI symptoms *HRI symptoms reported:* • 2% dizziness • 5% skin rash • 1% muscle cramps • 4% light-headedness • 14% headache • 12% heavy sweating • 3% extreme weakness • 3% nausea				*Type of beverages ingested:* • 89% water • 64% Gatorade • 19% energy drinks • 27% fruit juice • 12% coffee or tea • 26% Soda • 2% Beer • 58% began with a few hours of work before starting to

			• 1% dry skin				work a full day • 77% used shade under trees • 20% used shade structures • 13% used fans • 10% used rest stations • 11% wore wet hats or bandannas • 66% drank more water • 21% changed work hours • 2% used a vehicle with air conditioning • 23% changed work activities • 23% took rest breaks in the shade *Clothing always or usually worn:* • 23% light-colored short-sleeved shirt • 3% dark-colored short-sleeved shirt • 79% light-colored long-sleeved shirt • 5% dark-colored long-sleeved shirt • 5% shorts • 83% pants • 24% jacket *Head protection always or usually worn:* • 85% baseball cap • 22% wide-brimmed hat • 3% other hat • 60% bandanna • 8% hood from sweatshirt
Mac et al. 2016	Fernery workers (40)	13 males 30 females Age range: 18-54	• Body core temperature exceeded 38.0°C on 57% of the 86 workdays examined • 30 out of 40 participants had core body temperature that exceeded 38.0°C at least one workday		*Associated with an increase in the odds of the body temperature reaching or exceeding 38.0°C:* • Females (OR 5.38, 95% CI 1.58,18.30) compared to males • Workday energy expenditure (OR 1.12, 95% CI 1.03, 1.21)	• Age • BMI • Body mass • Body surface area • Years working in ferneries • Average WBGT • Workday duration	

Mac et al. 2019	Fernery workers (40)	13 males 30 females Age range: 18-54	• Body core temperature exceeded 38.0°C on 57% of the 86 workdays examined • 30 out of 40 participants had core body temperature that exceeded 38.0°C at least one workday		*Associated with an increase in the odds of the body temperature reaching or exceeding 38.0°C (bivariate models):* • Total workday energy expenditure (kcal) (OR: 1.08; 95% CI 1.01, 1.15) *Associated with an increase in the odds of the body temperature reaching or exceeding 38.0°C (multivariate models):* • Females (OR 5.38, 95% CI 1.58,18.30) compared to males • Workday energy expenditure (OR 1.12, 95% CI 1.03, 1.21)	*Bivariate model:* • Female sex • Age • BMI • Body mass • Body surface area • Years working in ferneries • Average WBGT • Workday duration *Multivariate model:* • Age • BMI • Body mass • Body surface area • Years working in ferneries • Average WBGT • Workday duration	
Miller, 1982	Tractor driver		•				
Mirabelli et al. (2010)	Latino farmworkers (281) H-2A workers:177 Non-H2-A workers: 104	Gender: Not specified Age range: 18-65	• 40 % of participants working in extreme heat reported at least one HRI symptom • 31% of H-2A workers reported HRI compared to 56% of non-H2A workers	*Associated with lower HRI:* • Change work hours and activities among H-2A workers (PR = 0.44, 95% CI=0.22, 0.89)	*Associated with higher HRI:* • Change work hours and activities among non–H-2A workers (PR=1.11, 95% CI=0.79, 1.55)	Among both H-2A and non-H-2A workers: • Drink more water • Rest in shaded areas • Go to air-conditioned places during or after work	• Change work hours (35% H2-A workers vs 40% non-H2-A workers) • Change work activities (30% vs 41%) • Change hours and activities (29% vs 39%) • Drink more water (97% vs 99%) • Take rest breaks in shaded areas (73% vs 93%) • Go to air-conditioned places during breaks or after work (<1% vs 5%) • Change hours or activities (35% vs 43%)
Mitchell et al. 2017	Farmworkers (588)	389 males 198 females	• 8.3% experienced a body temperature of ≥ 38.5°C • 11.8% experienced dehydration				

		Age range: 18 – 82	(loss of more than 1.5% of body weight) • 18% exceeded threshold for heart rate for 5 minutes or more				
Mix et al. 2018	Agricultural workers (192)	76 males 116 females Mean age: 38.0;8.2	• 33% of participants had AKI on at least one workday • 53% of workers were dehydrated (USG 1.020) pre-shift and 81% post-shift • 3% had USG > 1.030) preshift, indicating a clinically dehydrated state which increased to 13%, post-shift • 31% of participants had at least 1 day with a creatinine level above sex specific limits or an increase of 0.3 mg/dL during the day		*Association with higher AKI:* • Heat index (OR=1.47, 95% CI: 1.14 to 1.90)	• Age • Gender • Nationality • Education • BMI • Hypertension • Blood pressure • Diabetes • Work type • Years worked in agriculture • Hours worked per day • Drinks more sports drinks at work • Drinks more energy drinks at work • Drinks more juice at work • Drinks more soda at work	*Type of beverages consumed:* • 98% water • 69% sports drinks • 50% soda • 39% juice • 16% energy drinks • 9% coffee • 2% alcohol
Moyce et al. 2016	Agricultural workers (295)	Male: 190 Female:105	• 35 participants (11.8%) after a single work shift had cumulative incidence of AKI (stage 1 or stage 2)		*Association with AKI:* • Piece-rate work (AOR 4.52, 95% CI 1.61 to 12.70)	• Sex • Age • BMI • Diabetes status • Blood pressure • Level of education • Years in agricultural work • Farm task	
Moyce et al. 2017	Agricultural workers (283)	182 males 101 females Age range: > 18	• 12.4% of participants had AKI • AKI was present in 12.1% among men and 12.9% among females • 11.7% experienced heat strain among those who had AKI • 64.8% of men and 52.5% of women lost <1.5% body mass	*Association with lower AKI:* • Obesity (OR 0.29, 95% CI 0.10 to 0.82) • Overweight men (OR 0.29, 95% CI 0.08 to 0.97) • Obese men (OR 0.25, 95% CI 0.07 to 0.94)	*Association with higher AKI:* • Heat strain among men (OR 1.31, 95% CI 1.01 to 1.70) • Piece rate work (OR 4.24, 95% CI 1.56 to 11.52) • Piece rate work among females (OR 102.81, 95% CI 7.32 to 1443.20) • Years in agricultural work among females (OR 1.12, 95% CI 1.01 to 1.24)	• Volume depletion (% body mass lost) • Age • Gender • BMI • Diabetes • Blood pressure • History of kidney disease • Farm task	
Moyce et al. 2019	Agricultural workers (471)	298 males 173 females Age range: >18	• 14.9% of participants had AKI (indicated by increase in serum creatinine of ≥0.3 mg/dL or ≥1.5 times the preshift creatinine) after a single day of		*Association with higher AKI:* • Workload (1.92; 95% CI 1.05-3.51) • Piece-rate work (3.02; 95% CI, 1.44-6.34)	• Age • Gender • Diabetes • BMI • Blood pressure	

			agricultural work • 36% had elevations of core body temperature ≥1°C			• History of kidney disease • Max daily WBGT • Years in agricultural work • Farm task	
Moyce et al. 2020	Agricultural workers (445)	283 males 162 females Age range: >18	*Compared to females, more males:* • Experienced AKI (15.9% vs 12.9%) • Had a change in core body temperature that was greater than or equal to 1°C (131 vs 39) • Lost at least 1.5% of their body mass (dehydration indicator) (43 vs 4)		*Association with higher odds of AKI:* • Total volume consumed (AOR 1.47, 95% CI= 1,.9–1.99) • Maximum workload (1.01, 95% CI 1.01–1.02). • Picking (AOR 2.51, 95% CI 1.39–4.54) • Male with diabetes (AOR 6.76, 95% CI 1.49–30.77) • Male picking (4.12, 95% CI= 1.87–9.08)	• Age • BMI • Diabetes • Blood pressure • Payment method • Years in agricultural work • Maximum WBGT • Percentage body mass lost • Sugary drinks	• Men drink 2.9L of water compared to 1.9L for women
Mutic et al. 2018	Farmworkers (198)	78 males 120 females Age range: 19-54	• 84% of participants reported experiencing at least one symptom • 40% reported three or more symptoms *HRI symptoms reported:* • 66% heavy sweating • 58% headache • 32% dizziness • 30% muscle cramps • 24% nausea/vomiting • 10% fainting • 9% confusion *Symptoms fell into three latent classes:* • Mild (heavy sweating; class probability = 54%) • Moderate (heavy sweating, headache, nausea-vomiting and dizziness; 24%) • Severe (excessive sweating, headache, dizziness, nausea-vomiting, sudden muscle cramps and fainting; 22%)		*Association with higher odds of HRI:* • Female (OR = 2.86, 95% CI 1.18–6.89)	• Age • Nationality • BMI • Reported hypertension or diabetes • Education • Alcohol • Smoking • Work type • Days worked per week • Hours worked per day	
Nanayakkara et al. 2020	Paddy farmers (25)	Male: 25 Age: 23-64	• 12% and 4% of farmers in the morning had dehydration in non-farming and farming seasons respectively according to urine osmolarity • 24% and 40% of farmers in the			•	

			evening showed dehydration in the non-farming and farming seasons respectively urine osmolarity • 88% and 72% of farmers in the morning had dehydration in non-farming and farming seasons respectively according to plasma osmolarity • 2% and 40% of farmers in the evening had dehydration in non-farming and farming seasons respectively according to plasma osmolarity				
Nayha et al. 2017	Working population (4007) Agriculture: 136 (3.4%)	1860 males 2147 females Age range: 25-74			*Association with higher odds of cardiorespiratory symptoms:* • Working in agriculture (OR 2.27; 1.14–4.46) compared with working in industry		
Pogacar et al. 2017	Farmers (230)	143 males 87 females Age not specified	*HRI symptoms reported:* • Headache (women 64% vs men 46% %) • Exhaustion (69% vs 56%) • Nausea or vomiting (19% vs 8 %) • Fainting (11% vs 6%) • Prickly heat (8 % vs 13 %) • Muscle cramps (2 % vs 6 %) • Heat cramps (0 % vs 0.7 %)			•	• 79% drank more water • 44% change to lighter/less clothing • 54% took breaks in cooler areas • 34% took more breaks • 73% adjusted work schedule
Quandt et al. 2008	Migrant Latino farmworkers (304)	300 males 4 females Age range: 18-70	• Effects on skin related quality of life (QOL) measured using the Dermatology Life Quality Index (DLQI) were reported in 38.7% of observation		*Engaging in specific work tasks was associated with elevated DLQI* • Planting (OR: 4.16, CI 2.53–6.84) • Cultivating (OR: 2.39, CI 1.17–4.86) • Tobacco topping (OR: CI 2.44, 1.44-4.13) • Harvesting (OR: 2.20, CI 1.46–3.31) *Working in higher temperatures was associated with elevated DLQI* • Working in temperatures > 23.9°C and ≤26.7°C (OR:	• Self-rated health • Barning tobacco	

					2.29, CI 1.21–4.36) • Working in temperatures >26.7°C (OR: 3.33, CI 1.37–8.12)		
Raines et al. 2014	People with occupational history in agriculture (151 out of a total sample 424)	166 males 258 females Age range: 15–69	• 77% of agricultural workers had reduced eGFR		*Association with reduced GFR among current or former agricultural workers (univariate analysis):* • Male sex (p <0.001) • Lifetime days cutting or harvesting crops (p=0.004) • Lifetime days cutting or harvesting sugarcane (p=0.005) • Lifetime hours cutting or harvesting sugarcane in the dry season (p=0.001) *Association with reduced GFR among agricultural workers (multivariate analysis):* • Any lifetime history cutting sugarcane during the dry season (OR 4.07, 95% CI 1.32–12.58) • Pesticide inhalation (3.14, 95% CI 1.12–8.78) • Sugarcane chewing (OR 3.12, 95% CI 1.21–8.04) • Daily bolis at work (OR 1.48, 95% CI 1.02–2.14)	*Univariate analysis:* • Hypertension • Age • Diabetes • Nephrotoxic medications • Smoking • Fructose intake • Sugary beverage intake • Daily bolis at work • Water consumption • Alcohol consumption • Lifetime days seeding • Lifetime days watering • Lifetime days mixing pesticides • Lifetime days applying pesticides • Lifetime days working in fields with pesticide use • Inhaled pesticides • Cane chewing • Worked near burning sugarcane *Multivariate analysis:* • Age • Male sex • Systolic blood pressure • Alcohol consumption • >365 lifetime days harvesting any crop	
Rajewski et al. 2008	Agricultural worker (1)	1 male Age: 56	• Male agricultural worker working in the field for about 8 hrs without breaks, fluid intake and no PPE died of heat stroke. *Examination of patient revealed:* • Red skin • Body temperature: 41.2 ° C • Heart rate: 160 / min • Blood pressure: 130/80 mm Hg				

Raju et al. 2014	CKD Patients (198) Renal insufficiency (656)	Mean age: 46.64 (11.63)	• 24% of CKD patients were agricultural workers • Reduced GFR with increasing age *CKD patients compared to controls:* • Significant decrease (p<0.001) in creatinine clearance • Increase in blood urea (98.77 vs 28.55 mg/dl) • Increase in serum creatinine (4.6 vs 0.9 mg/dl)				
Ricco et al. 2017	Pesticide applicators (131)	107 males 24 females Age range: > 18	• 41.2% of participants reported 3 or more symptoms • 93.1% had at least one symptom *HRI symptoms reported:* • 79.6% profuse sweating • 29.0% asthenia • 8.4% confusion, feeling disoriented • 8.4% nausea and/or vomiting • 13.8% high heart rate • 37.4% headache • 15.3% dizziness • 23.7% fainting, rapid breathing • 8.4% blurred vision • 7.7% sudden loss of postural tone without even temporary loss of consciousness • 3.1% sudden loss of postural tone with even temporary loss of consciousness		*Associated with higher HRI (univariate analysis):* • Female sex (OR 3.632, 95%CI 1.392–9.135) • Being a professional farmer (OR 2.438, 95%CI 1.168–5.058) • Drink at least one glass of water every working shift (OR 0.059, 95%CI 0.016–0.211 • Drink at least five glasses of water every working shift (OR 2.753, 95%CI 1.327–5.709) • Alcohol consumption (OR 3.339, 95%CI 1.513–7.367) • Take rest breaks in shady, not air-conditioned areas (OR 4.174, 95%CI 1.473–11.828) • Perform pesticide application (OR 2.705, 95%CI 1.296–5.646) • Manual hoeing/weeding (OR 2.975, 95%CI 1.185–42.035) *Associated with higher HRI (multivariate analysis):* • Manual hoeing/ weeding (OR:8.847 95% CI 1.882–41.579) • Pesticide application (OR 8.847, 95% CI 1.882–41.579)	*Univariate analysis:* • Age • Seniority • Migration background • Education • ≥ 3 days a week • Seeding • Harvesting/Picking • Machine operation • Irrigation • Hoeing/weeding, mechanized • Pruning • Previous training about high temperatures • Drink more water • Take rest breaks in cooler, air-conditioned areas • Increased number and/or frequency of rest breaks • Anticipate/Delay hours of work activities *Multivariate analysis:* • Age • Female sex • Seniority • Migration background • Education • Being a professional farmer • ≥ 3 days a week • Seeding • Harvesting/Picking • Machine operation • Irrigation • Hoeing/weeding, mechanized	• 38.9% received HRI training during the previous 5 years • 90.8% drank water • 78.6% took rest breaks in shady, not air conditioned areas • 23.7% took rest breaks in cooler, air-conditioner areas • 66.4% increased number and/or frequency of rest breaks • 77.1% anticipated/delayed hours of work activities *Sun protection behavior:* • 72.5% used head protection • 61.1% used sunscreen • 93.1% used long sleeves shirts • 89.3% used specific clothes • 84.7% used sunglasses

					• Rests in shady, not air-conditioned areas (OR:5.491 95% CI 1.372–21.971)	• Pruning • Previous training about high temperatures • Drink at least one glass of water every working shift • Drink at least five glasses of water every working shift • Alcohol consumption • Drink more water • Take rest breaks in cooler, air-conditioned areas • Increased number and/or frequency of rest breaks • Anticipate/Delay hours of work activities	
Sadiq et al. 2019	Maize farmers (396)	251 males 145 females Age range: 15-60	*HRI symptoms reported everyday:* • 93.2% heavy sweating • 48.5% tiredness • 34.1% dizziness • 40.4% headache • 29.8% heat rash/pricking • 25.3% rapid pulse • 33.8% nausea/ vomiting • 19.7% elevated body temperature • 9.8% muscle cramp • 11.1% fainting				
Sahu et al. 2013	Rice harvesters (124)	124 males Age range:18-45	*Physiological symptoms:* • Heart rate recovery is fast in low temperature and slow in high temperature after work period indicating cardiovascular strain • Higher peak heart rate, sum of recovery heart beats and cardiac cost variables with increasing temperature *HRI symptoms reported:* • 37% discomfort • 50% heat exhaustion • 72% pain in different body parts				

Sen & Nag 2019	Farmworkers (1144)	Males:632 Females:512 Age range: 30-50	• 1/3 complained of moderate to high intensity of back pain, muscle pain and heavy sweating. • Females had more marked heat-related symptoms compared to males • 11% and 6% of female and male farmers, respectively had symptoms of tachycardia, dizziness, headache, and blurring of vision				
Smith et al. 2020	Migrant farmworkers (60)	49 males 11 females Age range: 18-51	• 68% of participants had one or more HRI symptoms • 12% had 3 or more symptoms *HRI symptoms reported:* • 50% heavy sweating • 25% cramps • 22% headache • 10% dizziness • 3% nausea			•	• 43.76% drank water • Mean liquid consumption was 72.95 oz per day, which is much less than the recommended 32 oz per hour
Sorensen et al. 2019	Sugarcane workers (105)	Age range: >18	• Average decline in cross-shift eGFR was 21.8% • 31% to 51% of workers had post-shift serum osmolality less than 280mmol/kg • Average albumin to creatinine ratio (ACR) ranged from 9 to 22mg/mg pre-shift to 18 to 30mg/mg post-shift and only increased significantly across the work shift in March		*Association with reduced cross-shift GFR (univariate analysis):* • Age (estimate -0.3, p<0.01) • Harvests worked (-0.5, p<0.01) • HbA1c (-7.8, p=0.02) • BUN (-0.9, p <0.01) • Serum osmolality (-0.3, p= 0.01) • Pre-shift urine specific gravity (-2.6, p<0.01) • Post-shift urine specific gravity (-3.3, p<0.01) *Association with reduced cross-shift GFR among post-shift biomarkers:* • Average WBGT (-1.6231, p=0.03) • Increasing age (-0.4177, p<0.01) *Association with reduced cross-shift GFR among pre-shift biomarkers:* • Diabetes indicator HbA1c (-7.35, p=0.04)	*Univariate analysis:* • Highland • BMI • Hypertension • NSAID • Smoking • Preshift GFR • Average WBGT • Maximum WBGT • Cane harvested on study day/previous day • Urine biomarkers (*Multivariate analysis among pre-shift biomarkers:* • Hypertension • Pre-shift GFR • Pre-shift specific gravity *Multivariate analysis among post-shift biomarkers:* • HbA1c • Osmolality	

					• Increasing Age (-0.26, p= 0.04)		
Spector et al. 2015	Crop workers (97)	51 male 46 female Age range: > 18	• 1/3 participants reported HRI symptoms which include dizziness/light-headedness and heavy sweating	*Associated with lower HRI:* • Age (OR = 0.92; 95% CI=0.87–0.98)	*Associated with higher HRI:* • Piece rate (OR = 6.20; 95% CI = 1.11–34.54) • Walking for more than 3 minutes to get to the toilet (OR = 4.86; 95% CI = 1.18–20.06)	• Male • BMI • Diabetes mellitus and/or antihypertensive medication use • Good/fair general health • No HRI Training • No light-colored shirt • Drank caffeine • Drank less than every 30 minutes • Heat index • No Extra breaks • Hard/very hard work	• 57% drank water every 30 minutes in the past week • More than 75% wore a light-colored shirt
Spector et al. 2018	Harvesters (46)	39 males 7 females Mean age: 39.1;14.1	• Mean pre-shift urine specific gravity was 1.025 which is considered minimal dehydration • 24% exhibited excessive sleepiness *Significant decrease across shift* • PVT mean reaction time (t [43] = 3.4, p=0.002) • Number of lapses (t[43]= 2.3, p=0.029) • Mean path length for both eyes open (t[45]= 3.8, p < 0.001) and eyes closed (t[45]= 3.1, p= 0.004)			• Heat exposure was not associated with impaired vigilance or balance	
Stoecklin-Maroi et al. 2013	Farmworkers (467)	263 males 211 females Age range: 18-55				•	• 91% received HRI training (87.5% male vs 96.7% female, p=0.0003) • 29.7% of workers bring their own water to work (44.9% vs 10.5%) • Workers drank 10.7 times/ day employer provided beverages (11.1 vs 10.3)
Stoklosa et al. 2020	Migrant Agricultural Worker (1)	Male Age: 25	• Elevated creatinine level (3.9 mg/dL) • Serum potassium level of 5.2 mmol/L • Mildly elevated total creatine kinase (219 U/L) • The diagnoses were heat exhaustion, severe dehydration,				

			and renal insufficiency *Symptoms included:* • Lightheadedness • Blurred vision • Fasciculation • Nausea • Vomiting • Abdominal cramping				
Trevisan et al. 2019	Sugarcane workers (32)	32 males Mean age: 47.4	• Rhinitis symptoms were (53.4%) compared to the non-harvesting period (26.7%, p = 0.039) and 6 months after the beginning of harvesting (20%, p = 0.0006) • Significant increase in IL-6 (inflammatory marker) after 3 months of harvesting compared to non-harvesting period (p = 0.012)				
Vega-Arroyo et al. 2018	Farmworkers (259)	168 males 91 females Age range: >18	• 45% had a body temperature greater or equal to 38°C • 15% percent of workers were hypohydrated based on loss of 1.5% of body fat		*Association with higher CBT:* • Work rate (β = .006, 95% CI [0.004, 0.009]) • WBGT (β = .03, 95% CI [0.017, 0.05])	• Gender • Age • Clothing ensemble insulation heat gain • Hydration status (weight loss) • Head gear insulation heat gain	
Wagoner et al. 2020	Farmworkers (28)	Age range: >18	• Mean S.G.s of post-shift March, June and August were 1.25, 1.025, and 1.02, respectively • 40% of June post-shift samples were clinically dehydrated and 57% were mildly dehydrated • The percentage of time workers' core body temperatures were over the 38 °C was minimal • Body temperatures between 37 °C and 38 °C made up over 80% of the workdays				

Wegman et al. 2018	Sugarcane workers (80) Intervention group (Inland): 40 Nonintervention group (Coastland): 40	Age range: 18-63 Intervention group: 39 males 1 female Nonintervention group: 28 males 12 females	*Decrease in cross harvest GFR:* • Intervention group −3.4 ml/min/1.73m2 (95% CI, −5.5 to −1.3) • Nonintervention group -5.3 (95% CI -7.9 to -2.7) • Compared to inland group, more workers had eGFR <60 in the Coastland group at baseline (5 versus 2), and at the end of the harvest (7 versus 2) • Comparing group differences in eGFR (ie, changes from baseline to end of harvest) showed a smaller decrease in the inland group compared with the coastland group that was close to significant; 2.8 percentage points (95% CI -1.1–6.5)				
Wesseling et al. (2016a)	Sugarcane workers (29)	29 males Age range: 17–38	*Cross harvest changes in pre-shift biomarkers:* • 10% decrease in GFR • 16% increase in creatinine • 40% increase in serum urea N • 4 times increase in NGAL				
Wesseling et al. (2016b)	Three working population groups (194) Construction workers: 56 Sugarcane cutters: 86 Small-scale farmers: 52	194 male Age range: 17–39	• Reduced eGFR (<80 mL/min/1.73 m2) (sugarcane cutters 16% vs farmers 2%) • Proteinuria >30 mg/dL (14.7% vs 6.1%) • SCr >1.2 mg/dL (17.4% vs 5.8%) • BUN >20 mg/dL (15.1% vs 1.9%) • Leucocyturia (22.1% vs 1.9%)	*Association with improved GFR among sugarcane cutters:* • Electrolyte solution (β 8.1, 95% CI −1.2 to 17.5, p=0.09)	*Association with reduced GFR among all workers and restricted to sugarcane cutters (univariate analysis):* • Work as a sugarcane cutter (p=0.007) • High intake of water (p=0.007) • Low intake of sugary beverages (p=0.007) • Increasing age (p=0.002) • Low haemoglobin (p=0.001) • High tobacco consumption (p=0.02) *Association with reduced GFR among sugarcane workers (univariate analysis):* • Cumulative time in job *Association with reduced*	*Association with reduced GFR among all workers and restricted to sugarcane cutters (univariate analysis):* • Work day (hours), median • Hours cutting cane, median • Total break time (min), median • Breaks ≤2/d, % (# cases) • No shade during breaks, % • High speed perception, % • Production (tons/d), median • Incentives to cut more, % • History of pesticide use • Total fluid intake (L), median • Low total fluid intake • High total fluid intake • Water (L), median • Low water intake • Sugary beverage, median • High sugary drink intake	

					GFR among all workers: • Age (β −1.3, 95% CI −1.8 to −0.8; p<0.001) • Serum uric acid (mg/dL) (β -10.4, 95% CI −12.2 to −8.5) *Association with reduced GFR among sugarcane cutters:* • Age (β −1.9, 95% CI −2.7 to −1.1, p<0.001) • Serum uric acid (mg/dL) (β -11.3, 95% CI -14 to -8.6)	• Intake electrolyte solution • Hypertension • BMI • Alcohol • Nephrotoxic medication *Association with reduced GFR among all workers and restricted to sugarcane cutters (multivariate analysis):* • Sugarcane cutter ever • Cumulative time in job • Work day (hours), median • Hours cutting cane, median • Total break time (min), median • Breaks ≤2/d, % (# cases) • No shade during breaks, % • High speed perception, % • Production (tons/d), median (10%; 90%) • Incentives to cut more, % • History of pesticide use • Total fluid intake (L), median • Low total fluid intake • High total fluid intake • Water (L), median • Low water intake • High water intake • Sugary beverage, median • Low sugary drink intake • High sugary drink intake • Hypertension • BMI • Tobacco • Alcohol • Nephrotoxic medication	
Wilmsen et al. 2019	Latino forestry workers (23)	Mean age: 30	• One worker had heat illness and didn’t achieve full recovery				

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