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Assessing Heat-Related Morbidity among Migrant and Seasonal Farmworkers

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Kai Zhang, PhD, Principal Investigator
Phone: 713-500-9249
Email: Kai.Zhang@uth.tmc.edu

Co-Investigator:
Sharon Cooper, PhD

The University of Texas Health Science Center at Houston (UTHealth)
PO Box 20036
Houston, Texas 77225-0036

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Abstract

Background: Migrant and seasonal farmworkers are highly vulnerable to ambient heat mainly because nearly 85% of U.S. farmworkers labor outdoors. The rate of heat-related deaths in the agriculture/forestry/fishing and hunting industry (0.3 deaths per 100,000 full-time workers) was the highest among all industry sectors, with this sector contributing 16% of all heat-related deaths in 1992-2006. Low social-economic status (SES) such as poverty, limited health insurance coverage and unauthorized work status might exacerbate their vulnerability in addition to their physical exposures to heat. However, to our knowledge, no studies have quantified the associations between extreme heat and heat-related illness among migrant and seasonal farmworkers in the U.S. using medical records and evaluated potential vulnerability indicators.

Objectives: The project involved two major activities: 1) to estimate effects of heat on mean daily counts of clinic visits among migrant and seasonal farmworkers by taking advantage of a unique electronic medical records database in the USA; and 2) to evaluate potential determinants of vulnerability.

Methods: We compiled a daily weather and electronic medical dataset based on data from five health centers located in in five states (California, Colorado, Michigan, New York and Washington) for the summer of 2013. We excluded data from Washington due to few migrant farmworkers included in the data. We used Poisson regression to estimate the associations between heat and daily all-cause clinic visits among migrant or seasonal farmworkers or other clinic patients. We defined heat effects as the percentage difference in average daily counts of clinic visits, comparing 90–50th percentiles of daily mean apparent temperature, a composite index accounting for both temperature and humidity.

Results: We observed positive associations between heat and clinic visits among migrant and seasonal farmworkers across four centers, point estimates of heat effects are positive up to 53.5% for migrant farmworkers in two centers (Colorado and Michigan) and positive up to 16.3% for seasonal farmworkers in two centers (Colorado and Michigan). We found statistically significant effects among male migrant farmworkers compared to female migrant farmworkers in two centers (Colorado and Michigan).

Conclusions: Our study appears to be the first multi-city study to examine heat effects among migrant and seasonal farmworkers using electronic medical records. This research suggests possible meaningful impact of heat on migrant farmworkers particularly on male migrant farmworkers and provides justifications for further studies.

Section 1

Significant or Key Findings

Although we did not observe many statistically significant associations between heat and clinic visits among migrant and seasonal farmworkers across four centers. However, we observed positive estimates of heat effects up to 53.5% for migrant farmworkers in two centers (Colorado and Michigan); and positive estimates up to 19.3% for seasonal farmworkers in two centers (Colorado and Michigan). Key findings were also observed for stronger and statistically significant effects among male migrant farmworkers compared to female migrant farmworkers. Heterogeneous effects are also observed among four centers.

Translation of Findings:

This study provides evidence on that heat is a risk factor for migrant and seasonal farmworkers even with mild summers and heavy-duty work can exacerbate the risk caused by ambient heat. Migrant farmworkers are more vulnerable than seasonal farmworkers and general populations. This study suggests there is an urgent need for employers to add heat in regular worker training, implement NIOSH's water, shade and rest recommendation for heat illness, and for decision makers to add heat into regulations (e.g., required rests/breaks under hot weather). Both can reduce health risk due to heat.

Research Outcomes/Impact

This study provides evidence on that heat might be a potential public health threat among farmworkers in four states with varying climate and weather patterns. It also demonstrates the feasibility of using electronic medical records (EMR) in farmworkers related research besides heat related health effects particularly on migrant and seasonal farmworkers who are challenging to access. This research provides justification for future studies with large sample size over a longer period to explore the etiological mechanisms associated with heat among migrant and seasonal farmworkers and provides insights to researchers, public health officials, and practitioners to inform interventions to prevent heat-related health effects among farmworkers and other outdoor workers.

Section 2

Specific Aims

Extreme heat has been linked with increased risk of a variety of mortality and morbidity outcomes (Kovats and Hajat 2007). Farmworkers are among the most likely workers in the U.S. to suffer from heat stress because nearly 85% of U.S. farmworkers labor outdoors (Calvert et al. 2012). The rate of heat-related deaths in the agriculture/forestry/fishing and hunting industry (0.3 deaths per 100,000 full-time workers) was the highest among all industry sectors, with this sector contributing 16% of all heat-related deaths in 1992-2006 (Jackson and Rosenberg 2010). Projected increases in the frequency and intensity of heat waves (Meehl and Tebaldi 2004), together with an aging workforce are expected to worsen vulnerabilities of farmworkers to heat stress in a changing climate (Carroll et al. 2011). Migrant and seasonal farmworkers are likely more vulnerable to heat than other workers because poverty, limited health insurance coverage and unauthorized work status might exacerbate their vulnerability in addition to their physical exposures to heat. However, to our knowledge, no studies have quantified the associations between extreme heat and heat-related illness among migrant and seasonal farmworkers in the U.S. using medical records and evaluated potential vulnerability indicators.

Our long-term goal is to reduce heat-related health effects for migrant and seasonal farmworkers in the U.S. *We are uniquely poised to achieve this goal because we can leverage resources from the electronic medical records database (Community Based Research Network [CBRN]) among migrant and seasonal farmworkers in the U.S*. Funded by the National Institute of Environmental Health Sciences, CBRN built the infrastructure to securely import and merge electronic health records data from five Community and Migrant Health Centers (C/MHCs) located in five states (California, Colorado, Michigan, New York and Washington) to build the first EMR database among migrant and seasonal farmworkers in the U.S.(Cooper et al. 2014). We propose to quantify heat-related health effects and evaluate vulnerability factors among farmworkers using the CBRN data. Specifically, we will:

Aim 1: To determine whether excess cases of all-cause and cause-specific (cardiovascular, respiratory, diabetes, renal and heat-related causes) illness occur among migrant and seasonal farmworkers included in the CBRN on hot days.

Hypothesis 1: All-cause and cause-specific clinical visits among migrant and seasonal farmworkers will be higher on hot days compared to average temperature days.

Aim 2: To evaluate potential determinants of vulnerability by assessing whether heat-morbidity associations differ, according to farmworker status (migrant, seasonal, and non-farmworker), individual characteristics (gender, age, race/ethnicity and smoking status), and geographic areas (health centers).

Hypothesis 2: Associations will be stronger among migrant farmworkers; men; elderly; minority; smokers; and areas associated with hot summers.

This project addresses a significant, but rarely studied extreme heat-related public health problem in a vulnerable population, and has implications for many other outdoor workers. This highly time- and cost-effective study will be the first to investigate heat-related illness on migrant and seasonal farmworkers using medical records in the U.S. The results of this study can help improve diagnosis and treatment by health care providers, support evidence-based policy development in the area of adverse heat-related health effects, develop and evaluate targeted interventions, and improve surveillance of occupational injuries and illnesses that is greatly needed in the agriculture sector. This proposed research will be conducted by an experienced team that has complementary expertise. The work is consistent with priorities identified by the National Occupational Research Agenda (NORA) of the National Institute for Occupational Safety and Health (NIOSH) related to the Agriculture, Forestry, and Fishing NORA sector: “Intermediate Goal 5.4 - Reduce illness and disease due to environmental and infectious exposures in agriculture such as ultraviolet radiation, heat and cold, noise and zoonoses.”(NIOSH 2008). This research also contributes to the NIOSH research-to-practice initiative by disseminating the research results to key stakeholders.

Background and Significance

Extreme heat poses a substantial risk to public health in the U.S. Epidemiological studies have linked heat and heat waves with increased risk of mortality, heat cramps, heat syncope, heat stroke, heat exhaustion, cardiovascular and respiratory diseases (Kovats and Hajat 2007). In the U.S., extreme heat was the leading cause of weather-related deaths and was the primary cause of 3,572 deaths from 1986-2011 (National Weather Service, 2013). Moreover, these numbers underestimated heat-related health effects because extreme heat can affect people with pre-existing diseases (e.g., respiratory diseases, cardiovascular diseases, diabetes and renal diseases), resulting in attribution of primary diagnosis of death to these diseases rather than to heat (Kovats and Hajat 2007).

Extreme heat does not affect everyone equally, and farmworkers are among the most likely to suffer from heat stress. Those vulnerable to heat include outdoor laborers, those with pre-existing chronic diseases, athletes, the elderly, children, the mentally ill, racial/ethnic minorities, and those living below the poverty line (O'Neill et al. 2003; O'Neill 2005; Schwartz et al. 2004). For examples, studies in New York and Phoenix reported that Hispanics are more susceptible to extreme heat shown by increased risk of renal hospitalizations and mortality (Fletcher et al., 2012; Uejio et al., 2011). Farmworkers in the U.S. are vulnerable to heat exposures, partly because 85% of farmworkers work outdoors, according to the 2010 National Health Interview Survey (Calvert et al. 2012), and 71% of U.S. farm workers were born in Mexico or Central America in 2007-2009 (Caroll et al., 2011). These workers are usually engaged in heavy work in clothing that retains heat, making it difficult to reduce heat stress (Rao, 2007). As a result, the rate of heat-related deaths in the agriculture/forestry/fishing and hunting industry (0.3 deaths per 100,000 full-time workers) was the highest among all industry sectors, and this sector contributed 16% of total heat-related deaths during 1992-2006 (Jackson and Rosenberg 2010). In North Carolina, workers accounted for 25% of heat-related deaths in 1977-2001, and agriculture industry contributed 45% of the operational deaths (Jackson and Rosenberg 2010).

Projected increases in the frequency and intensity of extreme heat days (Meehl and Tebaldi 2004) in a warming climate, together with and an aging workforce are expected to worsen vulnerabilities of farmworkers to heat stress in the future. Greenhouse gas emissions are increasing mainly driven by human activities, and the scientific community has a consensus that climate change is occurring with a general trend of increasing temperatures (IPCC 2007). As a consequence of climate change, heat waves are projected to occur more frequently, more intensely and to last longer (Meehl and Tebaldi 2004). For example, the heat wave that Europe experienced in 2003 caused 14,802 deaths in France alone; and the heat waves in the future were estimated to occur at least twice as frequently as the 2003 European heat wave (Stott et al. 2004). In addition, the U.S. is facing an aging population of farmworkers shown by that the average ages of U.S. farmworkers were 31 years old in 1992-1994 and 36 years old in 2007-2009, respectively (Carroll et al., 2011).

Migrant and seasonal farmworkers are likely more susceptible to heat than other workers because poverty, limited health insurance coverage and access to health care, and unauthorized work status can exacerbate their vulnerability in addition to their physical exposures to heat. Under the Public Health Service Act, a migrant farmworker is an individual with a primary employment in agriculture who has been employed for the last 24 months and establishes a temporary home for the purpose of such employment; and a seasonal farmworker is an individual who is not a migrant worker and his/her principal employment is in agriculture on a seasonal basis (U.S. Code). According to the National Agricultural Workers Survey 2007-2009, approximately 25% and 75% of hired crop farmworkers were identified as migrant or seasonal farmworkers, respectively (U.S. Department of Agriculture 2014). The migrant and seasonal farmworker population remains one of the most impoverished and underserved (Kandel 2008), and most are ineligible for health care coverage. In 2010, approximately 70% of adult farmworkers were uninsured (National Center for Farmworker Health (NCFH) 2014). When this is coupled with frequent mobility, it impedes access to adequate health care (Rosenbaum and Shin 2005). As a result, heat poses a significant health risk to migrant and seasonal farmworkers, e.g., the California Division of Occupational Safety and Health reported that 68% of heat-related deaths in 2005 occurred among Hispanic workers (Jackson and Rosenberg 2010).

Little research has gone into quantifying the links between extreme heat and illness among migrant and seasonal farmworkers (Jackson and Rosenberg 2010). Only two cross-sectional survey studies have been

conducted to examine heat-related illness and working conditions in hot environments among migrant farmworkers in North Carolina (Mirabelli et al. 2010) and Oregon (Bethel and Harger 2014). Mirabelli et al. (2010) reported that 94% and 40% of participants reported working in extreme heat and experiencing heat-related symptoms, respectively. Bethel and Harger (2014) showed that approximately 30% of participants reported having at least two heat-related symptoms. To the best of our knowledge, no studies have examined heat effects among migrant and seasonal farmworkers using clinical data. The long-term goal of this research is to reduce heat-related health risks for migrant and seasonal farmworkers in the U.S. We propose to conduct a heat-morbidity analysis using a prospective electronic medical record database in the U.S. by obtaining electronic health data from the national Community Based Research Network (CBRN), which is the first national clinical database that focuses on the health status of migrant and seasonal farmworkers.

The proposed research addresses the Agriculture, Forestry and Fishing Sector's "Strategic Goal 5: "Improve the health and well-being of agricultural workers by reducing occupational causes or contributing factors to acute and chronic illness and disease." (NIOSH, 2008), and contributes to the NIOSH research-to-practice initiative by disseminating the research results to key stakeholders (e.g., government officials, public health practitioners and community health centers).

In summary, extreme heat poses a substantial risk to migrant and seasonal farmworkers in a warming climate. This research addresses a significant but less-studied climate-related public health problem: namely, heat-related health effects in a vulnerable population. This proposed research, comprising one of the largest samples of farmworkers ever conducted, is highly significant and relevant to the growing interest in the impacts of extreme weather on vulnerable populations in a warming climate. The proposed research addresses the Agriculture, Forestry and Fishing Sector's "Strategic Goal 5: "Improve the health and well-being of farmworkers by reducing occupational causes or contributing factors to acute and chronic illness and disease".

Methods

CBRN, a database constructed based on electronic medical records
The lack of aggregated electronic health data on farmworkers has severely limited opportunities to conduct research to improve their health status. To address this problem, Dr. Cooper (co-I of this proposal) previously co-led a project with the NCFH and Battelle, funded by the National Institute of Environmental Health Sciences (1RC4ES019405-01), to create the CBRN anchored by a reciprocal and equitable partnership between well-established farmworker community advocates, clinics and dedicated academic leaders that transform the capacity to conduct such research (Cooper et al., 2014). It is through this unique partnership of academic researchers, community based experts and data and technology experts, that the CBRN has created the infrastructure necessary to develop and maintain a national Research Data Repository for the under-studied population of migrant and seasonal farmworker patients and other community members receiving medical care from Community and Migrant Health Centers (C/MHCs).

CBRN has worked with Integrated Care Collaboration, a non-profit alliance that manages a large regional Health Information Exchange in Austin, Texas, to securely transfer and merge electronic health records from five C/MHCs into a health information exchange platform and to create the CBRN Research Database that constitutes a Limited Data Set as defined by the Health Insurance Portability and Accountability Act (HIPAA). These five C/MHCs are geographically dispersed, and include the states of California, Colorado, Michigan, New York and Washington. Data for both farmworker and non-farmworker patients are included to allow internal comparative analyses. Data include variables related to providers, patients (e.g., age, gender, race, ethnicity, zip code, language, migrant or seasonal farmworkers), encounter (e.g., visit dates and time and visit type), diagnosis, procedure, vital signs, laboratory tests, medications, and others. Currently, there were a total of 311,331 unique patients (27,317 farmworkers) that were seen by five C/MHCs from January, 2013 to March, 2015. A total of 5,708,617 encounters were captured and all could be linked to a unique patient.

Environmental Data
Weather data: Hourly weather measurements (e.g., temperature and dew point temperature) during 2013–2015 will be obtained from weather stations located in the catchment areas covered by five C/MHCs through

the Integrated Surface Database at the National Climatic Data Center (www.ncdc.noaa.gov/oa/climate/isd/). These data are free and downloadable from the NCDC website. Then we will calculate daily mean/minimum/maximum apparent temperature (AT) following the formula:

$$AT = -2.653 + (0.994 \times Ta) + (0.0153 \times Td^2) \quad (1)$$

where Ta is air temperature and Td is dew point temperature (Zanobetti and Schwartz 2008). Daily apparent temperature has been commonly used in heat-related epidemiological studies because it accounts for both temperature and humidity, and our previous study has shown that apparent temperature appeared to be the most important predictor of heat-related all-cause mortality by comparing a variety of weather parameters including temperature, dew point temperature, barometric pressure, absolute humidity and apparent temperature (Zhang et al., 2014a).

Air pollution data: Data on ground-level 24-h integrated $PM_{2.5}$ and PM_{10} (particulate matter ≤ 2.5 and 10μm in diameter, respectively) measurements and other criteria pollutants (ozone, O_3; nitrogen dioxide, NO_2; sulfur dioxide, SO_2; and carbon monoxide, CO) from the catchment areas covered by five C/MHCs will be obtained from the US EPA Air Quality System during 2013–2015 (www.epa.gov/ttn/airs/airsaqs/). Daily average mean/minimum/maximum of criterial pollutants and daily maximum 8-hour concentrations of ozone will be derived from those hourly data.

Air Pollution and Temperature Exposure Assessment Strategy

Exposure to temperature and air pollutants will be assessed for each C/MHC separately. Exposure to apparent temperature will be assigned to each patient using weather observations at the airport weather station that is closest to the center of the catchment area covered by a C/MHC. According to our exploratory analysis, a C/MHC usually serves several surrounding counties. In heat-related epidemiological studies, it is common to assign temperature exposure from a central weather station to people living in a county, city or a metropolitan area (Zhang et al., 2014b, 2015). Exposure to air pollutants (O_3, $PM_{2.5}$, PM_{10}, NO_2, SO_2 and CO) will be estimated using the 'city-wide' average method, which calculates the average daily concentrations across all air monitors in the catchment area of each C/MHC. This exposure assessment method is commonly used in air pollution and heat-related epidemiological studies to adjust potential confounding effects from air pollution (Anderson and Bell, 2009).

Statistical Analysis

Aim 1: To determine whether excess cases of all-cause and cause-specific (cardiovascular, respiratory, diabetes, renal and heat-related causes) illness occur among migrant and seasonal farmworkers included in the CBRN on hot days.

Electronic health records from five C/MHCs that participated in the CBRN during 2013–2015 will provide the clinical data. Original patient health records include variables to identify migrant farmworkers, seasonal farmworkers, non-farmworkers. Patient data also include gender and age. International Classification of Diseases Ninth revision (ICD-9) codes were used in diagnosis. All-cause daily counts of patient clinical visits by patient type and gender will be used for data analysis. A patient visit on a day may result in more than one encounter records, and thus a clinical visit rather encounter counts will be used in our data analyses. Daily counts of clinical visits will be further classified into cardiovascular (CVD; ICD-9, 390-429), respiratory (ICD-9,460-519), diabetes (ICD-9:249, 250, 648.0, and 775.1), renal (ICD-9: 580-589) and heat-related causes (ICD-9: 992 or E900).

We will merge clinical, meteorological and air pollution databases by dates first and then exclude visits due to pre-scheduled appointments. We will apply GAMs to model daily counts of clinical visits among migrant and seasonal farmworkers as a function of temperature during 2013–2015. GAMs will be performed separately for all-cause and cause-specific clinical visits by each C/MHCs. We will decompose the risks of temperature on clinical visits into two parts: the 'heat effect' defined as the independent effect attributed to daily temperature, and the heat wave effect associated with heat waves lasting for at least two days(Gasparrini and Armstrong 2011). Two-day moving averages of daily mean apparent temperature will be used as a temperature metric to capture acute effects of heat (Zhang et al., 2014b). In addition, we will create one indicator variable for heat waves, which are defined as periods of 2 or more consecutive days in which daily mean apparent

temperatures reach levels greater than 95th percentiles of the summertime distributions (May 1st to September 30th) in each year. This definition has been commonly used in previous studies (Anderson and Bell, 2009; Zhang et al., 2014b). Our models will control for time trends and weekly patterns by including terms for both day of the week and day of the year. The model formula is described as:

$$Log[E(Y_t)] = \alpha + ns(meAT, 4) + HW_t + ns(DOY_t, 4) + \beta DOW_t \qquad (2)$$

where Yt is the number of clinical visits on day t; α is the intercept; ns, natural splines; meAT, two-day moving averages of daily mean apparent temperature (degrees of freedom (df)=4); HW_t is a heat wave indicator (taking on a value of 1 during a heat wave, 0 otherwise); DOY_t represents day of the year (df=4); DOW_t represents day of the week for day t. We will summarize heat effects in clinical visits by comparing 90th to 50th percentiles of meAT. The choice of these two percentiles was used by Anderson and Bell (2009) and Zhang et al. (2014b). GAM models will be fit using the "mgcv" R package (version 1.7-6) and R 2.15.2 software (R Development Core Team; http://R-project.org). The parameters specifying the distributions of daily counts of all-cause and cause-specific diseases will be assigned by quasi-Poisson distributions to account for their over-dispersion.

We will conduct sensitivity analyses to evaluate whether estimated heat and heat wave effects vary with temperature metrics, definitions of heat waves and with adjustment for air pollution. We will examine alternative temperature metrics including daily minimum/mean/maximum temperature, and daily mean/minimum/maximum temperature metrics with the adjustment of dew point temperature. We will explore heat wave definitions by using 97th, or 99th percentiles of the daily mean apparent temperature distribution. We will evaluate potential confounding by ozone, $PM_{2.5}$, PM_{10} and/or other criteria pollutants, we will model lag 0 ozone/other gaseous pollutants concentrations and lag 1 $PM_{2.5}$/PM_{10} concentrations using splines with 4 degrees of freedom (Anderson and Bell 2010).

Aim 2: To evaluate potential determinants of vulnerability by assessing whether heat-morbidity associations differ, according to farmworker status (migrant, seasonal, and non-farmworker), individual characteristics (gender, age, race/ethnicity and smoking status), and geographic areas (health centers).

We will use GAM models to evaluate potential vulnerability indicators of farmworkers exposed to heat, including farmworker status (migrant, seasonal, non-farmworker) and individual characteristics (gender, age, and race/ethnicity. Data for these potential vulnerability indicators will be extracted from five C/MHCs mentioned previously. We will stratify data by farmworker status, gender, age groups (< 18, 19-64, >65 years old), race (Hispanic, White, Black and other), and then will evaluate heat-clinical visit count associations per each stratified dataset. We will repeat these analyses for each C/MHC separately and then explore geographical variations of these associations.

Results

Integration of CBRN, weather and air pollution data

Year one of the funding period was the startup year for the project. The research team was established and project tasks began on schedule. We communicated with National Center for Farmerworker Health and went through a procedure in order to obtain the CBRN database. It has been a delay in getting access to this database due to the fact with we had to work with a third party (Integrated Care Collaboration) through a procedure to receive data, which harmonized raw electronic medical records from different EMR databases to compile a united database. The CBRN data we received are originally from five C/MHCs located in five states: CDCR, California; SALUD, Colorado; ICHN, Michigan; FILA, New York; and CBHA, Washington. We communicated with this company for a while in discussing some data issues. For example, the united database does not include type of admissions while the raw EMR database from C/MHC in Colorado we used for our pilot project does include such information. We compiled related weather and air pollution data accordingly.

Exploratory analysis of CBRN data

We initially liked to have 3-year data from the period of 2013-2015. However, the time period and encounter records of available data we received varied with center (See Table 1). The only year when all centers have complete data is Year 2013. We decided to choose the summer (May 1st to September 30th) of Year 2013 as our study period in order to facilitate comparison across centers.

Catchment area
Figure 1 shows the catchment areas of patients who visited each C/MHC. Not surprisingly, most of patients lived in the same areas of visited clinics. Interestingly, some patients enrolled in ICHN and FILA came from Florida, and they represent migrant farmworkers who originally lived in Florida. Some patients in ICHN were also from Texas. This finding coincides with two major route of migrant farmworkers starting from Florida and Texas.

Descriptive statistics
Tables 2 A-E show the demographic characteristics of patients who went to C/MHCs during the summer period of 2013. A total of 22,030 patients went to SALUD, Colorado, which was the highest among five centers, followed by CDCR, California (15,404); ICHN, Michigan (12, 607); CBHA, Washington (6,927); and FILA, New York (5,773). However, CBHA has the lowest number of patients who were migrant or seasonal farmworkers (15 and 57, respectively) while ICHN has the highest migrant farmworkers (2,483) and CDCR has the most of seasonal farmworkers (2,769). These patients consisted of a small proportion of elderly. For example, the elderly only accounted for 5.5%, 4.4% and 2.4% for all patients, migrant and seasonal farmworkers in SALUD, Colorado, respectively. Migrant and seasonal farmworkers were dominated by Hispanics (~90%) in SALUD, ICHN, and CBHA.

Tables 3 A-E show the summary of weather parameters and patient characteristics over the study period. All study areas associated with five centers had a cool summer shown by the average daily mean temperature (16.4 ^{o}C, 19.5 ^{o}C, 19.7 ^{o}C, 18.9 ^{o}C, and 20.5 ^{o}C, respectively for CDCR, SALUD, ICHN, FILA and CBHA). A small proportion of patients in encounter records were migrant farmworkers as shown by the averages of daily counts of clinic visits for migrant farmworkers with the range of 0.1 (CBHA) to 11.5 (CDCR) and seasonal farmworkers ranging from 0.4 (CBHA) to 21.4 (CDCR). Considering daily counts of visits for migrant and seasonal farmworkers in CBHA are too small, we removed CBHA from our analysis to estimate heat-related health effects because of small sample size of migrant and seasonal farmworkers.

Figures 2-4 show daily variations of clinic visits for migrant, seasonal farmworkers and others (non-farmworkers). Interestingly, different health centers show different monthly patterns for all clinical visits. The highest patient visits occurred in January, September-October, January, June, for CDCR, SALUD, ICHN, FILA respectively.

Heat-related health effects
Figures 5-8 show mixed results of heat-related health effects by center, farmworker type, and sex. We observed statistically significant effect of heat on male migrant farmworkers in SALUD, CO and ICHN, MI. We also observed positive effect estimates of heat on total migrant and seasonal farmworkers in these two centers. The estimated percent increases in patient visits by comparing 90th to 50th percentiles of meAT for male migrant farmworkers were 124.6% (95% confidence intervals (CI): 30.9%, 285.1%), 16.8% (95% CI:2.7%, 32.8%) for SALUD and ICHN, respectively. The estimated percent increases in patient for migrant and seasonal farmworkers were 53.5% (95% CI: -5.6%, 149.6%), 14.6% (95% CI: -11.6%, 48.5%), 11.3% (95% CI: -0.2%, 24.1%), 19.4% (95% CI: -1.5%, 44.6%) for SALUD and ICHN, respectively. Surprisingly, the estimated percent increases in patient visits for migrant and seasonal farmworkers in CDCR and FILA are negative.

Discussion
This study explored the impact of heat on clinical visits among an extremely vulnerable population: migrant and seasonal farmworkers, using EMR data in four regions with varying climate and weather patterns. Most of farmworkers work outside and engage in heavy tasks. Their physical exposure to heat along with their low SES exacerbate their vulnerability to heat. However, this population particularly migrant farmworkers has been challenging to follow up due to their moving as well as unauthorized working status. Previous studies on heat related health effects are very limited, and they rely to survey data. This study attempted to address this questions by utilizing EMR data from four regions. We have few novel findings for using EMR data in farmworker related research. We found positive effects of temperature on clinical visits among migrant and

seasonal farmworkers in two centers: SALUD and ICHN. In particularly, we observed statistically significant effects of heat on male migrant farmworkers in these two centers as well.

Heat has a larger impact on migrant farmworkers compared to seasonal farmworkers in two C/MHCs: SALUD, Colorado; and ICHN, Michigan. This finding is consistent with our previous results based on data from SALUD, Colorado (Zhang et al., 2016). This finding is likely due to four possible reasons. First, migrant farmworkers usually live in camps with bad living conditions (e.g., no or limited air conditioning) compared to seasonal farmworkers who usually established a home locally. For example, the National Center for Farmworker Health (NCFH) reported that housing for migrant farmworkers is often substandard and non-existent due to high rates of poverty (NCFH 2012). Most importantly, air conditioning might not be available in the living environment of migrant farmworkers which can ameliorate the heat-related effects during nighttime as it has been shown to having protective effects against heat-related morbidity and mortality (O'Neill et al. 2005). Second, migrant farmworkers generally lack family or other support for prolonged periods of time because they usually live in temporary camps or live in temporary homes for their short-term employment (Alderete et al. 1999). Third, farmworkers has a low SES, and poverty has been shown one of vulnerability factors for heat (Gronlund 2014). Fourth, migrants' immigration status may make them more vulnerable to labor abuses since undocumented workers may be less likely to report employers who do not comply with federal regulations and rules. The National Agricultural Workers Survey from 2001-2002 shows that 53% of farmworkers nationally were undocumented (U.S. Department of Labor 2005). Mirabelli et al. (2010) reported changes in work hours and activities during hot conditions were associated with a lower prevalence of heat illness among workers with H-2A visas, but not among non-H-2A workers. Also, Whalley et al. (2009) reported that workers with H2-A visas experience better conditions and practice more safety behaviors than do workers who do not have H2-A visas.

Heat had stronger effects on male migrant farmworkers than female migrant farmworkers, and effect estimates were statistically significant. One possible reason is that males more likely work outdoors and perform heavier tasks than females. Stoecklin-Marois et al. (2013) reported a similar finding that heat has a larger impact on males than females.

Negative effects estimates of heat on migrant and seasonal farmworkers in CDCR, CA and FILA, NY were puzzling. We have run additionally analysis using the May-August and the entire year, however, results remain similar. There are two possible reasons. First, migrant and seasonal farmworkers intended not to go to clinics during the harvesting season because they have a tight work schedule and may lost their stipends particularly if they have piece-rate wages. Second, the 2013 summer is mild in California and New York (average summertime temperature: 16.4 ^{o}C and 18.9 ^{o}C) that is cooler than that in SALUD, CO and ICHN in Michigan (average summertime temperature: 19.5 ^{o}C and 19.7 ^{o}C) as shown by Tables 3A-D.

This study has several strengths. One strength is that this study utilizes EMR records from four regions with varying climate and weather patterns. This is the first multi-city study on examining how heat affects migrant and seasonal farmworkers. Another strength is that this study provides a minimum heat effects because farmworkers intend to go to clinics unless they have serious illness because most of them do not have insurance. Thus, our effect estimates likely underestimate true effects.

This study has a few limitations. One limitation is that our study period includes only one summer given all EMR data from different health centers only share an entire summer. The second limitation is that the final harnessed database does not include type of visit information for all centers. Ideally, our study would focus on acute visit or visits without appointments because scheduled visits are not likely affected by heat. The third limitation is heat exposure misclassifications because this study used temperature measurements from a single weather station rather personal exposures to temperature. The last limitation is that this study does not explore some individual characteristics such as ethnicity and age among migrant and seasonal farmworkers because the sample size of migrant and seasonal farmworkers are dominated by adults and Hispanics. For example, Hispanics accounted for more than 90% farmworkers in SALUD, CO and IHCN, MI where positive heat effects were detected.

Conclusion and Next Steps

This study demonstrates the first multi-city study of exploring heat effects on a vulnerable population by taking advantage of EMRs on migrant and seasonal farmworkers in the U.S. We found that heat has a significant impact on excess risk of clinic visits for male migrant farmworkers in two centers located in Colorado and Michigan. Our estimates more likely underestimate true heat effects among migrant farmworkers because a large proportion of them do not have insurance and are undocumented workers. This research and the findings represent a substantial advancement for occupational health on heat-related health effects among agricultural workers in a warming climate. Although some caution should be taken in the implications of this study because we did not observe heat effects in two centers located in California and New York, this research provides justification for future studies to elucidate the biological mechanisms and interventions to reduce heat related adverse health effects. This study also provide insights in utilizing EMR data for farmworker related research. The next step is to publish these findings. We are preparing our manuscript to publish these findings.

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Tables and Figures

Table 1. Summary of encounter records by center and year

Year	CBHA	FILA	SALUD	CDCR	ICHN
2010	0	0	0	47	47
2011	0	0	0	10453	23407
2012	0	0	0	115501	69287
2013	228467	37701	294624	448013	249370
2014	252535	33647	489095	638366	87210
2015	81493	0	217939	98809	0

Table 2-A. Summary of demographic characteristics of patients who visited CDCR, CA, during the period of May 1st and September 30, 2013

Variable		All patient	Migrant	Seasonal
Gender				
	F	9190	810	1636
	M	6201	705	1133
	Missing	13	3	
Age				
	Age<65	14823	1479	2731
	Age>=65	581	39	38
Ethnicity				
	Hispanic or Latino	8011	704	1570
	Not Hispanic or Latino	1997	23	25
	Refused to Report/Unknown	5383	788	1174
	Missing	13	3	
Total		15404	1518	2769

Table 2-B. Summary of demographic characteristics of patients who visited SALUD, CO, during the period of May 1st and September 30, 2013

Variable		All patient	Migrant	Seasonal
Gender				
	F	12868	107	407
	M	9138	142	313
	Missing	24	1	
Age				
	Age<65	20810	239	703
	Age>=65	1220	11	17
Ethnicity				
	Hispanic or Latino	12958	224	649
	Not Hispanic or Latino	8463	17	56
	Refused to Report/Unknown	585	8	13
	Missing	24	1	
Total		22030	250	720

Table 2-C. Summary of demographic characteristics of patients who visited ICHN, MI, during the period of May 1st and September 30, 2013

Variable		All patient	Migrant	Seasonal
Gender				
	F	6744	1182	246
	M	5859	1299	261
	Missing	4	2	
Age				
	Age<65	12154	2434	497
	Age>=65	453	49	11
Ethnicity				
	Hispanic or Latino	5103	2388	470
	Not Hispanic or Latino	7351	87	37
	Refused to Report/Unknown	149	6	1
	Missing	4	2	
Total		12607	2483	508

Table 2-D. Summary of demographic characteristics of patients who visited FILA, NY, during the period of May 1st and September 30, 2013

Variable		All patient	Migrant	Seasonal
Gender				
	F	3120	216	322
	M	2606	440	284
	Missing	47	17	7
Age				
	Age<65	5379	657	547
	Age>=65	394	16	66
Ethnicity				
	Hispanic or Latino	1467	428	263
	Not Hispanic or Latino	3996	140	333
	Refused to Report/Unknown	264	88	10
	Missing	46	17	7
Total		5773	673	613

Table 2-E. Summary of demographic characteristics of patients who visited CBHA, WA, during the period of May 1st and September 30, 2013

Variable		All patient	Migrant	Seasonal
Gender				
	F	3406	7	32
	M	3515	8	25
	Missing	8		
Age				
	Age<65	6510	15	57
	Age>=65	417		
Ethnicity				
	Hispanic or Latino	4862	15	52
	Not Hispanic or Latino			
	Refused to Report/Unknown	2057		5
	Missing	8		
Total		6927	15	57

Table 3-A. Descriptive statistics for weather and patient characteristic during summertime (May to September) 2013 in CDCR, CA.

Variables' description	Variable nan	Unit	Means (ranges)
Daily mean temperature	meTMP	°C	16.44 (6.67, 26.67)
Daily mean apparent temperature	meAT	°C	15.83 (4.62, 24.66)
Daily mean dew point	meDWP	°C	10.28(-13.61, 17.78)
Daily counts of clinic visits among migrant farmworkers	C_Migrant	Counts	11.48(0.0, 49.0)
Daily counts of clinic visits among male migrant farmworkers	c_migrant_m	Counts	4.96(0.0, 26.0)
Daily counts of clinic visits among female migrant farmworkers	c_migrant_f	Counts	6.49(0.0, 28.0)
Daily counts of clinic visits among seasonal farmworkers	c_seasonal	Counts	21.41(0.0, 85.0)
Daily counts of clinic visits among male seasonal farmworkers	c_seacsonal_	Counts	8.91(0.0, 39.0)
Daily counts of clinic visits among female seasonal farmworkers	c_seasonal_f	Counts	12.5 (0.0, 48.0)
Daily counts of clinic visits among other patients	c_other	Counts	92.13 (2.0,268.0)
Daily counts of clinic visits among male other patients	c_other_m	Counts	37.68 (0.0, 117.0)
Daily counts of clinic visits among female other patients	c_other_f	Counts	54.39(0.0, 164.0)
Daily counts of clinic visits among people with CVD	c_cvd	Counts	0.95 (0.0, 5.0)

Table 3-B. Descriptive statistics for weather and patient characteristic during summertime (May to September) 2013 in SALUD, CO.

Variables' description	Variable nan	Unit	Means (ranges)
Daily mean temperature	meTMP	°C	19.54 (-1.67, 26.67)
Daily mean apparent temperature	meAT	°C	17.83 (-3.01, 25.5)
Daily mean dew point	meDWP	°C	6.77 (-6.39, 15.83)
Daily counts of clinic visits among migrant farmworkers	C_Migrant	Counts	1.96(0,24)
Daily counts of clinic visits among male migrant farmworkers	c_migrant_m	Counts	1.12(0,23)
Daily counts of clinic visits among female migrant farmworkers	c_migrant_f	Counts	0.84(0,5)
Daily counts of clinic visits among seasonal farmworkers	c_seasonal	Counts	5.67(0,20)
Daily counts of clinic visits among male seasonal farmworkers	c_seacsonal_	Counts	2.47(0,10)
Daily counts of clinic visits among female seasonal farmworkers	c_seasonal_f	Counts	3.21(0,14)
Daily counts of clinic visits among other patients	c_other	Counts	165.9(6,488)
Daily counts of clinic visits among male other patients	c_other_m	Counts	68.39(3,191)
Daily counts of clinic visits among female other patients	c_other_f	Counts	97.29(0,297)
Daily counts of clinic visits among people with CVD	c_cvd	Counts	27.68(0,109)

Table 3-C. Descriptive statistics for weather and patient characteristic during summertime (May to September) 2013 in ICHN, MI.

Variables' description	Variable nan	Unit	Means (ranges)
Daily mean temperature	meTMP	°C	19.66 (4.72, 28.61)
Daily mean apparent temperature	meAT	°C	19.87(2.11, 32.89)
Daily mean dew point	meDWP	°C	13.61(-3.61, 22.50)
Daily counts of clinic visits among migrant farmworkers	C_Migrant	Counts	19.40(0.0, 57.0)
Daily counts of clinic visits among male migrant farmworkers	c_migrant_m	Counts	9.83(0.0, 33.0)
Daily counts of clinic visits among female migrant farmworkers	c_migrant_f	Counts	9.56(0.0, 31.0)
Daily counts of clinic visits among seasonal farmworkers	c_seasonal	Counts	4.29(0.0, 16.0)
Daily counts of clinic visits among male seasonal farmworkers	c_seacsonal_	Counts	2.18(0.0, 8.0)
Daily counts of clinic visits among female seasonal farmworkers	c_seasonal_f	Counts	2.10 (0.0, 11.0)
Daily counts of clinic visits among other patients	c_other	Counts	82.7 (1.0,166.0)
Daily counts of clinic visits among male other patients	c_other_m	Counts	36.91 (0.0,69.0)
Daily counts of clinic visits among female other patients	c_other_f	Counts	45.77 (1.0, 97.0)
Daily counts of clinic visits among people with CVD	c_cvd	Counts	11.85 (0.0, 34.0)

Table 3-D. Descriptive statistics for weather and patient characteristic during summertime (May to September) 2013 in FILA, NY.

Variables' description	Variable nan	Unit	Means (ranges)
Daily mean temperature	meTMP	°C	18.89 (5.83, 28.33)
Daily mean apparent temperature	meAT	°C	19.27 (3.20, 33.37)
Daily mean dew point	meDWP	°C	13.10(-0.83, 23.06)
Daily counts of clinic visits among migrant farmworkers	C_Migrant	Counts	4.76(0.0, 27.0)
Daily counts of clinic visits among male migrant farmworkers	c_migrant_m	Counts	3.1(0.0, 18.0)
Daily counts of clinic visits among female migrant farmworkers	c_migrant_f	Counts	1.53(0.0, 11.0)
Daily counts of clinic visits among seasonal farmworkers	c_seasonal	Counts	5.09(0.0, 20.0)
Daily counts of clinic visits among male seasonal farmworkers	c_seacsonal_	Counts	2.28(0.0, 12.0)
Daily counts of clinic visits among female seasonal farmworkers	c_seasonal_f	Counts	2.76 (0.0, 31.0)
Daily counts of clinic visits among other patients	c_other	Counts	26.01 (3.0,62.0)
Daily counts of clinic visits among male other patients	c_other_m	Counts	10.12 (0.0,28.0)
Daily counts of clinic visits among female other patients	c_other_f	Counts	15.77 (0.0, 38.0)
Daily counts of clinic visits among people with CVD	c_cvd	Counts	6.1 (0.0, 29.0)

Table 3-E. Descriptive statistics for weather and patient characteristic during summertime (May to September) 2013 in CBHA, WA.

Variables' description	Variable nan	Unit	Means (ranges)
Daily mean temperature	meTMP	°C	20.47 (8.33, 30)
Daily mean apparent temperature	meAT	°C	18.68 (6.00, 30.64)
Daily mean dew point	meDWP	°C	6.92(-8.33, 16.11)
Daily counts of clinic visits among migrant farmworkers	C_Migrant	Counts	0.1095 (0.0, 6.0)
Daily counts of clinic visits among male migrant farmworkers	c_migrant_m	Counts	0.05839(0.0, 3.0)
Daily counts of clinic visits among female migrant farmworkers	c_migrant_f	Counts	0.05109 (0.0, 36.0)
Daily counts of clinic visits among seasonal farmworkers	c_seasonal	Counts	0.4161(0.0, 9.0)
Daily counts of clinic visits among male seasonal farmworkers	c_seacsonal_	Counts	0.1825 (0.0, 2)
Daily counts of clinic visits among female seasonal farmworkers	c_seasonal_f	Counts	0.2336 (0.0, 8.0)
Daily counts of clinic visits among other patients	c_other	Counts	50.04 (1.0,105.0)
Daily counts of clinic visits among male other patients	c_other_m	Counts	25.4(0.0, 64.0)
Daily counts of clinic visits among female other patients	c_other_f	Counts	24.58 (0.0, 52.0)
Daily counts of clinic visits among people with CVD	c_cvd	Counts	1.036 (0.0, 5.0)

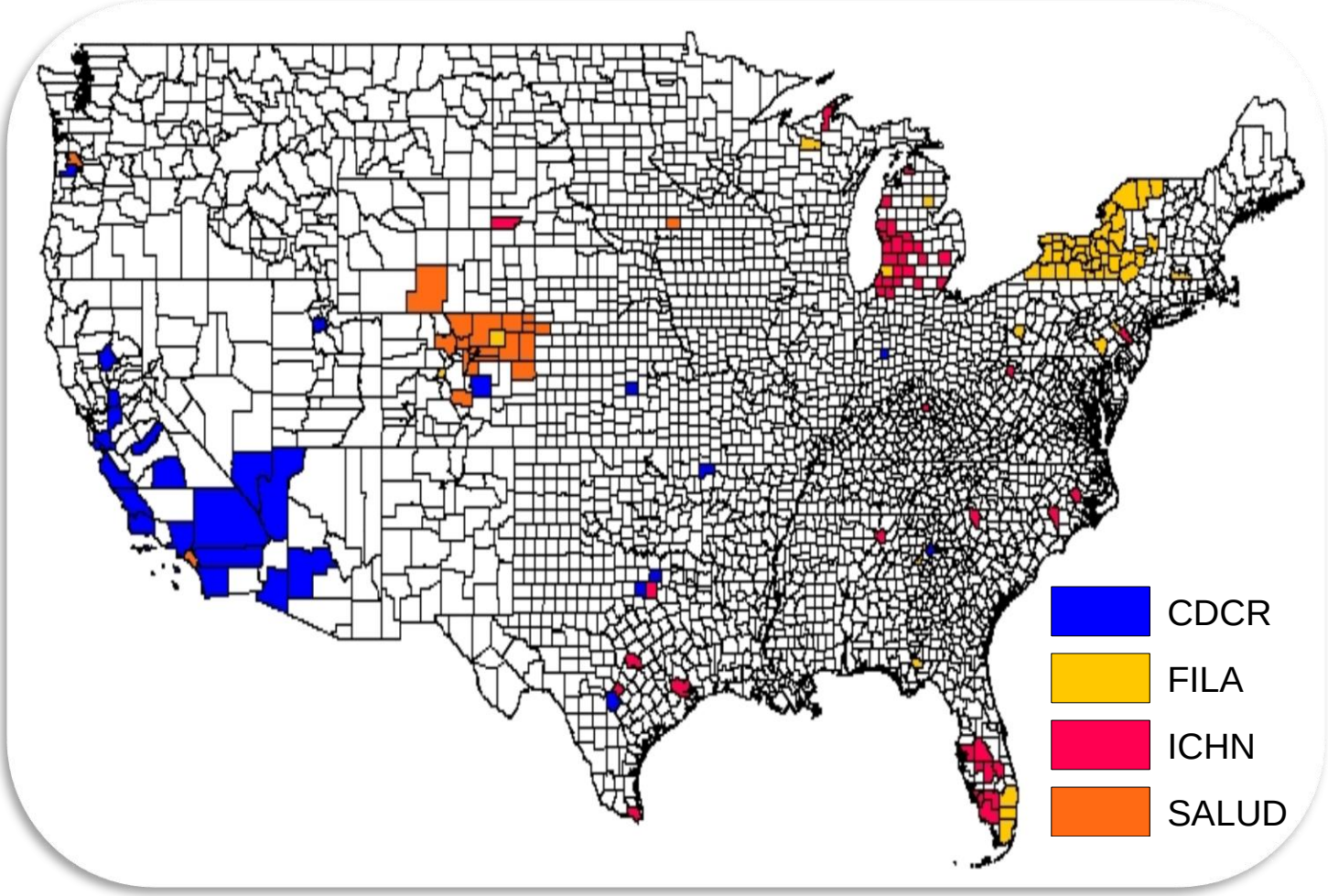
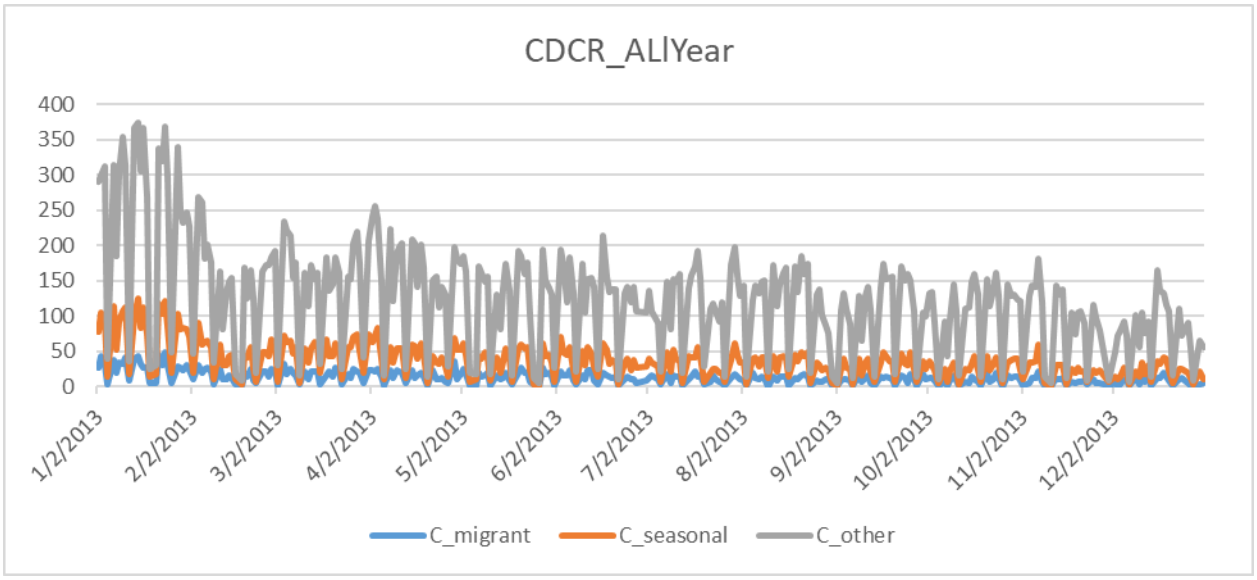


Figure 1. Catchment areas of patients who visited four C/MHCs.



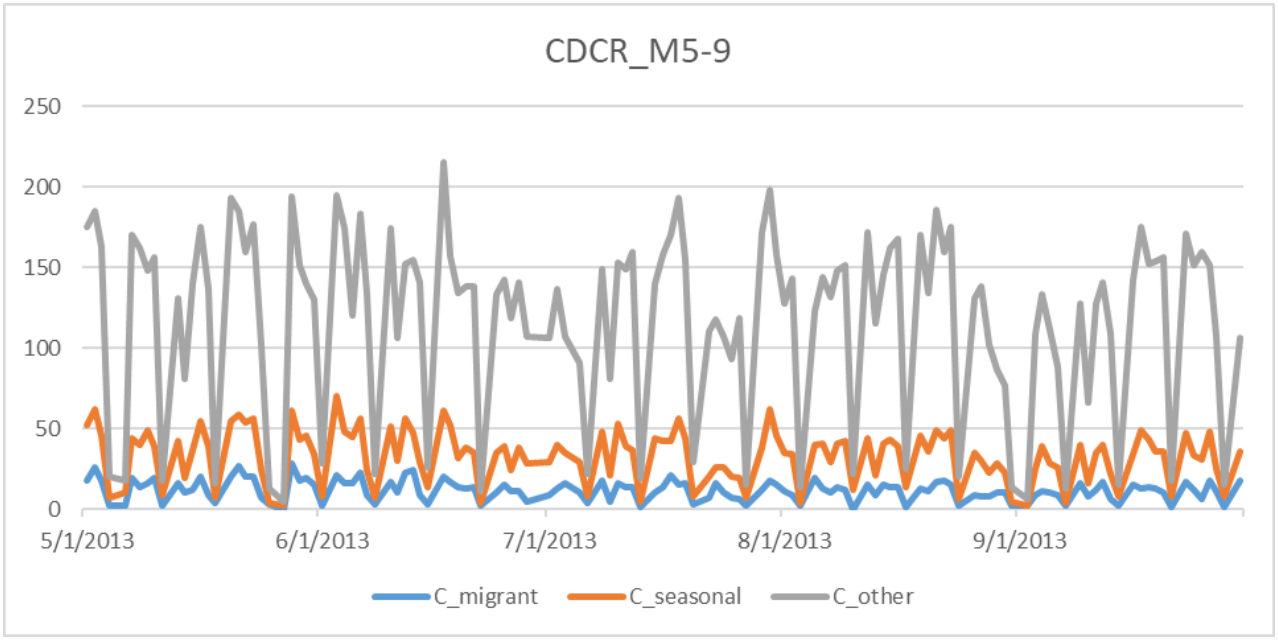
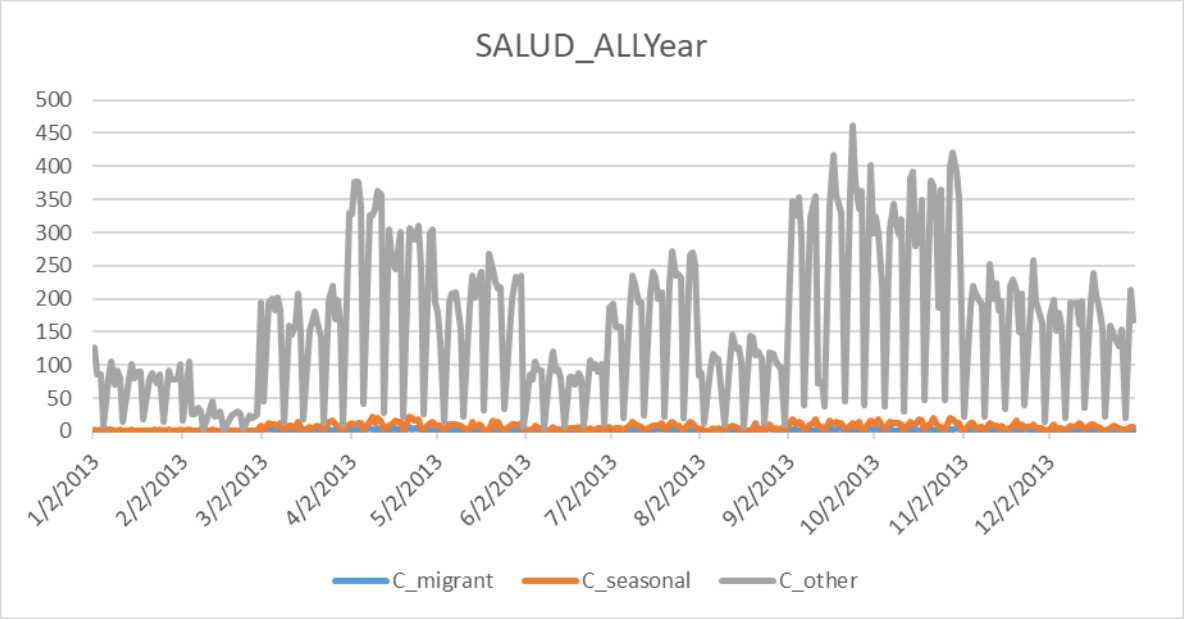


Figure 2. Time series plots of daily counts of migrant, seasonal farmworkers, and non-farmworkers who visited CDCR, CA.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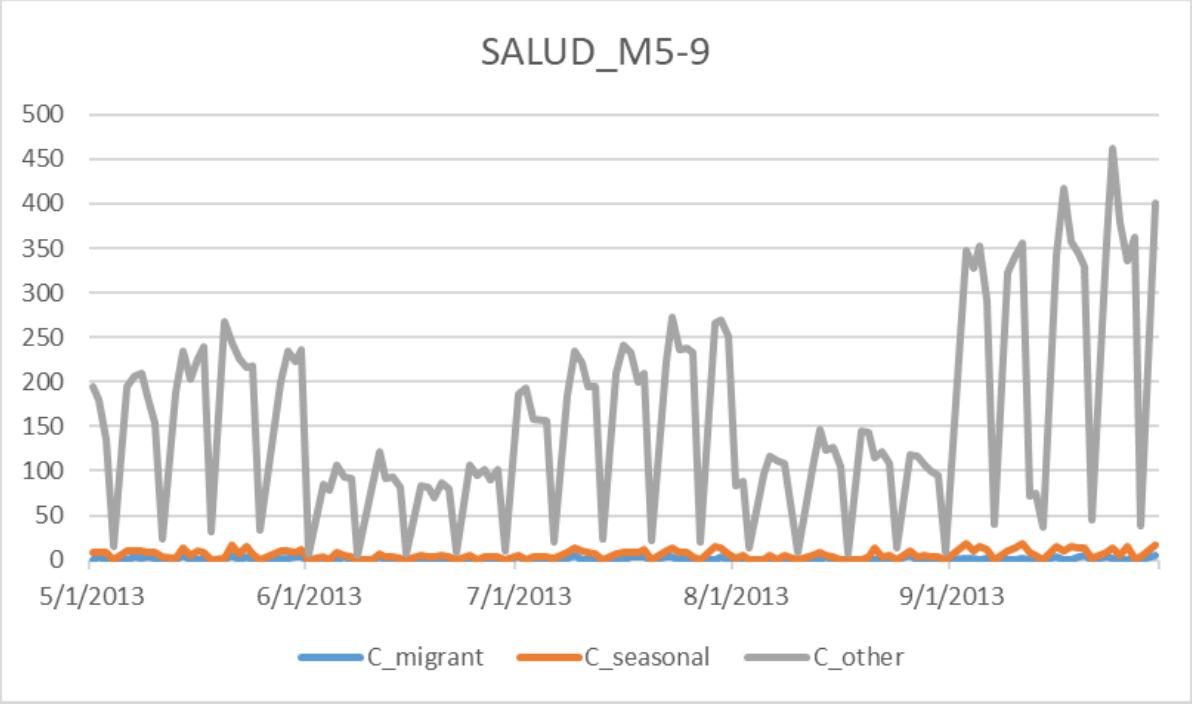
C_seasonal
C_other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9/1/2013
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C_seasonal
C_other

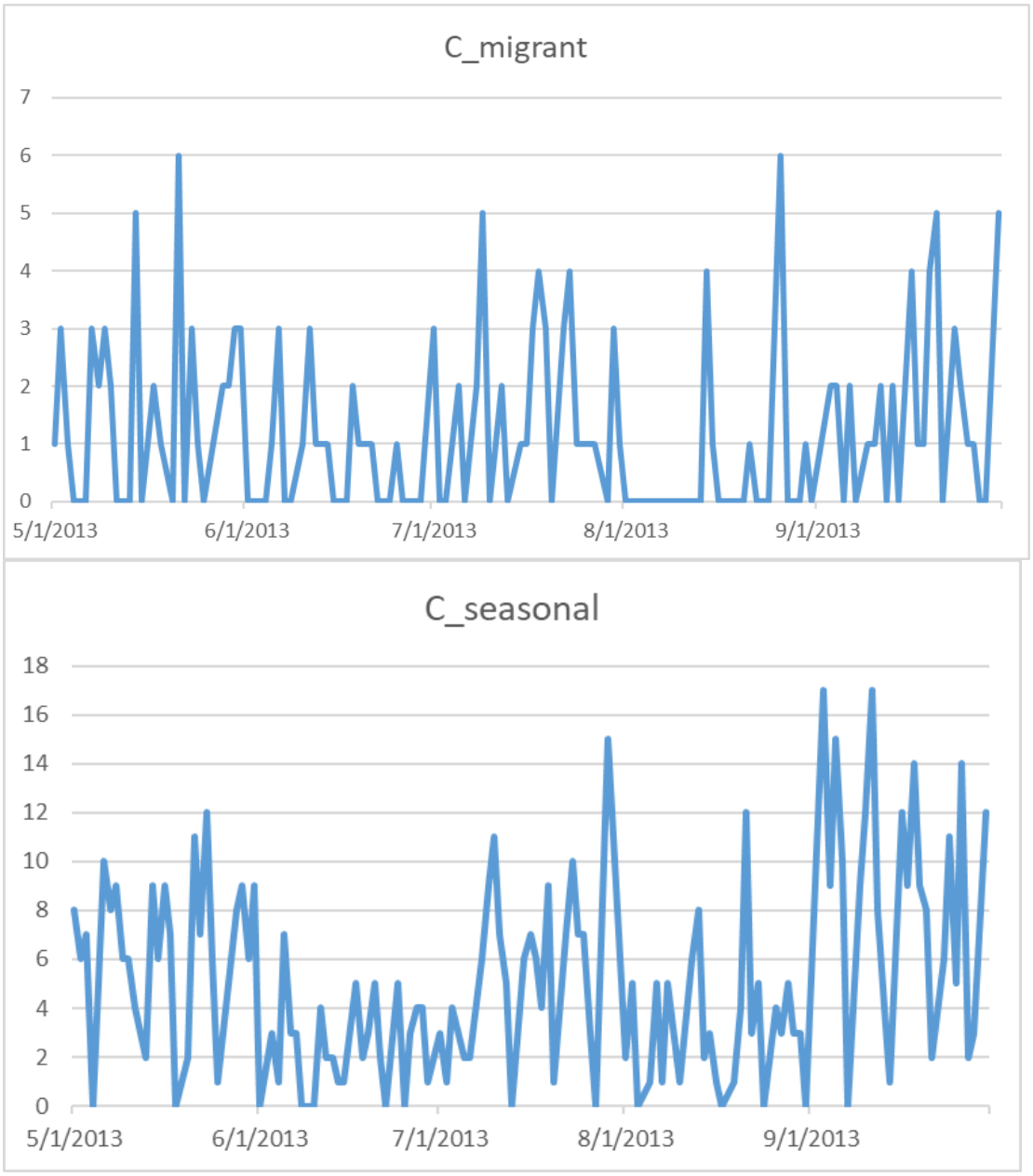
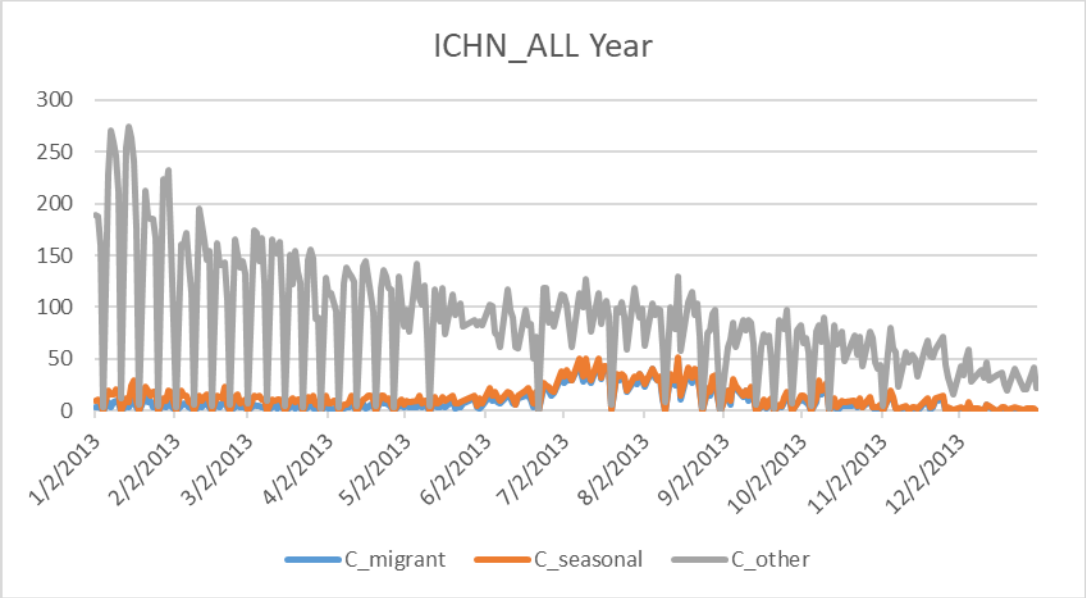


Figure 3. Time series plots of daily counts of migrant, seasonal farmworkers, and non-farmworkers who visited SALUD, CO.



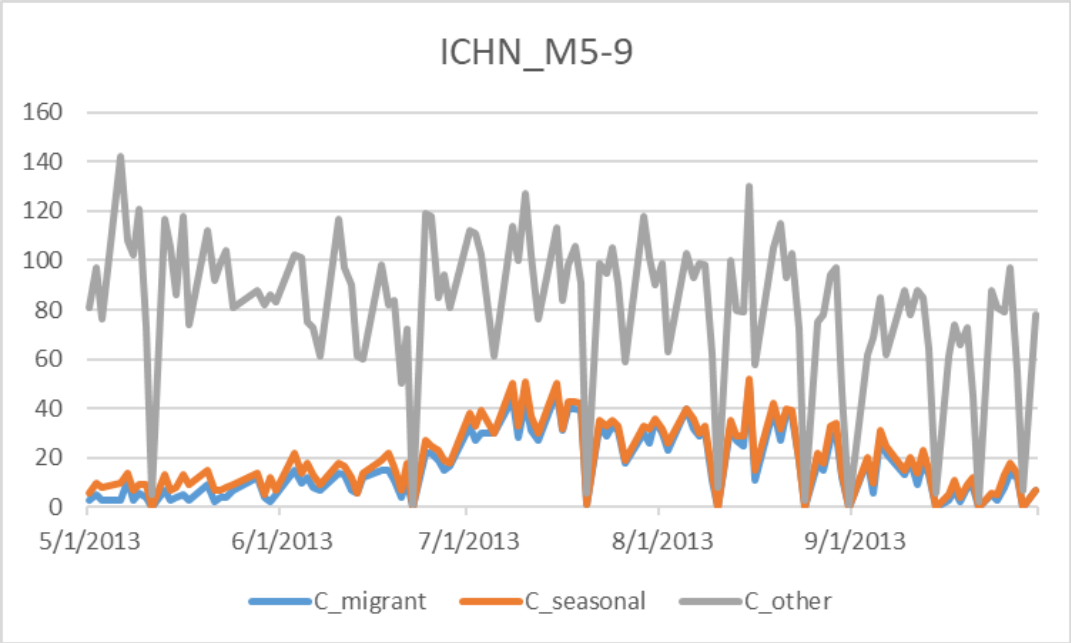
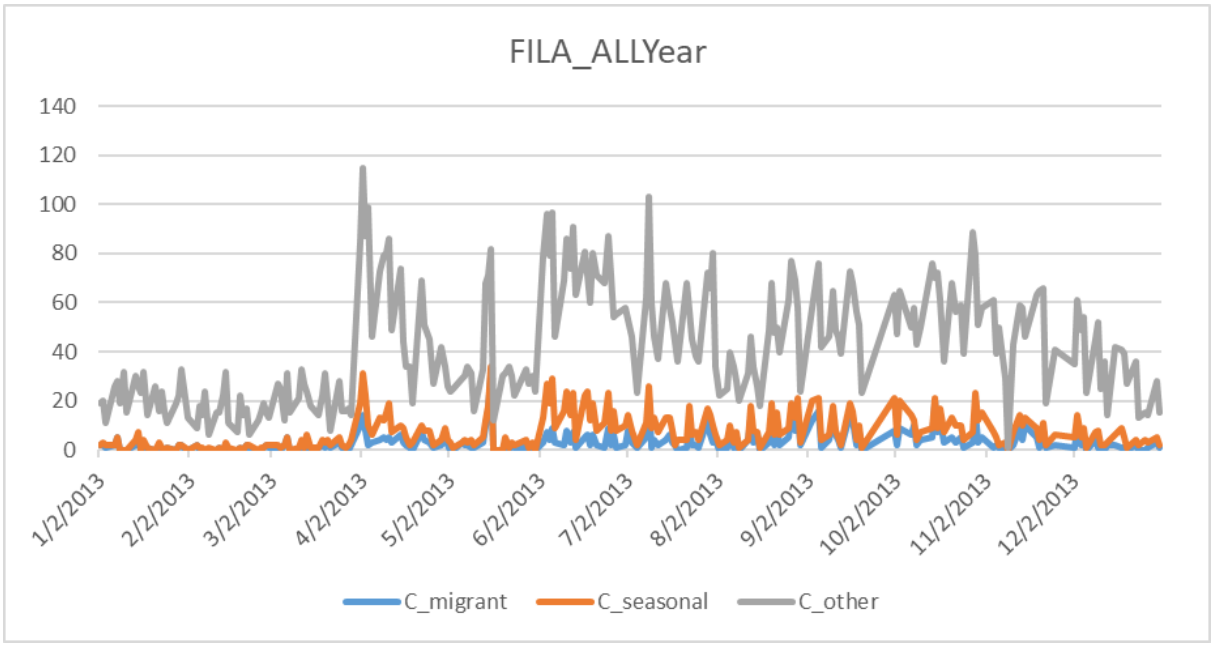


Figure 4. Time series plots of daily counts of migrant, seasonal farmworkers, and non-farmworkers who visited ICHN, MI.



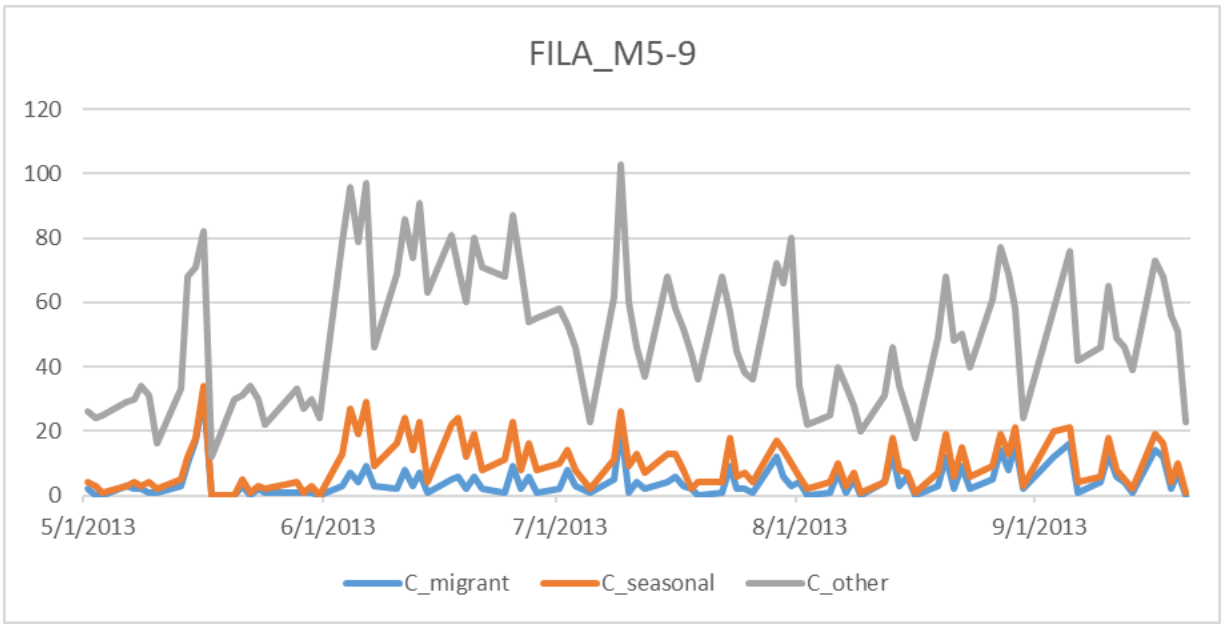


Figure 5. Time series plots of daily counts of migrant, seasonal farmworkers, and non-farmworkers who visited FILA, NY.

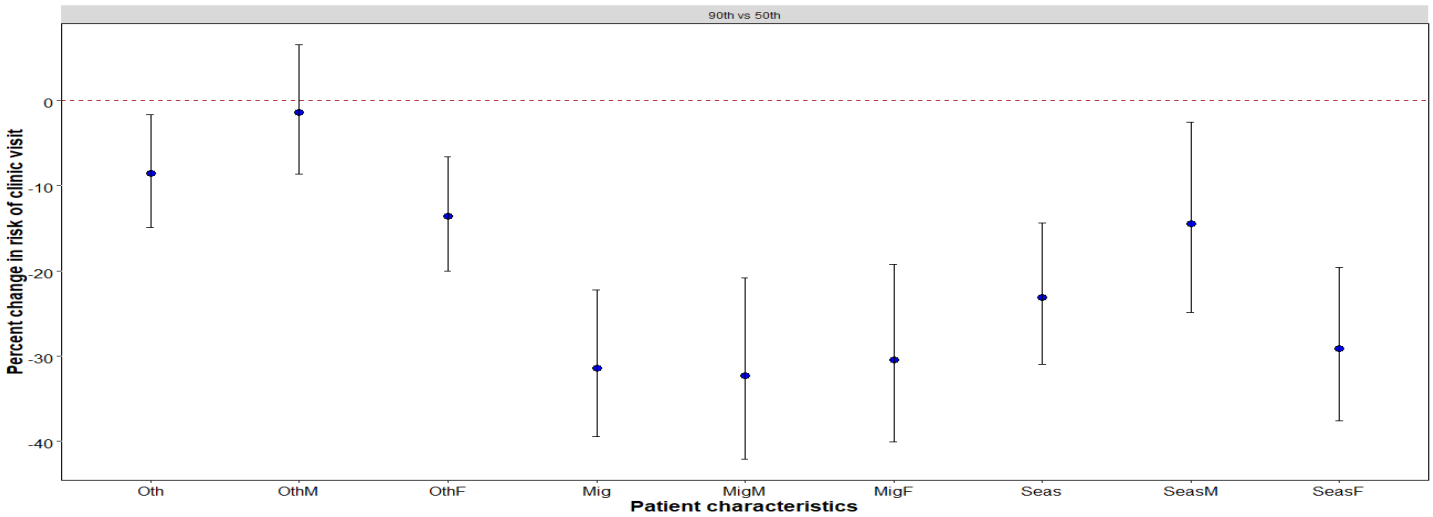


Figure 6. Percent change in risk of clinic visit by patient characteristics in CDCR located in California.

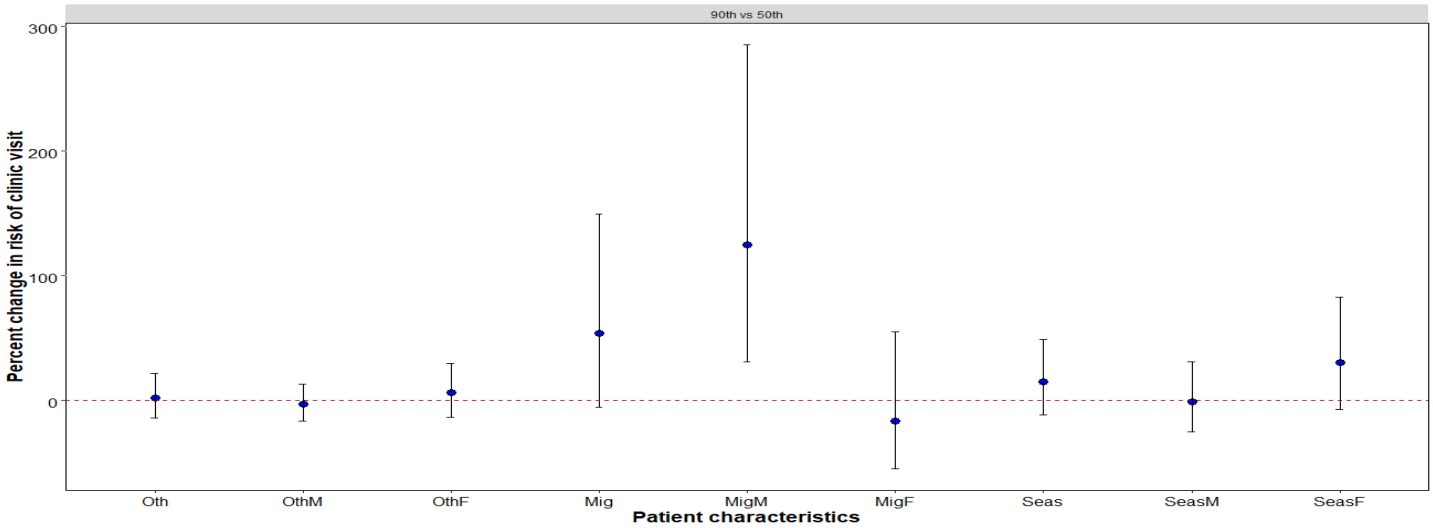


Figure 7. Percent change in risk of clinic visit by patient characteristics in SALUD located in Colorado.

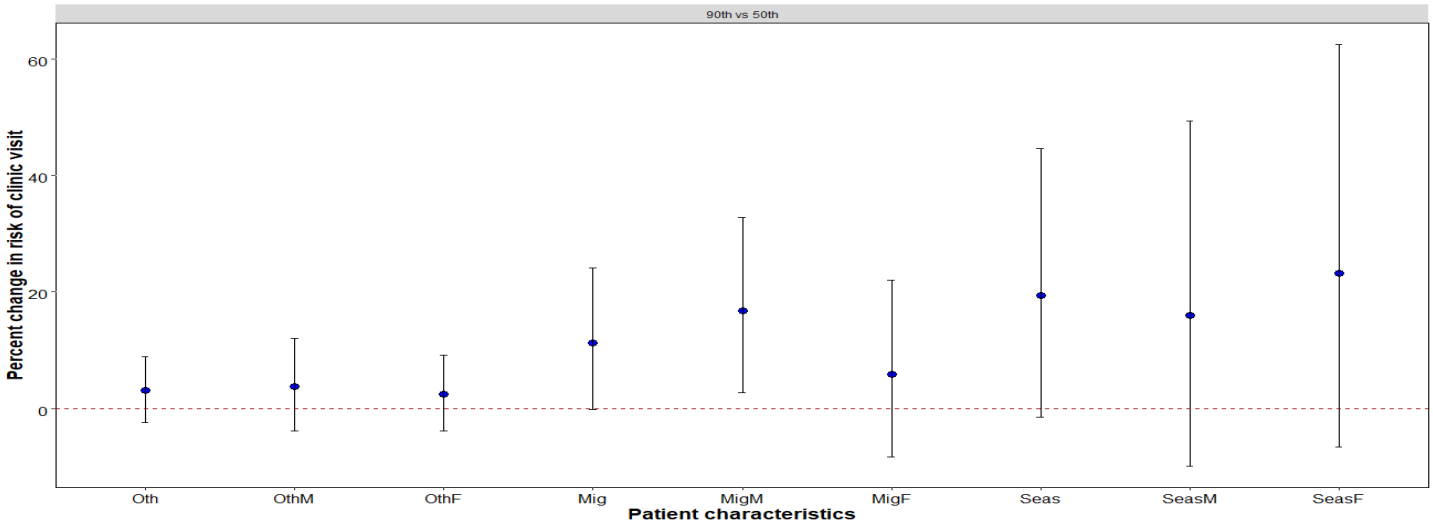


Figure 8. Percent change in risk of clinic visit by patient characteristics in ICHN located in Michigan.

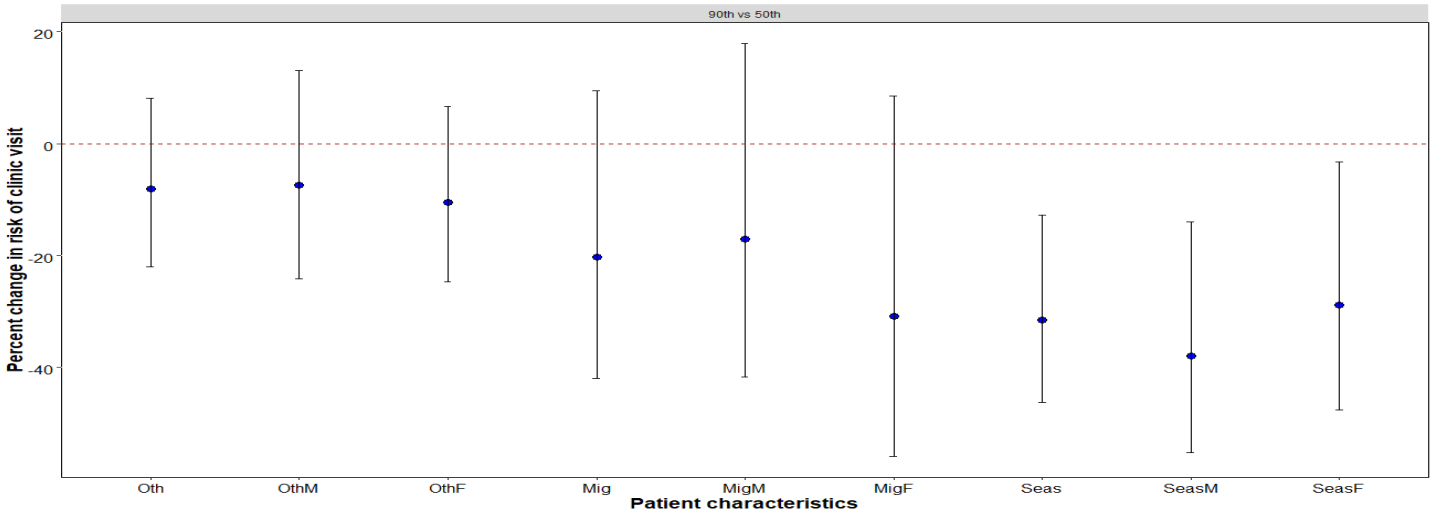


Figure 9. Percent change in risk of clinic visit by patient characteristics in FILA located in New York.

Presentations

Zhang K. Assessing Heat Effects among Migrant and Seasonal Farmworkers: a multi-state study". 2019 Western Agriculture Safety and Health Conference, Seattle, WA. August, 2019

Zhang K, Yu X, Li Y, Cooper S. 2018. Accessing Heat Effects among Migrant and Seasonal Farmworkers: A Multi-state Study. The Joint Conference of the International Society of Exposure Science and the International Society for Environmental Epidemiology, August, 2018 in Ottawa, Canada.

APPENDICES

Appendix A: UTHealth IRB Approval

Committee for the Protection of Human Subjects

6410 Fannin Street, Suite 1100
Houston, Texas 77030

Dr. Kai Zhang
UT-H - SPH - Environ & Occup Health Science

April 20, 2016

HSC-SPH-16-0350 - *Assessing Heat-Related Morbidity among Migrant and Seasonal Farmworkers NIOSH Grant (1R03OH011195-01)*

The above named project is determined to qualify for exempt status according to 45 CFR 46.101(b)

***CATEGORY #4** : Research, involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified directly or through identifiers linked to the subjects.*

Health Insurance Portability and Accountability Act:
Exempt from HIPAA

CHANGES: Should you choose to make any changes to the protocol that would involve the inclusion of human subjects or identified data from humans, please submit the change via iRIS to the Committee for the Protection of Human Subjects for review.

STUDY CLOSURES: Upon completion of your project, submission of a study closure report is required. The study closure report should be submitted once all data has been collected and analyzed.

Should you have any questions, please contact the Office of Research Support Committees at 713-500-7943.

Revised: 6/29/2016