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ORIGINAL ARTICLE

Heat effects among migrant and seasonal farmworkers: a case study in Colorado

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ABSTRACT

Background Although migrant and seasonal farmworkers are highly vulnerable to ambient heat because of their working conditions, heat effects in this population have been rarely studied.

Objectives We estimated effects of heat on mean daily counts of clinic visits among migrant and seasonal farmworkers by taking advantage of a unique longitudinal medical records database in the USA.

Methods We compiled a daily weather and clinic visit data set based on data from a health centre in Colorado for the summer of 2013. A total of 14 481 patients were included in our analysis, including 150 migrant farmworkers and 231 seasonal farmworkers with an average of 3 and 4 visits per day. We used Poisson regression to estimate the associations between heat and daily all-cause or cardiovascular-specific clinic visits among migrant or seasonal farmworkers or other stratified patients. We defined heat effects as the percentage difference in average daily counts of clinic visits, comparing 90–50th centiles of daily mean apparent temperature, a composite index accounting for both temperature and humidity. We conducted a sensitivity analysis to evaluate the impact of adjustment for ozone levels and different heat definitions.

Results Estimates of heat effects on average daily clinic visits among migrant farmworkers were positive (88.0%, 95% CI: 26.2% to 180.0%). We did not observe statistically significant associations between heat and clinic visits among other stratified groups.

Conclusions Our study appears to be the first to link heat effects with clinic data among migrant and seasonal farmworkers. This research suggests possible significant impact of heat on migrant farmworkers and provides justifications for further studies.

What this paper adds

- Little is known about the effect of heat on migrant and seasonal farmworkers.
- Effect estimates of heat on clinical visits among migrant farmworkers are positive.
- This research provides justifications for making regulations and developing heat preventive programs among migrant farmworkers.

INTRODUCTION

Heat has been reportedly linked to the increased risk of a variety of mortality and morbidity outcomes, and has a disproportionate impact on outdoor labourers, children, the elderly, racial and ethnic minorities, the poor and people with pre-existing diseases.[1 2] Farmworkers in the USA are vulnerable to heat partly because 85% of agricultural workers in the USA work outside according to the 2010 National Health Interview Survey.[3] Also, farmworkers are usually engaged in heavy work, which makes it more difficult for the body to support heat loss. For example, the average annual rate of heat-related deaths for crop workers was 0.39 per 100 000 workers, and crop workers contributed 16% of total heat-related deaths in 1992–2006.[4 5] Mirabelli and Richardson[6] examined death certificates during 1977–2011 with heat as the primary cause of death in North Carolina, and reported that farmworkers accounted for 40% of occupational heat-related fatalities.

Migrant and seasonal farmworkers are likely more susceptible to heat than other workers because poverty, an aging population, limited health insurance coverage and illegal working authorisations 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 past 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.[7] According to the National Agricultural Workers Survey 2001–2002, approximately 42% and 58% of 6472 interviewed crop farmworkers were identified as migrant or seasonal farmworkers, respectively.[8] The migrant and seasonal farmworker population remains one of the most impoverished and underserved,[9] is aging with varying proportions of older workers by region[10] and most are ineligible for healthcare coverage. In 2010, approximately 70% of adult farmworkers were uninsured.[11] When this is coupled with frequent mobility, it impedes access to adequate healthcare.[12]

Research on the effects of heat among migrant and seasonal farmworkers is very limited. Mirabelli *et al*[13] reported that 94% and 40% of participants reported working in extreme heat and experiencing heat-related symptoms, respectively. Bethel and Harger[14] showed that approximately 30% of participants reported having at least two heat-related symptoms. Fleischer *et al*[15] interviewed 405 migrant farmworkers in Georgia and reported

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one-third of participants experiencing three and more heat-related symptoms. They also identified several factors that potentially reduce heat-related illness, including increasing breaks in the shade, increasing access to medical attention, reducing soda intake or increasing access to regular breaks. Lam *et al*[16] interviewed 35 Hispanic farmworkers in Washington and identified several barriers to prevent them from heat-related illness. To the best of our knowledge, no studies examined heat effects among migrant and seasonal farmworkers using clinical data.

By taking advantage of the Community-Based Research Network (CBRN), a unique longitudinal medical records database, this study aims to examine heat effects on clinic visits and to evaluate what factors affect the heat clinic visit associations. Funded by the National Institute of Environmental Health Sciences, CBRN built the infrastructure to securely import and merge electronic health records (EHRs) data from five Community and Migrant Health Centres (C/MHCs) across the US to build the first longitudinal database among migrant and seasonal farmworkers in the USA.[17]

METHODS

Data sources

Clinical data

This study obtained EHRs data from one health centre in Colorado that participated in CBRN during the summer of 2013 (1 June to 31 August). Original patient health records included variables to identify migrant farmworkers, seasonal workers others based on the forms they filled. We created a new variable called 'other patients' to represent patients identified as neither migrant nor seasonal farmworkers for comparison purposes. Patient data also included gender and age. Both elective and non-elective visits were included in this study mainly due to the sample size reason because daily counts of acute visits were less than 1 on average. International Classification of Diseases Ninth revision (ICD-9) codes were used in diagnosis. All-cause daily counts of patient visits by patient type and gender were used for data analysis. Daily counts of clinic visits were further classified into cardiovascular diseases (CVD; ICD-9, 390–429), and other causes were not considered in this study because of their small sample size. This study was approved by the Committee for the Protection of Human Subjects of the University of Texas Health Science Center at Houston (HSC-SPH-14-0379).

Weather and air pollution data

Hourly weather data at the station located in the airport close to the centre during the summer of 2013 were downloaded from the National Climate Data Center (NCDC) through the Integrated Surface Database (ISD).[18] We calculated daily maximum, mean and minimum temperatures, and mean apparent temperature (meAT) for each day. Apparent temperature accounts for both temperature and humidity, and has been suggested as the most predictive weather parameter related to heat-caused mortality.[19] We used a 2-day moving average of meAT as the metric of heat exposures. Previous studies suggest heat effects were immediate and the temperature exposures on the same day and the previous day are commonly used to quantify heat effect.[19–22]

We obtained hourly ozone measurements over the study period from three US Environmental Protection Agency's (EPA) monitors close to the center, through the EPA's Air Quality System.[23] Ozone is a secondary pollutant and is formed through photochemical reactions in the air. We calculated daily ozone concentrations by averaging measured ozone levels across three monitors.

Statistical analysis

We linked clinic visits data, ozone and weather observations data by date. We used a time-series analysis to investigate the association between 2-day moving averages of meAT and daily clinic visits, by patient characteristic and using data on summertime clinic visits (1 June, 2013–31 August, 2013). We applied generalised additive models (GAMs) to model daily counts of clinic visits as a function of 2-day moving average of meAT while adjusting for time trends and weekly patterns by including terms for both day of the week and day of the year (see equation (1)). Daily counts of clinic visits were assumed to follow a quasi-Poisson distribution to account for overdispersion. GAMs were fit using the 'mgcv' R package (V.3.1.2) in the R statistical software (R Development Core Team; http://R-Project.org).

We modelled 2-day moving averages of meAT and clinic visits assuming daily counts of clinic visits following an over-dispersed Poisson distribution as:

$$\mathrm{Log}[E(Y_t)] = \alpha + \mathrm{ns}(\mathrm{meAT}_{t,t-1},\ 3) + \mathrm{ns}(\mathrm{DOY}_t,\ 3) + \beta \mathrm{DOW}_t \quad (1)$$

where Y_t is the number of visits on day t; α is the intercept; ns, natural cubic splines; meAT (degrees of freedom (df)=3); DOY_t represents day of the year (df=3); DOW_t represents day of the week for day t. We summarised heat effects in clinic visits by comparing 90th–50th centiles of meAT. Additionally, we also explored two more definitions of heat effects by comparing 95th and 97th–50th centiles of meAT to examine how our results varied with different definitions of heat effects.

Sensitivity analysis

We conducted sensitivity analyses to evaluate whether estimated heat effects on clinic visits varied with adjustment for ozone and with the degrees of freedom of *day of the year* for migrant and seasonal farmworkers. We included the same-day ozone concentration with daily counts of clinic visits. Moreover, we chose df of 2, 4, 5 and 6 for the time trends compared to three in our default setting. Finally, we found an outlier record of migrant farmworkers with a total of 27 visits much higher than the average of 2.8 visits per day. We repeated our analyses based on the data set excluding this outlier.

RESULTS

A total of 14 481 patients went to the clinics of the Colorado center during the study period. Among them, there were 8421 males and 6060 females, 150 migrant farmworkers, and 231 seasonal farmworkers. The elderly only accounted for 4.0%, 5.3% and 5.2% for all patients, migrant and seasonal farmworkers, respectively. Hispanics contributed to 62.0%, 88.7% and 86.6% for all patients, migrant and seasonal farmworkers.

Table 1 shows the summary of weather parameters, ozone and patient characteristics over the study period. The study area had a cool but dry summer shown by the average daily mean temperature (21.9°C) and dew point temperature (7.8°C). Average daily ozone concentrations ranged from 0.036 to 0.074 ppm. A small proportion of patients were migrant or seasonal farmworkers as shown by the averages of daily counts of clinic visits for migrant, seasonal farmworkers and others (2.8, 4.4 and 267.0, respectively). Approximately half of migrant

Table 1 Descriptive statistics for weather, air pollution and patient characteristic during summertime (June–August) 2013 in a health centre in Colorado

Variable description	Variable name	Unit	Means (ranges)
Daily mean temperature	meTMP	°C	21.9 (12.5–26.4)
Daily mean apparent temperature	meAT	°C	20.4 (10.8–25.2)
Daily mean dew point	meDWP	°C	7.8 (−1.4–15.0)
Daily mean ozone	meO_3	ppm	0.058 (0.036–0.074)
Daily counts of clinic visits among migrant farmworkers	Mig	Counts	2.8 (0.0–27.0)
Daily counts of clinic visits among male migrant farmworkers	MigM	Counts	1.4 (0.0–23.0)
Daily counts of clinic visits among female migrant farmworkers	MigF	Counts	1.4 (0.0–5.0)
Daily counts of clinic visits among seasonal farmworkers	Seas	Counts	4.4 (0.0–19.0)
Daily counts of clinic visits among male seasonal farmworkers	SeasM	Counts	1.6 (0.0–9.0)
Daily counts of clinic visits among female seasonal farmworkers	SeasF	Counts	2.8 (0.0–12.0)
Daily counts of clinic visits among other patients	Oth	Counts	267.0 (14.0–540.0)
Daily counts of clinic visits among male other patients	OthM	Counts	107.9 (6.0–201.0)
Daily counts of clinic visits among female other patients	OthF	Counts	151.9 (3.0–334.0)
Daily counts of CVD-specific clinic visits among all patients	CVD	Counts	11.4 (0.0–60.0)

CVD, cardiovascular disease.

farmworkers and one-third of seasonal farmworkers were male. CVD-specific clinic visits were 11.4 visits per day on average.

Figure 1A (see online supplementary table S1) shows that heat had a positive effect on migrant farmworkers and tobacco users. The estimated per cent increases in patient visits by comparing 90th–50th centiles of meAT for migrant, seasonal farmworkers and other patients were 88.0% (95% CI 26.2% to 180.0%), −2.4% (95% CI −29.3% to 34.8%) and 8.2% (95% CI −3.3% to 20.9%), respectively. The estimate of heat effects for CVD-specific visits among all patients was −20.2% (95% CI −45.8% to 17.5%). For migrant farmworkers, heat had a stronger association for males, and their risk of going to a clinic increased by 118.1% on hot days compared to normal days. Figure 1B, C (see online supplementary table S1) show that the estimates of heat effects increased slightly with more strict heat definitions, for example, for migrant farmworkers, the estimated per cent increases of excess risk on patient clinic visits were 88.0%, 105.7% and 118.4% by comparing 90th/95th/97th–50th centiles of apparent temperature, respectively.

The sensitivity analysis shows that our results were robust with adjustment for ozone (O_3) (figure 2). For example, for migrant farmworkers, the estimated per cent increases of excess risk on patient clinic visits were 88.0% without adjustment for O_3 and 92.6% with adjustment for O_3, respectively. Table 2 indicates that effect estimates generally decreased with increased df. The statistically significant effect estimates on heat among migrant farmworkers became not statistically significant with the degrees of freedom equal to or above 5. The analysis without the outlier shows that the estimates of heat effects among total, male and female migrant farmworkers were 20.8% (95% CI −23.6% to 90.9%), −4.8% (95% CI −49.5% to 79.5%) and 47.6% (95% CI −18.1% to 165.8%), respectively.

DISCUSSION

This study explored the impact of heat on clinical encounters among an extremely vulnerable population: migrant and seasonal farmworkers, using clinical data in an area with mild weather. Farmworkers usually work outside in the heat of summer while often performing heavy tasks. Although heat likely poses a significant health risk for them, it has been rarely studied, particularly among migrant and seasonal farmworkers mainly because available data are very limited. By taking advantage of a recent established research network on migrant farmworkers, we have a few novel findings. Mean daily temperature had statistically significant associations with daily counts of clinical encounters among migrant but not seasonal farmworkers.

The finding of positive effect estimates relating heat to clinical encounters among migrant but not seasonal farmworkers may be explained by four possible reasons. First, this result corresponds with findings previously reported that focus on the living environment for migrant farmworkers as being worse than the living conditions of seasonal farmworkers, who usually live in their home. Migrant farmworkers generally live in inexpensive apartments, mobile homes or temporary housing with poor living conditions. Arcury *et al*[24] reported that migrant farmworker housing regulation violations in North Carolina had at least four total violations for every camp, with 60.1% having 10–14 total violations, and 14.2% having 15–22 violations. At the national level, a report by the National Center for Farmworker Health (NCFH) found that housing for migrant

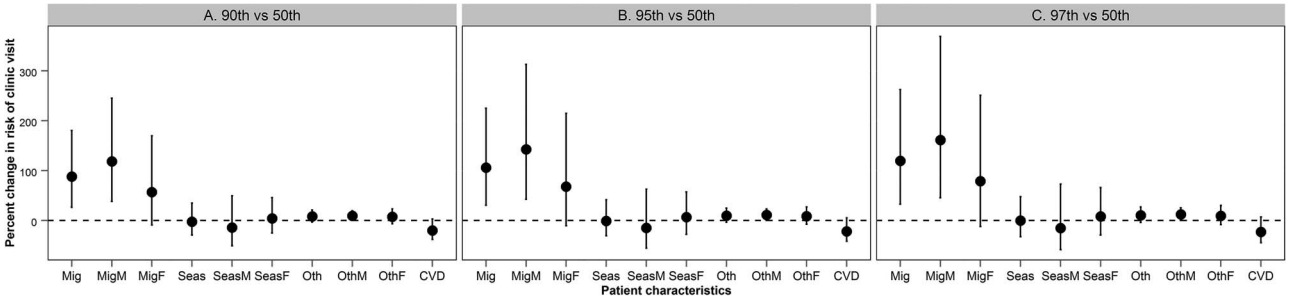

Figure 1 The per cent change in risk of clinic visit and 95% CIs for Mig, MigM, MigF, Seas, SeasM, SeasF, Oth, OthM, OthF and CVD for 2-day moving average meAT. Estimated per cent changes in clinical visits associated with 90th vs 50th, 95th vs 50th, and 97th vs 50th centiles of meAT. All models are adjusted for day of week and day of year. CVD, cardiovascular diseases; meAT, mean apparent temperature.

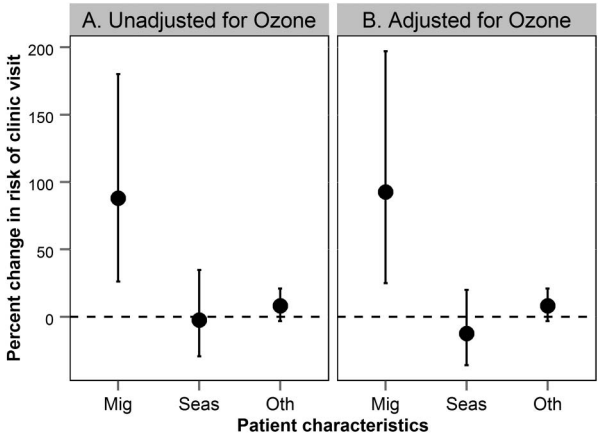

Figure 2 The per cent change in risk of clinic visit and 95% CIs for Mig, Seas and Oth, for 2-day moving average meAT. Estimated per cent changes in clinical visits associated with 90th vs 50th centile of meAT. All models are adjusted for day of week and day of year. (A) No air pollution adjustment, (B) adjustment for daily mean ozone concentration. meAT, mean apparent temperature.

farmworkers is often substandard and non-existent due to high rates of poverty and they generally endure abuses from landlords.[25] 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.[26] Considering the summer was not too hot, the availability of air conditioning is not likely a major factor to explain the discrepancy of heat effect estimates between migrant and seasonal farmworkers. Second, migrant farmworkers generally lack family support for prolonged periods of time due to their complex employment status.[27] Also, due to other circumstances, many may choose to leave their family behind so that their children continue attending the same school.[28] Third, farmworkers are among one of poorest groups, and poverty has been shown one of vulnerability factors for heat.[1] According to the National Agricultural Workers Survey from 2007 to 2009, the average individual and family income for farmworkers ranged from $12 500 to $14 999 and $17 500 to $19 999, respectively.[29] Fourth, migrants' immigration status may make them more vulnerable to labour 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 to 2002 shows that 53% of farmworkers nationally were undocumented.[8] Mirabelli *et al*[13] 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*[30] reported that workers with H-2A visas experience better conditions and practice more safety behaviours than do workers who do not have H-2A visas. Farmworkers with H-2A visas may work for agricultural employers seeking to hire temporary agricultural workers, usually in relation to the production and/or harvesting of a crop, or for a limited time period of less than one year when an employer can show that the need for the foreign workers(s) is truly temporary.[31]

Table 2 Sensitivity analysis on the df for time trend on the heat effects (per cent change in clinical visits by comparing 90th vs 50th centiles of meAT) by patient groups

Patient categories	df	Heat effects (95% CI)
Migrant	2	104.9 (41.3 to 196.9)
	3	88.0 (26.2 to 180.0)
	4	59.9 (7.0 to 139.1)
	5	40.0 (−10.1 to 117.8)
	6	42.0 (−9.1 to 121.8)
Seasonal	2	−3.0 (−27.2 to 29.3)
	3	−2.4 (−29.3 to 34.8)
	4	−16.2 (−38.0 to 13.2)
	5	−10.8 (−35.4 to 23.0)
	6	−10.8 (−35.5 to 23.5)

df, degrees of freedom; meAT, mean apparent temperature.

This study has several strengths with its focus on heat and health among an extremely vulnerable population that works in hot outdoor environments. First, this research utilises a unique prospective longitudinal medical records database. This database is, to the best of our knowledge, the first such clinical database on migrant and seasonal farmworkers in the USA. Second, findings likely reflect a minimum effect as the average daily temperature range only went to a high of 26.4°C, and provide insights for other states where migrant farmworkers have similar demographic characteristics and may work in even hotter climates with a larger number of farmworkers, and to other outdoor workers who are also exposed to heat on the job. Finally, this research provides justifications for making regulations and developing heat preventive programmes among migrant farmworkers. Culp *et al*[32] pointed out that current federal regulations are not sufficient to prevent migrant and seasonal farmworkers from heat-related illness and discussed culturally appropriate preventive strategies for Hispanic farmworkers.

This study has a few limitations. One limitation is that our study period includes only one summer given its pilot nature. This database is currently being expanded longitudinally in Colorado and other areas across the US. The second limitation is that our study includes both elective and non-elective visits. Non-elective visits are more likely affected by exposures to heat. Thus, the 'true' heat effects among migrant and seasonal farmworkers are likely larger than the estimates derived in this study. The third limitation is that this study does not explore geographic variability because we only examined data from one centre. We plan to use a data set covering a longer duration of time and data from multiple centres in our following research. The fourth limitation is heat exposure misclassifications because this study used temperature and ozone measurements from a single weather station and three ozone monitors rather personal exposures to temperature and ozone. Personal measurements of exposures are usually not feasible for such epidemiological studies because of cost and logistic reasons. The fifth limitation is that timing of visits may be influenced by crop calendar. However, we do not have information to assess this because of the lack of job information of farmworker patients and varying size of farmworkers by crop-specific calendar. The last limitation is that this study does not explore some individual characteristics such as race/ethnicity and age among migrant and seasonal farmworkers because the sample size in this initial study did not allow us to perform such analyses. For example, Hispanics accounted for 88.7% and 86.6% of migrant and seasonal farm workers; and elderly represented 5.3% and 5.2% of migrant and seasonal farmworkers, respectively. However, considering that migrant and seasonal farmworkers are vulnerable to heat stress, little is known about how heat affects their health,[32] and the population is challenging to access, this study can provide

insights to researchers, public health officials and practitioners to identify risk factors and ultimately inform interventions to prevent heat-related health effects among farmworkers and other outdoor workers.

CONCLUSION

This study demonstrates the first application of exploring heat effects on a vulnerable population by taking advantage of the first clinical database on migrant and seasonal farmworkers in the USA, to the best of our knowledge. We first found that heat has a positive impact on excess risk of clinic visits for migrant but not seasonal farmworkers. 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 of the limitations discussed above, this research provides justification for future studies with large sample size to explore the aetiological mechanisms associated with heat among migrant and seasonal farmworkers.

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Contributors KZ designed and drafted the manuscript. RA and T-HC performed all analyses and participated in the revisions of the manuscript. SPC designed the study and participated in the revisions of the manuscript. All authors read and approved the final manuscript.

Competing interests None declared.

Ethics approval This study was approved by the Committee for the Protection of Human Subjects of the University of Texas Health Science Center at Houston (HSC-SPH-14-0379).

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REFERENCE

1 Gronlund CJ. Racial and socioeconomic disparities in heat-related health effects and their mechanisms: a review. *Curr Epidemiol Rep* 2014;1:165–73.
2 O'Neill MS, Ebi KL. Temperature extremes and health: impacts of climate variability and change in the United States. *J Occup Environ Med* 2009;51:13–25.
3 Calvert GM, Luckhaupt SE, Sussell A, *et al*. The prevalence of selected potentially hazardous workplace exposures in the US: findings from the 2010 National Health Interview Survey. *Am J Ind Med* 2013;56:635–46.
4 Jackson LL, Rosenberg HR. Preventing heat-related illness among agricultural workers. *J Agromedicine* 2010;15:200–15.
5 Luginbuhl R, Jackson L, Castillo D, *et al*. Heat-related deaths among crop workers—United States, 1992–2006. *JAMA* 2008;300:1017–8.
6 Mirabelli MC, Richardson DB. Heat-related fatalities in North Carolina. *Am J Public Health* 2005;95:635–7.
7 The Public Health and Welfare, 42 U.S.C. § 254b (2010).
8 U.S. Department of Labor. Findings from the National Agricultural Workers Survey (NAWS) 2001–2002: a Demographic and Employment Profile of United States Farm Workers. Date published: March 2005. http://www.doleta.gov/agworker/report9/naws_rpt9.pdf (accessed 16 Jul 2015).
9 Kandel W. *Profile of hired farmworkers: a 2008 update*. Economic Research Report No. 60. Economic Research Service, U.S. Department of Agriculture, 2008.
10 Weigel MM, Armijos RX. Exploratory study of the occupational health and health-seeking of migrant and seasonal farmworkers on the U.S.-Mexico border. *J Immigr Minor Health* 2012;14:648–56.
11 NCFH (National Center for Farmworker Health). A Profile of Migrant Health: 2010. 2014. http://www.ncfh.org/fact-sheets--research.html (accessed 14 Jul 2015).
12 Rosenbaum S, Shin P. *Migrant and seasonal farmworkers: health insurance coverage and access to care*. Issue paper no. 7314. Washington DC: Kaiser Commission on Medicaid and the Uninsured; Date published: 29 April 2005.
13 Mirabelli MC, Quandt SA, Crain R, *et al*. Symptoms of heat illness among Latino farm workers in North Carolina. *Am J Prev Med* 2010;39:468–71.
14 Bethel JW, Harger R. Heat-related illness among Oregon farmworkers. *Int J Environ Res Public Health* 2014;11:9273–85.
15 Fleischer NL, Tiesman HM, Sumitani J, *et al*. Public health impact of heat-related illness among migrant farmworkers. *Am J Prev Med* 2013;44:199–206.
16 Lam M, Krenz J, Palmández P, *et al*. Identification of barriers to the prevention and treatment of heat-related illness in Latino farmworkers using activity-oriented, participatory rural appraisal focus group methods. *BMC Public Health* 2013;13:1004.
17 Cooper SP, Heyer N, Shipp EM, *et al*. Community based research network: opportunities for coordination of care, public health surveillance, and farmworker research. *Online J Public Health Inform* 2014;6:e190.
18 NCDC (National Climate Data Center). Integrated Surface Database. 2013. http://www.ncdc.noaa.gov/isd (accessed 6 Apr 2015).
19 Zhang K, Li Y, Schwartz JD, *et al*. What weather variables are important in predicting heat-related mortality? A new application of statistical learning methods. *Environ Res* 2014;132:350–9.
20 Anderson BG, Bell ML. Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. *Epidemiology* 2009;20:205–13.
21 Hajat S, Kosatky T. Heat-related mortality: a review and exploration of heterogeneity. *J Epidemiol Community Health* 2010;64:753–60.
22 Zhang K, Chen YH, Schwartz JD, *et al*. Using forecast and observed weather data to assess performance of forecast products in identifying heat waves and estimating heat wave effects on mortality. *Environ Health Perspect* 2014;122:912–18.
23 U.S. EPA (U.S. Environmental Protection Agency). Air Quality System. Daily Summary Data. 2013. http://www.epa.gov/airquality/airdata/ad_data_daily.html (accessed 9 Jun 2015).
24 Arcury TA, Weir M, Chen H, *et al*. Migrant farmworker housing regulation violations in North Carolina. *Am J Ind Med* 2012;55:191–204.
25 NCFH (National Center for Farmworker Health). Farmworker health fact sheet. 2012. http://hapgj.org/wp-content/uploads/2012/03/Factsheet-about-Farmworkers.pdf (accessed 1 Apr 2015).
26 O'Neill MS, Zanobetti A, Schwartz J. Disparities by race in heat-related mortality in four US cities: the role of air conditioning prevalence. *J Urban Health* 2005;82:191–7.
27 Alderete E, Vega W, Kolody B, *et al*. Depressive symptomatology: prevalence and psychosocial risk factors among Mexican migrant farmworkers in California. *J Community Psychol* 1999;27:457–71.
28 Health Outreach Partners. Chapter 1: understanding Farmworkers. Outreach Reference Manual 2nd Edition. 2013. https://www.outreach-partners.org/docs/Chapter%201%20-%20HOP%20FINAL.pdf (accessed 6 Jul 2015).
29 Carroll D, Georges A, Saltz R. Changing Characteristics of U.S. Farm Workers: 21 Years of Findings from the National Agricultural Workers Survey. 2011. https://migrationfiles.ucdavis.edu/uploads/cf/files/2011-may/carroll-changing-characteristics.pdf. (accessed 19 Jun 2015).
30 Whalley LE, Grzywacz JG, Quandt SA, *et al*. Migrant farmworker field and camp safety and sanitation in eastern North Carolina. *J Agromedicine* 2009;14:421–36.
31 U.S. Department of Labor. Work Authorization for Non-U.S. Citizens: Temporary Agricultural Workers (H-2A Visas). 2009. http://www.dol.gov/compliance/guide/taw.htm (accessed 6 Jul 2015).
32 Culp K, Tonelli S, Ramey SL, *et al*. Preventing heat-related illness among Hispanic farmworkers. *AAOHN J* 2011;59:23–32.

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