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Are Cal/OSHA Regulations Protecting Farmworkers in California From Heat-Related Illness?

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Ethical Considerations & Disclosures: The University of California, Davis Institutional Review Board approved the study protocols. Workers provided written consent before participating in the study.

Clinical significance: Whereas previous studies used questionnaires to assess risk of heat-related illness (HRI), this is the first study to objectively estimate HRI risk in farmworkers using physiological measurements. Further, this paper is the first to evaluate compliance with and effectiveness of California heat illness prevention standard.

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Abstract

Objective: Determine compliance with and effectiveness of California regulations in reducing farmworkers' heat-related illness (HRI) risk and identify main factors contributing to HRI.

Methods: In a cross-sectional study of Latino farmworkers, core body temperature (CBT), work rate, and environmental temperature (WBGT) were monitored over a work shift by individual ingestible thermistors, accelerometers, and weather stations, respectively. Multiple logistic modeling was used to identify risk factors for elevated CBT.

Results: Although farms complied with Cal/OSHA regulations, worker training of HRI prevention and hydration replacement rates were insufficient. In modeling (AOR [95% CI]) male sex (3.74 [1.22 –11.54]), WBGT (1.22 [1.08 – 1.38]), work rate (1.004 [1.002 – 1.006]), and increased BMI (1.11 [1.10 – 1.29]) were all independently associated with elevated CBT.

Conclusion: Risk of HRI was exacerbated by work rate and environmental temperature despite farms following Cal/OSHA regulations.

Keywords

environmental temperature; heat-related illness; immigrant farmworkers; work rate; occupational health; worker protections

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Heat-related illness (HRI) is a serious occupational health risk for California farmworkers, whose peak work season coincides with elevated summer temperatures and may involve prolonged and strenuous outdoor labor.[1–3] Deaths in US crop workers attributable to HRI average about five per year and occur at a rate 20 times higher than for all civilian workers.[3] California supplies the US with a diverse range of fruit and vegetable products[4] courtesy of over 400,000 full-time equivalent farmworkers (as many as 829,000 individuals)[5] of whom more than 90% are Latino, Spanish-speaking immigrants.[6]

There are still no federal heat standards to lower the risk of HRI, despite the National Institute of Occupational Safety and Health (NIOSH) publishing a criteria document in 1972, updating it in 1986, and again in 2016.[7] The California Division of Occupational Safety and Health (DOSH), more commonly referred to as Cal/OSHA, initiated emergency regulations in August 2005 after four farmworkers died that summer from HRI.[8,9] Further regulations were added as the number of deaths of farmworkers rose above 14 between 2005[10] and 2015.[11]

Unfortunately, prevalence of HRI is not systematically recorded in the occupational setting, and therefore not quantified.[2,12] Farms with fewer than 11 employees are not required to report HRI, and the Bureau of Labor Statistics only counts incidences when there has been at least one day's work lost.[13] In 2016, 3310 incidences of HRI were recorded across the USA, but only 40 cases were reported from the agriculture, forestry and fishing sector.[14] Despite the dearth of official figures, surveys of workers indicate HRI symptoms are common: 40% of farmworkers exposed to high heat over a work season in North Carolina experienced HRI.[15] When asked to recall HRI symptoms over the last week, prevalence ranged from 31% in Washington[16] to 84% in Florida.[17] Immigrant farmworkers will often suffer through HRI rather than report it as they do not want to be fired for being perceived as a bad worker, lose income, or let down coworkers, especially if they are being paid by piece rate rather than by time.[18,19]

Current Cal/OSHA regulations,[9] based on federal OSHA recommendations,[20] originate from data collected from military personnel, firefighters, and athletes, with limited applicability to agriculture.[21] The California Heat Illness Prevention Study (CHIPS)[1] collected objective data on the physiological responses of farmworkers to environmental heat across the spectrum of agricultural facilities and tasks that are present in the state. This analysis examines the compliance with and effectiveness of Cal/OSHA regulations and recommendations in protecting farmworkers from the risk of HRI and identifies the factors contributing to HRI.

METHODS

This cross-sectional study was conducted over the summers of 2014 and 2015 in the California Central and Imperial Valleys. A convenience sample of Latino farmworkers was recruited through farms and farm labor contractors (FLCs). Physiological and questionnaire data were collected over a single work shift for each participant with corresponding weather data from the work site. Further details of the study methods have been previously reported.[1] The University of California, Davis Institutional Review Board approved the study protocols.

Participation

A bilingual, bicultural field team recruited and monitored participants. Interviewers administered questionnaires to each participant, pre- and post-shift. The workers had to self-identify as Latino and be able to communicate in Spanish or English, be 18 years old or older, and work outdoors for at least five hours. Workers were excluded if they spent extensive time driving or working in air-conditioned spaces. Pregnant workers, those with an elevated body temperature at the start of the shift, or gastrointestinal upset were also excluded. Participants could withdraw at any time once recruited and could refuse to answer any questions. Workers who completed the full day of study participation were compensated for their time and effort.

Data Development and Cleaning

The primary objectively measured variables of interest and their derivatives are detailed in Table 1, including core body temperature (CBT), work rate, weight, height, and wet bulb globe temperature (WBGT). Details of data cleaning are provided in previous papers.[1,22] We used the maximum CBT reached at work, derived from the three-minute moving medians of CBT, as a summary measure of heat strain. If the maximum CBT reached or exceeded 38.58C, the subject was classified as at-risk of HRI (elevated CBT).[23–25] As an indicator of work rate, we calculated the three-minute moving mean, median, and maximum counts per minute (cpm) for each individual's work shift. A 1.5% change in body weight across the work shift was used as a proxy for dehydration.[24,26,27] High-heat days were categorized by maximum temperature (< or ≥ 35°C) as well as timing of work shift (normal shift or ended by 2 PM).

Participants described work conditions including availability of water, shaded rest breaks, restrooms, and any impediments to their use via interviewer-administered questionnaires (Table 2). Other information collected included demographic variables, hiring type (directly by farmer or FLC), pay type (hourly, salary, or any type of piece rate), length of time working in agriculture, whether they had ever been ill due to the heat, and if so, their symptoms. Workers self-reported the crop on which they worked and the tasks they undertook. Study staff audited approximately 70% of workers during the shift to verify the self-report. The study exposure specialist categorized the tasks. Using the recommendation to drink two 8-oz cups of water per hour when temperature less than 26.7°C (80°F) and three to four 8-oz cups when temperature greater than or equal to 26.7°C,[28] the hydration deficit was calculated using the recommended and self-reported volumes.

Statistical Analyses

Farms' compliance to Cal/OSHA heat illness regulations was determined by workers' questionnaire responses. Univariate associations between various demographic, occupational, and workplace characteristics and elevated CBT were estimated. A similar analysis was conducted comparing hiring type (direct or FLC) as varying hiring types differ in worker management which could impact risk of HRI. For categorical variables, tests of association were carried out using Pearson Chi-square tests except for small marginal counts when Fisher's exact test was used. For comparisons involving continuous variables, *t* test was used except for non-normally distributed variables when Wilcoxon tests were used.

Multiple logistic regression models were constructed with elevated CBT. Variables included in the models were those thought likely to be associated with elevated CBT, according to our review of the literature, as well as those exhibiting univariate associations ($P \leq 0.10$) with the dependent variable. The variables examined included: mean work rate, BMI, age, gender, median WBGT, dehydration, education, years worked in agriculture, piece-rate work, employer type, shift length, task, knowledge of HRI, previous HRI, and clothing level. We built the final logistic regression models to include age and gender and a selection of these additional candidate variables. Candidate variables that were not statistically significant ($P \leq 0.10$) were removed, and each removed variable was re-evaluated for inclusion in the final model. Models report the Adjusted Odds Ratio (AOR) and 95% confidence intervals (CI) and contain all independent variables listed in the appropriate table. Candidate interactions were tested between age, WBGT, work rate, and where relevant BMI, gender, and dehydration. Interactions were included if their *P* value was less than 0.05. All statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc.; Cary, NC). These analyses are the basis of discussing the effectiveness of HRI prevention regulations on farms in California.

RESULTS

In total, 587 farmworkers on 30 farms throughout the California Central and Imperial Valleys participated over the summers of 2014 and 2015. New high-temperature regulations came into effect in the summer of 2015, but we did not assess compliance. After data cleaning, 507 (86%) participants were included in analyses.

Compliance of Study Farms With Heat Standard

Based on workers' questionnaire responses, all of the farms complied with regulations as of 2014. However, farms' HRI prevention plans, monitoring acclimatizing workers, and the 2015 high-heat protections were not assessed. The main Cal/OSHA regulations are described in Table 3, notably the provision of water, shade, and rest periods and training workers about heat illness symptoms and prevention.

Almost all (99%) workers reported employers provided sufficient cool, clean water; only 4% mentioned they had a problem with provided water. In addition, 87% said that the water always moved with them. Shade provisions were similarly nearly universally available, although the workers did not always choose to use them. If workers feel unwell in the heat, regulations mandate additional rest and recovery periods; 97% of workers felt comfortable asking for at least a 5 min break to recover from HRI symptoms. California requires a lunch period after working four hours unless the shift is five hours or less; 93% of workers took a lunch break greater than or equal to 10 min. Only four workers (1%) took no lunch break. Other than their lunch, 15% did not take further rest breaks. As an approximate measure of acclimatization, 95% of the workers had worked at least 15 days that season and at least five days in the previous two weeks. Although 86% received training on HRI prevention within the previous year, only 42% correctly chose the length of time it takes a worker to acclimatize to the heat, and 42% knew how often and how much water they should consume at work.

Differences in Outcome Measures by Hiring Type

In California, workers are generally either hired directly by the farm or through an FLC that is responsible for the working conditions, pay, and training. In our sample, 47.5% were farm-hired and 52.5% were FLC-hired. We separated analyses by sex as FLC teams were either entirely female or mixed gender, whereas the farm hires were sometimes exclusively male. Women were more likely to be hired through an FLC (P=0.009).

Comparing the two management systems revealed 10% of direct farm hires versus 3.7% of FLC hires experienced elevated CBT. Although male FLC workers were less knowledgeable about HRI prevention, and more likely to be paid by the piece, male farm hires were more likely to experience an elevated CBT (13.3% v 4.9% respectively, P=0.01). In women, differences in work culture and physiology were generally not significant when comparing farm and FLC hires, although female farm hires took fewer breaks than women directly hired through FLCs (P=0.049). The biggest differences were between men and women regardless of hire type, with women less knowledgeable about HRI risk (P=0.004). Women worked fewer years in agriculture (P<0.0001), had lower mean work rate (cpm) over their shift (P<0.0001), and consumed less water and total beverages than men (P<0.0001).

Univariate Associations With Elevated CBT

Of the 35 participants who experienced an elevated CBT (Table 4), only four were women (P=0.002). Workers are at higher risk of elevated CBT if they are employed directly by the farm (P=0.005), if their hydration level decreased (percentage loss in weight, P=0.003), and if they reported consuming fewer beverages (P=0.02). The risk of elevated CBT was positively associated with the mean work rate (P<0.0001) and with the median WBGT (P=0.01). Workers with a higher BMI (P=0.02) or higher educational level (P=0.04) were more likely to experience higher CBT.

Characteristics Associated With Elevated CBT

Table 5 describes the multiple logistic model of characteristics associated with elevated CBT. For the complete set of data (all temperatures), (AOR [95% CI]) male sex (3.74 [1.22 – 11.54]), median WBGT (1.22 [1.08 – 1.38]), mean work rate (1.004 [1.002 – 1.006]), and BMI (1.11 [1.10 – 1.29]) were independently associated with elevated CBT. Age was not statistically associated with an elevated CBT. After restricting the model to workers who experienced dry bulb temperatures greater than or equal to 35°C, sex was no longer associated with elevated CBT but the AOR increased for median WBGT (1.42 [1.10 – 1.83]), mean work rate (1.005 [1.002 – 1.009]), and BMI (1.17 [1.02 – 1.33]).

DISCUSSION

Although the farms were a convenient sample throughout the main agricultural areas of California, the study subjects are a reasonable representation of the California farmworker population based on a comparison to a population-based sampling conducted by the National Agricultural Workers Study (NAWS) 2013–2014 in California.[1]

Cal/OSHA Training Regulations

As study farms cooperated and allowed workers to participate, the high compliance rates for HRI regulations outlined in Table 3 are expected. The one area where farms and FLCs were less successful was training their workers. Farmworkers in this study lack understanding and knowledge of the major HRI risks; only 14.2% correctly answered all questions regarding personal risk factors, acclimatization, and recommended water consumption, indicating that trainings were insufficient. This may be because over half have less than a 6th grade education. Reinforcement or evaluation of workers' understanding, and monitoring of subsequent behavior change, was rarely carried out (and not required in the regulations). Even those who knew the rules did not necessarily obey them. Nearly 60% of workers with an elevated CBT scored in the moderate to good range on HRI prevention knowledge but were also likely be less hydrated over the shift (P=0.003). Furthermore, the power structure dynamics on farms (especially piece-rate pay) makes self-care decisions difficult and expensive for farmworkers.[18,19] Trainings need to be tailored to lower education levels, and should include comprehension checks to ensure workers understand, remember, and apply preventative actions. Field supervisors are key to model healthy behaviors and remind workers of safety procedures.

HRI Risk Assessment: Elevated CBT

While unacclimatized workers account for 50% or more of recorded HRI-incidences and deaths,[10] study workers were nearly all acclimatized. Still, almost 7% of these acclimatized workers were at higher risk of HRI as assessed by elevated CBT. With an estimated 829,000 farmworkers in California,[5] 7% translates to 58,000 workers at risk of elevated CBT. Risk of HRI is likely to be even higher on less compliant facilities. Additionally, ambient temperature is very likely to further rise, further increasing the risk of HRI. Unsurprisingly, 10.7% versus 5% of workers experienced an elevated CBT on high-heat days compared to cooler days. This doubling in risk justifies Cal/OSHA requirements for additional worker protections on high-heat days.

For all environmental temperatures, elevated CBT was independently associated with male sex, higher median WBGT, higher mean work rate, and higher BMI. On high-heat days, the median WBGT, the mean work rate, and BMI were more strongly associated with elevated CBT, while women's risk increased compared to men.

Dehydration

Even a one percent reduction in body weight due to dehydration is thought to lead to elevated rectal body temperatures (0.3 to 0.4°C) when exercising in hot weather.[29] Further dehydration increases body temperature by 0.25°C for every 1% decrease in body weight.[30] Despite consuming more total volume and water compared to less active workers, those at risk (especially men) were not replenishing sweat and became dehydrated (15.7% of men versus 3.3% of women were dehydrated, P<0.0001). Only 9.3% of workers drank enough water, and only 12% drank enough total liquids. Workers consumed more liquids in higher temperatures (113.4 oz (95% CI 103.9 – 123.0) versus 93.7 oz (95% CI 86.7 – 100.6) on cooler days, P=0.001). However, neither the decreased hydration nor the ACGIH criterion of 1.5% weight loss over the shift[26] appeared to be independent risk factors in the multivariate model for elevated CBT. It is possible that the ACGIH benchmark is insufficient to show a consistent increase in the risk of elevated CBT in this population and sample size. Nevertheless, dehydration and the resulting blood volume depletion may have a cumulative effect and could lead to kidney disease. The workers in this study were shown to exhibit some degree of acute kidney damage[31,32] which may lead to chronic disease.[33] Cal/OSHA emphasizes sufficient water intake for the weather and work rate. However, according to our results, their recommendation of three to four 8-oz cups of water per hour is inadequate to maintain hydration. A more refined guideline based on activity level/task and environmental temperature may help workers understand their hydration requirements. Field supervisors are critical to both model and actively encourage hydration.

Rests

Four workers did not take a lunch break, and 29 others took a lunch break ≤10 min. An inadequate lunch break was correlated with shift length (r=0.267, P<0.0001): these 33 participants worked on average 7.24 h (95% CI 6.9–7.6), while the remainder averaged

8.8h (95% CI 8.7–9.0). Taking lunch and the number of other short breaks were not associated with elevated CBT and were also not correlated with work rate. The measure of work rate, the mean cpm over the shift, likely obscures any effect of short rest periods. NIOSH specifies a matrix of work-rest periods for different work rates and environmental temperatures which farms find impractical (see Table 6-2 “Work/rest schedules for workers wearing normal work clothing” on p 76 of the NIOSH criteria).[7] Whereas the current recommendations were based on military studies where specific work rates and rest breaks can be mandated,[21] Cal/OSHA could develop practical task-based recommendations reducing the work rate or increasing rest break frequency with increasing environmental temperature.

Work Rate

A previous paper from this study reported most farmworkers spent the largest portion of the day in light levels of work, with occasional bouts in the moderate level, and very rarely a few minutes in the vigorous level.[22] Workers mostly seemed to self-regulate work rate (albeit with probable influence of co-workers and economic pressures) and take short water and restroom breaks as needed. We did not assess whether supervisors reduced work rate as temperatures rose, but some study farms limited the length of the workday on high-heat days. The workers who were exposed to higher temperatures but worked a normal shift length (7.1%) were at increased risk of HRI compared to those who worked at cooler temperatures (5.1%) but the workers who were dismissed early were actually at highest risk (21%). The workers who worked a short day in high temperatures averaged 356 cpm over their shift (95% CI 298 – 414), while those who worked a full, cooler day averaged 347 cpm over their shift (95% CI 326 – 369), and those who experienced a high-heat day and worked a full shift averaged 319 cpm (95% CI 286– 354). We were unable to distinguish whether the latter group reduced work rates because of the heat or were working at lower activity tasks. Along with increasing environmental temperature, we found faster work rate was the main factor increasing the risk of HRI, in line with previous results from this study.[34] A physiological study of HRI risk separating rest breaks from farming activity is needed.

Worker Characteristics Associated with Risk of HRI

Previous studies have not thoroughly investigated the differences in HRI risk between male and female farmworkers; even an analysis of HRI deaths ignored gender.[3] Historically farmworkers were mostly male, and most deaths attributable to HRI were in men.[10,35] More recently, NAWS and CHIPS have found that women are now about one-third of the agricultural workforce in California.[1,36] Women are more likely to recognize early HRI symptoms and react to mitigate them,[18] and so would be expected to incur fewer incidences of HRI. Observational studies have indicated women are more likely to report HRI symptoms,[17] but CBTs allow an objective comparison between the sexes. A study of fernery workers (70% women) in Florida, under higher humidity conditions, found women were five times as likely to record a CBT greater than 38°C than men, but did not indicate what their initial temperatures were.[37] Women have between 0.09°C and 0.10°C higher internal body temperatures.[38] In an earlier paper we observed men and women were segregated by task,[22] with the more active tasks being performed by men, consequently increasing their risk of HRI.

We examined an increase in CBT of ≥1.5°C as a second measure of HRI risk (supplemental materials, http://links.lww.com/JOM/A890). There were 17 workers who experienced both an elevated CBT and an increase of greater than or equal to 1.5°C. Compared to the rest of the workers, these workers were more dehydrated (despite consuming more), experienced higher WBGT, and worked at a faster rate. Considering their tasks, these workers were more likely to irrigate (47% vs 10.1%), hand harvest (26.7% vs 16.6%), shovel (6.7% vs 1.2%), and carry (13.3% vs 1.8%). Further investigation of the tasks and work site factors which are overrepresented in this high-risk group is warranted; we suggest task as related to work rate should be added to Cal/OSHA's list of risk factors for HRI. As global temperatures increase, protecting workers will become more difficult and require more nuanced strategies. Not all workers are at high risk, eg, those working at low intensities in shaded areas. Our data indicate those working at faster rates, especially on days where the environmental temperature rises close to or above body temperature, need to be targeted with extra protection.

Strengths and Limitations

Although this study collected objective data on CBT, weather, work rate, and (de)hydration, some data come with limitations. We asked workers to come directly to the post-shift assessment without drinking water or other beverages but expect a proportion consumed beverages between ending work and arriving at our assessment station. This would most likely artificially improve their hydration status. Although we did not find an association with water or beverage amount and CBT, it is possible those associations exist given the potential unreliability of using self-reported consumption. We were unable to draw conclusions about the efficacy of rest breaks because we used mean work rate over the work shift, limiting our ability to measure rest periods. Similarly, we did not find an association of elevated CBTand piece-rate work beyond mean work rate. As most of the workers were acclimatized, we were unable to examine this important contributor to HRI. In addition, we administered the thermistor measuring CBT on the day of participation, rather than the night beforehand as is ideal due to lack of compliance in workers.[1] Finally, we eliminated 12% of traces from analysis due to data quality concerns.[1,22]

Study strengths include the number of workers monitored using the CBT internal thermistor, accelerometer and weather data, all collected minute-by-minute. This population is difficult to access and monitor, especially as all data have to be collected under often extreme field conditions where workers frequently change work location, have varied hours, do not speak English, and are suspicious of outsiders. Also, rather than restricting our study to a single area of agriculture, we enrolled participants tending a large variety of crops from a wide geographical area in California. Although a convenience sample, this study recruited a good representation of California's Latino/a farmworkers similar to the NAWS of the same period,[1] increasing the generalizability of our findings.

CONCLUSIONS AND RECOMMENDATIONS

These findings provide valuable insights to the effectiveness of current regulations and the main risk factors for elevated CBT in farmworkers. Risk of HRI was exacerbated by work rate and environmental temperature despite farms following Cal/OSHA regulations. Future revisions of regulations need to include practical recommendations to adjust work rates and rest breaks, targeted to specific tasks and especially on hot days; hydration recommendations adapted for type of work and temperature; and HRI training tailored to the cultural and behavioral needs of the workforce. Critically, supervisors need to model essential behaviors, as they are the main influence on the workers. Frequent water consumption does not need to be stressed when working at low rates in cooler weather; reminders should be saved for times of intense work rate and temperature stress. These conclusions and suggestions apply to labor intensive farming in hot, dry climates found in the main agricultural areas of California but would apply to other areas with similar climates, especially with a large population of migrant workers who are more likely to be vulnerable.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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REFERENCES

1. Mitchell DC, Castro J, Armitage TL, Vega-Arroyo AJ, Moyce SC, Tancredi DJ, et al. Recruitment, methods, and descriptive results of a physiologic assessment of Latino farmworkers: The California Heat Illness Prevention Study. J Occup Environ Med. 2017;59:649–658. [PubMed: 28414703]
2. Jackson LL, Rosenberg HR. Preventing heat-related illness among agricultural workers. J Agromedicine. 2010;15:200–215. [PubMed: 20665306]
3. Centers for Disease Control and Prevention. Heat-related deaths among crop workers – United States, 1992–2006. MMWR Weekly. 2008;57:649–653.
4. California Department of Food and Agriculture. California Agricultural Production Statistics [Internet]. State of California; 2020. Available at: https://www.cdfa.ca.gov/statistics/. Accessed December 11, 2020.
5. Martin PL, Hooker B, Akhtar M, Stockton M. How many workers are employed in California agriculture? Calif Agric. 2017;71:30–34.
6. Rogers P, Buttice MK. Farmworkers in California: A brief introduction. State of California: California Research Bureau, California State Library; 2013 p. S-13–017.
7. National Institute for Occupational Safety and Health. NIOSH criteria for a recommended standard: occupational exposure to heat and hot environments. Cincinnati OH: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; D 2016.C 192 p. Report No.: 2016–106
8. Cable J California: Worker deaths prompt emergency heat stress rule proposal [Internet]. Environmental Health Safety Today; 2005. Available at: http://www.ehstoday.com/news/ehs_imp_37724. Accessed December 11, 2020.
9. California Department of Industrial Relations. Title 8_3395 Heat illness prevention in outdoor places of employment [Internet]. Sacramento, CA: California Department of Industrial Relations Division of Occupational Safety and Health; 2015. Available at: https://www.dir.ca.gov/title8/3395.html. Accessed December 11, 2020.

10. Prudhomme JC, Neidhardt A. Cal/OSHA investigations of heat-related illnesses 2006. Memo. State of California: Department of Industrial Relations Division of Occupational Safety and Health; 2007, 20 p.
11. California Department of Industrial Relations. State OSHA annual report (SOAR) FY 2016. State of California: Department of Industrial Relations Division of Occupational Safety and Health; 2016, 34 p.
12. Gubernot DM, Anderson GB, Hunting KL. The epidemiology of occupational heat exposure in the United States: a review of the literature and assessment of research needs in a changing climate. Int J Biometeorol. 2014;58:1779–1788. [PubMed: 24326903]
13. Leigh JP, Du J, McCurdy SA. An estimate of the U.S. government's undercount of nonfatal occupational injuries and illnesses in agriculture. Ann Epidemiol. 2014;24:254–259. [PubMed: 24507952]
14. United States Bureau of Labor Statistics. Injuries, Illness, and Fatalities. Nonfatal occupational injuries and illnesses USA 2016. [Incidences involving days away from work in 2016]. [Internet]. Washington, DC: United States Bureau of Labor Statistics; 2020. Available at: https://data.bls.gov/gqt/RequestData. Accessed December 11, 2020.
15. Mirabelli MC, Quandt SA, Crain R, Grzywacz JG, Robinson EN, Vallejos QM, et al. Symptoms of heat illness among Latino farm workers in North Carolina. Am J Prev Med. 2010;39:468–471. [PubMed: 20965386]
16. Spector JT, Krenz J, Blank KN. Risk factors for heat-related illness in Washington crop workers. J Agromedicine. 2015;20:349–359. [PubMed: 26237726]
17. Mutic AD, Mix JM, Elon L, Mutic NJ, Economos J, Flocks J, et al. Classification of heat-related illness symptoms among Florida farmworkers. J Nurs Scholarsh. 2018;50:74–82. [PubMed: 29024370]
18. Courville M, Wadsworth G, Schenker M. We just have to continue working": Farmworker self-care and heat-related illness. J Agriculture Food Systems and Community Development [Internet]. 2016;6:1–22. Available at: https://www.foodsystemsjournal.org/index.php/fsj/article/view/453 DOI: 10.5304/jafscd.2016.062.014. Accessed December 11, 2020.
19. Wadsworth G, Courville M, Schenker M. Pay, power, and health: HRI and the agricultural conundrum. Labor Studies Journal. 2018;43:1–22. Available at: 10.1177/0160449X18767749 DOI: 10.1177/0160449X18767749. Accessed December 11, 2020.
20. United States Department of Labor. Using the heat index: A guide for employers [Internet]. Washington, DC: United States Department of Labor Occupational Safety and Health Administration; 2011. Available at: http://www.osha.gov/SLTC/heatillness/heat_index/pdfs/all_in_one.pdf. Accessed December 11, 2020.
21. California Department of Industrial Regulations. Occupational safety and health standards board documents cited to support rulemaking – heat illness [Internet]. Sacramento, CA: California Department of Industrial Regulations Occupational Safety and Health Standards Board; 2014. Available at: http://www.dir.ca.gov/oshsb/Heat_illness_prevention.html. Accessed December 11, 2020.
22. Mitchell DC, Castro J, Armitage TL, Tancredi DJ, Bennett DH, Schenker MB. Physical activity and common tasks of California farm workers: California Heat Illness Prevention Study (CHIPS). J Occup Environ Hyg. 2018;15:857–869. [PubMed: 30183551]
23. American Conference of Governmental Industrial Hygienists. Threshold limit values and biological exposure indices for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists; 2014.
24. National Institute for Occupational Safety and Health. Health hazard evaluation report: evaluation of heat and carbon monoxide exposures to border protection officers, El Paso, TX. Cincinnati, OH: US Department of Health and Human Services, Centers for Disease Control and Prevention. National Institute for Occupational Safety and Health; 2009, 36 p. Report No.: 2005-0215-3099.
25. National Institute for Occupational Safety and Health. Health hazard evaluation report: evaluation of heat stress, heat strain, and rhabdomyolysis in national park employees. Cincinnati, OH: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; 2014, 42 p. Report No.: 2013-0109-3214.

26. American Conference of Governmental Industrial Hygienists. Documentation of the threshold limit values and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists; 2011. p. 2002–2100.
27. National Institute for Occupational Safety and Health. Evaluation of heat stress, heat strain, and rhabdomyolysis during structural fire fighter training. Cincinnati, OH: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; 2015, 34 p. Report No.: 2012-0039-3242.
28. Grandjean A Water requirements, impinging factors, and recommended intakes [Internet]. Geneva, Switzerland: World Health Organization, Water Sanitation and Health; 2004. Available at: https://www.who.int/water_sani-tation_health/dwq/nutrientschap3.pdf. Accessed December 11, 2020.
29. Ekblom B, Greenleaf CJ, Greenleaf JE, Hermansen L. Temperature regulation during exercise dehydration in man. Acta Physiol Scand. 1970;79: 475–483. [PubMed: 5472114]
30. Sawka MN, Montain SJ, Latzka WA. Hydration effects on thermoregulation and performance in the heat. Comp Biochem Physiol A Mol Integr Physiol. 2001;128:679–690. [PubMed: 11282312]
31. Moyce S, Joseph J, Tancredi D, Mitchell D, Schenker M. Cumulative incidence of acute kidney injury in California's agricultural workers. J Occup Environ Med. 2016;58:391–397. [PubMed: 27058480]
32. Moyce S, Mitchell DC, Armitage T, Tancredi DJ, Joseph JG, Schenker MB. Heat strain, volume depletion and kidney function in California agricultural workers. Occup Environ Med. 2017;74:402–409. [PubMed: 28093502]
33. Roncal-Jimenez C, Lanaspa MA, Jensen T, Sanchez-Lozada LG, Johnson RJ. Mechanisms by which dehydration may lead to chronic kidney disease. Ann Nutr Metab. 2015;66(Suppl 3):10–13.
34. Vega-Arroyo AJ, Mitchell DC, Castro JR, Armitage TL, Tancredi DJ, Bennett DH, et al. Impacts of weather, work rate, hydration, and clothing in heat-related illness in California farmworkers. Am J Ind Med. 2019;62:1038–1046. [PubMed: 30964208]
35. Gubernot DM, Anderson GB, Hunting KL. Characterizing occupational heat-related mortality in the United States, 2000–2010: An analysis using the Census of Fatal Occupational Injuries database. Am J Ind Med. 2015;58: 203–211. [PubMed: 25603942]
36. Hernandez T, Gabbard S. Findings from the National Agricultural Workers Survey (NAWS) 2015–2016. Washington, DC: US Department of Labor, Employment and Training Administration, Office of Policy Development and Research; 2018, 84 p. Report No.:13.
37. Mac VVT, Tovar-Aguilar JA, Elon L, Hertzberg V, Economos E, McCauley LA. Elevated core temperature in Florida fernery workers: Results of a pilot study. Workplace Health Saf. 2019;67:470–480. [PubMed: 31315538]
38. Protsiv M, Ley C, Lankester J, Hastie T, Parsonnet J. Decreasing human body temperature in the United States since the industrial revolution. eLife. 2020;9:e49555. DOI: 10.7554/eLife.49555. [PubMed: 31908267]

TABLE 1.

Objectively Measured Variables and Their Derivatives

Variable	Source	Notes
Core body temperature (CBT)	CorTemp HT 15002 ingestible wireless thermistor transmitters [CorTemp HTI Technologies, St. Palmetto, FL]	The 10-mm long sensor transmitted CBT at 1-min intervals as it moved through the gastrointestinal tract. The manufacturer's reported accuracy of the sensor is 0.18°C. The 3-min moving medians were calculated.
Work rate	Actical™ accelerometer [Actical Philips Respironics, Murrysville, PA]	The accelerometer was attached to the waist belt at the iliac crest of the hip using both a Velcro band and zip ties. The accelerometer measured work rate at 1-min intervals, resulting in counts per minute (cpm). The 3-min moving means were calculated.
Weight	Seca Model 874 scale [Seca GMBH & Co., Hamburg, Germany]	Weight was measured twice at each time point (pre- and post-shift) on a scale placed on a leveled board. Workers removed their outer layers of clothing and footwear. A particular effort was made to ensure the same clothing was worn in the post-shift weighing. The average was calculated.
Height	Sec Model 213 stadiometer [Seca GMBH & Co., Hamburg, Germany]	Height was measured twice pre-shift. The average was calculated.
Wet bulb globe temperature (WBGT)	QUESTemp 36 thermal environment monitor on a 1.2-m tripod [Quest Technologies, Inc., Ocono-mowoc, WI]	The QUESTemp 36 provided a mobile measure of the local field conditions where participants were working. WBGT was collected at 1-min intervals.
	HOBO U30 weather station on a 3-m tripod [Onset Computer Corp., Bourne, MA]	The HOBO collected ambient conditions at a stationary central location on each farm for the duration of data collection (1 – 5 days). Adjusted HOBO data were used for participants lacking QUEST data.
Constructed variable	Source variable(s)	Definition
Elevated CBT	CBT	Categorical: 0: Maximum CBT < 38.5°C 1: Maximum CBT ≥ 38.5°C
Dehydration	Weight (pre- and post-shift)	Continuous: [(post-shift weight – pre-shift weight) / pre-shift weight] * 100 Categorical: 0: < 1.5% change in body weight over the work shift 1: ≥1.5% change in body weight over the work shift
BMI	Pre-shift weight and height	Continuous: (pre-shift weight in kg) / (pre-shift height squared, m^2)
High-heat day	Dry-bulb (shaded) thermometer	Categorical: 0: Maximum temperature < 35°C on sampling day 1: Maximum temperature ≥ 35°C and worked normal day 2: Maximum temperature ≥ 35°C and work shift ended before 2 PM.

BMI, body mass index; CBT, core body temperature; WBGT, wet bulb globe temperature.

TABLE 2.

Self-reported or Staff-observed Variables

Variable	Source	Definition
Tasks	Questionnaire: post-shift activity log	Participants reported their task(s) at work that day.
Knowledge of HRI prevention	Questionnaire: multiple-choice questions 1: Correctly answered all three questions concerning obesity, age, and prior heat illness as risk factor for HRI 0: At least one incorrect response Knowledge of recommended volume of water to drink per hour in the heat 1 if correct 0 otherwise Knowledge of time needed to acclimatize to heat 1 if correct, 0 otherwise	Summary score: 0–1: Low knowledge 2: Medium knowledge 3: Good knowledge
Rest breaks	Questionnaire: lunch break and any other short breaks they took on sampling day	Lunch breaks less than 10 mins were reclassed as a short break and added to the short break total. The number of short breaks was categorized into 0, 1, 2, or 3+ breaks.
Hydration deficit	Questionnaire: self-reported beverage consumption Recommended beverage consumption: Two 8-oz cups of water per hour when temperature < 26.7°C (80°F). Three to four 8-oz cups of water per hour when temperature ≥ 26.7°C.	Recommended volume: calculated amount of time (h) each worker was exposed to temperature < and ≥ 26.7°C and multiplied by 16 or 24 oz respectively, then added to give total recommended volume of water or total beverage. Hydration deficit: (self-reported volume of water or total beverages consumed) – (recommended volume)

TABLE 3.

Cal/OSHA Regulations and Recommendations and Compliance in Study Farms

Regulation/recommendation	Response n (%)	
PROVISION OF WATER		
Pure, cool, no-cost. Sufficient for each worker: 1 quart/hour/worker. Located as close as practicable to work area and relocate as needed.	Always	478 (95)
	Often	21 (4)
*Asked if employer provided drinking water.	Sometimes/never	4 (1)
Provide disposable cups.	Always	460 (95)
	Often	16 (3)
	Sometimes/never	8 (2)
Encourage frequent drinking (3–4 cups/hour) when hot.	Any problem	20 (4)
*Asked if they had any problem with water that was provided.		
PROVISION OF SHADE		
Shade provided when temperature exceeds 80°F. May be natural but not inside building or car without AC running. Located as close as practicable to work area and relocate as needed.	Yes	502 (99)
*Temperature criterion intensified in 2015; only provision of shade on day of participation was assessed.		
Enough shade to allow all employees on rest breaks to sit in normal posture fully in shade without touching.	Yes	461 (92)
*Asked if they used available shade.	No (Note: it was too cool to use shade)	41 (8)
PROVISION OF REST PERIODS		
Employees allowed to take minimum of 5-min rest break. Must not be ordered back to work until any symptoms of heat illness have gone.	Yes	492 (97)
*Asked if they felt comfortable taking a 5-min break every hour if they had HRI symptoms.		
Took a lunch break ≥ 10 mins (not in heat standard)	Yes	474 (93)
Number of short breaks other than lunch (not in heat standard)	0	74 (15)
	1	123 (24)
	2	244 (48)
	3+	66 (13)
When ≥ 95°F, a minimum of 10-min rest break in the shade every two hours must be enforced.	Criterion was added in 2015 and not assessed.	–
HIGH HEAT PROVISIONS		
When ≥ 95°F, need to:	Most of these provisions were added in 2015 and not assessed by our study.	–
Ensure frequent communication by voice, observation, or electronic means is maintained in case of emerging health issue.		
Observe/check employees for alertness and symptoms of HRI.		

Regulation/recommendation	Response n (%)	
Implement buddy system: workers monitor a buddy who reciprocates.		
ACCLIMATIZATION		
Newly assigned employees or those returning after an absence shall be closely monitored by a supervisor for the first 14 days. All employees should be observed in heat waves.	Worked ≥ 15 days that season and ≥ 5 days in previous 2 weeks	408 (95)
*Estimated from the number of days worked in the season and two weeks prior to participation in study. Approximately 85% of participants reported days worked for the season and days worked in previous two weeks.		
TRAINING		
Effective training before an employee begins work, and seasonally for permanent employees, covering risks, signs, and symptoms of HRI and emergency procedures.	Within the last month	211 (42)
	1 month to 1 year ago	224 (44)
	Never	17 (3)
*Asked when they had received HRI training.		
Workers were asked about HRI knowledge, including personal risk factors.	Correct response to:	210 (42)
Correct response to:	Acclimatization	212 (42)
Acclimatization (2 – 14 days to acclimatize).	Water	377 (74)
Importance of frequent drinking of cool water and recommended volumes (3 – 4 cups per hour).	Older age	377 (74)
	Prior heat illness	419 (83)
Older people at higher risk of HRI.	Overweight/obese	
Prior heat illness is a risk factor for HRI.		
People who are overweight or obese are at higher risk of HRI.		
Clothing: recommended workers wear minimum layers of lightweight, light-colored, loose-fitting long-sleeved tops and pants and brimmed hat.	No standard comparison.	–
SUPERVISOR TRAINING		
Supervisors must be trained to provide all provisions above as well as know employees' rights. They must track weather information, modify work schedules, maintain emergency contacts, etc.	Not assessed.	–
HEAT ILLNESS PREVENTION PLAN		
Employer must maintain a written plan at the worksite both in English and in the language of the most workers. Plan must be implemented and maintained and must contain all the procedures for provisions above.	Not assessed.	–

HRI, heat-related illness.

TABLE 4.

Univariate Associations With Elevated CBT

Characteristic	All (n = 507) Mean (SD)	CBT < 38.5°C (n = 472) Mean (95% CI)	CBT ≥ 38.5°C (n = 35) Mean (95% CI)	*P*-value
Age (y)	38.8 (12.3)	38.9 (37.8–40.0)	37.6 (33.6–41.5)	0.53
BMI	28.9 (4.6)	28.8 (28.4–29.2)	30.7 (29.3–32.0)	0.02
Total consumed (oz)	99.9 (64.4)	97.7 (92.0–103.4)	129.6 (102.7–156.5)	0.02
Total consumed per hour (oz/h)	11.6 (7.5)	11.3 (10.7–12.0)	15.4 (12.3–18.6)	0.002
Total hydration deficit (oz)	−71.6 (68.4)	−73.7 (−79.8– −67.6)	−43.8 (−73.2– −14.3)	0.05
Hydration deficit of water (oz)	−87.8 (67.4)	−89.9 (−95.9– −83.9)	−60.6 (−89.4– −31.9)	0.05
% change in body weight	−0.5 (0.8)	−0.5 (−0.6– −0.4)	−0.9 (−1.2– −0.6)	0.003
Work rate (cpm)	336.1 (191.6)	326.0 (308.6–343.4)	473.6 (417.9–529.2)	<0.0001
Work in agriculture (y)	14.4 (11.8)	14.5 (13.5–15.6)	11.9 (8.6–15.1)	0.19
Shift length (h)	8.7 (1.49)	8.7 (8.6–8.9)	8.7 (8.1–9.3)	0.83
WBGT (°C)	25.8 (3.3)	25.7 (25.4–26.0)	27.3 (26.0–28.6)	0.01
	n (%)	**n (%)**	**n (%)**	***P*-value**
Sex: Male	325 (64)	294 (62)	31 (89)	0.002
Female	182 (36)	178 (38)	4 (11)	
Immigrant: No	41 (8.1)	37 (8)	4 (11)	0.51
Yes	466 (91.9)	435 (92)	31 (89)	
Hiring: Farmer	241 (48)	216 (46)	25 (71)	0.005
FLC	266 (53)	256 (54)	10 (29)	
Pay type: Hourly	391 (77)	365 (77)	26 (74)	0.68
Piece Rate	116 (23)	107 (23)	9 (26)	
Rest breaks: > 1	310 (61)	291 (62)	19 (54)	0.47
0–1	197 (39)	181 (38)	16 (46)	
Dehydration (change in body weight): < 1.5%	450 (89)	424 (90)	26 (74)	0.01
≥ 1.5%	57 (11)	48 (10)	9 (26)	
*Education: ≤ 6th grade	148 (53)	142 (55)	6 (30)	0.04
> 6th grade	129 (47)	115 (45)	14 (70)	

HRI knowledge: Low	269 (53)	254 (54)	15 (43)	0.22
Moderate-Good	238 (47)	218 (46)	20 (57)	
Previous HRI: No	238 (47)	220 (47)	18 (51)	0.60
Yes	269 (53)	252 (53)	17 (49)	

* Approximately 54% of participants reported the number of years completed in school.

BMI, body mass index; CBT, core body temperature; CI, confidence interval; FLC, farm labor contractors; HRI, heat-related illness; SD, standard deviation; WBGT, wet bulb globe temperature.

TABLE 5.

Association of Risk Factors and Elevated CBT Across Environmental Temperatures

	All temperatures		Maximum dry bulb temperature ≥ 35°C	
n with elevated CBT/participant n (%)	35/507 (6.9%)		18/169 (10.7%)	
Variable	AOR	95% CI	AOR	95% CI
Male (female reference)	3.74	1.22–11.54	1.27	0.27–5.92
Age (y)	0.998	0.996–1.03	0.99	0.94–1.04
WBGT (°C)	1.22	1.08–1.38	1.42	1.10–1.83
Work rate (cpm)	1.004	1.002–1.006	1.005	1.002–1.009
BMI	1.11	1.10–1.29	1.17	1.02–1.33

BMI, body mass index; CBT, core body temperature; CI, confidence interval; WBGT, wet bulb globe temperature.