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Cooling Interventions Among Agricultural Workers:

A Pilot Study

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Abstract

Background: Adverse health effects among agricultural workers due to chronic heat exposure have been characterized in the literature as not only due to high ambient temperatures but also due to intensive manual labor in hot and humid conditions. The aim of this study was to use biomonitoring equipment to examine the effectiveness of selected cooling devices at preventing agricultural workers from exceeding the core body temperature threshold of 38.0°C (Tc38) and attenuating heat-related illness symptoms.

Methods: A convenience sample of 84 agricultural workers in Florida was randomized to one of four groups: (a) no intervention, clothing as usual; (b) cooling bandana; (c) cooling vest; and (d) both the cooling bandana and cooling vest. Biomonitoring equipment worn by the participants included core body temperature monitor and an accelerometer to capture physical activity.

Findings: A total of 78 agricultural workers completed one intervention workday trial. Compared with the control group, the bandana group had lower odds of exceeding Tc38 (odds ratio [OR] = 0.7, 90% confidence interval [CI] = [0.2, 3.2]) and the vest group had higher odds of exceeding Tc38 (OR = 1.8, 90% CI = [0.4, 7.9]). The simultaneous use of cooling vest and bandana showed an effect little different from the control group (OR = 1.3, 90% CI = [0.3, 5.6]).

Conclusion/Application to Practice: This is the first field-based study to examine cooling intervention among agricultural workers in the United States using biomonitoring equipment. This study found that using a bandana while working in a hot agricultural environment has the potential to be protective against exceeding the recommended Tc38 threshold.

Keywords

agricultural workers; cooling interventions; heat stress; heat-related illness; core body temperature

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Declaration of Conflicting Interests
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Supplemental Material
Supplemental material for this article is available online.

Background

It is estimated that between 2 and 3 million workers are employed in the U.S. agricultural industry (The National Institute for Occupational Safety and Health [NIOSH], 2018). Agricultural workers perform intense labor outside in direct sunlight and in humid environmental conditions, exposing workers to a high risk of heat-related illness (HRI). The U.S. Bureau of Labor Statistics reported agriculture was among the most dangerous industries (Bureau of Labor Statistics, 2017). An epidemiological study on occupational HRI fatalities found that agricultural workers had a risk of heat-related mortality that was 35 times greater than the general workforce population (Gubernot et al., 2015). Adding to agricultural workers' vulnerability are rising environmental temperatures and the increase in frequency and intensity of heat waves (U.S. Global Change Research Program, 2016).

HRI is a result of exposure to environmental and exertional heat that can lead to elevated core body temperatures (T_c) that exceed the compensatory limits of thermoregulations (Atha, 2013). Symptoms associated with HRI range from mild symptoms of heat exhaustion such as excessive sweating, headache, nausea or vomiting, and muscle cramps, to severe symptoms such as heat stroke and death (Atha, 2013). Normally, T_c is maintained at roughly 37°C. Once T_c exceeds 38°C, heat exhaustion can ensue and can lead to heat stroke when T_c reaches or exceeds 40°C. NIOSH and The American Conference of Governmental Industrial Hygienists (ACGIH) recommend that T_c not exceed 38°C during prolonged exposure to strenuous work (>2 hours). Studies have observed that the combination of high environmental temperatures and intense physical activity resulted in rapid onset of exertional heat stroke and was associated with higher T_c (Becker & Stewart, 2011). Multiple studies have reported agricultural workers experience symptoms of HRI and elevated T_c that exceed the threshold at which workers should stop activities to rest and rehydrate (Fleischer et al., 2013; Mac et al., 2017; Mirabelli et al., 2010; Mitchell et al., 2017; Mutic et al., 2018).

As of yet, there are no field-based U.S. studies of cooling interventions to protect agricultural workers from HRI symptoms or from exceeding T_c threshold of 38°C. This work describes the field-based pilot study conducted to examine the effectiveness and practicality of selected cooling devices that could prevent HRI without interfering with daily work routines. It was hypothesized that the use of cooling devices while working would attenuate rises in T_c and decrease self-reported HRI symptoms.

Methods

In collaboration with the Farmworker Association of Florida (FWAF), trained community health workers recruited a convenience sample of agricultural workers in Homestead, Florida (April to May 2018), and Pierson, Florida (April to May 2019). Workers were eligible to participate if they were between 18 and 54 years of age and were working in the agricultural sector for at least the last 4 weeks. Workers were excluded if they reported being pregnant or had Type I diabetes mellitus. Consenting workers came to the FWAF office for a baseline visit, followed by pre- and postworkday visits. The Institutional Review Board at Emory University provided approval for the study, and all participants provided informed consent to participate in the study. At the end of an exit interview, each participant received a US$50 gift card.

Intervention

Participants were randomized to one of four groups for the workday trial: (a) no intervention, clothing as usual; (b) cooling bandana only; (c) cooling vest only; and (d) both the cooling bandana and cooling vest. The a priori computer-generated block randomization schedule remained concealed from research staff and participants until participants arrived at the FWAF office the morning of the study workday.

Cooling vest (the TechNiche Elite Hybrid Cooling Vest; Vista, CA, USA) includes cooling inserts and weighs 5 pounds. This cooling vest used phase change material (PCM) cooling inserts. Participants were instructed to place the first set of phase change cooling inserts in the vest prior to wearing it and, once melted, to replace with the second set of inserts that had been kept frozen in an insulated bag. The PCM inserts were designed to remain at 58°F (14°C) for up to 3 to 5 hours. This vest was chosen because phase change technology has been used in previous occupational group studies (A. P. C. Chan et al., 2017).

Bandana (the Chill-Its® 6700CT Evaporative Cooling Bandana; Ergodyne, St. Paul, MN, USA) is constructed with polyvinyl acetate (PVA) material and weighs less than a pound. Participants saturated the bandana in water for 1 minute to active it, twirled the bandana to remove excess water, and tied the bandana around their head or neck, repeating the steps as needed to maintain the cooling effect. The bandana maintains its cooling effectiveness for ~4 hours due to a high-water absorption capability and resulting efficient water evaporation.

Procedure

At baseline, prior to the workday visit, participants answered sociodemographic questions, and anthropometric measurements were recorded. Participants were then given a CorTemp® pill sensor to swallow during the evening prior to the intervention work trial to monitor T_c. The morning of the intervention work trial, biomonitoring devices were provided, which included (a) a CorTemp® Data Recorder (HQInc.; Palmetto, FL, USA) to record T_c from the CorTemp® pill sensor and (b) an ActiGraph™ GTX3+ (ActiGraph, LLC; Pensacola, FL, USA) to capture physical activity. Participants in the intervention groups were given instructions on the use of the cooling devices. At the conclusion of the workday, a postworkday survey was administered.

Outcome Variables

The two key outcome variables for this analysis were T_c and self-reported HRI symptoms experienced during the intervention work trial. T_c was continuously recorded by an ingested CorTemp® temperature sensor (CorTemp HQ Inc.; Palmetto, FL. USA) at 30-second intervals. Participants who had two consecutive 30-second readings of T_c above 38.0°C were considered to have exceeded the recommended limit (Hertzberg et al., 2016). We then added the sum of all instances that a participant's T_c exceeded 38.0°C to obtain time spent above the limit. T_c files with ≥20% of missing data were removed because of the likelihood they being due to faulty device (Hertzberg et al., 2016). HRI symptoms were assessed during the postwork survey. Participants were asked whether they experienced any of the following symptoms of HRI while working: excessive sweating, headache, nausea or vomiting, confusion, dizziness, fainting, and sudden muscle cramps. Responses were recorded as a "yes" or "no," and we summed the number of a participant's "yes" responses.

Covariates

Height and weight measurements were used to calculate body mass index (BMI) using the formula BMI = (kg/m^2); World Health Organization [WHO] Work duration was based on self-reported time participant started and ended their workday. Years working in U.S. agriculture was queried at the baseline visit. To assess work activity, participants wore a triaxial accelerometer (ActiGraph™ GTX3+) on their right hip on an elastic waistband. Vector magnitude counts per minute (CPM) were derived from raw vector magnitude counts for every 30 seconds and summed into 1-minute counts. To determine intensity of work activity, we summed all of the minutes meeting the following established criteria of ≥2,690 CPM to indicate minutes of moderate to vigorous activity (Aguilar-Farías et al., 2014; Mix et al., 2019; Sasaki et al., 2011). Environmental work conditions on trial workdays were estimated by using data from the Homestead and Pierson weather stations of the Florida Automated Weather Network (FAWN); the stations collect readings every 15 minutes. The heat index was calculated using the National Weather Service (NWS) algorithm. The maximum heat index during work hours was recorded specific to each participant's self-reported work start and end times.

Statistical Analysis

Continuous variables were summarized as mean ± standard deviation (*SD*) or median interquartile range (IQR), and categorical variables were reported as counts and percentages (%). Logistic regression models were built to estimate the effect cooling interventions had on T_c (exceeding 38.0°C, yes/no) and on reporting one or more HRI symptoms (yes/no). Five possible confounders (BMI, workday duration, years working in U.S. agriculture, heat index, and moderate to vigorous physical activity during work hours) were assessed in single-covariate models. Due to the small sample, we limited the maximum model size to one confounder. The unadjusted and adjusted odds ratios (ORs) and 90% confidence interval (CI) for the models are reported. All statistical analyses were performed with SAS version 9.4 software (Cary, NC, USA).

Results

A total of 84 agricultural workers were enrolled in the study. The primary work settings were fernery (42%), nursery (41%), field crop (12%), and landscape (6%). The sociodemographic, anthropometrics, and work characteristics of the sample are reported in Table 1. The overall mean age of the participants was 42 years (*SD* = 9 years), and the majority were female (66%). The mean years of education was 6 years (*SD* = 3 years), mean BMI was 31 (*SD* = 7), mean years working in agriculture was 17 (*SD* = 9 years), and the median workday was 7:40 hours long. The maximum mean heat index to which participants were exposed was 88 °F. A total of 78 participants completed the workday trial: 20 in the bandana group, 20 in the vest group, 21 in the combination (bandana and vest) group, and 17 in the control group. Median CPM of vector magnitude and time spent per day in moderate to vigorous activity (2,690 or higher CPM vector magnitude) did not differ significantly by intervention groups (see Supplemental Table S1). The median time spent in moderate to vigorous physical activity was greatest for the control group and least for the bandana group, although the difference was not statistically significant (165 and 90 minutes, respectively).

The combination group had the highest proportion of participants reporting no HRI symptoms (80%), followed by the bandana group (68%), and vest group (60%), and the control group (40%) had the least participants reporting no HRI symptoms (Table 2). See Supplemental Table S2 for the types of HRI symptoms reported. T_c analyses included data from 61 participants. T_c differences were observed as follows: In the bandana group, 38% exceeded 38.0°C, followed by 46% in the control group, 53% in combination group, and 60% in the vest group. The median time spent above 38.0°C was 23 minutes (IQR = [16, 32]) for the bandana group. The control group median time spent above 38.0°C was 26 minutes [13, 188], followed by the combination group with a median of 32 minutes [21, 78]. The vest group had the highest amount, 53 minutes [13, 188].

Compared with the control group, the combination group's odds of having one or more symptoms decreased by 80% (OR = 0.2, 90% CI = [0.1, 0.8]); adjusting singly for BMI, years worked in agriculture, hours worked per day, and physical activity had little impact on the estimated effect (Table 3). Compared with the control group, the bandana group had lower odds of exceeding a T_c of 38.0°C (OR = 0.7, 90% CI = [0.2, 3.1]) and the vest group had higher odds of exceeding 38.0°C (OR =1.8, 90% CI = [0.4, 7.9]; Table 4). The use of both the cooling vest and bandana (combination group) showed no difference from the control group (OR = 1.3, 90% CI = [0.3, 5.6]). BMI, years working in agriculture, hours worked, and moderate to vigorous activity did not confound our estimates. Although these results are not statistically significant, we found that the bandana remained protective both in the unadjusted and adjusted models.

Discussion

This is the first field-based study to pilot test a cooling intervention among agricultural workers in the United States using biomonitoring equipment. This randomized trial showed the bandana was protective against exceeding a T_c of 38.0°C compared with the other groups, although, not statistically meaningful due to insufficient power. Compared with the control group, all the interventions seem to be protective against experiencing one or more HRI symptoms, with the combination group showing the greatest impact.

The bandana is lightweight and can be worn with little restriction to body movement. For agricultural workers who have physically demanding jobs that require a full spectrum of movement, comfort of personal cooling devices is critical for usage. Anatomically the neck area has large blood vessels close to the skin, which is optimal for heat removal and may explain the reason for less participants exceeding 38.0°C.

Studies with construction workers using cooling vest during their scheduled rest breaks (A. P. C. Chan et al., 2017; Zhao et al., 2018) and while working (Ashtekar et al., 2019) have shown the cooling vest to be effective at mitigating heat stress. However, we did not observe the cooling vest to mitigate heat stress in our sample of agricultural workers. The odds of exceeding a T_c of 38.0°C increased 80% if the vest was used while working. The vest group was the only group to report feeling three or more HRI symptoms. There are differences in the study design that could contribute to the different outcome. Primarily, the agricultural workers in our study do not have regularly scheduled rest breaks as the construction workers do in the studies conducted in China. Studies that have assessed cooling vests while working in the construction (Ashtekar et al., 2019), agricultural (Choi et al., 2008), and foundry (Shirish et al., 2016) sectors used the vest for about 2 hours—not an entire workday as the participants in our study. Thus, cooling vests may be more practical and effective to use during regularly scheduled rest breaks. However, using the cooling vest during rest breaks may not be feasible if regularly scheduled breaks are not a routine of the workday. Anatomically, whereas the neck area has larger veins and less adipose tissue, the torso area has smaller veins and more adipose tissue, which may limit the effectiveness of the cooling vest to maintain workers' cool. The vest was also worn *over* one layer of clothing whereas the bandana was placed around the neck touching the skin directly. Moreover, the five pounds of additional mass to the worker may result in more physiologic strain while working.

In a study by Choi et al. (2008) with red pepper pickers, those who wore two cooling devices while working in a chamber did not exceed rectal temperatures of ≥38°C. In our study, the combination of using a cooling vest and bandana was not protective against exceeding a T_c of 38.0°C, although they are the group with most participants reporting not experiencing any HRI symptoms during the workday. The difference between the Choi et al. (2008) study and ours is that our participants worked on the field for an average of 8 hours, whereas the red pepper pickers simulated working in a controlled climatic chamber for 120 minutes with a rest break. However, adjusting for hours worked per day, the combination group showed meaningful protection against experiencing HRI symptoms.

Methodological limitations should be taken into consideration when interpreting the results of this pilot study. First, this study had a small sample size that was further decreased during the analysis phase due primarily to loss of T_c files to technical issues. The control group also had fewer participants due to workers withdrawing from the study. A convenience sample of agricultural workers in central and south Florida were randomly assigned into the intervention groups or control group, which may limit the external validity of this study. Although the randomization was thought to be successful in creating the intervention and control groups with similar baseline characteristics, the vest and combination group had higher physical activity compared with the bandana and control groups over the course of the workday. Despite limitations, this pilot study has the important strength that it was conducted in real work conditions with agricultural workers during one full workday. This study demonstrated the feasibility of testing workers, and their biological responses, to these various interventions, suggesting that future studies with a larger sample would be beneficial for further testing.

Implications for Occupational Health Practice

HRI is preventable with early detection and using appropriate prevention strategies. Occupational health providers can play important roles in developing and training industries on HRI prevention and mitigating heat-related mortality. Cooling interventions have the potential to provside relief from experiencing HRI and other diseases associated with heat stress and dehydration. Preventive measures against HRI will further diminish the likelihood of complications from underlying conditions developed after the prolonged heat exposure that agricultural workers experience and better isolate other health hazards associated with long-term farm labor also affecting these vulnerable populations.

Conclusion

This study found that agricultural workers who used a bandana while working in a hot environment have the potential to be protective against exceeding a T_c of 38.0°C. Future studies with larger sample sizes and sufficient power to detect effect sizes are needed to determine whether using a cooling bandana and other cooling interventions reduce the risk of heat-related morbidity and mortality are warranted. Hydration assessment should also be included in future studies as it is an important factor in reducing the risk of heat stress. If cooling interventions are shown to be feasible and effective across diverse outside occupational groups, this innovative intervention could improve working conditions for vulnerable occupational groups at risk of increased ambient temperature due to climate change, such as agricultural workers, and improve their health outcomes. Heat-related morbidity and mortality are preventable, and vulnerable occupational groups merit protection.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Applying Research to Occupational Health Practice

Agricultural workers perform intense labor outside in direct sunlight and in humid environmental conditions exposing workers to a high risk of heat-related illness (HRI). This study randomized participants into one of four groups: (a) no intervention, clothing as usual; (b) cooling bandana only; (c) cooling vest only; and (d) both the cooling bandana and cooling vest. All the cooling interventions were protective against experiencing one or more HRI symptoms, with the combination group showing the greatest impact. The use of a cooling bandana, which is affordable, lightweight, and a reusable cooling device, had the lowest proportion of workers exceeding a core body temperature of 38.0°C among all groups, and nearly 70% of workers did not report any HRI symptoms. Cooling interventions could improve the working conditions and health outcomes not just for agricultural workers, but for other vulnerable occupational groups at risk of HRI due to high ambient temperatures.

Table 1.

Sample characteristics of agricultural workers randomized to various cooling intervention groups

	Overall n = 84	Control n = 17	Bandana n = 20	Vest n = 20	Combination n = 21
	mean (SD) % (n) median [Q1, Q3]				
Age	42(9)	42 (9)	45 (8)	41 (9)	43 (7)
Female	66% (55)	82% (14)	60% (12)	55% (11)	62% (13)
Years of education	6 (3)	6 (3)	7 (3)	7 (4)	7 (4)
Body mass index	31 (7)	31 (7)	32 (7)	31 (9)	30 (3)
Percent body fat					
Female	36% (7)	34% (10)	38% (6)	38% (7)	36% (3)
Male	26% (7)	25% (6)	30% (6)	23% (5)	25% (9)
Years worked in agriculture	17 (9)	17 (9)	20 (7)	13 (10)	13 (10)
Agricultural work type					
Fernery	42% (35)	47% (8)	40% (8)	45% (9)	38% (8)
Nursery	41% (34)	35% (6)	45% (9)	30% (6)	48% (10)
Crop	12% (10)	6% (1)	15% (3)	15% (3)	9% (2)
Landscape	6% (5)	12% (2)	0% (0)	10% (2)	5% (1)
Hours worked per day	7:40 [6:10–9:00]	7:50 [6:10–8:30]	8:10 [6:10–8:30]	8:40 [6:30–9:20]	8:00 [6:00–9:00]
Ambient Temperature, (°F) max	85 (3)	85 (2)	85 (2)	86 (3)	84 (3)
Relative Humidity, (%) max	84% (10)	83% (11)	82% (11)	83% (11)	84% (8)
Heat index, (°F) max	88 (4)	89 (4)	88 (4)	89 (4)	86 (5)

Table 2.

Heat-related illness symptoms and core body temperature among agricultural workers by cooling intervention groups

		>=1 HRI symptom		Core body temperature	
	Total Participants		**Total Participants**	**> 38.0°C**	**Minutes > 38.0°C**
Cooling Intervention	N	% n	N	% (n)	Median [Q1, Q3]
Control	15	53% (8)	13	46% (6)	26 [1, 66]
Bandana	19	32% (6)	16	38% (6)	23 [16, 32]
Vest	20	40% (8)	15	60% (9)	53 [13, 188]
Combination	20	20% (4)	17	53% (9)	32 [21, 78]

Note. Sample sizes are smaller than the full cohort due primarily to loss of core body temperature files to technical issues.

Table 3.

The effect of cooling interventions among agricultural workers on the self-report of one or more heat-related symptoms during the workday, n=74

	Unadjusted	**Adjusted for single covariate**				
		BMI	**Heat Index Max**	**Years worked in agriculture**	**Hours worked per day**	**Moderate-vigorous activity**
Cooling Intervention (ref=No intervention)	**OR [90%CI]**					
Bandana	0.4 [0.2, 1.3]	0.4 [0.2,1.4]	0.4 [0.1, 1.5]	0.4 [0.1, 1.4]	0.4 [0.1, 1.2]	0.7 [0.2, 2.4]
Vest	0.6 [0.2, 1.8]	0.5 [0.2, 1.8]	0.5 [0.2, 1.7]	0.5 [0.2, 1.7]	0.4 [0.1, 1.5]	0.8 [0.2, 2.8]
Combination	0.2 [0.1, 0.8]	0.2 [0.1, 0.7]	0.3 [0.1, 1.0]	0.2 [0.1, 0.8]	0.2 [0.1, 0.7]	0.3 [0.1, 1.2]

Note. OR= odds ratio; CI= confidence interval. The outcome is “during the workday, participant self-reported one or more heatrelated symptom, yes/no”. Odds ratios <1 suggest a protective effect of the intervention.

Table 4.

The effect of cooling interventions among agricultural workers on exceeding core body temperature above 38.0°C, n=61

	Unadjusted	Adjusted for single covariate				
		BMI	**Heat Index Max**	**Years worked in agriculture**	**Hours worked per day**	**Moderate-vigorous activity**
Cooling Intervention (ref=No intervention	**OR [90%CI]**					
Bandana	0.7 [0.2, 3.1]	0.9 [0.2,3.2]	0.7 [0.2, 2.6]	0.6 [0.2, 2.3]	0.8 [0.2, 2.6]	0.9 [0.3, 3.5]
Vest	1.8 [0.4, 7.9]	2.5 [0.6, 9.9]	1.6 [0.4, 5.9]	1.7 [0.5, 5.9]	1.8 [0.5, 6.4]	1.8 [0.5, 6.4]
Combination	1.3 [0.3, 5.6]	1.5 [0.4, 5.2]	1.7 [0.5, 6.3]	1.3 [0.4, 4.3]	1.4 [0.4, 4.8]	1.3 [0.4, 4.5]

Note. OR= odds ratio; CI= confidence interval. The outcome is “during the workday, participant exceeded a core body temperature of 38.0°C, yes/no”. Odds ratios <1 suggest a protective effect of the intervention.