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RESEARCH ARTICLE

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Physical activity and work activities in Florida agricultural workers

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Abstract

Background: Laboring in hot and humid conditions is a risk factor for heat-related illnesses. Little is known about the amount of physical activity performed in the field setting by agricultural workers, a population that is among those at highest risk for heat-related mortality in the United States.

Methods: We measured accelerometer-based physical activity and work activities performed in 244 Florida agricultural workers, 18 to 54 years of age, employed in the fernery, nursery, and crop operations during the summer work seasons of 2015-2017. Environmental temperature data during the participant's workdays were collected from the Florida Automated Weather Network and used to calculate wet bulb globe temperature (WBGT). Generalized linear mixed model regression was used to examine the association between WBGT on physical activity, stratified by the agricultural sector.

Results: Fernery workers had the highest overall volume of physical activity, spending nearly 4 hours in moderate to vigorous activity per workday. Activity over the course of the workday also differed by the agricultural sector. A reduction on average physical activity with increasing environmental temperature was observed only among crop workers.

Conclusions: The quantity and patterns of physical activity varied by the agricultural sector, sex, and age, indicating that interventions that aim to reduce heat-related morbidity and mortality should be tailored to specific subpopulations. Some workers did not reduce overall physical activity under dangerously hot environmental conditions, which has implications for policies protecting worker health. Future research is needed to determine how physical activity and climatic conditions impact the development of heat-related disorders in this population.

KEYWORDS
agricultural workers, heat exposure, heat illness, physical activity

1 | INTRODUCTION

Agricultural workers frequently perform strenuous physical activities in hot and humid conditions, which can result in dangerous increases in core body temperature.[1,2] Thermoregulatory mechanisms work to maintain internal body temperature within a safe range, but harsh environmental conditions can disrupt normal dissipation of heat, which can lead to heat stress and physiologic strain.[3,4] Heat-related illnesses (HRI) can result, which range from heat cramps to sequelae such as heat exhaustion, and in severe cases, heatstroke and death.[4] Agricultural workers are particularly vulnerable to heat-related mortality; between 2000 and 2010, heat-related fatalities among agricultural workers accounted for 22% of industry sector deaths, with a mortality rate over 35 times higher than the general population of occupational workers.[5]

In the United States, there is no federal standard mandating worker protection from heat stress. Two states, California[6] and Washington,[7] have implemented standards protecting outdoor workers from heat stress and only Minnesota has implemented standards protecting indoor workers from heat stress.[8] Without such standards, workers at the highest risk of HRI such as agricultural workers, are left on their own to monitor their conditions. Yet, agricultural workers have little personal control over their work environments and are seldom provided with amenities such as hazard or overtime pay, workday breaks, minimum wages, insurance coverage, or other protections afforded to workers in other professions. In addition, many workers are paid a piece-rate based on the amount of product harvested, which can lead to a strong economic incentive to work quickly, thus increasing physiologic risks.[9,10]

Physical activity in hot environments has been studied extensively in athletes and in laboratory and military settings,[2] but less is known about physical activity performed among US agricultural workers in the field setting who are uniquely vulnerable to HRI.[11] A recent article reviewing the literature on energy expenditure in various agricultural tasks found only a handful of relevant publications from the past 35 years, and these focused on small numbers of workers.[12] Although mechanical harvesting is being considered and/or being implemented in various agricultural sectors, hand-harvesting by agricultural workers of many noncommodity crops continues to be necessary. Characterizing physical activity and work tasks in this population are important for informing the development of safety interventions and policies among agricultural populations, especially in states without protective standards. The aims of this study were to (a) use accelerometry to objectively quantify physical activity in the summer months among Florida agricultural workers; (b) examine patterns of physical activity over the workday by agricultural work type; (c) investigate the impact of environmental heat on physical activity performed during the workday; and (d) describe the tasks and physical movements that workers performed.

2 | METHODS

2.1 | Study design and population

We analyzed data from the *Girasoles* (Sunflower) study, which was aimed to assess physiologic responses to environmental heat exposure in Florida agricultural workers during the workday. This project was a collaborative effort between university researchers at Emory University and the Farmworker Association of Florida (FWAF), a 35-year-old grassroots community-based membership organization. The FWAF has over 10 000 members statewide who work in various agricultural operations including ferneries, nurseries, and field crops. Trained community health workers from the FWAF used community outreach strategies to recruit a convenience sample of agricultural workers from five different agricultural communities in central and south Florida during the summer work seasons from 2015 to 2017. Data collection for each community occurred as follows: Pierson, FL (May to July 2015); Apopka, FL (August 2015 and June 2016); Immokalee, FL (September to October 2016); Fellsmere, FL (May 2017); and Homestead, FL (July to August, 2017).

Workers were eligible for the study if they were (a) 18 to 54 years of age at the time of the study; (b) English, Spanish, or Creole-speaking; and (c) had worked in agricultural settings for at least 1 month before study participation. Workers were excluded if they had a history of Type 1 diabetes or were currently pregnant. A prior feasibility study found the research protocol used was acceptable to this study population.[13]

2.2 | Data collection and study variables

Study participants were asked to complete an initial survey, anthropometric assessment, and to wear an accelerometer device for three consecutive workdays. The survey was adapted from a previous survey used with agricultural worker populations[14] and elicited information on sociodemographic variables, work characteristics, and HRI factors. Sociodemographic variables included (age, sex, nationality, marital status, and years of education); and work characteristics (years worked in agriculture, number of days worked per week, and type of crops currently working with). Community health workers administered the survey in the participant's primary language.

The agricultural sector was classified into three major categories according to the crops workers reported working with at the time of study: fernery, nursery, or field-crop work. Body mass index (BMI) was calculated from measured height and weight (kg/m^2) and was classified into normal weight (18.5-24.99), overweight (25.0-29.99), and obese (≥30) based on the World Health Organization criteria.[15] There were no workers in our sample that had a measured BMI less than 18.5.

On each workday, participants came to the study field office before and after going to work. Before work, a triaxial accelerometer (Actigraph GT3X+, Pensacola FL) was positioned at the worker's right iliac crest, which the participant was instructed to wear for the entire workday until returning to the study office after work. The accelerometer recorded acceleration on three individual planes of motion (vertical, anteroposterior, and mediolateral) every 30 seconds during the workday, which is summarized as vector magnitude counts, an indicator of the volume of physical activity.[16] After work, participants returned to the study office, where research staff removed the accelerometer equipment and were instructed to note any noncompliance.

A brief survey was administered to participants after work to collect information about specific work tasks that participants performed during their workday. Work tasks reported by participants included planting/potting, cultivating, harvesting/picking crops, loading/packing/transporting, cutting/trimming, moving plants or trees, washing plants or trees, weeding, cleaning the worksite, and mixing or spraying pesticides. In addition, participants provided information about the physical movements associated with the work tasks they performed including bending, walking, standing, cutting, twisting, lifting, sitting, kneeling, reaching, and squatting.

Ambient temperature and relative humidity during the participants' observed workdays were obtained from the Florida Automated Weather Network, which records data every 15 minutes at monitoring stations located in the study communities. A monitoring station was present in each of the five communities under study. The heat index, which approximates the apparent temperature by combining air temperature and moisture into a single scale, was calculated by using the National Weather Service algorithm.[17] Wet bulb globe temperature in the sun (WBGT) was estimated using the following formula:

$$\text{WBGT} = 0.7\left(T_{\text{pwb}} + 1\right) + 0.2(T_{\text{db}} + \Delta T_{\text{g-d}}) + 0.1\,T_{\text{db}},$$

where T_{pwb} is the wet bulb (°C), T_{db} is the ambient air temperature (°C) at 2 m, and $\Delta T_{\text{g-d}} = 8$.[18]

2.3 | Accelerometer data processing

We adapted accelerometer data-processing methods used in the National Health and Nutrition Examination Survey (NHANES)[19] to fit our study design. To assess physical activity occurring specifically during work, we included accelerometer data only if it occurred between a worker's self-reported workday start and stop time. Raw vector magnitude counts for every 30 seconds were summed and collapse into 1-minute counts to obtain the vector magnitude counts per minute (CPM). We defined invalid data as CPM that were not biologically plausible (CPM ≥ 16 000) or were a constant value greater than zero for 10 minutes or greater, which is an indicator of accelerometer malfunction.[20] We also defined nonwear time as CPM with a consecutive string of zeroes of 10 minutes or more. Additional quality-control checks were performed by visually inspecting plots of CPM by work hour among each individual participant for every workday. As we did not identify invalid data, all accelerometer data were utilized for summary measures.

To determine the amount of time spent in sedentary, light, or moderate to vigorous physical activity during the workday, we used thresholds derived from accelerometer calibration studies that measured the association between activity counts and measured energy expenditure.[19] Criteria established by Sasaki et al[21] and Aguilar-Farías et al[22] for categorizing the intensity of work activity using vector magnitude was used in our study as follows: sedentary activity: 0 to less than 200 CPM; light activity: 200 to less than 2690 CPM; and moderate to vigorous activity: 2690 CPM or above. The cumulative time per day spent in sedentary, light and moderate to vigorous activity was derived by summing all of the minutes which met the relevant threshold criteria for each activity level for each study day. In addition, we also calculated the time spent in sustained bouts of moderate to vigorous activity. Sustained bouts were defined as 10 or more consecutive minutes with the CPM meeting the moderate to vigorous activity threshold, with an allowance for interruptions of up to 2 minutes below the threshold.[19]

2.4 | Data analysis

Sociodemographic, health-related, and work-related data were summarized by calculating means and standard deviations for continuous variables and frequency counts and percentages for categorical variables. To summarize heat index (HI) and WBGT, we calculated the average for each participant's workday and then calculated an average for all three workdays. We summarized physical activity by summing the CPM for each participant's workday, and then calculated the median CPM of total observed workdays. Overall, a total of 702 total workdays were examined; 39 of these workdays came from 23 participants who were not observed for all three workdays; however, 91% (221 of 244) of participants were observed for all three workdays. Participants with fewer than 3 days of data did not differ in median CPM (1981, Quartile 1 [Q1] 1136, Q3: 2548) compared to workers with all three workdays (2010 [Q1: 1240; Q3: 3013]), $P = .3021$. In addition, the intraclass correlation coefficient of median vector magnitude was 0.71, which suggests that participant activity was similar over their workdays and that having 1 to 2 workdays should not introduce bias.

We assessed the pattern of physical activity over the workday by agricultural sector using functional data analysis methods.[23] For each participant, every workday's CPM vs time function was smoothed using a local regression method, LOESS, a locally weighted scatterplot smoothing technique based on nonparametric regression, which gives more weight to the points near the data points where the response is estimated.[24] Smoothing parameters were chosen based on the lowest Akaike information criterion (AIC). Next, the median of each participant's workday function was calculated and LOESS smoothed. Then, the median curve for each work type was calculated; the displayed curves use a smoothing parameter of 0.01. This technique has been previously used in our cohort to examine core temperature data.[25] For each minute of the workday, we evaluated the relationship between CPM and work type using analysis of variance. To adjust for multiple comparisons we applied a nonparametric permutation test[26]: for each minute, agricultural sector assignments were randomly permuted and a new test was run; this was repeated 400 times and maximal test statistics were noted. The null hypothesis of no difference between agricultural sector at any minute was rejected if the observed statistic for the actual assignments was in the top 5% of the maximal statistics.

We summarized median CPM by sex, agricultural sector, age, and BMI. The average percent of nonsedentary time (time spent in light activity and moderate to vigorous activity) was calculated and further analyzed using compositional data methods.[27] Generalized linear mixed models (GLMM) were used to test the difference between the percentage of time spent in moderate to vigorous activity by sex and agricultural sector (fernery, nursery, or field crop).

To evaluate the association between WBGT and overall CPM, we used GLMM. We constructed models stratified by primary agricultural work type to account for heteroscedasticity of the residuals. Further residual diagnostics indicated the need for data trimming and robust regression bisquare down-weighting.[28] We used a quadratic term in the model for field-crop workers to properly fit the data. Continuous variables were centered to provide an interpretation of the intercept to represent the average daily CPM for a 38-year-old male with a BMI of 29 who works 8 hours on a day with an average WBGT of 28.3°C. Each model was adjusted for sex, BMI, and hours worked per day.

Last, we examined self-reported work tasks and physical movements used to perform work tasks. We classified the task or movement as "ever" or "never" reporting on at least one of their workdays. All analyses were performed with SAS version 9.4 software (Cary, NC).

3 | RESULTS

A total of 257 participants were enrolled in the study. We restricted analyses to workers who had at least 1 day of accelerometer monitoring data and reported which agricultural sector they were currently working in on the baseline survey, excluding 13 participants. Of the 244 workers in the analytic sample, 65 worked in ferneries, 102 in nurseries, and 77 with field crops (81% with vegetables).

Sociodemographic, anthropometric, and work characteristics of the analytic sample are reported in Table 1. The mean age of participants was 38.2 (standard deviation [SD], 8.7), and the majority were female (62.7%), from Mexico (66.4%), and unmarried (58.4%). Average years of education was 6.7 (SD, 3.5), mean BMI was 28.7 (SD, 4.8), mean years in agriculture was 12.2 (SD, 8.1), and the average workday was 7.8 hours long. The mean heat index to which participants were exposed was 32.3°C and mean WBGT was 28.3°C.

Nationality, years worked in agriculture, hours worked per day, and environmental characteristics differed substantially by the primary agricultural sector. Fernery workers were nearly all from Mexico (93.9%), had been working in agriculture the longest (14.6 years), and worked shorter days (6.2 hours vs 7.8 [field crop] and 8.7 [nursery]). Nursery workers experienced the highest average HI (33.7°C) and WBGT (28.8°C).

CPM and time spent in sedentary, light, and moderate to vigorous physical activity also differed significantly by the agricultural sector (Table 2). Despite having the shortest workdays, fernery workers engaged in the largest amount of moderate to vigorous activity (220 minutes or 3.7 hours per day) and sustained bouts of such activity (231 minutes or 3.9 hours per day), and the least amount of light activity and sedentary activity (75 and 24 minutes, respectively). Physical activity was lowest among nursery workers.

Results describing the pattern of physical activity over the course of the day using functional data analysis are shown in Figure 1. Statistical comparisons after 9 hours were not considered robust because of sparse data. Fernery workers had significantly higher median CPM throughout the day compared to all other agricultural sector types. The pattern of activity over the workday among fernery workers differed from that among nursery and field-crop workers, with more intense activity occurring in the morning than the afternoon. Nursery and field-crop workers had well-defined midday breaks, with mornings and afternoons having about equal levels of activity. The presence of such dips in the median CPM indicates that many participants took their midday break at the same time.

The proportion of the day spent in moderate to vigorous physical activity was greatest for fernery workers and least for nursery workers (Figure 2). Within the agricultural sector, some sex differences were observed; female fernery workers spent more of their workday engaged in moderate to vigorous activity than did males coworkers, although the difference was not statistically significant (71% vs 61%; $P = .092$). Among nursery workers, the proportion of the day spent in moderate to vigorous activity among females was significantly lower than among males (17% vs 33%; $P < .0001$). Male and female field-crop workers both spent a little over a third of their day in moderate to vigorous activity.

The relationship of physical activity and age, displayed by agricultural sector and sex, is shown in Figure 3 and Table 3. An association between physical activity and age was found only in fernery workers. In male fernery workers, CPM increased slightly with age; in contrast, CPM among female fernery workers decreased with age. Average physical activity declined among field-crop workers as average WBGT exceeded about 28°C; this trend was not seen among other workers (Table 3 and Figure S1).

Work tasks such as loading outdoors and weeding were frequently reported among all agricultural sectors, while tasks such as cutting, moving plants, cultivating, and loading indoors varied (Figure 4A). Work tasks more frequently reported in fernery workers were cutting, loading outdoors, and harvesting. Types of physical movements performed are reported in Figure 4B. Overall, most workers reported working in a hot environment, walking, bending, standing, and lifting. Workers in ferneries more frequently performed bending and clipping movements. Some differences in work tasks and physical movements were observed by the sex. In ferneries, females more frequently reported harvesting work tasks than males (34% vs 9%, $P = .04$); in nurseries, females more

TABLE 1 Sociodemographic, health, work, and environmental characteristics by the primary agricultural sector, Girasoles Study, 2015-2017

	Agricultural sector				
	Overall (*n* = 244)	Fernery (*n* = 65)	Nursery (*n* = 102)	Field crop (*n* = 77)	*P* value*
Sociodemographic characteristics					
Age, mean (SD), y	38.2 (8.7)	37.0 (7.2)	38.9 (9.4)	38.2 (8.8)	.39
Sex, n (%)					.05
Male	91 (37.3)	23 (35.4)	31 (30.4)	37 (48.1)	
Female	153 (62.7)	42 (64.6)	71 (69.6)	40 (51.9)	
Nationality, n (%)					<.0001
Mexico	162 (66.4)	61 (93.9)	67 (65.7)	34 (44.2)	
Central America	50 (20.5)	0 (0)	31 (30.4)	19 (24.7)	
Caribbean	28 (11.5)	1 (1.5)	3 (2.9)	24 (31.2)	
United States	4 (1.6)	3 (4.6)	1 (1.0)	0 (0)	
Marital status					.02
Married	101 (41.6)	36 (55.4)	35 (34.3)	30 (39.5)	
Not married	142 (58.4)	29 (44.6)	67 (65.7)	46 (60.5)	
Education, mean (SD), y	6.7 (3.5)	6.8 (3.0)	7.1 (3.5)	6.0 (3.8)	.12
Body mass index, mean (SD), kg/m^2	28.7 (4.8)	29.4 (4.1)	28.6 (4.5)	28.4 (5.7)	.45
Body mass index categories, n (%)					.13
Normal (18.50-24.99)	51 (20.9)	9 (13.9)	21 (20.6)	21 (27.2)	
Overweight (25.0-29.99)	110 (45.1)	28 (43.1)	52 (51.0)	30 (39.0)	
Obese (≥30)	83 (34.0)	28 (43.1)	29 (28.4)	26 (33.8)	
Work characteristics					
Years in agriculture, mean (SD)	12.2 (8.1)	14.6 (6.4)	12.1 (8.2)	10.2 (8.6)	.001
Hours worked per day, mean (SD)	7.8 (1.8)	6.2 (1.7)	8.7 (1.2)	7.8 (1.6)	<.0001
Work start time, median [Q1, Q3]	07:30 [07:00-08:00]	07:00 [06:30-07:25]	07:30 [07:15-08:00]	07:30 [07:00-08:00]	<.0001
Work stop time, median [Q1, Q3]	15:30 [14:30-16:30]	13:00 [12:00-14:40]	16:30 [16:00-17:00]	15:30 [15:00-16:15]	<.0001
Environmental characteristics					
Ambient temperature, mean (SD), °C	28.5 (1.6)	28.1 (1.9)	29.2 (1.2)	27.8 (1.3)	<.0001
Relative humidity, mean (SD), %	76.2 (8.2)	76.6 (7.1)	74.0 (7.4)	78.9 (9.3)	<.0001
Heat index, mean (SD), °C	32.3 (3.1)	31.4 (3.1)	33.7 (2.8)	31.3 (2.7)	<.0001
WBGT, °C	28.3 (1.5)	27.9 (1.3)	28.8 (1.3)	27.9 (1.6)	<.0001

Abbreviation: WBGT, wet bulb globe temperature.
*P values derived from the one-way analysis of variance or the Kruskal-Wallis test, whichever was appropriate for the variable distribution.

TABLE 2 Summary of physical activity measures by primary agricultural work type, Girasoles Study, 2015-2017

	Agricultural sector								
	Overall (*n* = 244)		Fernery (*n* = 65)		Nursery (*n* = 102)		Field crop (*n* = 77)		
Physical activity measure	Median	IQR	Median	IQR	Median	IQR	Median	IQR	*P* value
Counts per minute									
Vector magnitude	1988	1215-2896	3759	2727-5081	1249	915-1818	2056	1482-2596	<.0001
Activity level[a]	Minutes per day								
Sedentary	52	31-86	24	14-45	69	42-102	58	40-88	<.0001
Light	243	141-343	75	46-145	332	262-389	235	170-290	<.0001
Moderate-vigorous	146	71-219	220	167-283	91	40-143	158	97-211	<.0001
Moderate-vigorous[b]	96	14-204	231	165-289	29	0-83	121	46-185	<.0001

Abbreviation: IQR, interquartile range.
[a]Activity levels are defined as the following vector magnitude counts per minute cutoffs: sedentary: 0 to less than 200; light: 200 to less than 2690; moderate to vigorous: 2690 or higher.
[b]Sustained bouts of activity of 10 consecutive minutes or more, allowing for up to a 2-minute interruption.

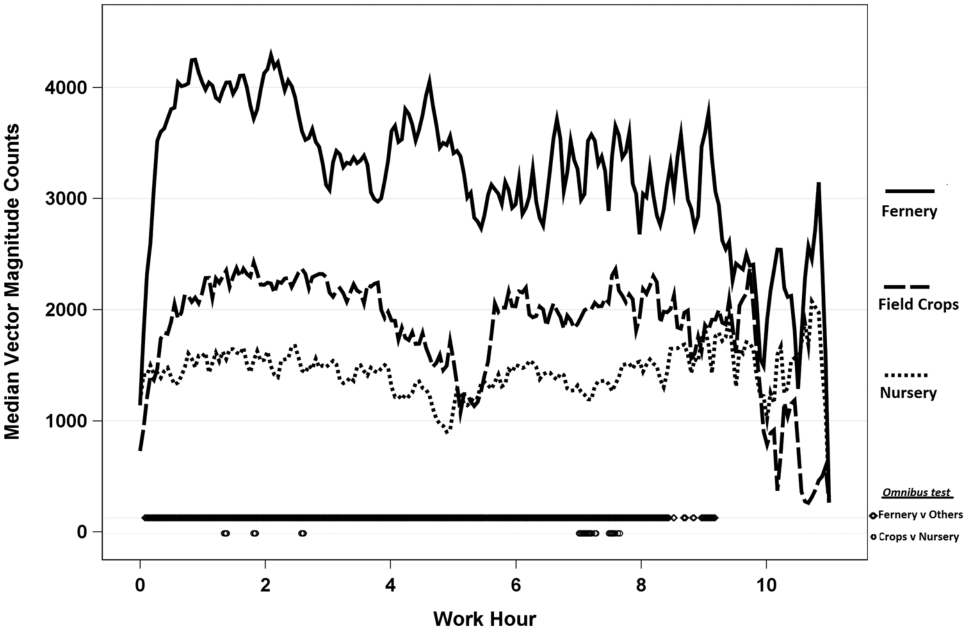

FIGURE 1 Pattern of work activity over the workday among Florida agricultural workers, by the agricultural sector (Girasoles Study, 2015-2017). Omnibus test results are significant at times points marked by a symbol (diamond for fernery vs other work types, circle for field crop vs nursery). Statistical comparisons beyond nine work hours are based on sparse data

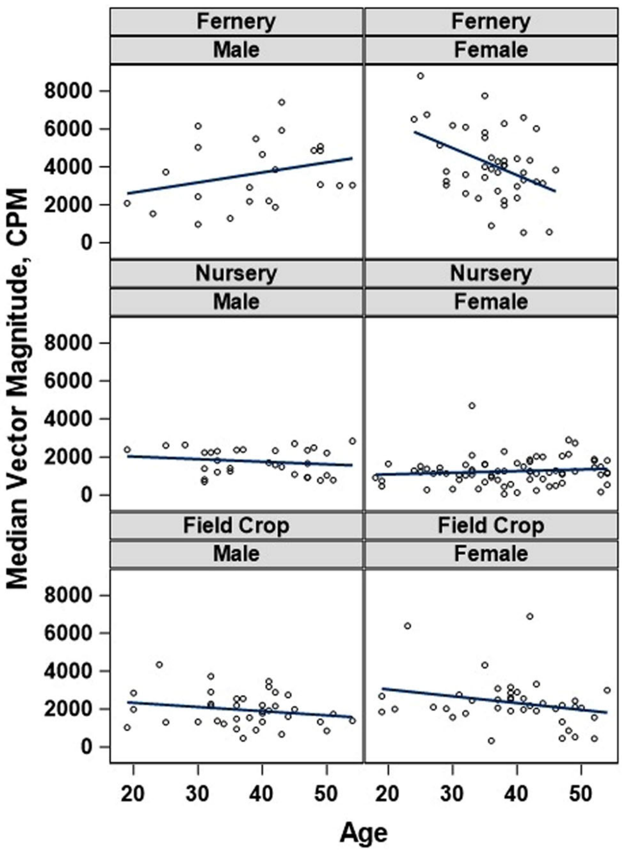

FIGURE 2 Vector magnitude counts per minute by age, sex, and agricultural sector, Girasoles Study, 2015-2017

frequently reported cleaning tasks (34% vs 23%, *P* = .02); in field-crop work, males more frequently engaged in lifting (42% vs 34%, *P* = .03) and squatting movements (17% vs 5%, *P* = .01).

4 | DISCUSSION

This study is the first to describe occupational physical activity among US agricultural workers using standardized, objective measurement. We found that Florida agricultural workers had a high overall volume of physical activity, with sustained bouts of moderate to vigorous activity during the workday. Within this high overall level of activity, there were substantial differences by the agricultural sector, reflecting the heterogeneity of crop-specific demands.

Crop workers reduced their typical physical activity in response to increasing environmental heat, but fernery and nursery workers did not. In a study using video monitoring of seven grape workers on multiple days, Ioannou et al[29] found that workers took more informal work breaks as the temperature climbed. The reasons why there was no evidence of heat impact among nonfield crop workers are speculative. Fernery workers had shorter hours and on average ended their workday around 1 PM, before the worst heat of the day, while nursery workers may have had more chance to enter air-conditioned buildings for a brief respite.

Within the different agricultural sectors, we found differences in the work tasks that may contribute to the observed difference in overall physical activity. Harvesting ferns involves intense physical including bending over, thrusting arms into masses of ferns, and cutting the fronds at their base. After the workers cut the fronds, they

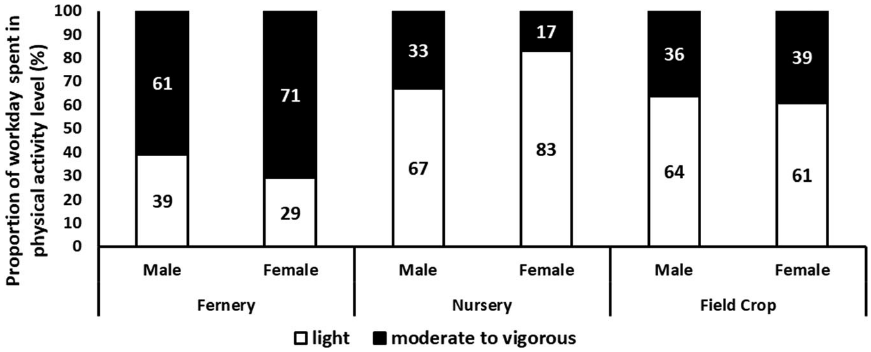

FIGURE 3 Proportion of workday spent in activity levels by the sex and agricultural sector in Florida agricultural workers, Girasoles Study, 2015-2017

secure them with a wire or plastic tie and then toss them aside until they have enough to carry by the armload to a loading area. Most often they are paid by the number of bunches they harvest. The intensity of the physical activity in fernery workers is validated with their sustained and substantially elevated activity levels. Perhaps reflecting their greater involvement in harvesting tasks, female fernery workers were more physically active than their male coworkers.

While we found that crop workers did have periods of moderate to vigorous physical activity, they were more likely to have periods of light or sedentary activity when compared to fernery workers. Participants worked with a wide variety of crops that necessitate different tasks using different physical movements and activity patterns. Vegetable harvesters bend over to pull or cut vegetables, placing the harvested crop in a bucket that they carry as they move along a row. They then carry the full bucket to deposit in a large bin or truck. Others, such as those harvesting sawtooth palmetto berries may walk long distances between trees. Additionally, it is likely that work tasks performed by field-crop workers vary more by season than in ferneries or nurseries.

Overall, the nursery workers were found to have less moderate to vigorous physical activity when compared to fernery or field-crop workers. Work tasks at nurseries are varied and include planting seeds and/or plants in pots, loading pots of plants onto trays and loading and carrying trays, boxes, or bags of soil. Other nursery workers are outside and maybe doing tasks such as loading and cutting plants.

Increasing our knowledge of the nature of agricultural work and the physical activity associated with that work can aid in designing interventions to protect workers during the hottest times of the workday, and to inform public policy regarding the work safety of agricultural workers. The finding that fernery workers have the highest volume of physical activity has important implications for occupational health policy. Guidelines from the Occupational Safety and Health Administration recommend the provision of water, rest, and shade to protect agricultural workers from occupational heat-related hazards.[2] Fernery workers are often paid by a piece-rate, which discourages workers from taking breaks for water or rest in lieu of economic considerations. A recent study showed that piece-rate pay is associated with a four-fold increased risk of HRI.[9] This information, as well as the information from the current study, highlights the need for workplace health and safety standards related to rest breaks to protect the health of these workers.

5 | LIMITATIONS AND STRENGTHS

There are some limitations to consider in interpreting the results of this study. Accelerometry measures objective physical activity but may underestimate upper-body movements. Agricultural tasks include frequent bending, stretching and reaching, hoisting loads

TABLE 3 The association between average daily physical activity and environmental heat, controlling for the agricultural sector, sex, age, body mass index, and work duration, Girasoles Study, 2015-2017

	Agricultural sector					
	Fernery		Nursery		Field crop	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Intercept[a]	3543	2914, 4171	1746	1548, 1944	2009	1760, 2259
WBGT, °C	188	−24, 399	−21	−82, 41	**−162**	**−306, −19**
WBGT squared	–	–	–	–	−35	−80, 9
Sex (ref = male)	291	−387, 970	**−494**	**−724, −264**	186	−123, 494
Age, y	27	−35, 89	8	−4, 19	−9	−27, 9
Age × sex	**−131**	**−235, −26**	–	–	–	–
BMI	−72	−166, 22	−3	−27, 21	−10	−42, 22
Work duration, h	−94	−257, 70	0.4	−39, 40	−46	−119, 28

Note: The bolded items are significant at the 5% level. Abbreviations: BMI, body mass index; CI, confidence interval; WBGT, wet bulb globe temperature.
[a]Continuous variables were centered; thus the intercept represents the average daily CPM for a 38-year-old male having a BMI of 29 who works 8 hours on a day with an average WBGT of 28.3°C.

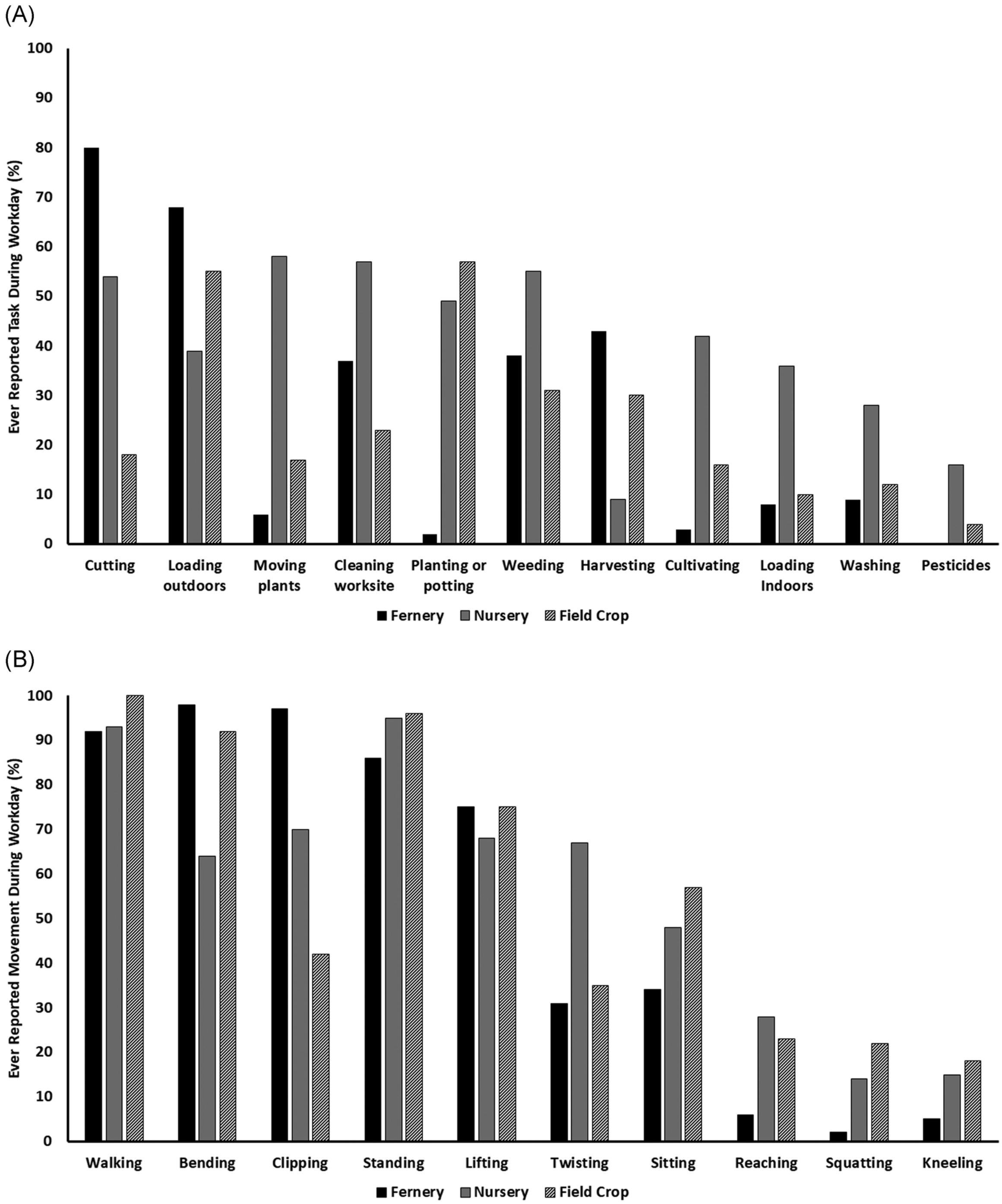

FIGURE 4 A, Work tasks performed by the agricultural sector in Florida agricultural workers, Girasoles Study, 2015-2017. B, Reported physical movements by the agricultural sector in Florida agricultural workers, Girasoles Study, 2015-2017

over the head, heavy lifting and carrying of sacks and buckets, and walking long distances from the field to a loading area. In this study, accelerometers were placed at the hip, which may not have fully captured work activities that involve movements such as lifting and twisting. These are common movements in agricultural work, such as when hauling crops in the field and loading large packages of produce into transport trucks. However, studies have reported moderate to high correlation between accelerometers placed at the hip and the wrist.[30,31] Additionally, the use of accelerometry to evaluate physical activity is more reliable than self-report measures, which are subject to recall error and misclassification.

Since we were unable to follow the worker to their worksite, we relied on self-reported start and stop times for the workday. As a result, it is possible that nonwork activity may have been misclassified as work activity, or vice versa. Another limitation is that we were not able to observe all workers for all three workdays. However, 91% participated for three workdays, and their daily median CPM were similar to those who participated in fewer workdays. We found that overall WBGT did not impact the overall amount of physical activity performed during the day among fernery and nursery workers. However, the relation between daily summary values may not reflect the relationship between heat and activity on a minute-by-minute basis. Additionally, worker response at hotter temperatures than we observed may be different.

Our findings may not be generalizable to all Florida agricultural workers. We relied on convenience sampling to recruit workers, which may have resulted in healthier, more motivated workers participating in this study. Our study captures the experience of agricultural workers who primarily work for subcontractors and labor crews, who often do not provide training on workers' safety, including preventing HRI. Additionally, our results apply to activities performed in the hot and humid Florida summer season; agricultural tasks and activities occurring during other seasons are likely to be different.

6 | CONCLUSION

This study increases our knowledge of the physical activity performed by Florida agricultural workers. Both the quantity and patterns of physical activity varied by the agricultural sector, sex, and age, indicating that interventions that aim to reduce heat-related morbidity and mortality should be tailored to specific subpopulations. Some workers did not reduce overall physical activity under dangerously hot environmental conditions, which has implications for policies protecting worker health. Future research is needed to determine how physical activity and climatic conditions impact the development of heat-related disorders in this population.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

Rodney Ehrlich declares that he has no conflict of interest in the review and publication decision regarding this article.

AUTHOR CONTRIBUTION

Data management: JMM and LE. Study planning: VMT, JF, AJT-A, VSH, and LAMC. Study-site visits: JMM, LE, VMT, and LAMC. Recruitment: JE and AJT-A. Data collection: VMT, JE, AJT-A. Statistical analysis: JMM, LE, and VSH. Manuscript preparation: JMM, LE, JF, and LAMC. Manuscript review: VMT, JE, AJT-A, and LAMC.

ETHICS APPROVAL AND INFORMED CONSENT

This study was approved by the Emory University Institutional Review Board (#IRB00075192). All study participants provided informed consent.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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