Distribution Agreement

Signature:

______________________________ _______________

Catherine I Obadina Date

Seasonal differences in the risk of acute kidney injury (AKI) and the effect of season on the associations between core temperature and AKI and between work intensity and AKI, among heat-exposed Florida agricultural workers

By

Catherine I. Obadina

MPH

Epidemiology

Vicki Stover Hertzberg Ph.D.

Committee Chair

Laura Plantinga Ph.D.

Field advisor

Seasonal differences in the risk of acute kidney injury (AKI) and the effect of season on the associations between core temperature and AKI and between work intensity and AKI, among heat-exposed Florida agricultural workers

By

Catherine I. Obadina

MB; BS

College of Medicine, University of Lagos

2011

Thesis Committee Chair: Vicki Stover Hertzberg, Ph.D.

An abstract of

A thesis submitted to the Faculty of the

Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of

Master of Public Health

in Epidemiology

2019

Abstract

Seasonal differences in the risk of acute kidney injury (AKI) and the effect of season on the associations between core temperature and AKI and between work intensity and AKI, among heat-exposed Florida agricultural workers

By Catherine I. Obadina

Introduction. Acute kidney injury (AKI) can result in a number of complications such as chronic kidney disease, end-stage renal disease, and death. Exposure to heat has been associated with AKI. There is, however, a limited understanding on how different seasons affect the incidence of AKI and how season modifies the association between core temperature and AKI, and work intensity and AKI among heat-exposed agricultural workers.

Methods. Physiological data along with blood and urine samples were collected from 245 agricultural workers employed in various agricultural industries in different communities in Central Florida. Data were collected during 3-day work periods in the summer of 2016 (n=183) and winter of 2017 (n=62). Pre- and post-shift samples were collected on each workday. Chi-square test was used to compare the risk of AKI across seasons while stratified logistic regression and interaction terms were used to examine the effect of core temperature and work intensity on the risk of AKI and potential modification of these effects by season.

Results. Among summer participants, 32% had a form of AKI on at least 1 workday as compared to 17% of winter participants (p=0.18); 28% of participants in the summer had stage 1 AKI on at least 1 workday compared to 12% in the winter. In the summer season, after adjusting for age and sex, the risk of developing AKI in agricultural workers with core temperature $\geq 38^{\circ}$C was 72% higher than the odds in those with core temperature $<38^{\circ}$C (OR, 1.72; CI, 1.20-2.46). In the logistic regression models examining the effect of the interaction between work intensity and season on AKI as well as the effect of the interaction between core temperature and season on AKI, there were no seasonal differences in the associations between Core temperature and AKI (p=0.27) or work intensity and AKI (p=0.63) when adjusted for age, sex and other covariates.

Conclusions. There was no significant difference in the risk of AKI across seasons and the associations between work intensity and AKI as well as core temperature and AKI did not differ significantly by season.

Seasonal differences in the risk of acute kidney injury (AKI) and the effect of season on the associations between core temperature and AKI and between work intensity and AKI, among heat-exposed Florida agricultural workers

By

Catherine I Obadina
MB; BS

College of Medicine, University of Lagos

2011

Thesis Committee Chair: Vicki Stover Hertzberg Ph.D.

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology
2019

Acknowledgements

I would like to thank everyone who has contributed to this work.

In particular, I would like to thank Dr. Vicki Hertzberg Ph.D., Professor and Director of the Center for Data Science, Nell Hodgson Woodruff School of Nursing, for providing me with the opportunity to work with her dataset and for her guidance and mentorship from the inception to the completion of this thesis.

I would like to thank Lisa Elon MS, MPH and Jacqueline Mix, Ph.D. for their insight, support and guidance throughout the process of putting this thesis together.

Finally, I would like to thank Dr. Laura Plantinga, Assistant Professor of Medicine, Emory University School of Medicine for her continued support and mentorship.

Table of Contents

Introduction

Acute kidney injury (AKI) is a global public health problem that affects about 13.3 million people every year around the world. It is thought to contribute to high morbidity, mortality (average of 1.7 million deaths per year), and healthcare costs (1, 2). AKI is a broad clinical syndrome encompassing various etiologies. It represents an abrupt decrease in kidney function and is associated with a range of subsequent kidney impairments from mild changes to total organ failure (3,4). There are different pathological processes and some physiological processes related to stress that can cause AKI (3). For example, strenuous physical exertion in hot environments can result in AKI (5). Outdoor workers, such as agricultural workers, are exposed to multiple environmental and occupational hazards that can result in AKI (6,7). Due to the nature of their job, agricultural workers spend a considerable amount of time under the sun and in intense heat (7). In the United States, they are 20 times more likely to develop a heat-related illness than workers in other industries (8).

Previous work suggests that heat strain after a single shift of agricultural work is associated with incident AKI. A cross-sectional study was carried out in the summer season across 15 farms in California's central valley to assess heat strain, volume depletion and kidney function. Among the 283 eligible field workers enrolled in the study, 11.0% met Kidney Disease Improving Global Outcomes (KDIGO) criteria for stage 1 AKI and 1.3% met the criteria for stage 2 AKI. Heat strain was found to be associated with 1.3-fold risk of AKI among the male worker [OR=1.29 (95% CI 1.03, 1.61)] (6). Another study in Wales (9) aimed to identify the seasonal variation in the occurrence of and outcomes following AKI using electronic alerts. Over a 1-year period, 48,457 alerts were recorded. The highest proportion of episodes (26.2%)

occurred between January and March, while the lowest proportion, 23.3%, occurred between October and December ($p<0.001$). A progressive fall in the number of AKI episodes was noted in each quarter of the calendar year. (9). While the earlier study focused on heat exposure and AKI in the summer season alone, the later study identified seasonal variations of AKI among participants without a focus on heat exposure.

Environmental temperatures differ between the summer and winter season and Florida is one of the states known for its very high temperatures, particularly during the summer season. In our previous study of AKI, the focus was on agricultural workers in the summer. This previous study examined the hydration status and kidney function in 192 agricultural workers in Florida showed a significantly high prevalence of dehydration and kidney injury among the workers, with 37% higher likelihood of AKI for every 5° F increase in heat index (10). The examinations of seasonal variation in AKI, particularly among the heat exposed population are limited and to our knowledge, non-existent in the U.S. The objectives of this study were to estimate the risk of AKI among heat-exposed Florida agricultural workers in summer and winter and to determine whether there are seasonal differences in the associations between work intensity and AKI as well as core temperature and AKI.

METHODS

Study Design and Population

The Girasoles study of heat exposure among migrant agricultural workers was conducted via an established collaboration between academic researchers from Emory University and the University of Florida and community researchers from the Farmworker Association of

Florida (FWAF). Farmworkers from several Florida communities (Immokalee, Apopka, Fellsmere, Pierson) employed in various types of agricultural operations within Florida were recruited for this study by trained community partners. Agricultural workers were eligible to participate in this study if they met the following criteria; male and female farmworkers between the ages of 18-54 years currently working in fernery, nursery, or crop field operations for 2 weeks or more. Workers were ineligible if they had a history of type 1 diabetes or were currently pregnant. Due to the use of ingestible core temperature sensor, workers who weighed less than 80 pounds (37 kg); had a history of esophagus, stomach, or intestinal disease; previous surgery of the esophagus, stomach, or intestine; swallowing difficulties; or presence of a pacemaker were excluded from the study. Baseline clinical and survey assessment on a non-working day, followed by pre- and post- shift clinical assessments for up to 3 consecutive workdays in a single week, were collected from consented participants. The study procedures were reviewed and approved by the Institutional Review Board and participation of human subjects occurred only after informed consent was obtained.

Data Collection and kidney function indicator

Data collection was carried out in the summer months of (May-July) 2016 while the cool weather controls were studied in December 2016 to January 2017. All data collection took place at the FWAF offices for the privacy and comfort of participants. At the baseline assessment, a questionnaire was used to collect sociodemographic (age, gender, education level), work characteristics (years worked in agriculture, number of hours worked per day, type of work), and health-related information. The survey was administered to workers in their primary language by trained research partners. Clinical and anthropometric data were then collected by trained research staff at baseline and on 3 consecutive work days (pre- and post-work shift) for each study participant. General data collected at baseline included height and weight [used to calculate BMI (kg/m^2)], systolic and diastolic blood pressure, and resting heart rate.

Outcome-AKI

Blood and urine samples were collected at baseline and at the 3 consecutive pre- and post-shift workday visits. Capillary blood samples were collected from each participant via finger stick with an iSTAT® Blood Analyzer for the measurement of metabolic panel (sodium, potassium, creatinine, BUN, hemoglobin). Urine specific gravity (USG) and urine osmolality were determined Using a urine osmolality meter (Osmocheck®) to analyze urine samples collected. A portion of urine samples were frozen for subsequent measurement of creatinine. The outcome, AKI was defined based on the Kidney Disease Improving Global Outcomes (KDIGO) criteria and was considered to be present when post-shift serum creatinine values (measured with the iSTAT® Blood Analyzer) increased by at least 0.3 mg/dL from pre-shift values or was at least 1.5 times the pre-shift values. Stage 1 was defined as serum creatinine increase of ≥ 0.3mg/dl or change in post shift value by 1.5 to 1.9 times of the pre-shift value. Stage 2 was defined as an increase in post shift serum creatinine by 2.0 to 2.9 the pre-shift value while stage 3 was defined as post shift value ≥ 3.0 times the pre-shift value (4).

Exposures- core temperature and work intensity

At each pre- workday visit, study equipment to obtain field measures for work intensity, heart rate (HR), and core body temperature were fitted onto each participant. Work intensity, represented by the number of minutes of moderate to vigorous exercise of each worker, was measured continually during the work day with a Waist Accelerometer (Actigraph® GT3X+) via ActiLife6 Software (11). Core temperature for each worker was obtained via an ingestible temperature sensor which transmitted core temperature data to a Polar® T31 HR transmitter strap, and a temperature of 38°C or higher represented the cutoff for high core body temperature. Heat index was calculated from ambient temperature and relative humidity levels using the National Weather Service algorithm during the study period.

Statistical analysis

Statistical analyses were performed using SAS Version 9.4. $p \leq 0.05$ was set as the cutoff for statistical significance.

Baseline sociodemographic, physiologic and work characteristics among summer and winter farmers were compared using the means and standard deviation for continuous variables and frequency counts and percentages for categorical variables. A two-sample t-test was used to compare the significance in the difference of the means across the two seasons. The distributions of kidney function measures were examined using normality plots and summary statistics. Chi square tests were further used to compare the seasonal differences in AKI, AKI stages and USG. Fisher's exact test was used for small cells. The unadjusted relationships between AKI and the predictors of interest (Work intensity and Core temperature) were also assessed by season. Due to the skewness in the distribution of work intensity, the median value was used to dichotomize the work intensity variable into low (defined as moderate to vigorous exercise < 163 minutes) and high (defined as moderate to vigorous exercise ≥ 163 minutes) work intensity groups.

To evaluate the effect of season on the association between AKI and work intensity and the association between AKI and core temperature, a generalized linear mixed model (GLMM) with a random effect (workers within the same household) was first examined. There was no clustering effect and therefore, the random effect was eliminated.
Logistic regression was then used. The models were constructed to include interaction terms that assessed whether the relationship between AKI and core temperature, AKI and work intensity differed by season. The model also contained other covariates to adjust for potential bias, specifically sociodemographic (age, sex), physiologic (systolic blood pressure, diastolic blood pressure, BMI, USG≥1.020) and work characteristics (work duration, primary work, years worked in agriculture). Adjusted odds ratios (AOR) along with 95% confidence intervals (CI), were estimated. Season-stratified models were also used to estimate the within-season effects of core temperature and work intensity on AKI.

Results

A total of 245 agricultural workers provided data at baseline and over 3 consecutive workdays in three primary work settings; 27% fernery, 29% nursery and 44% field crop; 75%(n=183) of the workers were studied in the summer and 25% (n=62) in the winter. Males were the minority (38%) in summer and the majority (56%) in winter. The mean ages for the summer and winter population were 37 and 38 years, respectively. Both summer and winter groups had an average of 7 years of education and 12 years of agricultural work experience. The average BMI was 29 and 28 kg/m^2 for summer and winter workers, respectively. Mean systolic and diastolic blood pressure was higher among winter participants 132 /83 mmHg when compared to summer participants 129/80 mmHg (Table 1a).

Of the summer participants, 32% had AKI on at least one of the working days, compared to 17% of the winter participants (P-value =0.18). There was no significant difference between AKI stages in the summer and winter (p-value=0.098). 85% of summer workers had USG that was ≥1.020 on at least 1 working day which was significantly higher than the proportion of winter workers (77%) with USG ≥1.020 (P-value=0.02). There was no significant difference between summer and winter workers who had USG≥ 1.030 on at least one working day (P-value=0.23). 82% and 22% of the summer workers had their core temperature ≥38°C and ≥38.5°C respectively on at least one of the working days as compared to 83% and 24% of winter workers who had their core temperature≥ 38°C and ≥38.5°C respectively. The differences were not statistically significant. Work intensity, calculated as the average number of minutes of moderate to vigorous physical activity, was higher among winter participants 194 compared to summer participants 173 (Table 2). 29% of workers with core temperature ≥ 38°C on at least one working day had AKI on at least a working day compared to 3% of workers who developed AKI with core temperature < 38°C. The difference was statistically significant (p-value=0.03) (Table 3).

In the summer cohort the risk of developing AKI in agricultural workers with core temperature ≥38°C was 72% higher than the risk in those with core temperature <38°C adjusting for age and sex. High vs. low core temperature had no significant association with AKI in the winter cohort (OR 1.00, 95% CI: 0.42, 2.38), nor was high vs. low work intensity associated with AKI in either the summer (OR 1.001, 95% CI: 0.996, 1.005) and winter (OR 0.998, 95% CI: 0.985, 1.010) after adjusting for age and sex (Table 4).

In the logistic regression models examining the effect of the interaction between work intensity and season on AKI as well as the effect of the interaction between core temperature and season on AKI, season had no significant effect on the relationship between AKI and core temperature ($p=0.27$) nor did season have any significant effect on the relationship between AKI and work intensity ($p=0.63$) when adjusted for age, sex and other covariates (Table 5).

Discussion

In this study, a high proportion of Florida agricultural workers had a high risk of AKI in both summer and winter. While AKI risk was almost 2-fold higher in the summer vs. winter participants (32% vs. 17%), the difference in AKI risk between the seasons was not statistically significant. Also, no statistically significant seasonal difference was found in the associations between Core temperature and AKI or work intensity and AKI. The effect of season on AKI risk and outcomes particularly in relation to heat exposure is an understudied area and current evidence base is small (12). Prior research has shown that season impacts the epidemiology of AKI, and the effects seen both in winter and summer months vary between regions depending on the local climate type (12).

Phillips *et al.* (9) and more recently Iwagami *et al.* (13) both studied the seasonal patterns of the incidence and outcome of AKI among hospitalized and primary care patients. They both concluded that their outcomes were most likely explained by the seasonal changes in the underlying diseases that precipitated AKI in those patients (12). The increase in environmental temperatures has greatly contributed to occurrence of AKI (14). Studies have shown an increase in the risk of AKI-associated hospitalizations during summer periods with higher temperatures (12, 14, 15).

Global ambient temperatures are projected to rise over the coming decades due to climate change and the impact of warmer temperatures on human health has become an area of increasing public health concern (16). Agricultural workers are a major part of the vulnerable population most adversely affected by this change in temperature due to constant heat exposure and other working conditions. When carrying out prolonged vigorous work or exercise in the heat, increased physiological strain due to thermoregulation may lead to dehydration (17). USG and urine osmolality are correlated and are pointers to the hydration level in an individual. USG>1.020 can indicate relative dehydration while a value > 1.030 indicates severe dehydration. (18). In this study, the proportion of workers with USG≥1.020, on at least one of the 3 working days was significantly higher in the summer compared to winter (P-value=0.02). These workers spent the same average amount of hours working in their various locations. concomitantly, the average heat index values for summer agricultural workers 89 (SD 6) was much higher than in the winter workers 68 (SD 9). A previous study done on a subgroup of participants of this study by Mix *et al.* (10) showed that a strikingly high proportion of workers were dehydrated before starting their work shift and this dehydration pattern increased substantially by the end of the work shift. They further found the mean heat index to be significantly associated with the incidence of AKI over the workday which demonstrated that AKI was occurring in the U.S agricultural workforce exposed to hot working environments. There was a statistically significant association between the core temperature and AKI status of agricultural workers in the summer when adjusted for age and sex (Table 4) but not in the winter. AKI was not significantly associated with the intensity of a farmer's work both in the summer and winter after controlling for age, sex and other covariates. Overall, despite increased heat being associated with AKI, we are not able to conclude in this study that season statistically significantly modifies the relationship between participant's core temperature and their AKI status (p=0.27) nor the relationship between participant's work intensity and their AKI status (p=0.63).

There were several limitations to this study. Power was limited with small sample sizes, particularly in the winter population. In addition, one of the exposures (work intensity) was converted to a categorical variable, and this may have further decreased the power to detect a difference. We had some missing data that may have resulted in selection bias, if those with missing data were more or less likely to develop AKI. There is also the question about how generalizable the study is to the general population as most workers were of Latino origin. Additionally, there is a possibility of residual confounding as there might be variables we were not aware of and therefore did not control for. Due to the nature of the climate in Florida, there is a possibility that the workers experienced acclimatization to the temperature because all enrolled worker had worked in Florida for at least 2 weeks prior to participating in the study. AKI should be evaluated in real time, which forms part of the complexity in practice, but real-time measures of AKI may be confounded by factors such as volume and type of fluid intake, food intake, medications, sweating and access to cooling systems. There is a possible chance of AKI being a result of a combination of factors such as medication use, chemical exposures, and heat exposures as studies of agricultural workers in central America have postulated in the past, although, chemical exposures such as pesticides that might theoretically have an effect on renal function, were not examined.

Regarding the strengths of this study, there was the risk of losing some of the workers as it is common for farmworkers to migrate and not be settled in one community. This would have reduced the sample size and further decreased the statistical power of the study but this was mitigated by targeting communities described by FWAF as seasonal (i.e. less migratory). Another strength of this study was the recruitment of workers across three different types of agricultural work settings which suggests that no one crop, or agricultural setting exposed workers to chemicals that could increase the likelihood of AKI (10).

In conclusion, while AKI risk was almost 2-fold higher in the summer compared to winter agricultural workers, this risk was not statistically significant. Additionally, no significant effect of season on the association between AKI and core temperature or between AKI and work intensity was found.

References

1. Mehta RL, Cerda J, Burdmann EA, et al. International Society of Nephrology's 0by25 initiative for acute kidney injury (zero preventable deaths by 2025): a human rights case for nephrology. Lancet. 2015;385:1–28.
2. Zuk, A., & Bonventre, J. V. (2016). Acute Kidney Injury. *Annual Review of Medicine*, *67*, 293–307.
3. Murugan, R., & Kellum, J. A. (2011). Acute kidney injury: what's the prognosis? *Nature Reviews. Nephrology*, *7*(4), 209–217.
4. Kidney Disease Improving Global Health Outcomes (KDIGO) Working Group. Definition and classification of acute kidney injury. *Kidney Int* 2012;2:(Suppl2):19.
5. Junglee NA1, Di Felice U, Dolci A, Fortes MB, Jibani MM, Lemmey AB, Walsh NP, Macdonald JH. Exercising in a hot environment with muscle damage: effects on acute kidney injury biomarkers and kidney function.
6. Balbus JM1, Malina C. Identifying vulnerable subpopulations for climate change health effects in the United States. Journal of Occupational and Environmental Medicine, JAN 2009; 51(1):33-37.
7. Armitage, T.L., Joseph, J., Moyce, S., Mitchell, D., Schenker, M.A., & Tancredi, D.J. (2017). Heat strain, volume depletion and kidney function in California agricultural workers. Occupational and environmental medicine, 74 6, 402-409.
8. Wilk VA. The occupational health of migrant and seasonal farmworkers in the United States. ERIC, 1986.

9. Phillips D, Young O, Holmes J, et al. Seasonal pattern of incidence and outcome of Acute Kidney Injury: A national study of Welsh AKI electronic alerts. *Int J Clin Pract*. 2017;71: e13000. h

10. Jacqueline Mix; Lisa Elon; Valerie Mac; Joan Flocks; Eugenia Economos; Antonio J. Tovar-Aguilar; Vicki Stover-Hertzberg; Linda A. McCauley. Hydration Status, Kidney Function and Kidney Injury in Florida Agricultural Workers. Journal of occupational and environmental medicine. 2017

11. Stec, Michael J and Eric S. Rawson. "Estimation of resistance exercise energy expenditure using triaxial accelerometry." Journal of strength and conditioning research 26 5 (2012): 1413-22.

12. Nicholas M Selby; Acute kidney injury changes with the seasons, *Nephrology Dialysis Transplantation*, Volume 33, Issue 8, 1 August 2018, Pages 1281–1283

13. Masao Iwagami, Hidekazu Moriya, Kent Doi, Hideo Yasunaga, Rei Isshiki, Izumi Sato, Yasuhiro Mochida, Kunihiro Ishioka, Takayasu Ohtake, Sumi Hidaka, Eisei Noiri, Shuzo Kobayashi; Seasonality of acute kidney injury incidence and mortality among hospitalized patients, Nephrology Dialysis Transplantation, Volume 33, Issue 8, 1 August 2018, Pages 1354–1362.

14. Youn-Hee Lim, Rina So, Choongho Lee, Yun-Chul Hong, Minseon Park, Logyoung Kim, Hyung-Jin Yoon, Ambient temperature and hospital admissions for acute kidney injury: A time-series analysis, Science of The Total Environment, Volumes 616–617, 2018, Pages 1134-1138, ISSN 0048-9697.

15. Association Between High Environmental Heat and Risk of Acute Kidney Injury Among Older Adults in a Northern Climate: A Matched Case-Control Study

McTavish, Rebecca K. et al. American Journal of Kidney Diseases, Volume 71 , Issue 2 , 200 – 208

16. Weinberger, R. K., Kirwa, K., Eliot, N. M., Gold, J., Suh, H. H. & Wellenius, A. G. (2018). Projected Changes in Temperature-related Morbidity and Mortality in Southern New England. Epidemiology, 29(4), 473–481. doi: 10.1097/EDE.0000000000000825.
17. Racnais S, Alonso JM, Coutts AJ, et al. Consensus recommendations on training and competing in the heat Br J Sports Med 2015;49:1164-1173.
18. Simerville, J. A. MD., Maxted W. C. MD., Pahira, J. J. MD. Urinalysis: a comprehensive review. Am Fam Physician. 2005 Mar 15;71(6):1153-1162.

Table 1a. Baseline Socio-demographic, Work and Baseline Physiologic Characteristics of Florida Agricultural Workers, Girasoles Study 2016-2017

Characteristics at baseline	**Overall Mean (SD) or % [n]**		**Summer Mean (SD) or % [n]**		**Winter Mean (SD) or % [n]**		**P-value**
Agricultural workers		[245]		[183]		[62]	
Age (years)	37.6	(8)	37	(8)	38	(8)	0.47
Gender							
Male	42%	[104]	38%	[69]	56%	[35]	0.0009
Female	58%	[141]	62%	[114]	44%	[27]	<0.0001
Years of education (years)	7	(3)	7	(3)	7	(3)	0.46
Years working in agriculture	12	(8)	12	(8)	12	(8)	>0.99
Hours worked per day	7.8	(1.7)	7.7	(1.7)	8.2	(1.4)	0.04
Work type							
Fernery	27%	[66]	30%	[54]	19%	[12]	
Nursery/landscapes	29%	[70]	33%	[59]	18%	[11]	
Crops	44%	[105]	37%	[66]	63%	[39]	
Body mass index (kg/m^2)	29	(50)	29	(5)	28	(5)	0.77
Systolic blood pressure (mmHg)	129	(18)	128	(13)	132	(19)	0.15
Diastolic blood pressure (mmHg)	80	(11)	79	(11)	83	(10)	0.02

Table 1b. Agricultural operations in Florida farmworker's community, Girasoles Study 2016-2017

Work type	Characteristics Community	Overall Mean (SD) or % [n]		Summer Mean (SD) or % [n]		Winter Mean (SD) or % [n]	
Fernery		27%	[66]	30%	[54]	19%	[12]
	Immokalee	2%	[1]	2%	[1]		0
	Apopka		0		0		0
	Fellsmere		0		0		0
	Pierson	98%	[65]	98%	[53]	100%	[12]
Nursery/landscapes		29%	[70]	33%	[59]	18%	[11]
	Immokalee	6%	[4]	3%	[2]	18%	[2]
	Apopka	77%	[54]	76%	[45]	82%	[9]
	Fellsmere	16%	[11]	19%	[11]		0
	Pierson	1%	[1]	2%	[1]		0
Crops		44%	[105]	37%	[66]	63%	[39]
	Immokalee	65%	[68]	77%	[51]	44%	[17]
	Apopka	5%	[5]	6%	[4]	2%	[1]
	Fellsmere	30%	[32]	17%	[11]	54%	[21]
	Pierson		0		0		0

Table 2. Risk of AKI and high urine specific gravity in summer and winter cohorts, Girasoles Study 2016-2017

	Summer		Winter		
Characteristics	**Mean SD) or %**	**[n]**	**Mean (SD) or %**	**[n]**	**P-Value**
AKI on at least 1 working day					0.18
Yes	32%	[50]	17%	[9]	
AKI stage					0.06
Stage 0	68%	[104]	83%	[43]	
Stage 1	28%	[43]	12%	[6]	
Stage 2	4%	[6]	6%	[3]	
Stage 3	1%	[1]	0	[0]	
High urine specific gravity (USG) on at least 1 working day					
USG> 1.020	85%	[136]	77%	[40]	0.02
USG > 1.030	21%	[33]	19%	[10]	0.23
Core temperature ever ≥ 38^{0}C on at least 1 working day					
	82%	[134]	83%	[49]	0.24
Core temperature ever ≥ 38.5^{0}C on at least 1 working day					
	22%	[36]	24%	[14]	0.40
Work intensity (mins of moderate to vigorous exercise)					
	169	(96)	194	(117)	

Table 3. Crude associations between AKI and core temperature and AKI and work intensity in summer and winter cohorts, Girasoles Study 2016-2017.

	Summer			Winter		
Characteristics	**% [n]**	**% [n]**	**P-Value**	**% [n]**	**% [n]**	**P-Value**
	Core temperature ≥ 38^0C on at least one working day	Core temperature < 38^0C on at least one working day		Core temperature ≥ 38^0C on at least one working day	Core temperature < 38^0C on at least one working day	
AKI on at least one day	29% [45]	3% [5]	0.03	15% [8]	2% [1]	0.71
	moderate to vigorous exercise ≥ 163 mins	moderate to vigorous exercise <163 mins		moderate to vigorous exercise ≥ 163 mins	moderate to vigorous exercise < 163 mins	
AKI on at least one day	18% [28]	14% [22]	0.25	12% [6]	6% [3]	0.48

Table 4. Comparison of AKI and Work intensity, AKI and Core Temperature within different seasons, Girasoles Study 2016-2017

Characteristic		**Summer** OR (95%CI)	**Winter** OR (95%CI)
AKI and high vs. low work intensity (mins of moderate to vigorous exercise)	**Model 1[a]**	1.002 (0.998 1.005)	1.001 (0.995 1.008)
	Model 2[b]	1.001 (0.996 1.005)	0.998 (0.985 1.010)
AKI and high vs. low core Temperature(°C)	**Model 1[a]**	1.72 (1.20 2.46)	1.00 (0.42 2.38)
	Model 2[b]	1.48 (0.98 2.23)	1.36 (0.38 4.95)

1[a]Adjusted for age and sex

2[b]Adjusted for age, sex, diastolic blood pressure, systolic blood pressure, work duration, primary work, number of years in agriculture, USG>1.020, BMI.

Table 5. Assessing the effect of the interaction between season and work intensity and the interaction between season and core temperature on AKI Girasoles Study 2016-2017

		AKI OR (CI)		P-value
Model 1[a]	**Season *work intensity**	1.00	(0.99, 1.01)	0.63
	Season *core temperature	1.70	(0.66, 4.43)	0.27
Model 2[b]	**Season *work intensity**	1.00	(0.99, 1.01)	0.63
	Season *core temperature	1.73	(0.65, 4.57)	0.27

[a]Adjusted for age and sex

[b]Adjusted for age, sex, diastolic blood pressure, systolic blood pressure, work duration, primary work, number of years in agriculture, USG>1.020, BMI.