A meta-analysis of social factors predicting household-level heat-related illness in Phoenix, Arizona

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Introduction

The social and environmental characteristics that make residents more vulnerable to heat-related mortality and morbidity have been the subject of extensive study, particularly in the hot, desert city of Phoenix, Arizona. As part of this effort, numerous social surveys have been conducted in the Phoenix area over the past decade (including the Phoenix Area Social Survey (PASS)). Social surveys are highly valuable to the heat vulnerability research community because they are time and resource-intensive to collect yet are the only way to obtain information related to households' adaptive capacity to heat and experiences with heat that do not necessarily result in formal medical care or mortality. Unfortunately, the findings from these surveys are often not published and the administration of the surveys in Phoenix has been fairly disparate.

Thus, to synthesize the valuable knowledge contained in these surveys, we conducted a meta-analysis of the various risk factors predicting heat-related illness using eight heat-oriented social surveys conducted in Phoenix over the past decade to address how survey measures of heat vulnerability are related to incidence of heat-related illness.

Methods

Heat surveys in the Greater

Seven surveys (right) were included in the metaanalysis. Each survey asked about residents' experience with heat-related illness.



Survey	Administered by	Ν	year
PASS 2011	Central Arizona-Phoenix Long-Term Ecological Research (CAP LTER)	744	2011
CASPER	Maricopa County Department of Public Health	328	2015
3HEAT	ASU, Georgia Tech, and University of Michigan researchers	163	2016
PASS 2017	Central Arizona-Phoenix Long-Term Ecological Research (CAP LTER)	487	2017
HOME-Air	ASU Urban Climate Research Center	303	2017
Schmidt Futures	ASU Knowledge Exchange for Resilience via Schmidt Futures project	45	2019
Tempe	City of Tempe	193	2020

Selection of survey measures

Sixteen survey measures (Figure 1) related to heat vulnerability occurred in at least three of the surveys, and so were included in the meta-analysis.

Figure 1: Conceptual diagram demonstrating the relationship between specific survey measures, their broader constructs, and the relative proximity of each construct to adverse heat-health outcomes. +/- symbols are used to indicate the hypothesized relationship between the specific survey measures and adverse heat-health outcomes.



Using meta-analysis to synthesize survey responses in relation to heatrelated illness (HRI)

Calculate effect sizes as odds ratios, controlled for household size where appropriate Synthesize effect sizes \rightarrow "summary effect"

In a random-effects model, individual studies are weighted to minimize both within study variance and between study variance

Can quantify heterogeneity of effect sizes between studies:

- T^2 estimated between studies variance
- I^2 proportion of observed variance that reflects real differences in effect size
- Q test statistic to assess certainty of apparent heterogeneity

Used a random-effects meta-analysis model with restricted maximum-likelihood (REML) to estimate T^2

Survey Measures (Hypothesized

1. Low household income (+) 2. Struggle to afford essentials (+) B. Have enough food to eat (-) 4. Ethnic/racial minority (Hispanic) (+) 6. Low educational attainment (+) 7. Gender (Female) (+/-) 12. Have Window A/C (+/-) 13. Cost limitations on A/C use (+) _16. Left home because too hot (+) Self-reported heat-related illness

Heat Exposure

Are you or members of your ho nome?	usehold ever t	too hot in your	Have you or me because it was t
Survey		Odds Ratio [95% CI]	Survey
3HEAT CASPER HomeAir PASS2011		2.08 [0.84, 5.16] 1.46 [0.92, 2.33] 2.81 [1.34, 5.92] 2.93 [2.11, 4.07]	3HEAT CASPER Schmidt
PASS2017 Tempe	∎ 1 	2.27 [1.48, 3.49] 4.24 [1.22, 14.74]	Tempe
Summary Estimate	k	2.34 [1.76, 3.10]	Summary Estimate
			Г
0.05 0.25 1	2 4 10		0.0
Oc	dds Ratio		

REML Model for All Surveys (Q = 6.87, df = 5, p = 0.230; $I^2 = 34.2\%$, $\tau^2 = 0.04$) Do you or does any member of your household ever work outdoors?

Survey				Odds Ratio [95% Cl]
3HEAT				1.29 [0.65, 2.57]
CASPER			· B 1	1.88 [1.17, 3.04]
PASS2011			⊷∎⊷	2.78 [1.95, 3.97]
Schmidt		F		3.89 [0.54, 27.87]
Tempe			· =	2.29 [1.10, 4.75]
Summary Es	stimate		þ 1	2.16 [1.58, 2.95]
	[
	0.05	0.25	1 2 4 10	
			Odds Ratio	
EML Model f	or All Surveys (Q = 4.71, df :	= 4, p = 0.319; l ² = 25.9%	$, \tau^2 = 0.03)$

Socio-demographics



HomeAir PASS201 Schmidt Tempe Summary Estimate Key takeaways

Survey

3HEAT



Social isolation and health status

Survey					0	dds Ratio [9	5% CI]	Surv	ey
3HEAT CASPER HomeAir PASS2011 PASS2017 Schmidt Tempe				-	→ 1	0.35 [0.13, 1.24 [0.61, 0.64 [0.28, 0.72 [0.44, 0.91 [0.46, 6.10 [1.27, 2 0.47 [0.17,	0.92] 2.51] 1.46] 1.19] 1.79] 203.81] 1.29]	3HE, PAS Schr Tem	AT S2011 nidt pe
Summary Estima	ate					0.77 [0.57,	1.02]	Sum	mary Estim
	0.05	0.25	1 2	4	10				
			Odds R	Ratio					
EML Model for Al general, co our health i	ll Surveys ompare s fair o	(Q = 11.20, ed to oth r poor?	df = 6, p = (er peop	0.083; I ² le you	= 0.0%, τ	² = 0.00) would yo	ou say	REML	Model for A
EML Model for Al general, co our health is Survey	ll Surveys ompare s fair o	(Q = 11.20, ed to oth r poor?	df = 6, p = (er peop l	0.083; I ² le you	= 0.0%, τ I r age, γ	² = 0.00) would yc dds Ratio [9	ou say 5% cıj		Abdel for A By ta Livi prot
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EML Model for Al general, co Dur health i Survey 3HEAT PASS2011	ll Surveys ompare s fair o	(Q = 11.20, ed to oth r poor?	df = 6, p = (er peop	0.083; I ² le you –	= 0.0%, τ i r age, τ Ο	² = 0.00) would yc dds Ratio [9 1.34 [0.63 2.16 [1.47	5% CI] 5, 2.87] 7, 3.17]		Apple for A Events Livi prot Hea sigr
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Results **Residential A/C use** Do you and/or your household use central AC to cool yo nbers of your household ever left your home too hot? home? Odds Ratio [Survey Odds Ratio [95% CI] **3HEAT** 0.61 [0.1] 2.95 [1.50, 5.78] CASPER 0.97 [0.3 1.84 [1.09, 3.09] HomeAi 0.94 [0.1 PASS201 0.77 [0.4 14.27 [2.52, 80.90] PASS201 0.28 [0.0 17.60 [5.52, 56.12] Schmidt 0.21 [0.03 5.19 [1.71, 15.77] 0.62 [0.39 Summary Estimat Odds Ratic Odds Ratio REML Model for All Surveys (Q = 15.48, df = 3, p = 0.001; l^2 = 84.5%, τ^2 = 1.01) REML Model for All Surveys (Q = 4.29, df = 5, p = 0.508; $I^2 = 0.0\%$, $\tau^2 = 0.00$) Does the cost of using your household's air conditionin restrict air-conditioning use in your home? Survey Odds Ratio [**3HEAT** 1.41 [0.66 CASPER 1.62 [0.95 4.05 [0.96 HomeAi PASS201 2.60 [1.88 3.16 [0.61 Schmidt Tempe 3.25 [1.6 ------Summary Estimate 2.28 [1.70 -0.05 0.25 1 2 4 1 **Odds Ratio** REML Model for All Surveys (Q = 5.53, df = 5, p = 0.355; I^2 = 18.6%, τ^2 = 0.03) **Socio-demographics (financial measures)** Is your household income less than \$40,000 USD? Odds Ratio [95% CI] Survey **3HEAT** 1.11 [0.59, 2.09] ------HomeAir 0.73 [0.34, 1.53] PASS201 1.16 [0.84, 1.62] PASS2017 3.20 [0.79, 13.02] Schmidt 1.00 [0.52, 1.93] Tempe · ____ 1.11 [0.86, 1.42] Summary Estimate 0.25 1 2 4 0.05 0.25 1 2 4 10 Odds Ratio Odds Ratio such as food, housing, utilities and medicine? Survey **3HEAT** \rightarrow Women are not more or less at risk Schmidt Tempe ·----Summary Estimate 0.05 0.25 1 2 4 10

Does your household always have enough to eat and the kinds of food you want? Odds Ratio [95% CI] Odds Ratio [95% Cl] Survey 0.68 [0.32, 1.47] **3HEAT** 0.34 [0.16, 0.74] ------1.06 [0.49, 2.33] PASS201 0.41 [0.29, 0.57] 2.24 [1.58, 3.16] 2.06 [1.26, 3.35] Schmidt 0.08 [0.01, 0.51] ---- 1.16 [0.25, 5.40] Tempe 0.14 [0.06, 0.30] 2.49 [0.91, 6.79] 0.25 [0.13, 0.48] 1.57 [1.02, 2.40] Summary Estimate 0.05 0.25 1 2 4 10 Odds Ratio REML Model for All Surveys (Q = 10.39, df = 5, p = 0.065; $l^2 = 56.4\%$, $\tau^2 = 0.14$) REML Model for All Surveys (Q = 8.55, df = 3, p = 0.036; I^2 = 65.1%, τ^2 = 0.25) Key takeaways Do you or your household ever struggle to afford essentials \rightarrow Measures of resource availability have a much stronger relationship Odds Ratio [95% CI] with heat illness than income alone 2.22 [1.16, 4.23] \rightarrow All measures of financial wellness 4.98 [2.20, 101.95] indicate a statistically significant 4.84 [2.44, 9.60] association with heat illness 4.04 [1.77, 9.24] \rightarrow High heterogeneity of variance for enough food to eat, though all surveys indicate negative **Odds Ratio** relationship with heat illness REML Model for All Surveys (Q = 4.99, df = 2, p = 0.082; I^2 = 60.3%, τ^2 = 0.30)

Discussion

 \rightarrow Measures of financial wellness other than income may be better indicators of heat vulnerability. Cost restrictions on AC use, not being able to afford essentials, and not having enough food to eat all have a larger effect size on heat illness than household income. \rightarrow The ability to modify the indoor thermal environment without restriction protects residents from heat illness; having a central AC unit, being able to use AC without restriction, and home ownership (potentially indicates ability to modify home weatherization) all have a protective effect. \rightarrow Living alone, elderly, and health status did not align with the general expectations of heat vulnerability and will require further investigation.

Acknowledgements

Thank you to the institutions, organizations, and individuals that provided the survey data for this project: the Maricopa Department of Public Heath, the City of Tempe, the Urban Climate Research Center, the Knowledge Exchange for Resilience, CAP LTER, and 3HEAT. **FUNDING:** DEB-1637590 (CAP LTER), SES-1520803 (3HEAT) **Contact:** Mary.K.Wright@asu.edu



heat illness

of experiencing heat illness \rightarrow Hispanic people are 1.5x more likely to experience heat illness (due to systemic social



h status is not statistically ficantly related to heat illness le over the age of sixty-four 0% LESS likely to experience illness

neral, these results do not with expected results

Central Arizona-Phoenix Long-Term Ecological Research



Do you and/or your home?	househol	d use wind	low A	C to cool your
Survey				Odds Ratio [95% Cl
ЗНЕАТ				2.45 [0.79, 7.56
CASPER	•	-		1.02 [0.33, 3.18
HomeAir		·		6.02 [1.29, 28.14
PASS2011	•			1.18 [0.55, 2.53
PASS2017		₽	I	2.46 [1.10, 5.49
Schmidt	۴	=		2.73 [0.51, 14.58
Summary Estimate		Þ 4		1.90 [1.20, 3.00
0.05	0.25	1 2 4	10	
	(Odds Ratio		
REML Model for All Surveys ((Q = 5.57, df =	Odds Ratio 5, p = 0.350; I ²	² = 11.0%	$6, \tau^2 = 0.04)$
REML Model for All Surveys	(Q = 5.57, df = W ays	Odds Ratio 5, p = 0.350; l ²	² = 11.0%	$(0, \tau^2 = 0.04)$
REML Model for All Surveys (Key takea) → Househo	(Q = 5.57, df = Ways olds tha	Odds Ratio 5, p = 0.350; I ² At have	e cei	6, τ ² = 0.04)
REML Model for All Surveys (Key takea) → Househo are LESS	(Q = 5.57, df = Ways olds that blikely	Odds Ratio 5, p = 0.350; I ² at have	² = 11.0% CEI	$h(\tau^2 = 0.04)$
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