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

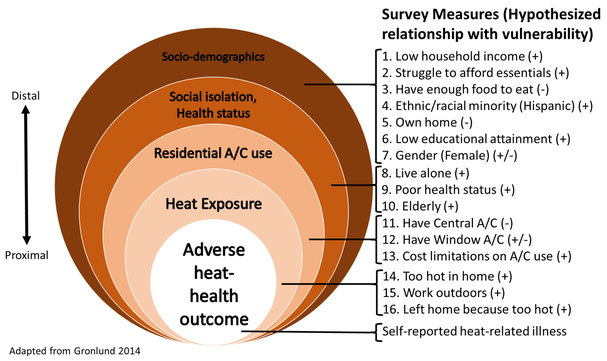
Heat surveys in the Greater Phoenix Area (2010-2020)

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

Survey	Administered by	N	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.



Adapted from Gronlund 2014

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 heat-related illness (HRI)

Calculate effect sizes as odds ratios, controlled for household size where appropriate

Synthesize effect sizes → "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:

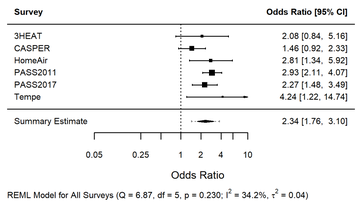
- T^2 – estimated between studies variance
- I^2 – proportion of observed variance that reflects real differences in effect size
- Q – test statistic to assess certainty of apparent heterogeneity

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

Results

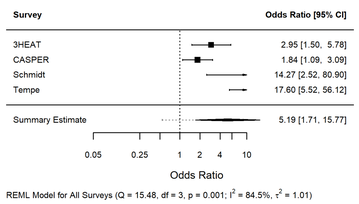
Heat Exposure

Are you or members of your household ever too hot in your home?



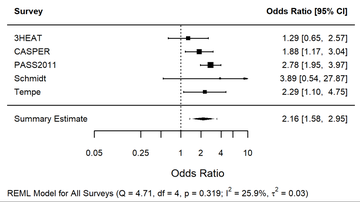
REML Model for All Surveys (Q = 6.87, df = 5, p = 0.230; I^2 = 34.2%, τ^2 = 0.04)

Have you or members of your household ever left your home because it was too hot?



REML Model for All Surveys (Q = 15.48, df = 3, p = 0.001; I^2 = 84.5%, τ^2 = 1.01)

Do you or does any member of your household ever work outdoors?



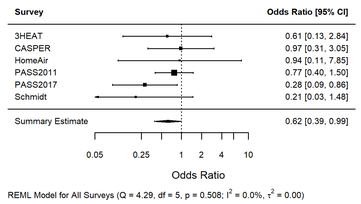
REML Model for All Surveys (Q = 4.71, df = 4, p = 0.319; I^2 = 25.9%, τ^2 = 0.03)

Key takeaways

- → Residents that are too hot in their home are 2x more likely to experience heat illness
- → Residents that work outdoors are 2x more likely to experience heat illness
- → High heterogeneity of variance for whether residents left their home because it was too hot

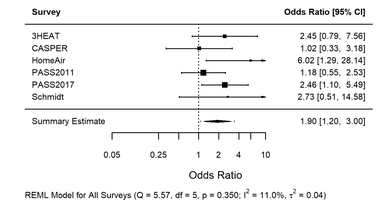
Residential A/C use

Do you and/or your household use central AC to cool your home?



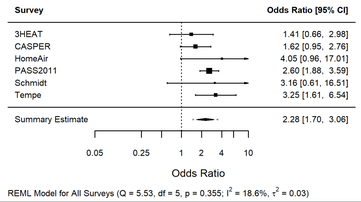
REML Model for All Surveys (Q = 4.29, df = 5, p = 0.508; I^2 = 0.0%, τ^2 = 0.00)

Do you and/or your household use window AC to cool your home?



REML Model for All Surveys (Q = 5.57, df = 5, p = 0.350; I^2 = 11.0%, τ^2 = 0.04)

Does the cost of using your household's air conditioning restrict air-conditioning use in your home?



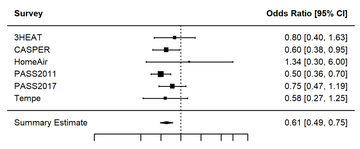
REML Model for All Surveys (Q = 5.53, df = 5, p = 0.355; I^2 = 18.6%, τ^2 = 0.03)

Key takeaways

- → Households that have central AC are LESS likely to experience heat illness
- → Households that have window AC are MORE likely to experience heat illness
- → Households that cannot always afford to use their AC are 2x as likely to experience heat illness

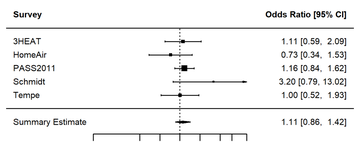
Socio-demographics

Do you or someone you live with own your home?



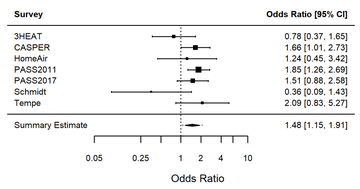
REML Model for All Surveys (Q = 3.73, df = 5, p = 0.589; I^2 = 0.1%, τ^2 = 0.00)

Do you consider yourself female?



REML Model for All Surveys (Q = 3.61, df = 4, p = 0.461; I^2 = 0.0%, τ^2 = 0.00)

With which group or groups do you identify? [Hispanic, Latino, Mexican, Mexican-American or Spanish]



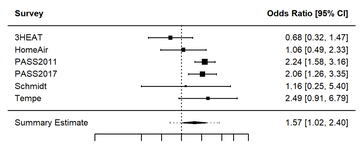
REML Model for All Surveys (Q = 8.97, df = 6, p = 0.175; I^2 = 11.2%, τ^2 = 0.01)

Key takeaways

- → Households that own their home are 40% less likely to experience heat illness
- → Women are not more or less at risk of experiencing heat illness
- → Hispanic people are 1.5x more likely to experience heat illness (due to systemic social inequalities)

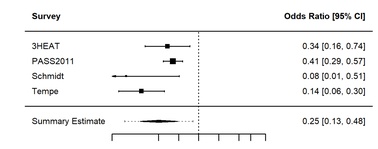
Socio-demographics (financial measures)

Is your household income less than $40,000 USD?



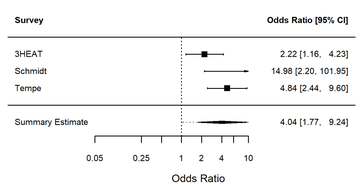
REML Model for All Surveys (Q = 10.39, df = 5, p = 0.065; I^2 = 56.4%, τ^2 = 0.14)

Does your household always have enough to eat and the kinds of food you want?



REML Model for All Surveys (Q = 8.55, df = 3, p = 0.036; I^2 = 65.1%, τ^2 = 0.25)

Do you or your household ever struggle to afford essentials such as food, housing, utilities and medicine?



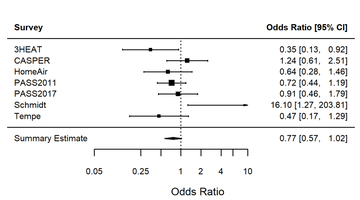
REML Model for All Surveys (Q = 4.99, df = 2, p = 0.082; I^2 = 60.3%, τ^2 = 0.30)

Key takeaways

- → Measures of resource availability have a much stronger relationship with heat illness than income alone
- → All measures of financial wellness indicate a statistically significant association with heat illness
- → High heterogeneity of variance for enough food to eat, though all surveys indicate negative relationship with heat illness

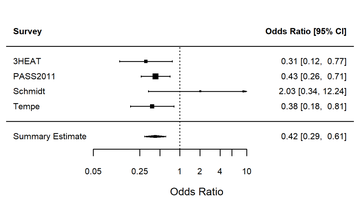
Social isolation and health status

Do you live alone?



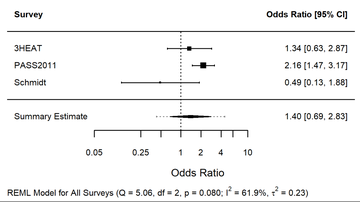
REML Model for All Surveys (Q = 11.20, df = 6, p = 0.083; I^2 = 0.0%, τ^2 = 0.00)

Are you over the age of 64?



REML Model for All Surveys (Q = 3.46, df = 3, p = 0.327; I^2 = 0.0%, τ^2 = 0.00)

In general, compared to other people your age, would you say your health is fair or poor?



REML Model for All Surveys (Q = 5.06, df = 2, p = 0.080; I^2 = 61.9%, τ^2 = 0.23)

Key takeaways

- → Living alone indicates a potential protective effect
- → Health status is not statistically significantly related to heat illness
- → People over the age of sixty-four are 60% LESS likely to experience heat illness
- → In general, these results do not align with expected results

Discussion

- → 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.
- → 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.
- → Living alone, elderly, and health status did not align with the general expectations of heat vulnerability and will require further investigation.

Acknowledgements

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