Supplemental Material

Predicting Hospitalization for Heat-Related Illness at the Census Tract Level: Accuracy of a Generic Heat Vulnerability Index in Phoenix, Arizona (USA)

Wen-Ching Chuang and Patricia Gober
| Reference | Approach/method | Variables (measures) | Study area | Spatial unit | Evaluate HVI with health data? |
|-----------|-----------------|----------------------|------------|--------------|-------------------------------|
| Vescovi et al. 2005 | Integrated climate variables and socio-economic parameters in GIS to produce maps that estimate present and future public health risk to excessive heat. | Temperatures, proportion of residents > 65 years old, poverty, social isolation (proportion of single person household), education level. | Southern Quebec, Canada | Census subdivision | No |
| *Lindley et al. 2006 | Proposed a framework/method to visualize areas that are vulnerable to heat hazards, and project risks to heat. | Maximum temperature, population > 75 years of age living alone, population < four years old, population with chronic illness, population with mental health problems or is bedridden, income disparity, land-use type. | Greater London, the United Kingdom | Census block | No |
| *Reid et al. 2009 | Used factor analysis to analyzed 10 heat vulnerability indicators, and calculated HVI using the sum of factor scores. | Prevalence of diabetes, race other than white, population > 65 years old, living alone, population > 65 years old and living alone, population below poverty line, population without high school diploma, no green space, no central AC, no AC any kind. | Metropolitan statistical areas, USA | Census tract | No |
| *Rinner et al. 2009 | Proposed 14 measures that represent exposure, sensitivity, and adaptive capacity to assess potential vulnerability to heat. | Remotely sensed land surface temperature, lack of tree canopy, green space, old dwellings without AC, high-density dwellings without AC, behavior, pre-existing/chronic illness, cognitive impairment, elderly residents, infants and young children, low-income households, rental households, socially isolated people, homeless, low education level, population not speaking English, recent immigrants, racialized groups, access to cooling centers. | Toronto, Canada | Census tract | No |
| Chow et al. 2012 | Constructed a HVI by combining the normalized scores of five socioeconomic variables and three environmental indicators. | Summer temperatures, vegetation index, proportion of residents > 65 years old, median household income, proportion of foreign-born noncitizens, proportion living in the same house < five years. | Metropolitan Phoenix area, AZ, USA | Census track | No |
| Uejio et al. 2011 | Used Generalized Linear and Mixed Models to identify risk factors of heat vulnerability linked to heat mortality or morbidity. | Selected 22 variables, including vegetation index, remotely sensed surface temperatures, impervious surface, housing density, single family detached homes, poverty, households renting, proportion of residents > 65 years old, proportion living alone, proportion of people with disabilities, linguistically isolated households, household with more than seven residents, percent ethnic minorities, proportion living in the same house < five years, vacant households, house age, housing value. Their statistical results suggested four and 13 significant factors for Philadelphia and Phoenix respectively. | Philadelphia, PA; metropolitan Phoenix, AZ, USA | Census block groups | Heat-mortality identified by The Philadelphia Department of Health between July 8 and August 4, 1999 (n=64). Heat-related emergency calls identified by the City of Phoenix Regional Fire Department Dispatch Center between June and September, 2005 (n=637). |
| *Reid et al. 2012 | Used Poisson regression to relate HVI to heat and non-heat-related health conditions during extremely hot days in five states in the USA. | Prevalence of diabetes, race other than white, proportion of residents > 65 years old, living alone, population > 65 years old and living alone, population below poverty line, population without high school diploma, no green space, no central AC, no AC any kind. | California, New Mexico, Washington, Oregon and Massachusetts, USA. | Zip-code area | Counts of hospital admission for electrolyte imbalance, cardiovascular, cerebrovascular disease, respiratory illness, nephritis and nephrotic syndrome, acute renal failure, heat-related illness, and internal causes of hospitalization, and number of daily mortality. |
| Reference            | Approach/method                                                                 | Variables (measures)                                                                                                                                                                                                 | Study area | Spatial unit        | Evaluate HVI with health data? |
|----------------------|----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|---------------------|-----------------------------|
| Johnson et al. 2012  | 1) Used factor analysis to build heat vulnerability index (EHVI) from 15 census   | 28 variables were presented. Only 19 variables were used for the construction of EHVI: females > 65 years old, males > 65 years old, females > 65 years of age and living alone, males > 65 and living alone, white population, females head of household, mean family income, per capita income, mean household income, population > 25 years old and without high school diploma, Asian population, proportion of residents > 65 years old and living alone, other race population, Hispanic population, population > 25 years old with a high school education, built-up index, vegetation index, Black population, remotely sensed land surface temperature. | Chicago, IL, USA | Census block group   | Heat mortality data from death certificate during a heat wave in July 1995 (n=586). Residential heat death is defined by the Illinois State Vital Records Department. |
| Harlan et al. 2013   | 1) Used factor analysis to construct a set of HVIs from U.S. Census data and remotely sensed vegetation and land surface temperature; 2) used binary logistic regression and spatial analysis to associate heat-related death with HVI. | Ethnic minority, Latino immigrant, population below poverty line, population without high school diploma, proportion of residents > 65 years old, proportion of residents > 65 years of age living alone, population living alone, no air conditioning, unvegetated area, remotely sensed surface temperature. | Maricopa County, AZ, USA | Census block group | Heat-mortality data from death certificate (n=278) from 2000 to 2008. Heat death is identified by a surveillance system specifically designed to identify heat-caused and heat-related deaths associated with weather in Maricopa County. |
| Hondula et al. 2012  | 1) Used randomization test to identify mortality exceedances for several apparent temperature thresholds; 2) used factor analysis to identify the environmental, demographic and social factors associated with high-risk areas. | 25 explanatory variables from five aspects: zoning and land use, social demographics, income level, and remotely sensed land surface temperature. | Philadelphia County, PA, USA | Zip code area | All-cause mortality records from 1983 to 2008 (n=409,554). |
| Loughnan et al. 2013 | 1) Identified threshold temperatures at which risk of mortality or morbidity increase in eight Australian cities; 2) used factor analysis to derived vulnerability index; 3) used climate model output to predict changes of days with excessive heat; 4) estimated changes in risk related to changing population density and aging population. | Populations < 4 and > 65 years old, aged care facilities, socioeconomic status, urban design (non-single dwellings), proportion of single-person households, population need for assistance (disability), population density, ethnicity, remotely sensed surface temperature, land cover, accessibility to emergency service. | Brisbane; Canberra; Darwin; Hobart; Melbourne; Perth; Adelaide; Sydney, Australia | postal area | No |
| *Wolf et al. 2013    | 1) Derived a HVI using factor analysis of nine proxy measures of heat risk; 2) discussed drivers of uneven spatial patterns of heat vulnerability. | Households in rented tenure, household in a flat (one-storey), population density, household without central heating, population > 65 years old, aged population with long-term limiting illness, population with self-reported health status “not good”, receive any kind of social benefit, single pensioner household. | London, United Kingdom | Census district | No |
| *Wolf et al. 2014    | Examine the performance of the HVI on heat-wave days and non-heat-wave days. | Mortality and ambulance callout data from 1990 to 2006. |

*Including at least one health variable (preexisting health condition) as a component of HVI.
Figure S1. The distribution of the hospitalization rates for heat-related illness, positively skewed, with a mode of 0, median of 0.02, mean of 0.03, and standard deviation of 0.05.
Figure S2. A flow chart of the research procedures.
Figure S3. Maps of individual factor scores. (A) Factor 1: Poverty, ethnic minority, and low-education level; (B) Factor 2: lack of AC and vegetation; (C) Factor 3: diabetes and social isolation.
Figure S4. Neighborhoods that are misclassified in the MLR model: (A) The high-incidence neighborhoods that are predicted as zero-incidence neighborhoods. (B): The zero-incidence neighborhoods that are predicted as high-incidence neighborhoods.
References

Chow WTL, Chuang W, Gober P. 2012. Vulnerability to extreme heat in metropolitan Phoenix: Spatial, temporal, and demographic dimensions. The Professional Geographer 64(2):286-302; doi: 10.1080/00330124.2011.600225.

Harlan SL, Declet-Barreto JH, Stefanov WL, Petitti DB. 2013. Neighborhood effects on heat deaths: Social and environmental predictors of vulnerability in Maricopa County, Arizona. Environ Health Perspect 121(2):197-204; doi: 10.1289/ehp.1104625.

Hondula D, Davis R, Leisten M, Saha M, Veazey L, Wegner C. 2012. Fine-scale spatial variability of heat-related mortality in Philadelphia county, USA, from 1983-2008: A case-series analysis. Environ Health 11(1):16.

Johnson DP, Stanforth A, Lulla V, Luber G. 2012. Developing an applied extreme heat vulnerability index utilizing socioeconomic and environmental data. Appl Geogr 35(1–2):23-31; doi: 10.1016/j.apgeog.2012.04.006.

Lindley SJ, Handley JF, Theuray N, Peet E, Mcevoy D. 2006. Adaptation strategies for climate change in the urban environment: Assessing climate change related risk in UK urban areas. Journal of Risk Research 9(5):543-568.

Loughnan M, Tapper N, Phan T, Lynch K, McInnes J. 2013. A spatial vulnerability analysis of urban populations during extreme heat events in Australian capital cities. Gold Coast: National Climate Change Adaptation Research Facility.

Reid CE, O'Neill MS, Gronlund CJ, Shannon J. Brines, Brown DG, Diez-Roux AV et al. 2009. Mapping community determinants of heat vulnerability. Environ Health Perspect 117(11):1730-1736.

Reid C, Mann J, Alfasso R, English P, King G, Lincoln R et al. 2012. Evaluation of a heat vulnerability index on abnormally hot days: An environmental public health tracking study. Environ Health Perspect 120(5):715-720; doi: doi: 10.1289/ehp.1103766.

Rinner C. 2009. Development of a Toronto-Specific, Spatially Explicit Heat Vulnerability Assessment [Electronic Resource] Phase I Final Report. Toronto (Ont.) Dept of Public Health.

Uejio CK, Wilhelmi OV, Golden JS, Mills DM, Gulino SP, Samenow JP. 2011. Intra-urban societal vulnerability to extreme heat: The role of heat exposure and the built environment, socioeconomics, and neighborhood stability. Health Place 17(2):498-507.
Vescovi L, Rebetez M, Rong F. 2005. Assessing public health risk due to extremely high temperature events: Climate and social parameters. Climate Research 30(1):71; doi: 10.3354/cr030071.

Wolf T, McGregor G. 2013. The development of a heat wave vulnerability index for London, United Kingdom. Weather and Climate Extremes 1(0):59-68; doi: http://dx.doi.org/10.1016/j.wace.2013.07.004.

Wolf T, McGregor G, Analitis A. 2014. Performance assessment of a heat wave vulnerability index for greater London, United Kingdom. Wea Climate Soc 6(1):32-46; doi: 10.1175/WCAS-D-13-00014.1.