Excess Mortality During the September 2022 Heat Wave in California

August 2023

Office of Health Equity
California Department of Public Health

CDPH California Department of PublicHealth

Acknowledgements

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Many thanks to those who assisted with the development and editing of this report: Linda Helland, Dan Woo, and the many stakeholders who gave input on the methods and concept.

Suggested Citation:

Milet M, Samuel M, Hoshiko S, Radhakrishna R, Aragón T. (July 2023). Excess mortality during the September 2022 heat wave in California. Sacramento, CA: California Department of Public Health, Office of Health Equity.

At a Glance

- Episodes of extreme heat are increasing with climate change.
- Heat can lead to death directly, or indirectly by affecting other conditions such as cardiovascular or respiratory conditions.
- During the September 2022 record-breaking 10-day heat wave in California, there was a 5% increase in deaths – 395 more deaths than would be expected.
- The highest increases in deaths were seen among people aged 25-64, Hispanic Californians, and of the South Coast region.
- Deaths due to extreme heat can be prevented or reduced through actions to decrease exposure and improve resilience.
- California has invested $404 million towards addressing extreme heat impacts, guided by the state's Extreme Heat Action Plan, and many initiatives have been carried out or are already underway.

Background

Extreme heat is of increasing public health concern. With the impacts of climate change, heat waves are becoming longer, more frequent, and more intense.[1] Heat-related deaths in the United States have been projected to rise to more than 100,000 per year by the end of the century.[2] In California specifically, researchers estimate heat-related mortality could rise to 6,700-11,300 deaths per year by 2050.[3]

Certain populations are at higher risk of health impacts from extreme heat, due to physical vulnerability and/or lack of resources to prepare for or respond to heat, including:

- older adults (particularly those living alone),
- children,
- people who are pregnant,
- people with pre-existing chronic health conditions and/or taking specific medications,
- outdoor workers and others engaging in vigorous activity in hot environments,
- populations with low socioeconomic status,
- socially or geographically isolated populations,
- people with mental or physical disability,

- people who do not have air conditioning in their homes or are not able to afford to use it,
- residents of urban areas,
- people experiencing homelessness, and
- some communities of color.

From August 31 through September 9, 2022, a record-breaking heat wave occurred across California. Temperature records were set in approximately 1,500 locales and excessive heat warnings were issued for much of the state.[4] This report presents an analysis of excess mortality (increase in deaths) in California during this period, using California vital statistics death data (death certificates).

Heat can lead to death directly from heat stroke or hyperthermia, or, more commonly, from its impact on other conditions, such as cardiovascular, respiratory, and other diseases. Multiple studies have demonstrated that analyzing only deaths that have been noted on death certificates as directly caused by excess heat greatly underestimates the full magnitude of the impact of heat on mortality.[5, 6, 7, 8] **This analysis quantifies excess mortality using all causes of death. It also includes an assessment of excess mortality by diagnostic categories as well as by demographic factors including sex, age, race/ethnicity, and region.**

Methods

Death records for calendar year 2022 were obtained from the California Department of Public Health's Dynamic California Comprehensive Death Files as of March 29, 2023. At that time, 1.2% of summer 2022 records (June – September) were still pending final cause of death; these records were used in the overall analysis of all-cause mortality, but were excluded from analysis by cause of death category. Records were limited to deaths occurring in California among California residents.

The heat wave period was defined as August 31 through September 9, 2022. An additional time frame which further included the 3-day period from September 10 through September 12 was also examined to account for possible lagged deaths. Although some deaths due to heat occur rapidly, others can have a lagged effect after the heat subsides. Reference periods were chosen in the summer of 2022 to represent normal summer conditions and were matched to the heat wave period by day of the week; they include ten 10-day Wednesday through Friday spans from July through September 2022, excluding periods that overlapped with the heat wave.

The expected number of deaths was calculated as the average of the number of deaths in these 10 reference periods. Excess deaths were calculated by subtracting the expected number of deaths from the observed number of deaths during the heat wave period. Assuming the population size remained constant over the summer, rate ratios (RR) were calculated as the number of observed deaths in the heat wave period (A1) divided by expected number of deaths from the reference periods (A0): RR = A1/A0. The 95% confidence intervals were calculated using large sample size statistics for person-time rate ratios: $\exp([\ln(RR) \pm 1.96\sqrt{(1/A1 + 1/A0)}])$. These methods were based on a 2010 analysis outlining a simple method for excess mortality calculations (9). Statistical significance was assessed based on the confidence intervals for the RRs not including 1.0.

Excess deaths and rate ratios were also calculated separately for several major disease categories and by demographic factors. Disease categories were based on an analysis of United States mortality data that outlined the most common causes of death when heat was a contributing cause.[5] These were:

- major cardiovascular diseases (ICD-10 I00-I78);
- diseases of the respiratory system (ICD-10 J00-J99);
- endocrine, nutritional, and metabolic disorders (ICD-10 E00-E90);
- genitourinary disorders (ICD-10 N00-N98);
- diseases of the digestive system (ICD-10 K00-K93);
- musculoskeletal disorders (ICD-10 M00-M99);
- external causes (ICD-10 V01-Y98); and
- mental and behavioral disorders (ICD-10 F00-F99).

An analysis of the cases for which heat-related illness was listed as the underlying cause of death is also included (ICD-10 X30, P81.0, T67).

The analysis by region used the county where death occurred and grouped counties into climate regions that were adapted from the U.S. Climate Divisions for California.[10] Regions are composed of counties as follows (Figure 1):

- **Central Coast**--Alameda, Contra Costa, Monterey, San Benito, San Francisco, San Luis Obispo, San Mateo, Santa Clara, Santa Cruz;
- **Central Valley**--Amador, Calaveras, Fresno, Kern, Kings, Madera, Mariposa, Merced, Placer, Sacramento, San Joaquin, Stanislaus, Tulare, Tuolumne;
- **North Central**--Alpine, Butte, Colusa, El Dorado, Glenn, Lassen, Modoc, Mono, Nevada, Plumas, Shasta, Sierra, Siskiyou, Sutter, Tehama, Yolo, Yuba;
- **North Coast**--Del Norte, Humboldt, Lake, Marin, Mendocino, Napa, Solano, Sonoma, Trinity;
- **South Coast**--Los Angeles, Orange, San Diego, Santa Barbara, Ventura;
- **Southeast Desert/Inland Empire**--Imperial, Inyo, Riverside, San Bernardino.

Figure 1: Regions Used for Analysis

Results

During the 10-day span of the heat wave, there were 8,324 deaths in California, compared to an average of 7,929 in the comparison periods during summer 2022 (Table 1). This translates to 395 excess deaths during the heat wave period, or 5.0 percent more deaths than would be expected (RR=1.05, 95% CI 1.02-1.08, Table 1). With the additional three days included, there were an estimated 441 excess deaths or an increase of 4.0 percent (RR=1.04, 95% CI 1.02-1.07).

Table 1

Excess Deaths During the 2022 Labor Day Heat Wave: Total Observed and Expected Number of Deaths, August 31 – September 9, 2022, California

Time Frame	*10-day Heat Wave*	*+3 days*
Expected Number of Deaths (Average of Reference Periods in Summer 2022)	7,929	10,296
Observed Number of Deaths (2022 Labor Day Heat Wave)	8,324	10,737
Excess Deaths	395	441
Rate Ratio (95% CI)	**1.05 (1.02-1.08)**	**1.04 (1.02-1.07)**

Excess deaths were observed for all disease categories and were statistically significant for heat-related illness and external causes (Table 2). The highest rate ratio was for cases that directly listed heat-related illness as the underlying cause of death, RR=5.00 (95% CI 1.71-14.63).

Table 2

Excess Deaths During the 2022 Labor Day Heat Wave, By Underlying Cause of Death Disease Category: Total Observed and Expected Number of Deaths, August 31 – September 9, 2022, California

ICD-10 Category	*Number of Deaths During Heat Wave*	*Expected Number of Deaths*	*Number of Excess Deaths*	*Rate Ratio*	*(95% CI)*
Heat Illness (X30, P81.0, T67)	20	4	16	**5.00**	**(1.71-14.63)**
Cardiovascular (I00-I78)	2,310	2,210	100	1.05	(0.99-1.11)
Respiratory (J00-J99)	545	521	24	1.05	(0.93-1.18)
Endocrine (E00-E90)	451	438	13	1.03	(0.90-1.17)
Genitourinary / Renal (N00-N98)	194	175	19	1.11	(0.90-1.36)
Digestive (K00-K93)	351	332	19	1.06	(0.91-1.23)
Musculoskeletal (M00-M99)	37	32	5	1.15	(0.71-1.84)
External Causes (V01-Y98, excluding X30)	817	724	93	**1.13**	**(1.02-1.25)**
Mental/Behavioral (F00-F99)	242	232	10	1.04	(0.87-1.25)

Females and males had similar rate ratios for mortality during the heat wave period (RR 1.04 and 1.06 respectively), though males were statistically significant (Table 3). By age group, the highest and only significant increase in deaths was in the 25-64 age group, RR=1.11 (95% CI 1.05-1.19). There was a statistically significant increase in mortality during the heat wave period among Hispanic Californians, RR=1.10 (95% CI 1.03-1.17), but not among other race/ethnicity groups. By region, the South Coast region had the highest and only statistically significant increase in mortality, RR=1.09 (95% CI 1.04-1.14).

Table 3

Excess Deaths During the 2022 Labor Day Heat Wave, By Demographic Factors: Total Observed and Expected Number of Deaths, August 31 – September 9, 2022, California

Demographic Group	*Number of Deaths During Heat Wave*	*Expected Number of Deaths*	*Number of Excess Deaths*	*Rate Ratio*	*(95% CI)*
Sex					
Female	3,849	3,691	158	1.04	(0.997-1.09)
Male	4,475	4,237	238	**1.06**	**(1.01-1.10)**
Age Group					
0-4	48	59	-11	0.82	(0.56-1.20)
5-24	105	103	2	1.02	(0.77-1.33)
25-64	2,126	1,908	218	**1.11**	**(1.05-1.19)**
65+	6,045	5,858	187	1.03	(0.995-1.07)
Race and Ethnicity					
American Indian / Alaska Native	42	40	2	1.05	(0.68-1.62)
Asian	855	864	-9	0.99	(0.90-1.09)
Black	653	624	29	1.05	(0.94-1.17)
Hispanic	1,913	1,740	173	**1.10**	**(1.03-1.17)**
Multiple	138	125	13	1.11	(0.87-1.41)
Native Hawaiian / Pacific Islander	39	35	4	1.12	(0.71-1.78)
White	4,621	4,453	168	1.04	(0.996-1.08)
Region					
Central Coast	1,354	1,315	39	1.03	(0.95-1.11)
Central Valley	1,445	1,425	20	1.01	(0.94-1.09)
Desert / Inland Empire	1,042	1,006	36	1.04	(0.95-1.13)
North Central	331	327	4	1.01	(0.87-1.18)
North Coast	372	390	-18	0.95	(0.83-1.10)
South Coast	3,779	3,462	317	**1.09**	**(1.04-1.14)**

Discussion

This analysis found a significant increase in all-cause mortality during the 2022 Labor Day heat wave in California. Deaths increased by 5.0 percent during the heat wave period. This is similar to previous analyses in California and other locations, which have found 4-8 percent increases due to past heat waves.[6, 9, 11]

In this analysis, the estimated number of all-cause excess deaths was many times higher than the number of excess deaths specifically coded as heat-related on death certificates (395 vs. 20). These findings are consistent with literature establishing a relationship between high temperatures and mortality, as well as studies demonstrating that heat impacts are greatly underestimated when relying on the relatively few deaths coded as being directly caused by heat.[5, 6, 7, 8]

Although generally lacking statistical significance when examined separately, this analysis found consistent increases in deaths across all the heat-sensitive disease categories included. Not surprisingly, there was a very large increase in deaths among those coded directly as heat-related, 5 times higher than expected.

Analysis by demographics found the highest excess mortality among adults ages 25-64. This is notable, as previous literature has often found that older adults and very young are the most vulnerable to heat impacts on mortality.[12] It is important for heat interventions to consider the vulnerability of working-age adults, which may include working in hot conditions or other types of over-exposure.

Analysis by race and ethnicity found Hispanic Californians to be a particularly vulnerable group with statistical significance. Other race and ethnicity groups also had increases in mortality but were based on small numbers of deaths and not statistically significant.

The South Coast region had the highest and only statistically significant increase in mortality by geography during the heat wave period, which may be consistent with low air conditioning saturation. Other regions had 1-4 percent increases in mortality but were not statistically significant.

Limitations

The findings in this report are subject to several limitations. More complex statistical modeling such as case-crossover and time series analyses have advantages in better understanding the temperature-mortality association,

although they are computationally intensive. This analysis is sensitive to the chosen comparison periods, as heat-related mortality can occur at times other than a designated heat wave, creating possible excesses across the season. This analysis did not include several factors that could influence or further characterize the results, such as presence of air conditioning, levels of air pollution, including from wildfire smoke, and the impact of occupation or homelessness status, all potentially important considerations for future analyses.

Conclusion

Extreme heat can cause significant excess mortality; however, these deaths are largely preventable. Many state and local initiatives have been carried out or are underway to reduce negative health outcomes due to heat exposure.

Given the extent of the public health impact and in anticipation of more extreme heat events due to climate change, public health urgency for increasing interventions is warranted. Some promising strategies to build resilience to heat include providing accessible cooling centers, improving building insulation and shading, using light-colored surfaces that stay cooler (such as roofs and streets), planting trees, installing affordable and energy efficient air conditioning, creating state, regional, and community-wide heat response plans, protecting outdoor workers, outreach to vulnerable communities to increase awareness, improved social cohesion and programs to check in with heat-vulnerable individuals, and improved data collection and coordination across health and other sectors.

For more information on protecting Californians from extreme heat, please visit:

- Heat Ready California: HeatReadyCA.com
- CDPH's Extreme Heat website: Extreme Heat (ca.gov)
- California Department of Industrial Relations information on heat illness prevention for workers and employers: Cal/OSHA - Heat related illness prevention and information (ca.gov)
- California's 2022 Extreme Heat Action Plan: Protecting Californians From Extreme Heat: A State Action Plan to Build Community Resilience
- The Centers for Disease Control (CDC) Extreme Heat website: Extreme Heat | Natural Disasters and Severe Weather | CDC

References

(1) U.S. EPA (U.S. Environmental Protection Agency). Climate change indicators: Heat waves. 2022. Climate Change Indicators: Heat Waves | US EPA

(2) Shindell D, Zhang Y, Scott M, Ru M, Stark K, Ebi KL. The effects of heat exposure on human mortality throughout the United States. Geohealth. 2020 Apr 1;4(4):e2019GH000234.

(3) Ostro B, Rauch S, Green S. Quantifying the health impacts of future changes in temperature in California. Environmental Research. 2011;111(8):1258-1264.

(4) Davis D, Bushard B. Sacramento and San Jose break all-time heat records: These are the key record-breaking temperatures for summer 2022. Forbes. 2022 Sept 7.

(5) Vaidyanathan A, Malilay J, Schramm P, Saha S. Heat-related deaths—United States, 2004-2018. MMWR. 2020 Jun 19;69(24).

(6) Ostro B, Roth L, Green R, Basu R. Estimating the mortality effect of the July 2006 California heat wave. Environmental Research. 2009;109:614-619.

(7) Basu R, Samet JM. Relation between elevated ambient temperature and mortality: A review of the epidemiologic evidence. Epidemiologic Reviews. 2002 Dec;24(2):190-202.

(8) Berko J, Ingram DD, Saha S, Parker JD. Deaths attributed to heat, cold, and other weather events in the United States, 2006– 2010. Hyattsville (MD): National Center for Health Statistics; 2014 National Health Statistics Reports No.: 76.

(9) Hoshiko S, English P, Smith D. A simple method for estimating excess mortality due to heat waves, as applied to the 2006 California heat wave. Int J Public Health. 2010;55:133-137.

(10) Knowlton K, Rotkin-Ellman M, King G, et al. The 2006 California heat wave: impacts on hospitalizations and emergency department visits. Environ Heatlh Perspect. 2009 Jan:117(1):61-7.

(11) Tong S, Wang X, Guo Y. Assessing the short-term effects of heatwaves on mortality and morbidity in Brisbane, Australia: Comparison of case-crossover and time series analyses. PLoS ONE. 2012 May;7(5):e37500.

(12) Basu R. High ambient temperature and mortality: A review of epidemiologic studies from 2001-2008. Environmental Health. 2009 Sept 16;8(40).