



Population Health: San Francisco Excess Deaths and 911-Medically related calls
During the 2017 Labor Day Heat Wave Event.

Student: Juan Medina-Echeverria
Mentor: Tomás J. Aragón MD, DrPH
University of California, Berkeley
School of Public Health
Honors Thesis, 2019



Abstract:

On average, San Francisco experiences three to six extreme heat events each year. Climate change is expected to increase the frequencies of these events up to an average of 13 per year by 2100. During the 2017 Labor Day extreme heat event, increased mortality rates were observed among individuals 65 years and older, and across both gender groups and all ethnic/racial groups. Exposure to extreme heat can exacerbate underlying health conditions, leading to hospitalization and even premature death. During the event, there was an estimated excess of 66 deaths. This rate increase was observed among individuals age 65 and older and across all racial groups and genders. Increased mortality was highest among individuals where the underlying cause of death was classified as cancer and cardiovascular disease. During the event, there were significant increases in 911-phone calls across all neighborhoods, indicating increases hospitalizations and stress on city infrastructure.

Introduction:

Heat wave is a leading cause of weather-related illness and death across the world. In 2003, unprecedented heat waves in Western Europe resulted in approximately 70,000 excess deaths; and the 2010 heat wave in Russia caused an estimated 55,000 deaths.¹ In the United States of America, the 2006 heat wave in California resulted in 1200 additional hospitalizations and 16,000 additional emergency room visits.² In Australia, heat waves are the most dangerous natural hazard over the past 200 years.³ Since 1800, over 4000 deaths have been attributed to heat waves in Australia, twice the number of deaths due to either flood or cyclones.⁴ According for the Center for disease Control (CDC), more than 600 people in the United States are killed by extreme heat every year.⁵ To make matters worse, there is growing evidence that the intensity, frequency, and duration of heat waves are likely to escalate in the future because of climate change, urban heat island and population ageing.⁶

In 2006, California's heat wave even had a substantial effect on morbidity, including regions with relatively modest temperatures, such as San Francisco.⁷ Climate change results in extreme weather events that are not only detrimental to the environment, but also human health. Extreme heat events in San Francisco are anticipated to increase due to climate change. As a result, San Franciscans will be at higher risk for heat related illness, a largely preventable illness. Heat related illness is a broad range of disease from mild heat stress to the most severe, life threatening— heat stroke. Extreme heat events increase all-cause mortality, and mortality related to heat, respiratory, and cardiovascular causes, resulting in a significant public health burden.^{8,9}

For the last decade, cities have invested in developing climate action plans to reduce their greenhouse gas emissions, yet lesser attention has been paid to developing adaptive measures to

protect the public's health in the event of climate change-related extreme weather events, or to expanding the capacity of public health departments to plan and prepare for such events.^{10,11}

Due to San Francisco's temperate climate, most people don't view San Francisco as a place of concern for extreme heat events, but climate change models project that heat waves will increase in frequency and severity and San Francisco is particularly vulnerable because of the lack of human physiologic and technologic adaptations.⁸ It typically takes human biology 2 weeks to adapt to temperature extremes.¹² Since we do not regularly experience extreme heat events for extended durations, as a population, human bodies have a more difficult time thermoregulating, which can cause heat stress and increase risk of heat related illness and sometimes death.^{5,12} In San Francisco, there's fewer technologic adaptations because the housing stock is less likely to have central air conditioning both because of its age and because of the typically cooler climate.¹³

While everyone is vulnerable to heat-related illness, certain populations are more at risk, including the elderly, low-income and those with chronic mental disorders and pre-existing medical conditions. Community vulnerability to heat-related morbidity and mortality can be defined by many factors, including individual pre-existing conditions, environmental determinants for exposure and socioeconomic and demographic factors. By taking a comprehensive approach to understanding vulnerability, interventions must target those communities and populations at highest risk for illness in order to advance urban health, social justice and environmental justice.

This research, in conjunction with the San Francisco Department of Public Health, identifies excess heatwave related deaths that occurred during the period of Labor Day Weekend, September 1st, 2017 to September 4th, 2017. In addition, other factors are identified, such as but

not limited to, areas of population vulnerability and areas in which infrastructure was stressed.

The main objective this research paper, is to estimate the excess deaths that occurred during the 2017 Labor Day weekend and the excess 911 -Medically related calls that were made.

2.0 Material and Methods

2.1 Study Area

San Francisco (37.7749° N, 122.4194° W), is the 13th-most populous city in the United States, and the fourth-most populous in California, with 883,305 residents as of 2018.⁸ It covers an area of about 46.89 square miles (121.4 km²),⁸ making it the second-most densely populated large US city, and the fifth-most densely populated U.S. county (citation of density). San Francisco is famous for its temperate weather and foggy conditions. The climate in San Francisco belongs to a number of extremely varied microclimates within its 46 square miles. According to Golden Gate Weather Services, Summer time in San Francisco is characterized by cool marine air and persistent coastal stratus and fog, with average maximum temperatures between 60°F and 70°F, and minima between 50°F and 55°F.^{11, 14, 15} Nonetheless, with increase climate change, San Francisco has been vulnerable to increase heat wave events during the summer and early fall periods, in specifically, during labor day weekend.



Figure 1, Study Area Location and Different Districts. Image adapted from Wikimedia.¹⁶

2.2 Data Collection and Processing.

(2.2a) Land Surface Temperature (LST Data)

Surface Temperatures from Labor Day Extreme Heat Event in 2017, were obtained in Conjunction with the San Francisco Department of Public Health and Data from NASA ASTER Satellite.

Surface Temperature- Labor Day Extreme Heat Event 09/01/2017

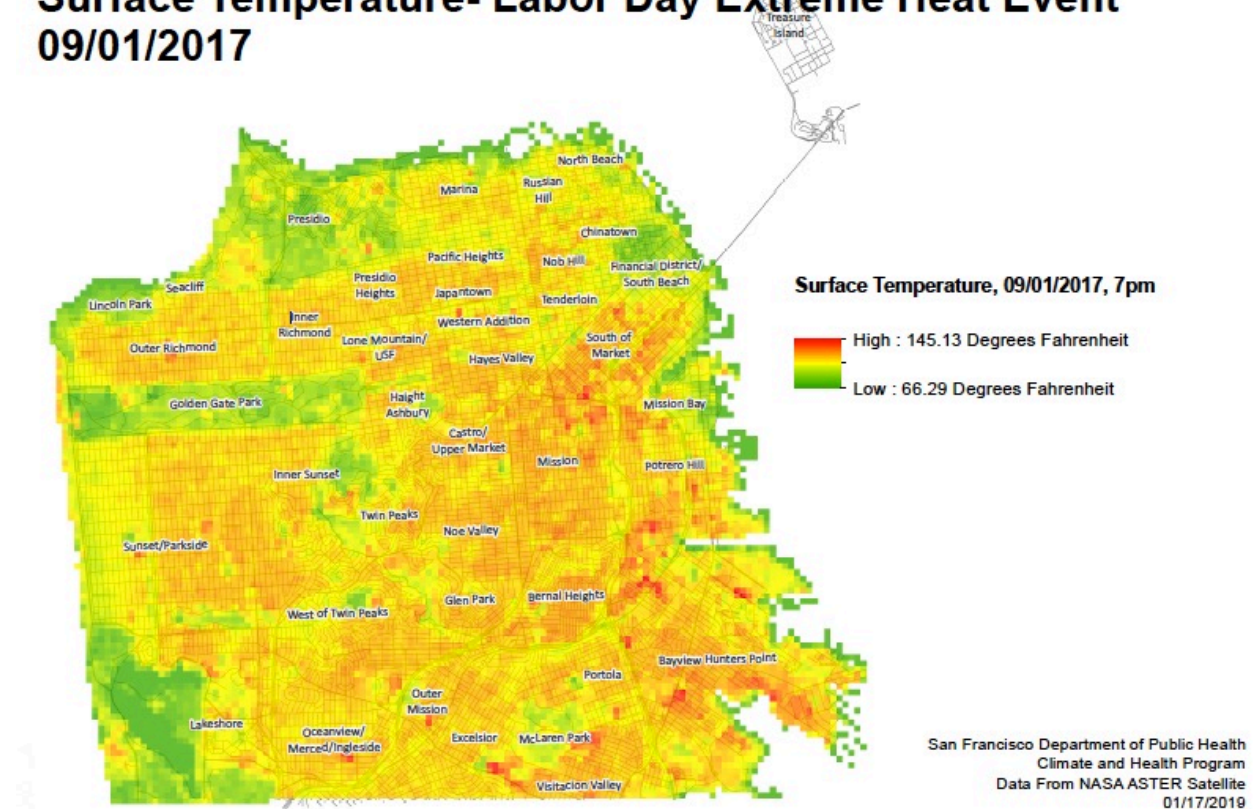


Figure 2, Surface Temperature on Labor Day (09/01/2017), at 7pm

(2.2b) San Francisco Department of Public Health, Data Collection

Data was collected through the San Francisco Department of Public Health. While a range of dates in 2016 and 2017 were analyzed, the specific dates of interest for the study was, the 2017 Labor Day Heat Wave (8/31/17 to 9/4/17). Heat event reference period defined as having occurred between 8/10/17 and 8/14/17. Furthermore, a post heat wave event period was

also identified (9/5/17 to 9/9/17), with the 2nd reference period being 8/15/17 to 8/19/17. For the Heat wave and reference period data collected was: temperature (Fahrenheit), AQI levels, fire service calls, and heat event mortality ratios. Data was then stratified based on several factors of interest, such as, but not limited to Gender, Race/Ethnicity, Age, and Neighborhood in the San Francisco County.

(2.2c) Calculation of Excess and Expected Death

In order to characterize excess mortality during the 2017 Labor Day Heat Wave event, mortality rate ratios were calculated, using a reference period of the same number of days from August, 2017. Methods for calculating “Excess Deaths” and “Expected Deaths,” was adapted from a published paper by, Sumi Hoshiko, titled, “A simple method for estimating excess mortality due to heat waves, as applied to the 2006 California heat wave.”¹⁷ Heat event is defined as having occurred between 8/31/17 and 9/4/17. Expected deaths, is equal to deaths per day during reference days times the number of days in the heat period. Heat event reference period defined as having occurred between 8/10/17 and 8/14/17. Furthermore, data was excluded from 2 weeks following reference period, to avoid comparison with a period in which deaths could be lower because some very ill persons may have died prematurely during reference period. Excess Deaths, were calculated by subtracting expected reference period deaths from heat event deaths. The rate ratio was calculated by dividing total deaths (2017 Labor Day heat event) by expected deaths (reference period).

(2.2b) Data from SFClimate.org

Data and finding were analyzed from SFClimate.org. In specific, the report in, Climate and Health was researched, for understanding the risks and assessments of San Francisco's Vulnerable populations to Heat Events.⁹

3.0 Results

(3.1) Heat Event Mortality Totals and Rate Ratios for All Deaths by Demographic

Characteristics

Mortality Data was collected from the: State of California, California Department of Public Health, VRBIS Death Statistical Master File Plus 2005-2017, created on January 30, 2018. Expected death, were deaths per day during the reference days. Expected deaths, equal deaths per day during the reference days (8/10/17 and 8/14/17 for Heat Event[†] & 8/15/17 and 8/19/17 for Post-Heat Event[‡]). Excess Deaths, calculated by subtracting reference period deaths from heat event deaths. In addition, rate ratios were calculated by dividing heat event deaths by reference period deaths. Mortality was stratified based on: Gender, Race/Ethnicity, and Age.

Increased mortality rates during the heat event were observed among both Females (103% increase with a 95% confidence interval of 40-162%), and Males (74% increase with a 95% confidence interval of 20-154%). Confidence intervals for each group were wide.

Increased mortality rates during the heat event were observed among Whites (58% increase with a 95% confidence interval of 2-144%), Latino/Hispanics (240% increase with a 95% confidence interval of 25-822%), and Asian/Pacific Islanders (79% increase with a 95% confidence interval of 12-184%). While excess levels of deaths were observed among African/Black Americans, levels were not statistically significant (111% increase with a 95%

confidence interval of -4%-367%). This is likely due to smaller population totals for this group.

Overall, confidence intervals for each group were wide.

Increased mortality rates during the heat event were observed among individuals age 65 and older (92% increase with a 95% confidence interval of 40-162%), but not among other age groups.

Table 1. Heat Event Mortality Totals and Rate Ratios for All Deaths by Demographic Characteristics

Demographic Categories	Heat Event				Post- Heat Event			
	Total Deaths	Expected Deaths	Excess Deaths	Rate Ratios (95% CI)	Total Deaths	Expected Deaths	Excess Deaths	Rate Ratios (95% CI)
Gender								
Female	67	33	34	2.03 (1.34, 3.08)	43	22	21	1.95 (1.17, 3.27)
Male	75	43	32	1.74 (1.20, 2.54)	52	48	4	1.08 (0.73, 1.60)
Race/Ethnicity								
Asian/ Pacific Islander	50	28	22	1.79 (1.12, 2.84)	26	22	4	1.18 (0.67, 2.09)
Black/ African American	19	9	10	2.11 (0.96, 4.67)	13	9	4	1.44 (0.62, 3.38)
Latino/Hispanic	17	5	12	3.40 (1.25, 9.22)	8	8	0	1.00 (0.38, 2.66)
Other/ Multi-ethnic	4	0	4	.	4	3	1	1.33 (0.30, 5.96)
Unreported/ Missing	0	1	-1	.	0	0	0	.
White	52	33	19	1.58 (1.02, 2.44)	44	28	16	1.57 (0.98, 2.52)
Age								
0-4	1	0	1	.	0	4	-4	.
5-64	26	16	10	1.63 (0.87, 3.03)	30	13	17	2.31 (1.20, 4.42)
65+	115	60	55	1.92 (1.40, 2.62)	65	56	9	1.16 (0.81, 1.66)
Total	142	76	66	1.87 (1.41, 2.47)	95	70	25	1.36 (1.00, 1.85)
Source: State of California, California Department of Public Health, VRBIS Death Statistical Master File Plus 2005-2017, created on January 30, 2018.								
Notes: (1) Heat event is defined as having occurred between 8/31/17 and 9/4/17; (2) Expected deaths = deaths per day during reference days x the number of days in the post-event period. Heat event reference period defined as having occurred between 8/10/17 and 8/14/17; (3) Calculated by subtracting reference period deaths from heat event deaths; (4) rate ratios calculated by dividing heat event deaths by reference period deaths; (5) Post-heat event is defined as having occurred between 9/5/17 and 9/9/17; (6) Post-heat event reference period defined as having occurred between 8/15/17 and 8/19/17								

(3.2) Heat Event, Post-Event Period, and Reference Period Dates with Observed

Temperature and AQI Levels

Frist, Data was stratified based on: Heat event, post event, and reference period dates, for comparison. The data includes, temperature and Air Quality Index level (AQI) based on the dates of interest. Furthermore, a column of level of concern of AQI. This is noted on Table 2.

During the Labor Day Heat wave event (8/31/17 to 9/4/17), the highest temperature recorded was 106 (F) and the minimum was 55 (F), with the highest temperature being on 9/1/2017. Compared to the reference period #1(8/10/17 to 8/14/17), the maximum temperature in Fahrenheit was 77 (F) and minimum was 59 (F). Furthermore, the Air Quality Index (AQI) was unhealthy for sensitive groups during the Labor Day weekend event. With Highest AQI being 136 on 9/3/2017, compared to an the highest AQI level of 38, on 8/12/2017 (Reference period #1).

Post-event period (9/5/17 to 9/9/17) did show higher temperature when compared to post event reference period, with highest temperature being 77 (F) compared to 68 (F) and AQI levels of 53 vs 40, respectively.

Table 2: Heat Event, Post-Event Period, and Reference Period Dates with Observed Temperature and AQI Levels

Time Period	Date	Day of Week	Temperature (F)		AQI	Level of Concern
			Low	High		
Heat Event 8/31/17 to 9/4/17	8/31/2017	Thursday	55	86	69	Moderate
	9/1/2017	Friday	69	106	125	USG
	9/2/2017	Saturday	75	102	103	USG
	9/3/2017	Sunday	65	84	136	USG
	9/4/2017	Monday	64	79	125	USG
Post-Event Period 9/5/17 to 9/9/17	9/5/2017	Tuesday	64	77	53	Moderate
	9/6/2017	Wednesday	62	73	45	Good
	9/7/2017	Thursday	61	71	52	Moderate
	9/8/2017	Friday	59	68	26	Good
	9/9/2017	Saturday	59	72	39	Good
Heat Event Reference Period #1 8/10/17 to 8/14/17	8/10/2017	Thursday	57	67	35	Good
	8/11/2017	Friday	56	67	33	Good
	8/12/2017	Saturday	55	63	38	Good
	8/13/2017	Sunday	54	66	16	Good
	8/14/2017	Monday	55	62	40	Good
Post-Event Reference Period #1	8/15/2017	Tuesday	55	62	40	Good
	8/16/2017	Wednesday	57	68	40	Good
	8/17/2017	Thursday	59	67	40	Good

8/15/17 to 8/19/17	8/18/2017	Friday	58	68	38	Good
	8/19/2017	Saturday	58	66	30	Good
Labor Day 2016 9/1/16 to 9/5/16	9/1/2016	Thursday	68	63	33	Good
	9/2/2016	Friday	71	55	50	Good
	9/3/2016	Saturday	66	57	42	Good
	9/4/2016	Sunday	67	56	46	Good
	9/5/2016	Monday	72	53	51	Moderate
Full Summer 6/20/17 to 9/22/17	6/20/17 to 9/22/17					
Data Sources: EPA and NOAA. 2018 Notes: (1) Air Quality Index (AQI) is the index for reporting daily air quality; (2) Unhealthy for sensitive groups						

(3.3a) Heat Event Fire Calls for Service by Call Types

Data was analyzed from 911 calls from www.datasf.org, This data was stratified by incident type. In addition, Calls were additionally stratified by Heat Event Calls, Expected Calls, and Excess Calls. This is noted on Table 2 below.

Expected calls were calculated by: calls per day during reference days, multiplied by (x) the number of days in the post-event period. Heat event reference period defined as having occurred between 8/10/17 and 8/14/17.

Excess Calls were calculated by subtracting reference period calls from heat event calls. During the Heat event is defined as having occurred between 8/31/17 and 9/4/17, and there were 4,536 Medically related Fire (911) calls as opposed to, 2,840 Fire Calls, with an Excess of 1,696 calls (RR: 1.6 (1.52, 1.67)).

Table 3: Heat Event Fire Calls for Service by Call Types

Call Classifications	Unique Incidences ^a				Total Respondents ^a			
	Heat Event Calls ^a	Expected Calls ^a	Excess Calls ^a	Rate Ratios (95% CI) ^a	Heat Event Calls	Expected Calls	Excess Calls	Rate Ratios (95% CI)
Incident Type								
Alarms	262	172	90	1.52 (1.26, 1.85)	772	536	236	1.44 (1.29, 1.61)
Citizen Assist / Service Call	71	36	35	1.97 (1.32, 2.95)	96	41	55	2.34 (1.62, 3.38)
Electrical Hazard	21	19	2	1.11 (0.59, 2.06)	24	19	5	1.26 (0.69, 2.31)
Elevator / Escalator Rescue	28	16	12	1.75 (0.95, 3.23)	34	17	17	2.00 (1.12, 3.58)
Fuel Spill	3	0	3	.	5	0	5	.
Gas Leak (Natural and LP Gases)	9	15	-6	0.60 (0.26, 1.37)	20	36	-16	0.56 (0.32, 0.96)
HazMat	0	3	-3	.	0	6	-6	.
Medical Incident	2,218	1,506	712	1.47 (1.38, 1.57)	4,536	2,840	1,696	1.6 (1.52, 1.67)
Mutual Aid / Assist Outside Agency	1	0	1	.	6	0	6	.
Odor (Strange / Unknown)	3	1	2	3.0 (0.31, 28.84)	3	1	2	3.0 (0.31, 28.84)
Other	67	36	31	1.86 (1.24, 2.79)	110	53	57	2.08 (1.5, 2.88)

Outside Fire	49	22	27	2.23 (1.35, 3.68)	85	36	49	2.36 (1.6, 3.49)
Smoke Investigation (Outside)	13	6	7	2.17 (0.82, 5.7)	18	6	12	3.0 (1.19, 7.56)
Structure Fire	76	63	13	1.21 (0.86, 1.68)	484	271	213	1.79 (1.54, 2.07)
Traffic Collision	71	61	10	1.16 (0.83, 1.64)	184	179	5	1.03 (0.84, 1.26)
Vehicle Fire	8	3	5	2.67 (0.71, 10.05)	17	7	10	2.43 (1.01, 5.86)
Water Rescue	4	3	1	1.33 (0.3, 5.96)	52	41	11	1.27 (0.84, 1.91)
Final Call Disposition								
Against Medical Advice	39	25	14	1.56 (0.94, 2.58)	77	54	23	1.43 (1.01, 2.02)
Cancelled	74	51	23	1.45 (1.02, 2.07)	148	89	59	1.66 (1.28, 2.16)
Code 2 Transport	1,486	1,072	414	1.39 (1.28, 1.5)	3,034	2,066	968	1.47 (1.39, 1.55)
Code 3 Transport	170	84	86	2.02 (1.56, 2.63)	454	214	240	2.12 (1.8, 2.5)
Fire	599	391	208	1.53 (1.35, 1.74)	1,646	1,015	631	1.62 (1.5, 1.75)
Gone on Arrival	20	7	13	2.86 (1.21, 6.76)	33	14	19	2.36 (1.26, 4.4)
Medical Examiner	41	19	22	2.16 (1.25, 3.72)	127	48	79	2.65 (1.9, 3.69)
No Merit	204	127	77	1.61 (1.29, 2)	425	254	171	1.67 (1.43, 1.95)
Other	49	22	27	2.23 (1.35, 3.68)	106	41	65	2.59 (1.8, 3.71)
Patient Declined Transport	142	111	31	1.28 (1, 1.64)	265	197	68	1.35 (1.12, 1.62)
SFPD	20	16	4	1.25 (0.65, 2.41)	32	28	4	1.14 (0.69, 1.9)
Unable to Locate	60	37	23	1.62 (1.08, 2.44)	99	69	30	1.43 (1.06, 1.95)
Call Type Group								
Alarm	555	359	196	1.55 (1.35, 1.77)	1,548	973	575	1.59 (1.47, 1.72)
Fire	60	28	32	2.14 (1.37, 3.36)	178	82	96	2.17 (1.67, 2.82)
Non-Life-threatening	889	753	136	1.18 (1.07, 1.3)	1,413	1,122	291	1.26 (1.16, 1.36)
Potentially Life-Threatening	1,398	822	576	1.7 (1.56, 1.85)	3,302	1,912	1,390	1.73 (1.63, 1.83)
Total	2,904	1,962	942	1.48 (1.4, 1.57)	6,446	4,089	2,357	1.58 (1.52, 1.64)
<i>Source: DataSF, 2018</i> Notes: (1) Unique incidences refers to the specific incident that units responded to; (2) Total respondents refers to the number of units that respond to a unique incident; (3) Heat event is defined as having occurred between 8/31/17 and 9/4/17; (4) Expected calls = calls per day during reference days x the number of days in the post-event period. Heat event reference period defined as having occurred between 8/10/17 and 8/14/17; (5) Calculated by subtracting reference period calls from heat event calls. (6) Rate ratios calculated by dividing heat event deaths by reference period calls								

(3.3b) Heat Event Fire Calls for Service per population

Based on a preliminary spatial analysis of fire calls for services, positive relationship between services calls and poverty (p-value < .000), and positive relationship with median age (p-value < .05). The following Figures 3 & 4 examine the relation between calls per population and variables. Figure 4, is graphed on basis of, Heat Event Fire Calls per Population (1,000) by Census Tract Percent Poverty (100% FPL). Figure 4, is graphed on basis of Heat Event Fire Calls per Population (1,000) by Census Tract Median Age.

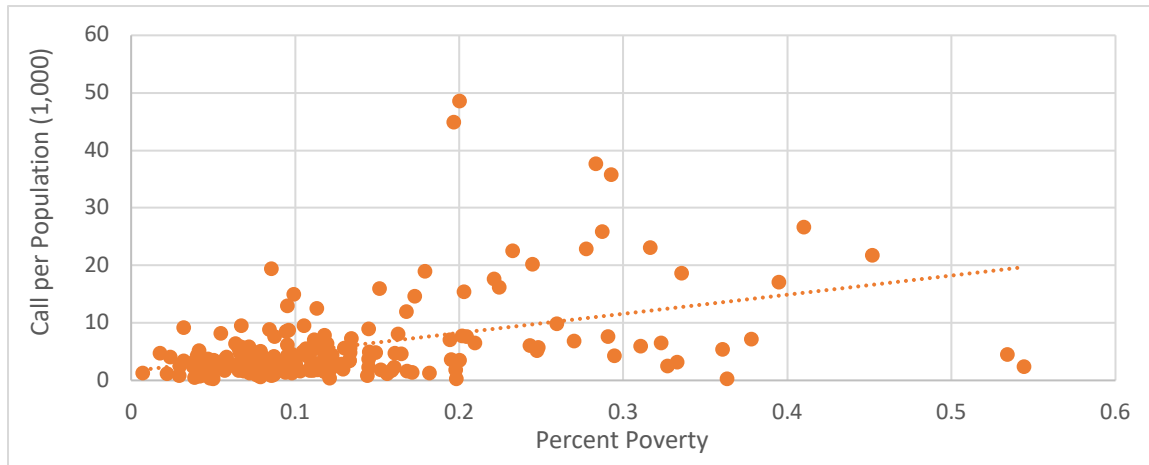


Figure 3. Heat Event Fire Calls per Population (1,000) by Census Tract Percent Poverty (100% FPL)

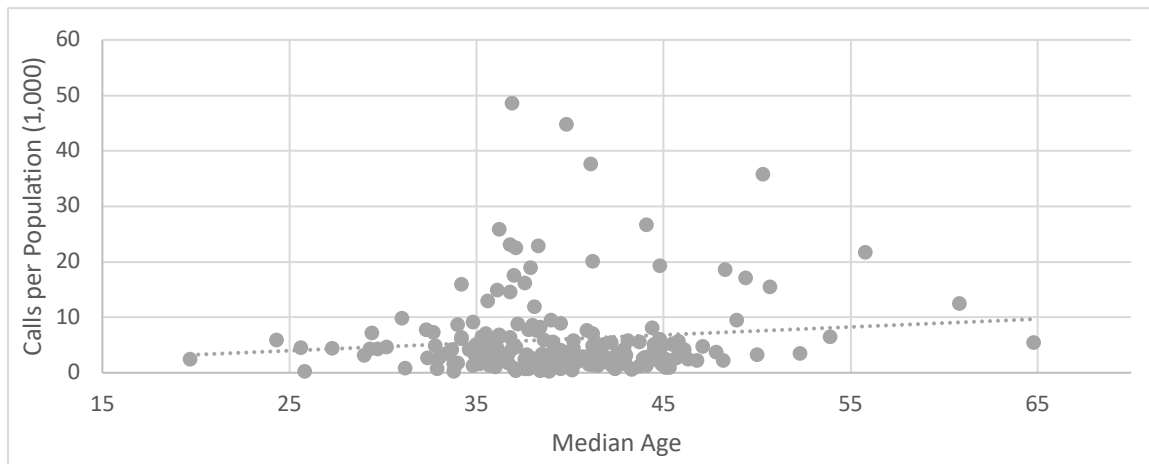


Figure 4. Heat Event Fire Calls per Population (1,000) by Census Tract Median Age

(3.4) Heat Event Fire Calls for Service by Neighborhood

Using data from www.datasf.gov, Fire Medically related calls were stratified based on Neighborhoods and Districts (zip codes).

Zip Codes range from 94102 (Downtown Civic Center, Western Addition) to 94158 (Mission Bay, Potrero Hill). Rate ratios calculated by dividing heat event deaths by reference period calls. Zip code 94102 (Downtown-Civic Center/Western Addition) experienced the

highest number of excess calls at 112 (53% increase in the rate of calls at a 95% confidence interval of 29%-82%).

In addition, zip code 94110 (Mission, Bernal Heights) experienced 49 excess calls (36% increase in rate of calls at 95% CI of 10%-72%). Furthermore, zip code 94134 (Visitacion Valley, Excelsior, Bayview), had 44 excess calls (120% increase in rate of calls).

There was a total of 4,536 Fire (911) medically related called, and 1,699 excess calls, during the Heat Wave period (8/31/17 to 9/4/17).

Table 4: Heat Event Fire Calls for Service by Neighborhood

Zip Code	Neighborhoods	Unique Incidences ^a				Total Respondents ^a			
		Heat Event ^b	Expected Calls ^b	Excess Calls ^b	Rate Ratios (95% CI) ^b	Heat Event	Expected Calls ^b	Excess Calls ^b	Rate Ratios (95% CI)
94102	Downtown Civic Center, Western Addition	324	212	112	1.53 (1.29, 1.82)	641	398	243	1.61 (1.42, 1.83)
94103	South of Market, Mission, Financial District, Mission Bay	283	192	91	1.47 (1.23, 1.77)	574	365	209	1.57 (1.38, 1.79)
94104	Financial District	6	9	-3	0.67 (0.24, 1.87)	16	17	-1	0.94 (0.48, 1.86)
94105	Financial District, South of Market	46	38	8	1.21 (0.79, 1.86)	86	64	22	1.34 (0.97, 1.86)
94107	Potrero Hill, South of Market, Mission Bay	91	64	27	1.42 (1.03, 1.96)	189	106	83	1.78 (1.41, 2.26)
94108	Nob Hill, Chinatown, Financial District, Downtown Civic Center	42	25	17	1.68 (1.02, 2.76)	91	44	47	2.07 (1.44, 2.96)
94109	Russian Hill, Nob Hill, Downtown Civic Center, Pacific Heights, Western Addition	187	142	45	1.32 (1.06, 1.64)	399	270	129	1.48 (1.27, 1.72)
94110	Mission, Bernal Heights	181	132	49	1.37 (1.10, 1.72)	363	257	106	1.41 (1.20, 1.66)
94111	Financial District, North Beach	39	29	10	1.34 (0.83, 2.17)	71	48	23	1.48 (1.03, 2.13)
94112	Outer Mission, Crocker Amazon, Ocean View, Excelsior, West of Twin Peaks, Bernal Heights	127	85	42	1.49 (1.14, 1.97)	245	159	86	1.54 (1.26, 1.88)
94114	Castro/Upper Market, Noe Valley, Twin Peaks	69	50	19	1.38 (0.96, 1.99)	135	87	48	1.55 (1.19, 2.03)
94115	Western Addition, Pacific Heights	84	61	23	1.38 (0.99, 1.91)	172	114	58	1.51 (1.19, 1.91)
94116	Parkside, Outer Sunset, West of Twin Peaks, Inner Sunset	59	22	37	2.68 (1.64, 4.38)	121	44	77	2.75 (1.95, 3.88)
94117	Haight Ashbury, Western Addition	75	45	30	1.67 (1.15, 2.41)	164	87	77	1.89 (1.45, 2.44)
94118	Inner Richmond, Presidio Heights	59	30	29	1.97 (1.27, 3.05)	134	68	66	1.97 (1.47, 2.64)
94121	Outer Richmond, Seacliff	49	51	-2	0.96 (0.65, 1.42)	104	100	4	1.04 (0.79, 1.37)
94122	Outer sunset, Inner Sunset, Golden Gate Park	88	66	22	1.33 (0.97, 1.83)	197	122	75	1.61 (1.29, 2.02)
94123	Marina, Pacific Heights	29	25	4	1.16 (0.68, 1.98)	53	47	6	1.13 (0.76, 1.67)
94124	Bayview	89	67	22	1.33 (0.97, 1.82)	183	117	66	1.56 (1.24, 1.97)
94127	West of Twin Peaks, Ocean View, Outer Mission	31	7	24	4.43 (1.95, 10.06)	58	15	43	3.87 (2.19, 6.82)
94129	Presidio	7	3	4	2.33 (0.60, 9.02)	14	5	9	2.80 (1.01, 7.77)
94130	Treasure Island	4	2	2	2.0 (0.37, 10.92)	13	7	6	1.86 (0.74, 4.65)

94131	Diamond Heights/Glen Park, Twin Peaks, Noe Valley, Inner Sunset, Outer Mission	53	21	32	2.52 (1.52, 4.18)	100	42	58	2.38 (1.66, 3.41)
94132	Lakeshore, Ocean View	33	25	8	1.32 (0.79, 2.22)	68	51	17	1.33 (0.93, 1.92)
94133	North Beach, Russian Hill, Nob Hill, Chinatown	73	49	24	1.49 (1.04, 2.14)	157	102	55	1.54 (1.20, 1.97)
94134	Visitation Valley, Excelsior, Bayview	81	37	44	2.19 (1.48, 3.23)	169	70	99	2.41 (1.83, 3.19)
94158	Mission Bay, Potrero Hill	9	16	-7	0.56 (0.25, 1.27)	19	31	-12	0.61 (0.35, 1.08)
Total		2,218	1,505	713	1.47 (1.38, 1.57)	4,536	2,837	1,699	1.60 (1.53, 1.68)

Source: DataSF. 2018
Notes: (1) Unique incidences refers to the unique incident that units responded to; (2) Total respondents refers to the number of units that respond to a unique incident; (3) Heat event is defined as having occurred between 8/31/17 and 9/4/17; (4) Expected calls = calls per day during reference days x the number of days in the post-event period. Heat event reference period defined as having occurred between 8/10/17 and 8/14/17; (5) Calculated by subtracting reference period calls from heat event calls; (6) rate ratios calculated by dividing heat event deaths by reference period calls; (7) Post-heat event is defined as having occurred between 9/5/17 and 9/9/17; (8) Post-heat event reference period defined as having occurred between 8/15/17 and 8/19/17

(3.5) Heat Event Mortality Relative Risk by Underlying (Primary) Cause of Death

Furthermore, Heat Event and Post-Heat Event, was stratified based on Underlying (Primary) cause of death. Source for underlying cause of death was obtained via: State of California, California Department of Public Health, VRBIS Death Statistical Master File Plus 2005-2017, created on January 30, 2018.

Underlying Cause of Deaths were stratified to 17 categories, with 1 of the categories being “Totally Unknown.” Categories that demonstrated a greater excess death, include: Cancer, Cardiovascular Disease, Extreme Heat, and Asthma or COPD.

Increased mortality rates during the heat event were observed among individuals where underlying cause of death was classified as cancer (130% increase with a 95% confidence interval of 20-342%) and cardiovascular disease (190% increase with a 95% confidence interval of 74-382%). During the four-day period following the heat event, individuals whose underlying cause of death was cardiovascular disease continued to die at an elevated rate (94% increase with a 95% confidence interval of 10-243%).

Table 5: Heat Event Mortality Relative Risk by Underlying (Primary) Cause of Death

Underlying Cause of Deaths.	Heat Event				Post- Heat Event			
	Total Deaths	Expected Deaths	Excess Deaths	Rate Ratios (95% CI)	Total Deaths	Expected Deaths	Excess Deaths	Rate Ratios (95% CI)
Cancer	30	13	17	2.31 (1.20, 4.42)	14	15	-1	0.93 (0.45, 1.93)

Cardiovascular Disease	58	20	38	2.90 (1.74, 4.82)	35	18	17	1.94 (1.10, 3.43)
Extreme Heat	1	0	1	.	0	0	0	.
Falls	0	1	-1	.	0	0	0	.
Other Respiratory Diseases	4	12	-8	0.33 (0.11, 1.03)	2	5	-3	0.40 (0.08, 2.06)
Substance Use	0	1	-1	.	3	1	2	3.00 (0.31, 28.84)
Traffic Accidents	0	0	0	.	0	1	-1	.
Asthma or COPD	9	1	8	9.00 (1.14, 71.04)	4	2	2	2.00 (0.37, 10.92)
Digestive System Diseases	0	1	-1	.	1	2	-1	0.50 (0.05, 5.51)
Drowning	0	0	0	.	0	0	0	.
Endocrine Diseases	8	3	5	2.67 (0.71, 10.05)	4	4	0	1.00 (0.25, 4.00)
Genito-Urinary Disease	2	2	0	1.00 (0.14, 7.10)	0	1	-1	.
Homicide	1	1	0	1.00 (0.06, 15.99)	1	2	-1	0.50 (0.05, 5.51)
Infectious And Parasites	2	2	0	1.00 (0.14, 7.10)	3	1	2	3.00 (0.31, 28.84)
Nervous System Disease	12	6	6	2.00 (0.75, 5.33)	7	7	0	1.00 (0.35, 2.85)
Suicide	1	2	-1	0.50 (0.05, 5.51)	3	0	3	.
Totally Unknown	5	9	-4	0.56 (0.19, 1.66)	16	7	9	2.29 (0.94, 5.56)
Total	133	74	59	1.80 (1.35, 2.39)	93	66	27	1.41 (1.03, 1.93)
Source: State of California, California Department of Public Health, VRBIS Death Statistical Master File Plus 2005-2017, created on January 30, 2018.								
Notes: (1) Heat event is defined as having occurred between 8/31/17 and 9/4/17; (2) Heat event reference period defined as having occurred between 8/10/17 and 8/14/17; (3) Calculated by subtracting reference period deaths from heat event deaths; (4) rate ratios calculated by dividing heat event deaths by reference period deaths; (5) Post-heat event is defined as having occurred between 9/5/17 and 9/9/17; (6) Post-heat event reference period defined as having occurred between 8/15/17 and 8/19/17; (7) Limitations within data extraction process prevented full classification of underlying cause of death for all cases, and therefore not all deaths included in table for each time period.								

(3.6) Heat Event Mortality Relative Risk for All Deaths by Zip Code

Lastly, Heat Event and Post-Heat Event Mortality was stratified based on Neighborhood. Source for Mortality for all deaths by Zip Code was obtained via: Source for underlying cause of death was obtained via: State of California, California Department of Public Health, VRBIS Death Statistical Master File Plus 2005-2017, created on January 30, 2018.

Increased mortality rates during the heat event were observed in the Zip code 94110 (Mission/Bernal Heights neighborhood), with a total of 15 deaths, and 10 excess deaths. (300% increase with a 95% confidence interval of 9-725%).

In addition, Zip code: 94112 (Outer Mission/Crocker Amazon/Ocean View/Excelsior/West of Twin Peaks/Bernal Heights) had a total of 18 deaths, and 12 excess deaths (300%

increase with a 95% confidence interval of 19-656%) neighborhoods. Confidence intervals for both estimates were wide.

Table 6: Heat Event Mortality Relative Risk for All Deaths by Zip Code

Zip Code	Neighborhood	Heat Event ^a				Post Heat Event ^a			
		Total Deaths	Expected Deaths ^b	Excess Deaths ^c	Rate Ratios (95% CI) ^d	Total Deaths	Expected Deaths ^b	Excess Deaths ^c	Rate Ratios (95% CI) ^d
94102	Downtown Civic Center, Western Addition	9	4	5	2.25 (0.69, 7.31)	4	6	-2	0.67 (0.19, 2.36)
94103	South of Market, Mission, Financial District, Mission Bay	7	6	1	1.17 (0.39, 3.47)	8	4	4	2.00 (0.6, 6.64)
94104	Financial District	0	0	0	.	0	0	0	.
94105	Financial District, South of Market	1	0	1	.	1	0	1	.
94107	Potrero Hill, South of Market, Mission Bay	3	1	2	3 (0.31, 28.84)	3	1	2	3.00 (0.31, 28.84)
94108	Nob Hill, Chinatown, Financial District, Downtown Civic Center	3	4	-1	0.75 (0.17, 3.35)	1	0	1	.
94109	Russian Hill, Nob Hill, Downtown Civic Center, Pacific Heights, Western Addition	8	4	4	2 (0.6, 6.64)	10	4	6	2.50 (0.78, 7.97)
94110	Mission, Bernal Heights	15	5	10	3.0 (1.09, 8.25)	6	6	0	1.00 (0.32, 3.1)
94111	Financial District, North Beach	1	0	1	.	1	0	1	.
94112	Outer Mission, Crocker Amazon, Ocean View, Excelsior, West of Twin Peaks, Bernal Heights	18	6	12	3.0 (1.19, 7.56)	7	6	1	1.17 (0.39, 3.47)
94114	Castro/Upper Market, Noe Valley, Twin Peaks	3	3	0	1 (0.2, 4.95)	3	2	1	1.50 (0.25, 8.98)
94115	Western Addition, Pacific Heights	3	5	-2	0.6 (0.14, 2.51)	4	5	-1	0.80 (0.21, 2.98)
94116	Parkside, Outer Sunset, West of Twin Peaks, Inner Sunset	13	5	8	2.6 (0.93, 7.29)	7	6	1	1.17 (0.39, 3.47)
94117	Haight Ashbury, Western Addition	3	4	-1	0.75 (0.17, 3.35)	8	2	6	4.00 (0.85, 18.84)
94118	Inner Richmond, Presidio Heights	1	1	0	1 (0.06, 15.99)	3	3	0	1.00 (0.2, 4.95)
94121	Outer Richmond, Seacliff	9	6	3	1.5 (0.53, 4.21)	1	2	-1	0.50 (0.05, 5.51)
94122	Outer sunset, Inner Sunset, Golden Gate Park	7	5	2	1.4 (0.44, 4.41)	1	4	-3	0.25 (0.03, 2.24)
94123	Marina, Pacific Heights	2	1	1	2 (0.18, 22.06)	0	2	-2	.
94124	Bayview	5	2	3	2.5 (0.49, 12.89)	3	2	1	1.50 (0.25, 8.98)
94127	West of Twin Peaks, Ocean View, Outer Mission	3	3	0	1 (0.2, 4.95)	2	0	2	.
94130	Treasure Island	0	0	0	.	0	1	-1	.
94131	Diamond Heights/Glen Park, Twin Peaks, Noe Valley, Inner Sunset, Outer Mission	7	3	4	2.33 (0.6, 9.02)	2	5	-3	0.40 (0.08, 2.06)
94132	Lakeshore, Ocean View	6	2	4	3 (0.61, 14.86)	7	2	5	3.50 (0.73, 16.85)
94133	North Beach, Russian Hill, Nob Hill, Chinatown	8	4	4	2 (0.6, 6.64)	8	5	3	1.60 (0.52, 4.89)
94134	Visitacion Valley, Excelsior, Bayview	5	2	3	2.5 (0.49, 12.89)	4	2	2	2.00 (0.37, 10.92)
94158	Mission Bay, Potrero Hill	0	0	0	.	0	0	0	.
Total		142	76	66	1.87 (1.41, 2.47)	95	70	25	1.36 (1.00, 1.85)

Source: State of California, California Department of Public Health, VRBIS Death Statistical Master File Plus 2005-2017, created on January 30, 2018.

Notes: (1) Heat event is defined as having occurred between 8/31/17 and 9/4/17; (2) Heat event reference period defined as having occurred between 8/10/17 and 8/14/17; (3) Calculated by subtracting reference period deaths from heat event deaths; (4) rate ratios calculated by dividing heat event deaths by reference period deaths; (5) Post-heat event is defined as having occurred between 9/5/17 and 9/9/17; (6) Post-heat event reference period defined as

having occurred between 8/15/17 and 8/19/17; (7) Limitations within data extraction process prevented full classification of underlying cause of death for all cases, and therefore not all deaths included in table for each time period.
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Discussion

What is Unique about SF.

Climate change is scientifically real and it puts the City and County of San Francisco in a unique and vulnerable position for excess deaths, during a heat event. Since San Francisco built-environment is made mainly for temperate weather, homes and buildings aren't built to mitigate increase frequency and severity of extreme heat waves.¹⁸ Furthermore, heat events in San Francisco don't typically last longer than 1 week. Since it takes on average 2 weeks for humans to adjust to new climate, it puts residents of San Francisco, in a vulnerable position, for not being able to adjust to climate change, and thus excess deaths are noted. Heat wave event in San Francisco are like heat-shocks that don't last for an extended period of time, but have lasting damage.

Extreme temperatures are common for other areas in the world, such as in desert geography- Las Vegas, Nevada. However, houses and buildings in Las Vegas are equipped with climate control and air conditioners. The built-on environment of Las Vegas, is built for extreme temperatures. Thus, residents of Las Vegas are able to mitigate heat events and are prepared for extreme temperatures. In addition, residents in Las Vegas are better prepared to adjust to extreme heat, since they expect heat events to occur frequently throughout the year, and thus are able to better prepare and prevent deaths. With a combination of building physiology and human physiology for heat waves, San Francisco is at risk for climate change and heat waves.

Contributors to Neighborhood-Specific Relative Heat Vulnerability.

According to SFClimatE.Org, there are several factors that put each district in San Francisco vulnerable to heat waves; neighborhoods that were identified as highly vulnerable

include: Chinatown, Downtown Civic Center, Bayview, and Mission district. Different components of vulnerability include: Socioeconomic Vulnerability (ethnicity; linguistics; low education; low tree density), Social Isolation (living alone; employment density), Air Quality (air quality; asthma; September temperature), Urban Density (population density; building age),

Chinatown (zip code: 94133), has socioeconomic vulnerability and “high urban density/old buildings.” Downtown Civic Center (zip code: 94102), has socioeconomic vulnerability, “social isolation and high urban density/old buildings.” Mission district (zip code: 94110), tends to have “higher temperatures and air quality is affected the most,” in the months of September. In addition, mission district also has urban density and old buildings. Bayview (zip code: 94134), lacks vegetation and is at risk for socioeconomic factors.

Furthermore, according to the San Francisco Climate and Health report, the City as a whole, socio-economic vulnerability accounted for the most variability of all the variables (18.5%), suggesting that socioeconomic factors have the greatest effect on an individual’s ability to prepare and respond to an extreme heat event.⁹ For example, per the report on Climate and Health, many residents may lack access to health care and services; have an inability to receive and understand heat warnings and emergency preparedness tips, lack the ability to forgo working outdoors during the work day, may not have sufficient capital to purchase and use technologic adaptations, or to live in an area with protective resources like parks and other green spaces.⁹ This vulnerability assessment reveals that factors such as ethnicity, linguistic isolation, and low education contribute significantly to relative heat vulnerability.

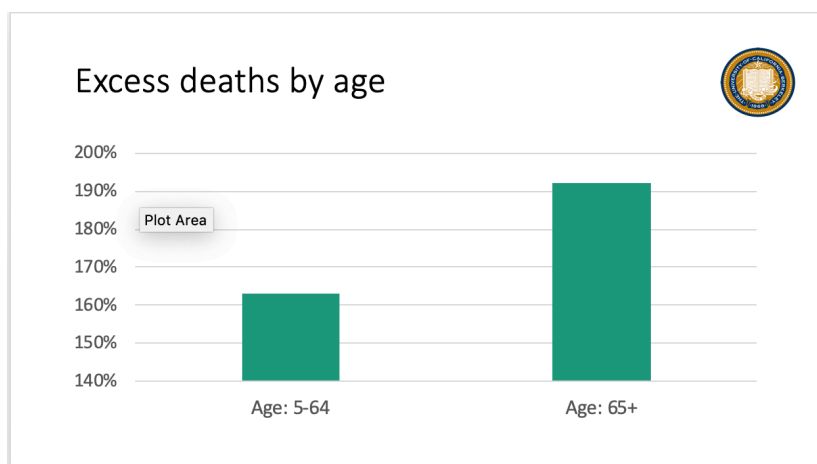
Mortality Rate

During the 2017 heat event there was a total of 142 deaths, with an excess of 66 deaths, or 82% increase in the mortality rate compared to expected rates (95% confidence interval, 41%-

147%). Similar numbers of excess deaths and mortality rate ratios were found using reference periods based on the 2017 summer and 2016 Labor Day weekend. This is noted on Table X. below.

Of the 66 excess deaths, 55 excess deaths were observed among individuals 65 years and older. Increased mortality rates during the heat event were observed among individuals age 65 and older (92% increase with a 95% confidence interval of 40-162%), but not among other age groups. Since 55 significant excess deaths out of the 66 excess deaths happened in the elderly age 65+, further research needs to be done to better understand the why there's a significant excess death in the elderly during heat waves. Increase in deaths in age 65+ maybe associated to increase susceptibility of dehydration and also social isolation. Dehydration is the most common fluid and electrolyte problem among the elderly. In addition, Age-related changes in total body water, thirst perception probably predispose to dehydration.¹⁹

Figure 5. Percentage Excess Deaths by age:



Furthermore, Post-event mortality rates do not demonstrate mortality displacement. Rather, there may have continued to be an elevated death rate following the heat event (36% increase with a 95% confidence interval of 0%-85%). This is noted on Table Y below.

Lastly, the research demonstrated excess deaths that occurred during the heat event. The limitation of excess deaths is that, human life is not infinite and is based on a spectrum. There's a possibility that excess deaths that occurred during the heat event, were prematurely and exacerbated by the heat. Thus, further research needs to be conducted, to further understand the etiology of the excess deaths that occurred, during the heat wave.

Mortality Analysis Findings: Labor Day Heat Event

Table X. Heat Event Mortality Totals and Rate Ratios for All Deaths by Different Reference Periods

Heat Event	2017 August Reference Period ^a			Labor Day 2016 Reference Period ^a			Summer Reference Period ^a		
Total Deaths ^a	Expected Deaths ^a	Excess Deaths ^a	Rate Ratios (95% CI) ^a	Expected Deaths ^a	Excess Deaths ^a	Rate Ratios (95% CI) ^a	Expected Deaths ^a	Excess Deaths ^a	Rate Ratios (95% CI) ^a
142	76	66	1.87 (1.41, 2.47)	81	61	1.75 (1.33, 2.30)	76	66	1.87 (1.41, 2.47)

Source: State of California, California Department of Public Health, VRBIS Death Statistical Master File Plus 2005-2017, created on January 30, 2018.

Notes: (1) Heat event is defined as having occurred between 8/31/17 and 9/4/17; (2) 2017 August reference period defined as having occurred between 8/10/17 and 8/14/17; (3) Expected deaths = deaths per day during reference days x the number of days in the post-event period; (4) Calculated by subtracting expected deaths from heat event deaths; (5) rate ratios calculated by dividing heat event deaths by reference period deaths; (6) 2016 Labor Day event is defined as having occurred between 9/1/16 and 9/5/16; (7) Summer event reference period expected deaths calculating average daily number of deaths during 2017 summer multiplied by length of 2017 heat event.

Table Y. Post-Heat Event Mortality Totals and Rate Ratios for All Deaths by Different Reference Periods

Total Deaths	Expected Deaths ^a	Excess Deaths ^a	Rate Ratios (95% CI) ^a
95	70	25	1.36 (1.00, 1.85)

Source: State of California, California Department of Public Health, VRBIS Death Statistical Master File Plus 2005-2017, created on January 30, 2018.

Notes: (1) post-heat event was defined as having occurred between 9/5/17 and 9/9/17; (2) Expected deaths = deaths per day during reference days x the number of days in the post-event period. Post-heat event reference period defined as having occurred between 8/15/17 and 8/19/17; (3) Calculated by subtracting expected number of deaths from total deaths; (4) rate ratio calculated by dividing total deaths by expected deaths

Heat Event and Fire Service Calls

During the heat event there was an excess of 942 calls for service, or 48% increase (95% confidence interval, 40%-57%). Medical incident-related calls for services saw the largest absolute increase, and also experienced a 47% increase in rate of calls (95% confidence interval, 38%-57%).

Furthermore, during the Labor Day Heat Wave event, there was an excess of 1245 medically related 911 calls. This is noted on the graph below, titled, 2017 Daily Call Volume-Medical Incidents. There were 4,536 Medically related Fire (911) calls as opposed to, 2,840 Fire

(911) Calls, with an Excess of 1,696 calls (RR: 1.6 (1.52, 1.67), during the 4-day, Heat Wave event in 2017. The greatest number of calls were on 9/1/17 and 9/2/17, with 1147 and 1245 Fire (911) medical incident calls, respectively.

Increase call 911- Medically related calls pose a serious threat to city infrastructure. With increase heat wave frequencies, special consideration needs to be taken for staffing medical providers and first responders. In addition, an excess 911 medically related incidents, puts other life-threatening medical attention (i.e. A 911 call for chest pain or stroke) at risk for responding in a timely manner.

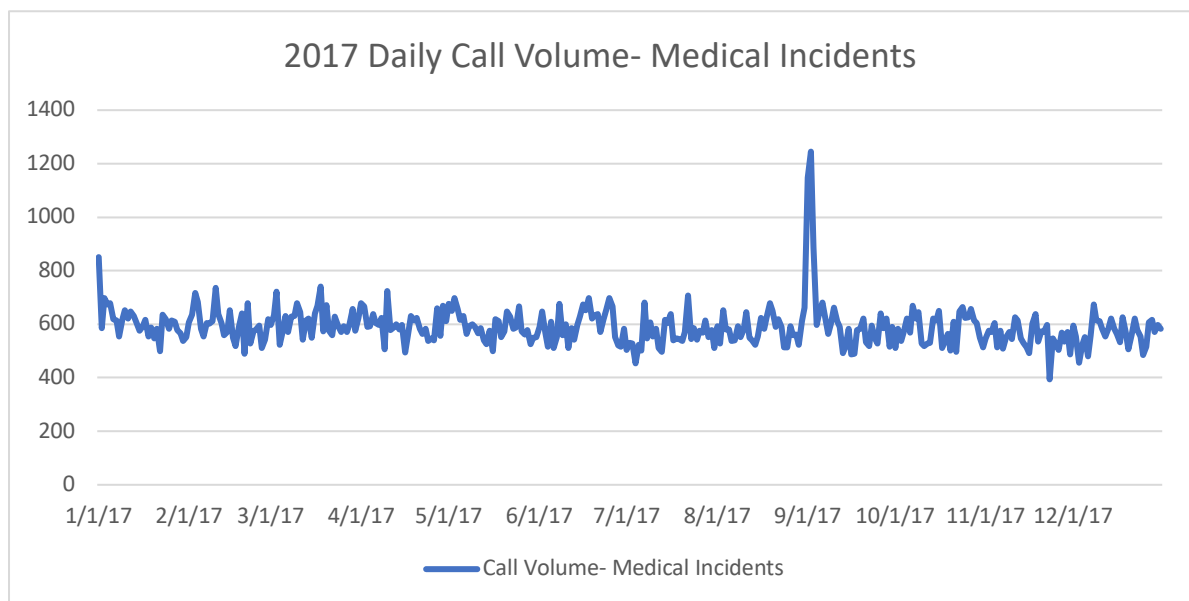


Figure 6. Total number of Daily Call Volume-Medical Incidents for the 2017 year. Calls were obtained via www.datasf.gov. Includes period of Heat Wave Event, as noted by an increase in calls with a peak.

Limitations:

Further research needs to be conducted to fully understand what risk factors cause excess deaths, by neighborhood and age. In addition, excess death and excess 911 calls calculation methods are limited to statistical analysis that was adapted from a previously published article in excess deaths from heat waves.¹⁷

Conclusion

On average, San Francisco experiences three to six extreme heat events each year. Climate change is expected to increase the frequencies of these events up to an average of 13 per year by 2100.¹¹ During the Labor Day extreme heat event, increased mortality rates were observed among individuals 65 years and older, and across both gender groups and all ethnic/racial groups. During the event, there were significant increases in 911-phone calls across all neighborhoods, indicating increases hospitalizations and also increase in fire personnel attending to calls.

Hospitals are vulnerable to impacts from hazard events like extreme heat given the medically and socially vulnerable population they serve, the complexity of services they provide, and their reliance on outside resources to function. Any significant damage or disruption to a hospital facility could have cascading impacts to health. According to the San Francisco Climate and Health Profile, failure of a hospital facility could also impact surrounding hospitals during a hazard event and create a surge in patients that stress their medical capacity.¹¹

Extreme heat events pose a significant public health threat. Over the previous 15 years, heat waves have claimed more lives in California than all other declared disaster events combined. San Francisco residents may be especially vulnerable to the health impacts of these events because they are less acclimatized to higher temperatures. A study on 2006 California heatwave found that the San Francisco-Central Coast Region experienced the highest rate increases in emergency department visits for heat related illness.⁷ Historically, San Francisco has experienced three to six extreme heat events per year, generally between May and October.¹¹ Although an extreme heat event in the city impacts every neighborhood, it does not affect all inhabitants equally. The elderly, the very young, and those with chronic health problems are

most at risk when extreme heat occurs. There were 55 significant excess death that occurred during the 2017 Labor Day heat wave event. Climate change is expected to increase the frequency and severity of extreme heat events. Annual extreme heat days are expected to increase to an average of 13 per year by 2100.¹¹

Next Steps:

The City & County of San Francisco, should implement programs and policies to better mitigate heat events. Such programs could focus on ages 65+, since there were significant excess deaths in that age population. Maybe programs that subsidize fans for homes, could mitigate extreme temperatures, and help elderly better adapt to heat waves. In addition, education should be implemented at senior centers, to educate on the importance of hydration and how to better adapt to extreme temperatures. Seniors living at home alone, are at more vulnerable to hear wave events. Greater precautions should be taken at senior homes, due to social isolation. Recommending to have a system in place for neighbors to check-on each other and encourage hydration. Maybe having multiple hydration stations throughout senior homes, will be beneficial, to prevent dehydration and death.

During the 2017 Labor Day extreme heat event, San Francisco experienced the highest temperature ever recorded, with temperatures of 106 degrees observed. The event also coincided with poor air quality (levels similar to measures during the October wildfires). It is estimated that during the event, at least three people died and 50 people were hospitalized directly due to heat-related illness. While there were three deaths directly classified as caused by heat-related illness, there was a significant increase in all-cause mortality during the event. Exposure to extreme heat can exacerbate underlying health conditions, leading to hospitalization and even premature death. During the event, there was an estimated excess of 66 deaths. This rate increase was

observed among individuals age 65 and older and across all racial groups and genders. Increased mortality was highest among individuals where the underlying cause of death was classified as cancer and cardiovascular disease.

Another measure of the health burden from the event are fire calls for service (i.e. 911-calls), which could indicate increases in hospitalization. During the heat event there was an estimated 48% increase in 911-calls compared to a normal period, with an excess of 1,696 calls. Neighborhoods across San Francisco experiences increased calls, with Downtown-Civic Center/Western Addition experiencing the highest increase. Based on a spatial analysis of calls during the event, there was an association between areas with higher call rates and areas with greater poverty levels.

Following the findings on the Labor Day Heat Wave Event and climate change, San Francisco Department of Public Health, must take necessary steps to mitigate excess deaths and focus on vulnerable populations and programs need to be accessible to the elderly at highest risk. Such programs could include subsidizing fans for the elderly and have educating about hydration. Further data analysis may also be conducted to better understand the relationship between Heat Wave hospitalizations and Emergency rooms visits, as this may provide better insight into the types and distribution of Heat Wave health impacts

Acknowledgements

Thank you so much for all those who supported and advised me through this Honors Thesis. In Particular, thank you: Dr. Tomas J. Aragon, SFDPH, for being my mentor and advisor of this Honors thesis. Thank you, Matt Wolf, SFDPH, for helping me by providing data and guidance on data analysis. Dr. Madsen, UC Berkeley Honors Thesis Professor, for guiding me on this

Honors thesis and preparing me to conduct research. Thank you, Dr. Smith, UC Berkeley, for being a huge mentor at UC Berkeley and my Public Health career. Lastly, a thank you to my family, friends, and kids for all their love and support throughout this process.

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