2026 Heat-Related Mortality Report: Methods Appendix and Supplemental Information

This is the sixth annual heat-related mortality report. This report updates heat-related mortality estimates using similar methodologies as previous reports. Heat stress counts and rates are based on a 10-year dataset with the latest years of data available included and removing the earliest years used in last year's analysis. The two most recent years of data are provisional. This allows us to describe the impact of hot weather in more recent years while including enough years of data to provide stable rates. Heat-exacerbated mortality estimates are based on 10-year moving time windows, beginning with 1974 through the most recent year for which data are available (2023), to characterize trends over time while including enough years of data to provide stable estimates. We provide below a detailed description of methods and data sources used in the report.

1. *Heat stress death review*

We used death certificate data provided by the NYC Department of Health and Mental Hygiene's (Health Department) Bureau of Vital Statistics from 2016 to 2025 to examine heat stress deaths. These deaths are defined as those with underlying or contributing cause codes X30 (exposure to excessive natural heat) or T67 (effects of heat and light), as delineated in the International Classification of Diseases, 10th Revision (ICD-10). Records with a man-made cause of heat exposure (W92) were excluded.

To assess the burden and risk factors specific to the city, we analyzed deaths occurring during the warm season months of May through September occurring in NYC among city residents. From 2016-2025, there were 10 deaths of non-NYC residents in NYC; see Appendix Table 1 below. Most deaths occurred in July (see Appendix Figure 1). To provide more information about circumstances of exposure and risk factors, we also examined a subset of heat stress deaths in Office of the Chief Medical Examiner (OCME) records over the same period. Rates were calculated using the Health Department's population estimates, modified from U.S. Census Bureau intercensal population estimates from 2016-2019 (last updated in 2022) and 2020-2023 (last updated in 2024). Refer to Appendix Table 2 below for numbers and percentages of heat stress decedents from 2016-2025 by race and ethnicity.

We present heat stress deaths by Neighborhood Tabulation Area (NTA), which are aggregations of census tracts with populations of at least 15,000 people. Even with aggregation of 10 years of data, the sample size for heat stress mortality is very small at the NTA level, making estimates potentially unreliable. When death numbers are small, it is difficult to interpret differences, which could be due to random fluctuation in numbers (because, for instance, one additional death may double the counts) or true variation in community risk[1]. The Heat Vulnerability Index, described in more detail below, is based on larger numbers of heat-exacerbated deaths and is a more reliable way to compare community-level risks of heat-health impacts across the city.

Years of data included

For heat-stress, data for 2024 and 2025 are considered preliminary because death data are still being compiled by the Bureau of Vital Statistics. These numbers may be updated in future reports as final data become available. All heat-stress tables are based on heat-stress deaths from 2016-2025. The heat-exacerbated mortality analysis requires complete daily death counts to produce accurate estimates, making 2023 the most recent available year of data.

Table 1: Heat Stress Deaths by Residence, NYC residents and non-NYC residents, May-September, 2016-2025.

Place of residence	n	%
Brooklyn	25	31
Queens	16	20
Bronx	12	15
Manhattan	11	14
NY State outside NYC	6	7
Homeless*	5	6
Outside of NYS	4	5
Staten Island	2	2
Total	**81**	**100**

*Based on residence unknown in death certificate.

Figure 1. Percent of heat stress deaths by month, NYC residents, May-September, 2016-2025

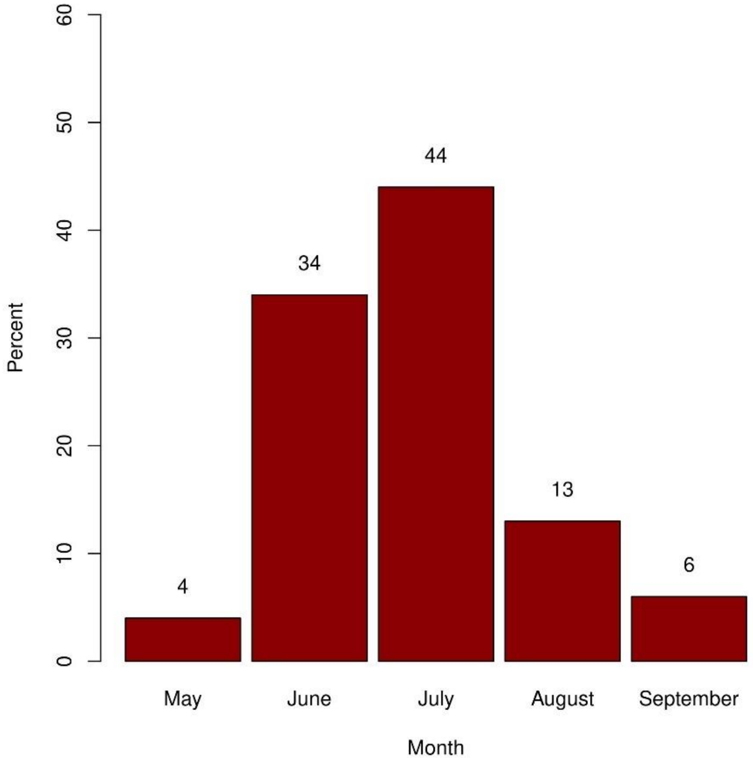

Table 2: Race and ethnicity of heat stress decedents, NYC residents, May-September 2016-2025.

	Avg. annual

	n	%	age-adjusted rate per million
Latino	24	34	1
Asian and Pacific Islander	2	3	0.1
Non-Latino White	15	21	0.4
Non-Latino Black	26	37	1.2
Other or Unknown*	4		

Notes: The Latino category includes people of any race. Data on people identified as two or more races or races/ethnicities not listed are included in the other or unknown category. The rates for the other or unknow category was not calculated due to lack of appropriate denominator data. Differences in health outcomes among racial and ethnic groups are due to long-term institutional and personal biases against people of color. Persistent racism and an inequitable distribution of resources needed for wellness cause these health inequities. These resources include jobs that pay a living wage, health care, housing with air conditioning, among others, which can lead to worse health outcomes.

2. *Heat-exacerbated death estimation*

We estimated heat-exacerbated mortality using weather and natural cause death data for May through September in NYC. Natural cause deaths were defined as those with ICD-9 codes <800 (prior to 1999) and ICD-10 codes in the range of A00-R99 occurring in NYC among city residents, with ICD-10 U codes categorized as external or natural as appropriate. In two previous reports (2021 and 2022), we used 9-year study periods (2010-2018 for the 2021 report; 2011-2019 for the 2022 report) to estimate heat-exacerbated deaths. In 2023-2025, we reported heat-exacerbated deaths in 5-year moving time windows to characterize trends. The shorter time period has a trade-off of more uncertainty, however, as seen in the wider confidence intervals around the estimates in last year's report [3]. For a more stable assessment of heat-exacerbated mortality, in 2026 we report trends based on a rolling 10-year study period, with the most recent time period reflecting 2014-2023 average annual estimates. The 10-year model yields more stable estimates, provides long-term trends, and aligns with the 10-year period used to describe the temperature-risk relationship in the report (see Figure 4 of main report). During the five decades covered in this report, the average daily natural-cause death count during the warm months declined from ~26,000 for 1974-1983 to ~19,000 for 2014-2023. Additional details on model specification and interpretation are provided below.

2.1 Heat exposure metrics

We estimated heat-exacerbated deaths using two epidemiologic models with differing measures of hot weather:

(1) an indicator for the extreme heat event days as defined by the NWS threshold for issuing a heat advisory for NYC: at least 2 consecutive days with 95°F or higher daily maximum heat index (HI) or any day with a maximum HI of 100°F or higher; and
(2) continuous daily maximum temperature for the range of summer hot temperatures that includes both extreme heat event days and other "hot" (greater than the median temperature over the warm season) days.

For both measures, we used data from the NWS weather station at LaGuardia airport, because it had the fewest missing hourly observations among the NYC area weather stations. The temperature data for LaGuardia airport were obtained from National Centers for Environmental Information, National Oceanic and Atmospheric Administration (NOAA), Global Historical Climatology Network (hourly: https://www.ncei.noaa.gov/products/global-historical-climatology-network-hourly and daily: https://www.ncei.noaa.gov/products/land-based-station/global-historical-climatology-network-daily).

(1) *Extreme heat event indicator*

We created a 0/1 indicator for extreme heat event defined as the NWS heat advisory threshold for NYC, which was based on the Health Department's previous analysis of heat-exacerbated mortality[]. Therefore, the estimated risk and the deaths attributed to this indicator represent the mortality burden associated with this level of extreme heat, which results in City-led emergency response activities. The extreme heat event indicator was computed based on the threshold definition but not the actual heat advisories, which rely on forecasted weather from multiple stations and are issued within 24 hours of the onset of the event.

The extreme heat event indicator alone does not capture the impacts of temperature in the rest of the temperature range, resulting in poor model fit. Therefore, we created two additional categorical variables based on the distribution of the larger of the daily maximum heat index or daily maximum temperature (denoted as "MAX"). The heat index considers both air temperature and relative humidity to estimate human-perceived heat, but it is not defined when the temperature is below 80°F or relative humidity is below 40%. For days when the maximum heat index was not defined, we substituted the missing value with the daily maximum temperature (i.e., maximum of heat index or temperature). The indicator for the lowest temperature corresponds to the first quartile (<75°F) of this maximum heat index/temperature indicator, and the indicator for non-extreme hot days covers the range at or above 82°F (the median value) but excluding extreme heat event days. With the three indicators in the model, the reference category corresponds to the second quartile (75°F ≤ MAX <82°F), based on the data distribution for May through September, 2010-2018, a fixed period in this series of heat mortality reports to make comparisons of heat impacts over time possible. For the analysis of trend in excess deaths attributable to extreme heat in 10-year moving time windows between 1974 and 2023, we used the same temperature range categorization as above to make interpretation of the risk associated with specific temperature range consistent.

(2) *Continuous daily maximum temperature*

The risks and deaths attributable to extreme heat event days do not fully capture heat impacts on mortality, as hot days other than extreme heat days are also associated with mortality. The Health Department's previous analysis of temperature and mortality relationships examined multiple temperature indicators, including daily maximum temperature and MAX (described above), and these two variables yielded similar model fits[]. Therefore, given that daily maximum temperature is easily understood and widely reported in the media throughout summer months, we chose this continuous temperature metric for estimating risk and attributable deaths.

2.2 Methods

We applied distributed lag non-linear models (DLNM)[] to estimate the cumulative relative risk of dying during hot weather and to estimate the number of heat-exacerbated deaths. In DLNM, three parameters are specified to construct a *cross-basis*: the extent of lagged days to be fitted; the functional form of the response relationship; and the functional form to (or not to) constrain weights of response across lagged days. Based on the Health Department's previous analyses of temperature-mortality relationships[2,], for the cross-basis of the continuous temperature variables, we considered: 0- through 3-day lags to capture delayed effects; a non-linear functional form using a natural cubic spline of 4 degrees of freedom at equal interval spanning the temperature range; and with the non-linear relationships unconstrained across lagged days. The extent of lagged days considered (0-3) and the functional non-linear form of temperature-mortality relationship specified are also consistent with those used in a recent study of 445 cities in 24 countries[]. For the extreme heat event 0/1 indicator model, the functional form for cross-basis was necessarily linear but the extent of lag days (0-3) and unconstrained form of the slope across lags were the same as those used for daily maximum temperature.

These cross-basis specifications were fitted in Poisson time-series regression models to estimate relative risk of natural-cause deaths, adjusting for day-of-week and trends within the five-month window using a natural cubic spline of 5 degrees of freedom of the warm season day of year, and adjusting for over-dispersion. In addition, we adjusted for daily counts of COVID-19 deaths in order to account for their temporal trends, which were different from those for the rest of non-external causes of deaths combined.

In calculating relative risks, we used the daily maximum temperature at which the minimum mortality risk was observed (70°F; see Figure 4 in the main text)—often referred to as “minimum mortality temperature”[]—as the reference temperature. We estimated attributable (heat-exacerbated) deaths above the median temperature (82°F) during the past decade. The current median temperature provides a policy-relevant floor for excess death estimates, defining a meaningfully “hot but less than extreme” reference for public health messaging.

The regression model described above was run in each of the 10-year moving time windows between 1974 and 2023 (yielding 41 estimates). Note that the natural cubic splines used for the non-linear temperature-mortality relationship and adjustment for within-season trends allow these fits to change over the years. The minimum mortality temperature described above was also allowed to change for each time window within a range of 70 to 78, using the method suggested by Tobias et al. 8].

The attributable deaths from these models were estimated using *attrdl* function developed by Gasparrini and Leon []. All models were fitted using *dlnm* package[] with R statistical software (version 4.2.3; R Development Core Team). In the summary, we round point estimates to the nearest 10, to avoid conveying a false sense of precision about modeled estimates.

2.3 Results

The annual average attributable deaths for the extreme heat event indicator for the most recent 10-year period (2014-2023) were 88 (95% Confidence Interval [95% CI]:51, 122). Corresponding attributable deaths for daily maximum temperature above 82°F were 489 (95% CI:264, 706). They correspond to approximately 0.5% and 3%, respectively, of all natural-cause deaths during May-September on average each year. The trend in estimated heat-exacerbated deaths shown in the main text Figure 3 in part reflects the change in the average warm-season deaths, which ranged from ~26,000 for 1974-1983 to ~19,000 for 2014-2023. However, the overall pattern of a decline in the first 30 years and an increase in the past decade was also seen when the attributable fraction, rather than the absolute counts, was plotted over time.

The 88 (95% CI: 51, 122) estimated heat-exacerbated deaths per summer attributable to extreme heat in this analysis for the most recent 10-year period is comparable to previous estimates for extreme heat days by year for 1997-2013 [3], within the 95% confidence intervals.

Two studies allow comparison to our attributable-death estimate above 82°F using continuous temperature variables: a NYC study for projected temperatures[] and a nationwide study with an estimate for northeast cities per million people[1]. Both studies used DLNM methods and data through 2006. In the NYC study, the estimated projected excess deaths for 2010-2039—assuming declining relative risk impact due to air conditioning prevalence—were 492, 412, and 191 for no adaptation, low adaptation, and high adaptation, respectively, for Representative Concentration Pathway 4.5. For Representative Concentration Pathway 8.5, the estimated projected excess deaths for 2010-2039 were 549, 460, and 215 for no adaptation, low adaptation, and high adaptation, respectively. This study's multi-city estimate for northeast cities for 1997-2006 applied to the current NYC population resulted in an estimated 407 deaths. These estimated heat-exacerbated deaths for the continuous temperature variable, despite the differences in study years and minor differences in methods, such as reference temperatures, are comparable to that for the recent decade in this report, given the range of their confidence intervals.

3. Case-only analysis to characterize risk factors for heat-exacerbated deaths

Because this segment is an update of previously published analysis,[] we only provide additional details here. Previously, we conducted a case-only analysis to identify individual- and neighborhood-level factors associated with heat-exacerbated deaths using a case-only design (Madrigano et al., 2015) []. In that analysis, using 2000-2011 data, dying at home and non-Latino Black as the decedent's race/ethnicity category were found to be positively associated with heat-exacerbated deaths for extreme heat event days (as defined by NYC's heat advisory threshold) and two days following these days. In the current report (2026), we repeated the same analysis but using 2014-2023 data. The percentage of deaths that occurred at home during this period was higher (31%) than that for 2000-2011 data (21%), and the percentage of non-Latino Black decedents was approximately the same (28%) as that for 2000-2011 (27%). The details of the methods are described in the 2015 Madrigano et al. paper, but briefly, we ran logistic regression models with a 1/0 indicator of these attributes (1 for at-home deaths and 0 for others; 1 for non-Latino Black and 0 for the other race/ethnicity categories) as the dependent variable and a 1/0 indicator for extreme heat event days (and two following days). Additionally, because the place of death for COVID-19 deaths were skewed towards in-hospital, we included a 1/0 indicator variable for COVID-19 deaths in the regression model. The regression model was fit using the base R generalized linear model (GLM function with "family=binomial"). Odds ratios were computed by taking the exponent of the regression coefficient for the extreme heat indicators.

The original analysis and updated analysis described above used the dichotomous indicator of the extreme heat event days. However, given that heat-exacerbated deaths also occur even during non-extreme heat days, we expanded the case-only analysis by using a quintile indicator of temperature ranges rather the 0/1 indicator. In constructing the quintile indicator, we first created a time-series of the average of daily maximum temperature at lag 0 through 3 days to take into consideration the lagged effects of temperature. While the original daily maximum temperature data for LaGuardia airport from NOAA were whole numbers (e.g., "81"), the 4-day average values yielded fractional numbers, and the quintile cut-off temperatures were 74.25, 79.75, 83.5, and 87.25°F for 20th, 40th, 60th, and 80th percentiles, respectively. These unrounded cut-offs were used to create the quintile indicator, but rounded numbers are used in the main text and Figures 5 and 6. The lowest quintile was used as a reference for odds ratios. We repeated the analysis for each of the major race/ethnicity categories: non-Latino White (40%), non-Latino Black (28%), and Latino (21%). Mortality counts for Asian (9%) and other race/ethnicity groups (1%) were not large enough to provide estimates with precision for this analysis.

4. *Community-level heat impacts*

We used the NYC Heat Vulnerability Index (HVI) to describe community-level health impacts. The Health Department partnered with researchers from Columbia University's Mailman School of Public Health to create the HVI in 2015, which was based on an analysis of social and environmental factors associated with heat-exacerbated death in NYC neighborhoods during and shortly after extreme heat events[].

The factors included in the HVI are surface temperature, green space, percentage of households with access to home air conditioning, the percentage of residents who are low-income defined by area median household income, and the percentage of residents who are non-Latino Black. Income and race data are from the American Community Survey (2016-2020 5-year estimates), green space data are from the New York City Department of Parks and Recreation (2017), surface temperature data are from the NASA's ECOSTRESS (2020), and air conditioning prevalence data are from the US Census NYC Housing and Vacancy Survey (2017). The HVI is mapped by 2020 Neighborhood Tabulation Area (NTA) boundaries, which are aggregations of census tracts.

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