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The Association between Temperature and Fatal Police Shootings in the United States: 2015-2020

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The Association between Temperature and Fatal Police Shootings in the United States: 2015-2020

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An abstract of a thesis submitted to the Faculty of the
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Abstract

The Association between Temperature and Fatal Police Shootings in the United States: 2015-2020
By Ellen Martinson

Purpose: Police violence is a significant public health and justice issue, with an estimated 30,800 police deaths occurring between 1980 and 2019. Aside from traditional factors that influence police use of force such as department policies, officer sociodemographic characteristics, and incident context, less is known about the influence of environmental conditions on policing. Temperature has previously been associated with increased rates of violence, but there is a lack of research on the association between temperature and police violence specifically. Our study objective is to investigate the association between temperature and fatal police shootings in the United States from 2015 to 2020.

Methods: Here we use a case-crossover study design and conditional logistic regression to investigate the association between temperature and fatal police shootings. We used The Washington Post's "Fatal Force" database to access fatal police shooting data, linking each incident to daily meteorological data from Daymet. Fatal police shooting incidents (N=5,629) were matched to up to four control days in the same month and year of the shooting. We performed stratified analyses by the victim's race, age, armed status, region, and season. In addition to our a priori metric of choice, maximum same-day temperature, we also investigated lagged maximum temperature.

Results: Across all incidents, one-degree Celsius increase in temperature was associated with a 1.006 [0.999, 1.013] increased odds of fatal police shootings. In stratified analyses, we found significant associations in several strata including White Non-Hispanic victims (1.011 [1.002, 1.021]), victims aged 45 and above (1.027 [1.013, 1.040]), and incidents that occurred in the Southern (1.013 [1.002, 1.023]), and Western (1.012 [1.000, 1.024]) United Sates. Across nearly all population subgroups, there was an elevated effect in victims who were armed.

Conclusion: We found suggestive evidence of an association between maximum same-day temperature and fatal police shootings overall, but stronger evidence for several population sub-groups. Presence of a civilian weapon may be an important factor in the relationship between outdoor temperature and police shootings. Overall, these findings could help inform climate change adaptation policies moving forward.

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Additionally, I would like to thank my parents for supporting all of my educational endeavors and reading endless drafts of my papers over the years.

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Table of Contents

Tables and Figures

Introduction:

Police violence is a significant public health and justice issue, negatively impacting overall community well-being. Between 1980 and 2019, it was estimated that 30,800 Americans were killed by police, the overwhelming majority of which resulted from a firearm.[1] Police shootings are estimated to cause 94% of police-caused fatalities annually.[2] Aside from the individual impacts of police violence, spillover effects can significantly impact surrounding communities. Students exposed to nearby police violence experienced worse classroom performance than their peers, while residents living in communities with increased exposure to lethal policing experienced greater risk of high blood pressure and obesity.[3,4] Black Americans are disproportionately affected by police violence, and police killings and high-profile shootings have been associated with negative mental health spillover effects in this population.[5,6,7,8,9]

Several factors have been shown to influence a police officer's decision to use force including a suspect's behavior and resistance, department policies, sociodemographic factors of the officer, and contextual factors of the incident.[10,11,12,13] Less is known about possible environmental factors, for example weather conditions, that may influence a police officer's behavior during civilian interactions. However, research has demonstrated that rates of violence amongst the general population are influenced by temperature, especially extreme heat.[14,15] Environmental conditions such as weather and temperature may contribute to short-term fluctuations in crime not entirely explained by long-term crime trends and individual sociodemographic factors.[16] Violent crimes, typically defined as homicide, assault, domestic violence, burglary, and rape, have all been positively associated with temperature.[14,15,17,18,19] Several studies have quantified positive linear associations between violence and temperature, demonstrating that violent crime is associated with temperature across seasons and geographic regions in the United States.[15,20,21] A recent global review identified 16 studies published between 1997 and 2018 investigating the association between temperature and homicide in any geographical setting. Nine of those reported significant positive associations, while the remaining seven reported non-significant positive associations.[22] Several studies published since 2018 have also identified significant positive associations between homicide and temperature.[23,24]

Two primary theories help to explain why temperature may influence violence. First, the temperature-aggression hypothesis suggests that temperature increases are biologically associated with individual behavior and increased violent tendencies.[17,25] Also known as the heat hypothesis, hot temperatures may directly increase feelings of hostility and indirectly increase aggressive thought.[26] Biologically, heat exposure has also been associated with sleep disturbance and changes in neurophysiological signaling, factors that possibly contribute to violence.[27] A second explanation is that warmer temperatures may increase social interactions, and in doing so, may increase the potential for violent encounters between perpetrators and their victims. This theory is known as the routine activity theory and suggests that the execution of a crime requires the convergence of a motivated offender, a suitable target, and absence of a guardian.[28] Short-term weather fluctuations may alter an individual’s activities, increasing the likelihood of the convergence of these three factors.

Although there is an established relationship between heat and violence, there is limited research on the impacts of temperature on police violence and police behavior. Vrij et al. (1994) conducted a field experiment with Dutch police officers demonstrating that officers had a higher tendency to draw and fire their weapons in a Fire Arms Training System in a high temperature condition versus low temperature condition.[29] Police officers were also found to be more likely to issue traffic citations in warmer temperatures.[30] In a working paper, Annan-Phan et al. (2020) investigated the relationship between temperature, police threat level, and police-involved civilian deaths in the United States using county-level crime data.[31] The authors found a higher number of incidents in which a suspect posed serious threat of injury or death to officers on warmer days (>17°C), but a null association between temperature and fatal shootings by police officers. However, the number of police deaths associated with Taser use and physical restraints was significantly higher on extremely warm days (>32°C), suggesting a relationship between policing and heat.

Overall, there is limited research on the impacts of temperature on police violence and police behavior in real-world settings in the United States. The objective of the study is to analyze the association between maximum temperature and national fatal police shootings, investigating the association across the victim's race, age, region, season and whether the deceased was armed. Since the overwhelming majority of police-related deaths involve firearms, this study has chosen to specifically focus on police shootings rather than on other forms of police violence. Based on existing research regarding the relationship between heat and violence, our *a priori* hypothesis is that maximum same-day temperature is positively associated with fatal police shooting incidents.

Methods:

Below I first describe the datasets and then the statistical approach.

Data on Fatal Police Shootings

The primary national systems that aim to capture police killings are the National Center for Health Statistics' (NCHS) National Vital Statistics System (NVSS) and the Federal Bureau of Investigation's (FBI) Uniform Crime Reporting (UCR) program. The NVSS and UCR substantially underreport police killing incident rates, eliminating them as a potential data source and justifying the use of open-sourced data.[1,32,33,34,35,36,37] Here we use fatal police shooting data from The Washington Post's "Fatal Force" database, a publicly available dataset that began on January 1, 2015 and is collected from local news reports, law enforcement websites, public records, social media, and original reporting.[38] Although there are other popular open-sourced databases documenting police violence, The Washington Post database was chosen because it has the most restrictive case definition, reporting specifically on fatal shootings of civilians by on-duty police officers. Additionally, the data source has been validated in several studies, and has been used in other peer-reviewed research on fatal police shootings.[39,40,41,42,43,44,45]

The Washington Post dataset includes the date and location of the incident, as well as the victim's race, age, and whether or not they were armed and with what type of weapon. For stratified analyses, the victim's armed status was classified into two groups: armed and unarmed. We excluded incidents in stratified analyses that had missing or "undetermined" data under the Washington Post's armed variable, as well as incidents with toy weapons.

Temperature Data

Latitude, longitude, and date were used to link each shooting incident to meteorological data from NASA's Daymet product.[46] Daymet reports 1 km^2 gridded estimates of daily weather parameters throughout the United States. We excluded incidents from Hawaii due to a lack of data. Variables used for analysis included daily maximum temperature, daily minimum temperature, daily average dew-point temperature, and daily total precipitation. We explored lags of up to three days before the shooting incident to investigate potential delayed effects of temperature, but used maximum same-day (lag 0) temperature as our *a priori* metric of choice.

Data Analysis:

A case-crossover design was used to estimate the association between maximum temperature and fatal police shootings. In the case-crossover design, each case day [fatal police shooting] is compared to its own control days, here using days on the same day of the week within the same month and year of the fatal shooting. Case-crossover studies can be used when the outcome is rare and exposure is transient, and is frequently used in violence research.[47,48,49] The study design intrinsically controls for day of the week, month, location, and individual-level factors that do not change within a month such as race, sex and age group.

Since the case-crossover study is a matched design, conditional logistic regression models were fit to estimate odds ratios. Results are reported as odds ratios for every 1 degree Celsius increase in temperature, along with 95% confidence intervals. Effects on specific subgroups were analyzed by stratification, including on the victim's race, age group, armed status, season, and region. Regions were defined by the United States Census Bureau's four classifications: South, West, Northeast, and Midwest.[50] In sensitivity analyses, humidity and precipitation were considered as potential confounders. In addition, potential non-linear temperature effects were analyzed by grouping maximum temperature into quintiles and then comparing each quintile to the coldest quintile. Analyses were conducted using SAS version 9.4 (Cary, North Carolina) and RStudio Cloud.[51,52]

Results:

The dataset was downloaded from the Washington Post website on September 29, 2021 and included 6,600 incidents.[38] Due to a lack of temperature data in Daymet, we removed incidents from 2021 (n=654) as well as from Hawaii (n=31). Incidents without latitudes and longitudes were also excluded (n=286). The final dataset, from January 1, 2015 to December 31, 2020, included 5,629 fatal police shooting incidents, with a mean of 938 incidents per year, a maximum of 992 in 2015 and a minimum of 910 in 2018.

Table 1 displays descriptive information on the victim's race, age group, armed status, incident region, and incident season, as well as the proportion of victims that were armed in each subgroup. The majority of incidents occurred among victims who were White, Non-Hispanic (46.6%), aged 25 to 44 (54.0%), and who were armed (84.1%). Incidents occurred relatively evenly across all four seasons. Temperature on case and control days is reported in **Figure 1**; temperatures were similar but slightly higher on case days.

	N (%)	**N (%) of subgroup that was armed**
Overall Sample	5,629	
Race of Victim		
White, Non-Hispanic	2,623 (46.6%)	2,180 (83.1%)
Black, Non-Hispanic	1,382 (24.6%)	1,115 (80.7%)
Hispanic	986 (17.5%)	795 (80.6%)
Other	199 (3.5%)	167 (83.9%)
Age Group of Victim		
24 and Under	897 (15.9%)	688 (76.7%)
25-44	3,037 (54.0%)	2,528 (83.2%)
45 and Above	1,473 (26.2%)	1,322 (89.7%)
Region		
Northeast	391 (6.9%)	314 (80.3%)
Midwest	891 (15.8%)	747 (83.8%)
South	2,361 (41.9%)	1,912 (81.0%
West	1,986 (35.3%)	1,565 (78.8%)
Season		
Fall	1,334 (23.7%)	
Spring	1,428 (25.4%)	
Summer	1,421 (25.2%)	
Winter	1,446 (25.7%)	
Armed Status of Victim		
Armed	4,736 (84.1%)	
Unarmed	384 (6.8%)	
Toy Weapon	201 (3.6%)	
Undetermined	308 (5.5%)	

Table 1. Descriptive information on the victim's race, age, whether they were armed, incident region, incident season, and proportion of each subgroup that was armed. Victim race and age percentages do not add to 100% due to missing demographic information in the Washington Post dataset.

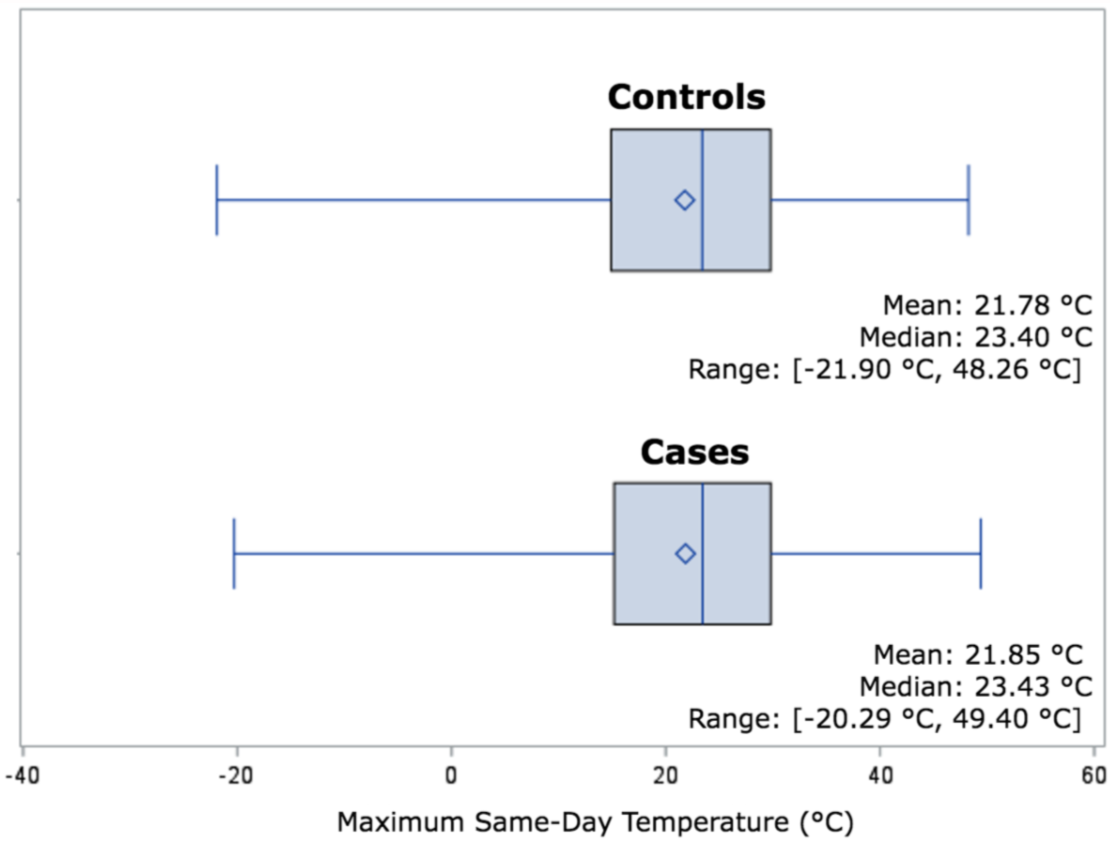

Figure 1. Distribution of maximum same-day temperature for case and control days in degrees Celsius.

Overall, a one-degree Celsius increase in maximum same-day temperature was associated with a 1.006 [0.999, 1.013] increased odds of fatal police shootings. Odds ratios stratified by race, age group, armed status, region, and season are displayed in **Figure 2**. Several strata including White, Non-Hispanic victims, victims aged 45 and above, incidents in the South, and incidents in the West reported significant, positive associations. All other strata reported null central estimates, with no strata reporting a significant negative association.

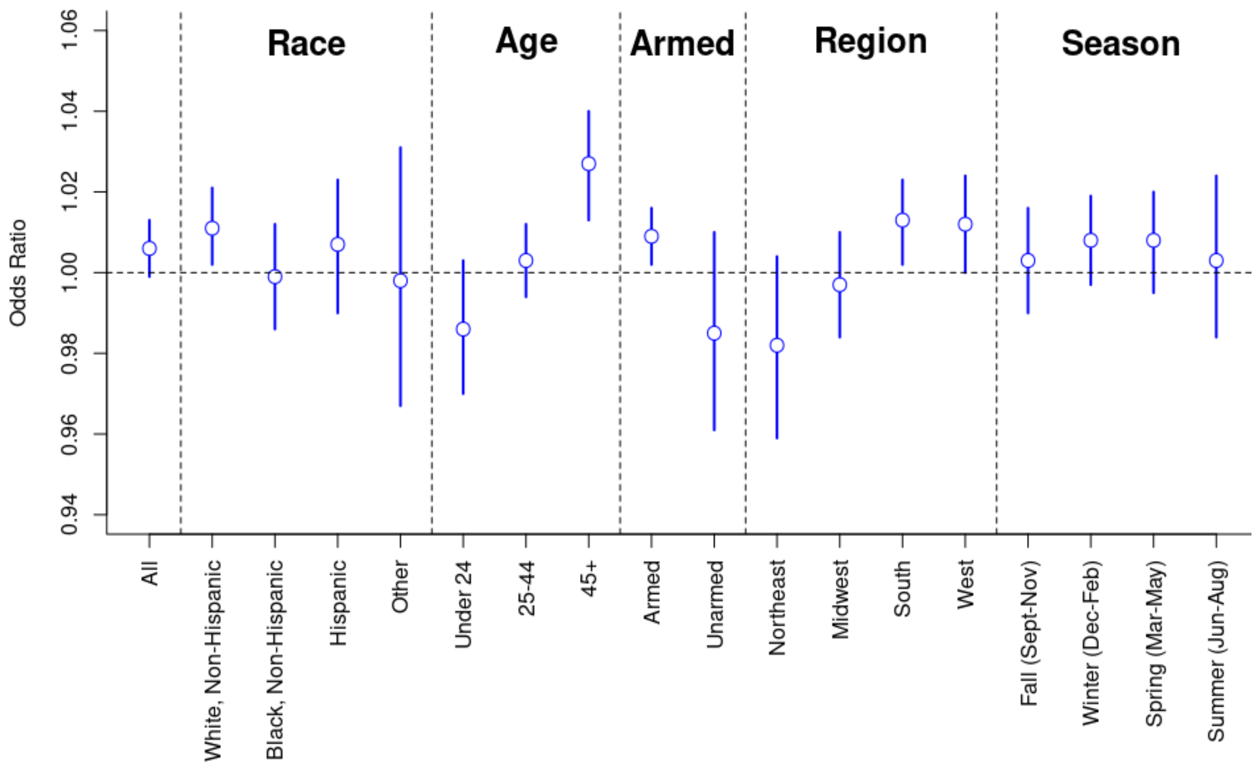

Figure 2. Association between maximum same-day temperature and fatal police shootings, stratified by subgroup and reported as odds per one degree Celsius. Bars represent 95% confidence intervals.

When stratified by age group, the age groups of victims 24 and under and victims 45 and above reported a significant difference in central estimates, demonstrated through non-overlapping 95% confidence intervals. There was an increasing trend with age, which became highly significant in the oldest age group. Victims aged 45 and above had the highest odds ratio across all investigated subgroups, reporting a central estimate of 1.027 [1.013, 1.040].

White, Non-Hispanic victims reported the highest odds ratio across racial groups with a central estimate of 1.011 [1.002, 1.021] . No racial subgroup reported a significant difference with another racial subgroup. Black, Non-Hispanic victims reported a central estimate of 0.999 [0.986, 1.012], while Hispanic victims reported a central estimate of 1.007 [0.990, 1.023].

Victims not classified in one of the above racial categories reported a null central estimate of 0.998 [0.967, 1.031].

Regionally, the Northeast had the smallest sample size of fatal police shootings with only 391 incidents between 2015 and 2020. The central estimate for the Northeast strata was the lowest of all four regions with a null negative association 0.982 [0.959, 1.004]. The Midwest similarly reported a null negative association of 0.997 [0.984, 1.010]. The South had the highest regional central estimate of 1.013 [1.002, 1.023], while the West also reported a significant, positive association of 1.012 [1.000, 1.024].

Odds ratios stratified by each subgroup's presence of a weapon (armed versus unarmed) are reported in **Figure 3**. All subgroups besides victims aged 24 and Under and victims in the "other" racial category reported a higher odds ratio in the armed strata. The largest differences in

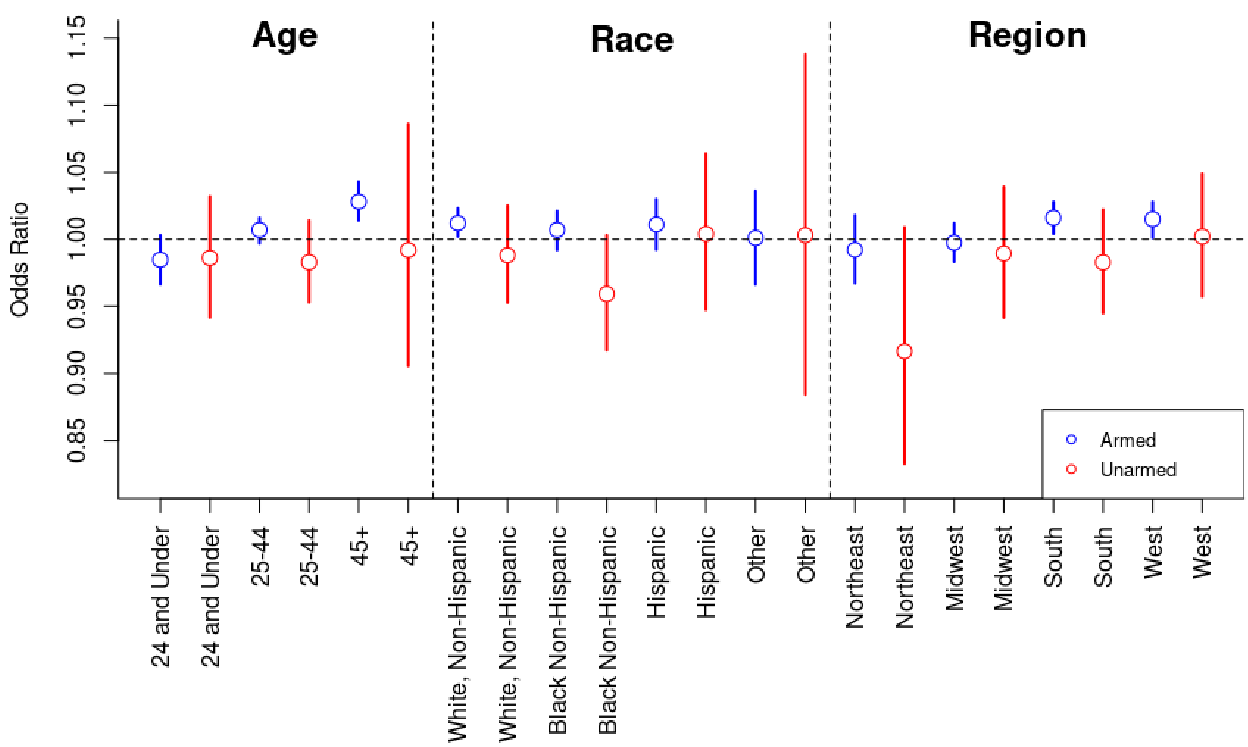

Figure 3. Association between maximum same-day temperature and fatal police shootings, stratified by subgroup and armed status of the victim and reported as odds per one degree Celsius. Bars represent 95% confidence intervals.

odds ratios between armed and unarmed strata occurred in incidents in the Northeast (0.075), among victims aged 45 and above (0.036), and among incidents in the South (0.033).

Sensitivity analyses investigating minimum same-day temperature, lagged maximum temperature, and the inclusion of humidity and precipitation in the model are displayed in **Figure 4**. Including humidity and precipitation as potential confounders in the model did not meaningfully change our results. Same-day minimum temperature was associated with a null central estimate of 1.001 [0.994, 1.009]. Maximum same-day temperature was associated with a higher odds ratio in comparison to lags of one, two, and three days. Although the differences between temperature lags were not significant, central estimates decreased as days preceding the incident increased.

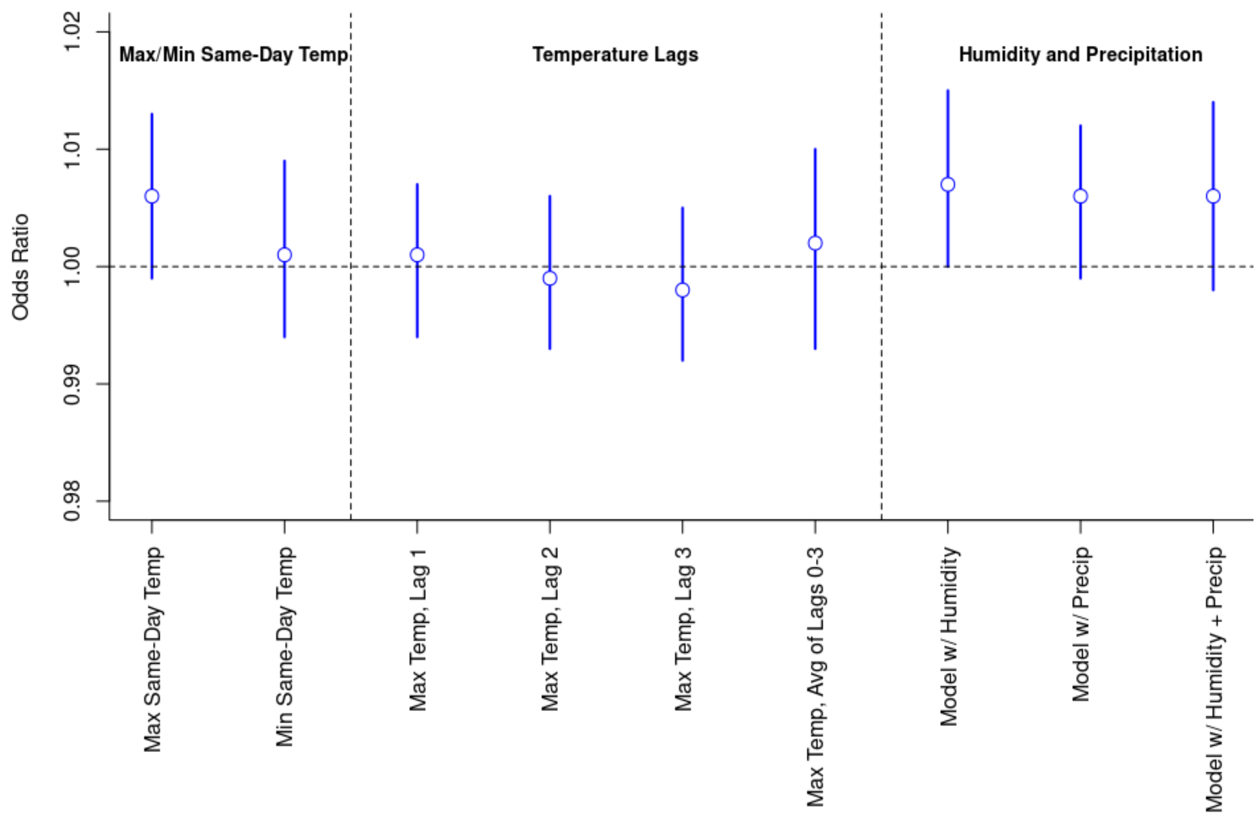

Figure 4. Sensitivity analyses displaying the association between fatal police shootings and the maximum and minimum same-day temperature, lagged maximum temperature, and consideration of humidity and precipitation as confounders. Odds ratios are reported for a one-degree Celsius increase in temperature. Bars represent 95% confidence intervals.

The association did not display any clear non-linear trend, displayed in **Figure 5**, though the association may plateau at very high temperatures.

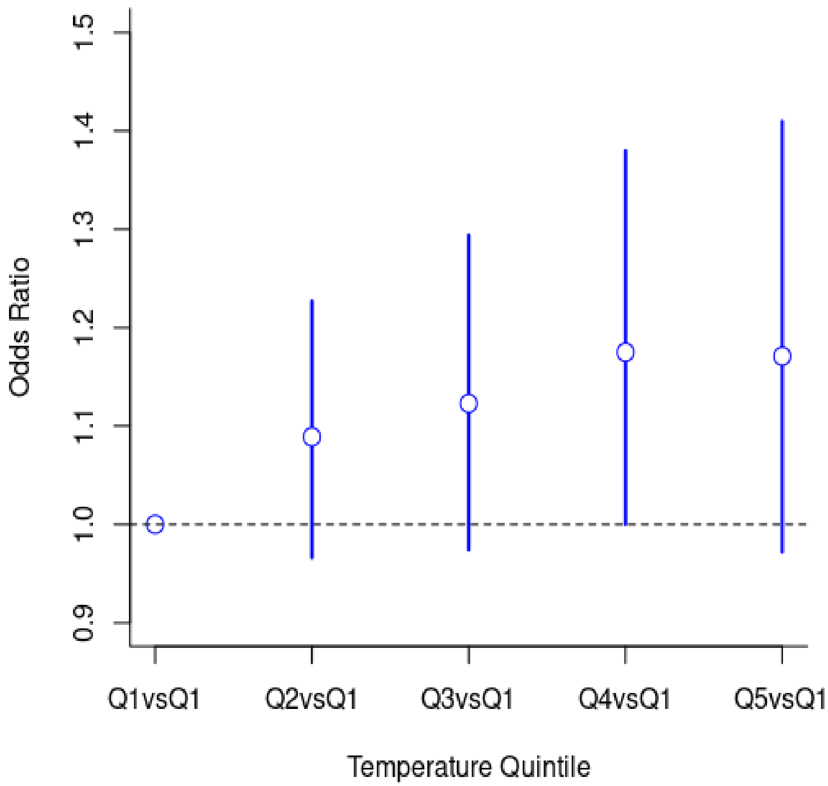

Figure 5. Association between maximum same-day temperature and fatal police shootings using case and control temperature quintile groups, referencing the coldest quintile group.

Discussion:

Using a case-crossover study design, we estimated the association between maximum same-day temperature and fatal shootings by police officers in the United States from 2015 to 2020. We found that maximum same-day temperature was associated with a 1.006 [0.999, 1.013] increased odds of fatal police shootings for every one-degree Celsius increase in temperature. Our association did not meaningfully change when considering humidity and precipitation as confounders and did not show any clear signs of non-linearity. Same-day temperature had the highest central estimate in comparison to lagged maximum temperature. Although the unadjusted overall central estimate was not significant at the 5% level, several subgroups reported significant positive associations in stratified analyses. These strata include White, Non-Hispanic victims (1.011 [1.002, 1.021]), armed victims (1.009 [1.002, 1.016]), victims aged 45 and above (1.027 [1.013, 1.040]), incidents in the South (1.013 [1.002, 1.023]), and incidents in the West (1.012 [1.000, 1.024]). No strata reported significant negative associations between maximum same-day temperature and fatal police shootings.

There are two primary explanations for why fatal police shootings may increase on warmer days. The first, known as the routine activity theory, posits that citizens or perpetrators of a crime may encounter police more frequently on warmer days, increasing the odds of a fatal police shooting occurring. The second, known as the temperature-aggression hypothesis, suggests that police may physiologically or behaviorally react to warmer temperatures, in turn changing their police behavior. We found that associations with temperature were higher in armed versus unarmed victims across nearly all subgroups. We believe this argues in favor of the temperature-aggression hypothesis, indicating that police officers are physiologically or behaviorally reacting to heat exposure. The proportion of armed victims in different subgroups may also help to explain the observed differences in stratified analyses (e.g. higher effects in older ages).

Regionally, the West and South both reported significant positive associations between maximum same-day temperature and fatal police shootings. The South and West have the highest regional violent crime rates, responsible for 41% and 26% of US violent crime respectively, both proportions modestly higher than the US populations that they represent.[53] Gun ownership rates are highest in the South, while the Northeast has the lowest rate of gun ownership.[54] One study demonstrated that police shooting rates are positively associated with household gun ownership, suggesting that regions with higher rates of gun ownership will experience more fatal police shootings.[41] It is possible that higher gun prevalence in a geographic region may put police more on edge during civilian interactions, reactions which could be exacerbated by heat. However, we were not able to directly test this hypothesis. Another possible contributing factor is natural temperature differences between regions.

Limitations

Our study has several limitations. The first limitation in our study design is the potential for exposure misclassification. The Washington Post does not capture incident time-of-day in its reporting, and the temperature of a police shooting that occurs at night will not be the same as a shooting that occurs during the middle of the day. Additionally, the majority of violent crime occurrences do not occur at the same time across age groups. Violent crimes peak between 3 p.m. and 4 p.m. for juvenile offenders, while violent crime peaks around 9 p.m. for adult offenders.[55] Therefore, using minimum same-day or previous day temperature may be a more appropriate metric for crimes committed at night by older offenders, while maximum same-day temperature may be a more appropriate metric for younger offenders who primarily commit crime during the day. Additionally, complex temperature phenomena such as the urban heat island effect may not be fully captured by Daymet, potentially biasing our temperature exposure data.[56]

A second source of exposure misclassification is the possibility that the date is incorrect for some incidents. To our knowledge, this has not been assessed in the Washington Post's dataset, for example by comparing records with official (yet less complete) homicide sources such as the Uniform Crime Reporting Program. One study found a 7% date mismatch rate between Fatal Encounters, another popular open-sourced police violence database, and official data released by the city of Dallas on officer-involved shootings.[35] Most date mismatches did not exceed one day. Since maximum same-day temperature is directly related to the incident day, date mismatching could bias our results.

Another limitation is that the Washington Post likely does not capture the entire sample of fatal police shooting incidents in the United States. We chose this data source due to The Washington Post's rigor, its use in other peer-reviewed literature, and the undercounting of national fatal police shootings in other official government sources. However, other data sources suggest that it may still miss some incidents. We do not expect that any missing data from the Washington Post dataset is biased in respect to temperature, and therefore do not expect our central estimates to be biased from undercounting. Additionally, the Washington Post dataset does not capture incidents in which police discharge their weapon but the shooting is not fatal. Approximately 45% of police shootings were non-fatal in the four states (Colorado, California, Florida, and Texas) that publicly report on injurious police shootings.[57] Survival rates varied by race, age, and armed status. Black victims were less likely to die from their gunshot wounds, as well as younger victims under 25, and victims who were unarmed. Other factors that determine whether a victim survives include proximity to a trauma care center, whether officers engage in "scoop and run" practices versus first aid, the number of rounds fired by an officer, and whether a bullet hit a vital organ.[11,58,59] Therefore, the population within our sample is not fully generalizable to the population in which police use force.

Future Research Directions

In addition to police shootings, future research could analyze the impacts of temperature on other forms of police killings such as physical restraints and Tasers. One previous study, Annan et al. (2020), similarly quantified the impact of temperature on police violence using a Poisson modeling approach.[31] The authors found a null association between temperature and fatal shootings when accounting for increased civilian-police interaction on warmer days (>17°C). However, they found a significant positive association between temperature and other forms of police killings including Tasers and physical restraints on extremely warm days (>32°C). Therefore, future research could use a case-crossover design to investigate the association between maximum same-day temperature and other forms of police killings, drawing on alternative open-sourced databases such as Fatal Encounters for data collection.

Another possible research direction is to consider the demographic information of involved officers. The Washington Post data only collects sociodemographic information on victims rather than on involved officers. Many factors determine whether an officer will discharge their weapon, and there is variability between agencies in firearms use.[11] For example, agencies that require officers to file a report if they point their gun at a civilian experience significantly lower rates of police shootings.[13] Individual sociodemographic factors also contribute, with male officers being more likely to discharge their firearms as well as younger officers.[12] Based on this literature, it is possible that sociodemographic variables related to the officer may influence the association between temperature and fatal police shootings. Since officers are responsible for discharging their weapon, these sociodemographic factors may be of more relevance than the victims. Additionally, individual officers in different regions or environments may be physiologically adapted to heat in different ways, also known as heat acclimatization, possibly influencing an officer's behavioral reaction to heat exposure. As our study only investigated temperature lags up to three days, future research could study the impacts of prolonged heat waves on police behavior.

Conclusion:

In conclusion, our analysis shows a positive, null association between maximum same-day temperature and fatal police shootings. However, when stratified on race, age group, armed status, season, and region, several subgroups report significant positive associations, suggesting a relationship between temperature and fatal police shootings. No strata reported significant negative associations. Additionally, nearly all stratified subgroups reported higher associations among armed victims in comparison to unarmed victims, indicating a preference for the temperature-aggression hypothesis rather than the routine activity theory. Aside from established factors that impact police behavior such as department policies, sociodemographic factors, and local crime rates, these findings demonstrate that environment and temperature may also play a role in policing behavior. As climate change accelerates, it will be important to better understand the association between short-term temperature fluctuations and police response for adaptation and policy purposes.

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