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Does heatwaves/above-average temperature increase interpersonal violent behavior? A scoping review

Daniela ACQUADRO MARAN[1], Gaia DIBIASE[2], Sofia FILIPPETTI[3], Riccardo SANDRETTO[4], Antonella VARETTO[5], Claudio Giovanni CORTESE[6], Elisabetta CARRARO[7]

Affiliations:
[1]*Department of Psychology, Università di Torino, Torino, Italy. E-mail: daniela.acquadro@unito.it* ***ORCID****: 0000-0002-9924-4093*
[2]*Città della Salute e della Scienza, Torino, Italy E-mail: gaia.dibiase@edu.unito.it* ***ORCID****: 0009-0009-8737-9378*
[3]*Department of Public Health and Pediatrics, Università di Torino, Torino, Italy. E-mail: sofia.filippetti@unito.it* ***ORCID****: 0000-0003-3676-9885*
[4]*Department of Psychology, Università di Torino, Torino, Italy. E-mail: riccardo.sandretto@unimi.it* ***ORCID****: 0000-0003-0200-5895*
[5]*Città della Salute e della Scienza, Torino, Italy. E-mail: avaretto@cittadellasalute.to.it* ***ORCID****: 0000-0003-3002-8533*
[6]*Department of Psychology, Università di Torino, Torino, Italy. E-mail: claudio.cortese@unito.it* ***ORCID****: 0000-0003-2339-9838*
[7]*Department of Public Health and Pediatrics, Università di Torino, Torino, Italy. E-mail: elisabetta.carraro@unito.it* ***ORCID****: 0000-0002-9811-6372*

Corresponding Author:
Claudio Giovanni Cortese, Department of Psychology, Università di Torino, Via Verdi 10, 10124 Torino (I); email: claudio.cortese@unito.it

Abstract

Introduction: This scoping review aimed to analyze the literature on the relationship between heatwaves or above-average temperature and interpersonal violence. Because of the nature of third-party violent behavior and our focus on the most direct effects of abnormal temperature on it, we excluded self-directed and collective violence, such as social conflicts.

Methods: This review was conducted in accordance with the JBI methods outlined for scoping reviews and in line with the Preferred Reporting Items for Systematic Reviews (PRISMA-ScR). The publication period under consideration was 2012-2024 and was conducted on Scopus, PubMed, Web of Science, and PsycINFO databases.

Results: Of the original number of 5,146 studies, 15 were included in the scoping review. Works including historical and longitudinal data were considered. Overall, the results of the studies included in the review highlighted a relationship between heatwaves and above-average temperature and interpersonal violence, and highest temperatures are presented as a predictor of interpersonal violence.

Discussion: The literature analysis underlines how climate change may affect people's well-being, mental health, and behavior. However, it is essential to point out that most authors acknowledge their study's limitations and that the results should be cautiously viewed. Future research is needed to better understand the relationship between heatwaves or above-average temperature and human health. Policymakers should implement programs to prevent violent behavior in terms of increased temperature adaptation and mitigation (e.g., promoting green spaces and reducing pollution) and at the level of individual city institutions, which can monitor the phenomenon and take action, such as increasing the presence of security personnel in anticipation of periods of highest temperatures.

Take-home message: This scoping review shows a link between heatwaves/above-average temperature and interpersonal violence, with highest temperatures presented as a predictor of interpersonal violence. Further research should show how heatwaves and above-average temperature may affect people's well-being, mental health, and behavior.

Key words: interpersonal violence; high temperature; violent behavior.

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INTRODUCTION

The rise in temperature is currently at the center of scientific debate as the scientific community is increasingly concerned about its short and long-term consequences. The European Environment Agency (EEA) [1] reports a 1.13-1.17 °C increase in global surface temperature between 2013 and 2022. In this decade, many studies have looked at the consequences of increased temperatures on human health. According to the World Health Organization (WHO) [2], increased temperatures is responsible for deaths and diseases caused by extreme weather events, the increase in zoonoses, vector-borne diseases and malnutrition. In addition, several studies report a relationship between increased temperature and mental health, as well as aggravation in patients already suffering from mental disorders [3-5].

Temperature is a key variable to be studied in the context of human behavior for two reasons:
1. According to several studies conducted in the mid-20th century, temperature is an interesting environmental variable that correlates with human behavior. In particular, several studies have investigated the relationship between temperature and aggressive and violent behavior [6-9].
2. Temperature is one of the most reliable markers for monitoring climate change (EEA) [1]. For this reason, in recent decades, more and more data on temperature trends and deviations from seasonal averages have become available.

As temperatures are estimated to be increasing compared to seasonal and annual averages [10], studying the relationship between temperature increase above average and violent behavior is crucial for a deeper understanding of the impact of this phenomenon on human health [2].
The aim of this paper is to analyze the literature examining the effects of heatwaves and above-average temperatures on interpersonal violence.

Definition of violence and violent behavior

Violence is defined by the World Health Organization [11] as "the intentional, threatened or actual use of physical force or power against oneself, another person, or a group or community that either results in, or is reasonably likely to result in, injury, death, psychological harm, maldevelopment, or deprivation." This definition emphasizes that a person or group must have the intention to use force or power against another person or group for an act to be considered violent. Violence is thus distinguished from injuries or damage caused by unintentional actions and incidents (e.g. traffic accidents, work accidents). This definition also draws attention to the use of threatened or actual power that can be directed against oneself (self-directed violence), against another person (interpersonal violence), or against a group or community (collective violence).

As described by Rutherford et al. [12] (see also [13]), self-directed violence is a broad term that includes suicidal thoughts or actions and forms of self-harm. The term "fatal suicidal behavior" is often used to refer to suicidal acts that result in death. "Nonfatal suicidal behavior," "suicide attempt," "parasuicide," and "self-harm" or "self-injury" refer to suicidal behavior that does not result in death. The term "suicidal ideation" is used clinically to describe the intention to intentionally

end one's life. At the same time, "self-mutilation" refers to the direct and deliberate destruction or alteration of body parts without conscious suicidal intent.

Interpersonal violence includes acts of violence and intimidation that occur between family members, life partners, or individuals, whether they know each other or not, and where the violence is not specifically aimed at promoting the interests of a particular group or cause. This category includes domestic violence, child abuse, youth violence, gender-based violence, some forms of sexual violence and elder abuse [14].

Collective violence is described as the instrumental use of violence by people who identify themselves as members of a group against another group or group of people to achieve political, economic or social goals. Collective violence includes war, terrorism, violent political conflicts between or within states, violence perpetrated by states (genocide, torture, systematic human rights violations) and organized violent crime such as gang warfare. It can include all categories of violence, whether physical, sexual, psychological or characterized by neglect or discrimination [15].

Relationship between temperature and violence

Previous studies show some correlations between high temperatures and increased levels of aggression or violence in its various forms [16]. Highest temperatures in some studies have been associated with earlier manifestations or mediators of violence as episodes of mania in the elderly [3], episodic mood disorders, and an increase in hospital admissions for mental illness. When the temperature rises above the threshold of 20 degrees, there is an increase in substance abuse-related mental disorders [17]. There has also been an increase in hospital emergency room admissions for behavioral disorders, neurotic disorders, schizophrenia, and schizotypal disorders [3,5]. In addition, studies show that environmental variables such as temperature and humidity are correlated with an increase in conflict, crime, self-harm, and suicide [6]. Psychologists and sociologists have long studied the relationship between heat (understood as an uncomfortably hot temperature) and aggression [18], for example, by examining how particularly high temperatures can influence people's thoughts, slightly aggressive perceptions, feelings, and behaviors [19]. Zetter et al. [20] suggest that the relationship between temperature, aggression, and violence is linked to increased irritability.

This increase in irritability, even if subtle, can increase aggressive behavior by triggering violent thoughts and false attributions of feelings. In an irritable state, even trivial provocations can trigger overly aggressive responses, which in turn can escalate the cycle of violence [6,21] Some studies have shown that the mere thought of heat causes an increase in thoughts, feelings, and aggressive behavior. In a study by Wilkowski et al. [22], participants were exposed to images of heat and temperature: the authors indicated that people exposed to heat images were more likely to categorize neutral facial expressions as aggressive and were more likely to think aggressively. There are several theoretical explanations for the connection between heat and aggression. Physiological explanations are that warm temperatures activate the part of the brain that is responsible for both thermoregulation and emotion regulation. In addition, more adrenaline is released when it is hot, which could lead to more aggressive behavior in some situations, for example after a provocation [7,23].

Some psychological theories attempt to explain this relationship. These theories are called theories of embodied cognition. They assume that environmental stimuli influence the way we think. In the case of the relationship between heat and aggression, higher temperatures produce discomfort, which increases hostile perceptions of others and, consequently, aggression [23,24]. The temperature-aggression hypothesis is one of the most influential theories about the relationship between temperature and aggression/violence. This hypothesis falls within the broader theoretical framework of the "General Aggressive Model," which examines the effects of social, individual, and environmental factors on aggression. Temperature is one of the main factors influencing the potential for aggressive behaviour [25]. Another explanation is the routine activity theory [26,27]. Routine activities likely differ between hot and cold temperatures, e.g., people who do not have working air conditioning spend more time outdoors and consume more substances, such as alcohol, which could

influence the likelihood of aggressive behavior (this theory explains, for example, the increase in violent crime on weekends).

However, some mitigating factors exist when discussing high temperature and aggression. Van Lange et al. [28] have developed the CLASH model, namely Climate, Aggression, and Self-control in Humans. This model highlights that cultures in regions with colder climates (especially those with multiple seasons) adopt slow living strategies and favor planning and self-control, discouraging violent behavior. When variables such as income inequality and wealth are also considered, this model helps to understand how cultural values and norms mitigate aggressive and violent behavior.

Overall, the phenomenon must also be considered in terms of its impact on the future. We refer to the indirect effect by which global warming increases violence: the likelihood of a child becoming a violent adult is increased by increasing temperature [6]. The risk factors that can lead to a child becoming a violent adult are exacerbated by high temperature and the environmental disasters it causes. Some of these factors could be amplified in poverty, inadequate prenatal and childhood nutrition, dysfunctional and disadvantaged families, neighborhood violence, war and conflict, low education, and poor living conditions [29,30]. Environmental disasters thus increase the proportion of children exposed to several known risk factors for violence in adulthood. The third indirect effect by which high temperature increases violence relates to potential conflicts between groups due to competition for resources [19].

The current study

As described below, a significant positive correlation was found between high temperature and violence. Mares and Moffett's [31] and Mahendran et al.'s findings [32] confirm the results of several studies showing a broadly positive relationship between temperature and interpersonal violence. They show that an average annual increase of one degree Celsius is associated with an average rise in national homicide rates of 5.9. As Algahtany et al. [33] note, while many studies have found a significant relationship, the nature of this relationship is controversial.

Thus, this article aims to analyze the literature investigating the effect of heatwaves and above-average temperature on interpersonal violence. Heatwaves are defined by the World Meteorological Organization as a period where local excess heat accumulates over a sequence of unusually hot days and nights (https://wmo.int/topics/heatwave) [34]. Above-average temperatures are defined as temperatures that are measured in standard deviations above the mean value [35]. In this study, we chose heatwave and above-average temperatures to focus on the temperature increase that correlates (or not) with interpersonal violent behavior. More specifically, our goal is to analyze the above-average temperature component that may lead to an increase in interpersonal violent behavior. The choice between interpersonal violence and self-directed and collective violence lies in the violent behavior itself. In terms of self-directed violence, for example, there has been an increase in suicidal behavior and self-directed injuries during the COVID period [36,37]. This suggests that the data on the relation between higher temperature and self-directed violent behavior may be influenced by other variables, such as forced confinement and lack of socialization [38], fear for one's health [39], and experience of the death of loved ones [40]. As for collective violent behavior, it could be caused by socio-political conditions that are deeply rooted and probably only indirectly justified by heatwaves and higher temperature than average, such as geopolitical conditions, the escalation of decades-long conflicts, changes in the political order, etc. [41].

For this reason, the focus of this work is on interpersonal behaviors, i.e., the intentional use of physical force or power, threatened or actual, against another person that either results in or has a high likelihood of resulting in abuse, injury, death, psychological harm, harassment, maldevelopment, or deprivation [42]. This definition emphasizes that a person must intend to use force or power against another person for the act to be classified as violence. Only studies that analyze interpersonal violence in relation to heatwaves and above-average temperature were considered. These studies analyze data over a long period and focus on the impact on the interpersonal violence of heatwaves and temperature increase from the average.

We decided to use temperature over other consequences related to other meteorological conditions (such as amount of precipitation, floods and hurricanes) because for this parameter data are available for long periods of time, with daily, weekly or monthly detection frequency. This allows comparisons to be made by detecting anomalies, such as deviations from the period average [43,28].

METHODS

Search strategy

This scoping review was conducted in accordance with the JBI methods outlined for scoping reviews and in line with the Preferred Reporting Items for Systematic Reviews (PRISMA-ScR) [44]. Searches were conducted in June 2024 to provide insight into the effects of climate change on aggressive behavior on the following databases: Scopus, PubMed, Web of Science, and PsycInfo. Based on our research questions, we searched for explicit reference to violent or aggressive behavior and temperature increase, developing the following search string with Boolean operators: (violen* OR aggressiv* OR crim* OR injur* OR abus*) AND ((temperatur* OR (high* AND temperatur*) OR (risin* AND temperatur*) OR (temperatur* AND warm*) OR (heat wave*) OR heatwave*)).

In any case, several preliminary restrictions were applied: language (only papers written in English), publication type (only journal research articles), publication date (only papers published after January 2012), and full-text availability. The review covered articles published from 2012 to 2024. It was decided to start from 2012 because from this year onward there has been a more rapid increase in temperature compared to the previous period for which temperature data is available (1998-2011) [45].

2012 was also the year of the COP18, the 18th United Nations Framework Convention on Climate Change, held in Doha, Qatar in which an agreement was reached to extend the life of the Kyoto Protocol. We collected 2,407 articles from PubMed, 1,232 articles from Web of Science, 122 from PsycInfo, and 2,430 from Scopus, for a total of 6,191 articles. Five reviewers (DAM, SF, GD, RS and EC) used Rayyan's intelligent systematic review to select articles. Rayyan is a web and mobile app for systematic reviews. Rayyan has been shown to be effective in conducting a systematic review and has significant potential to reduce the burden on reviewers [46]. The articles filtered from the four main databases were entered into the Rayyan application.

Inclusion and exclusion criteria

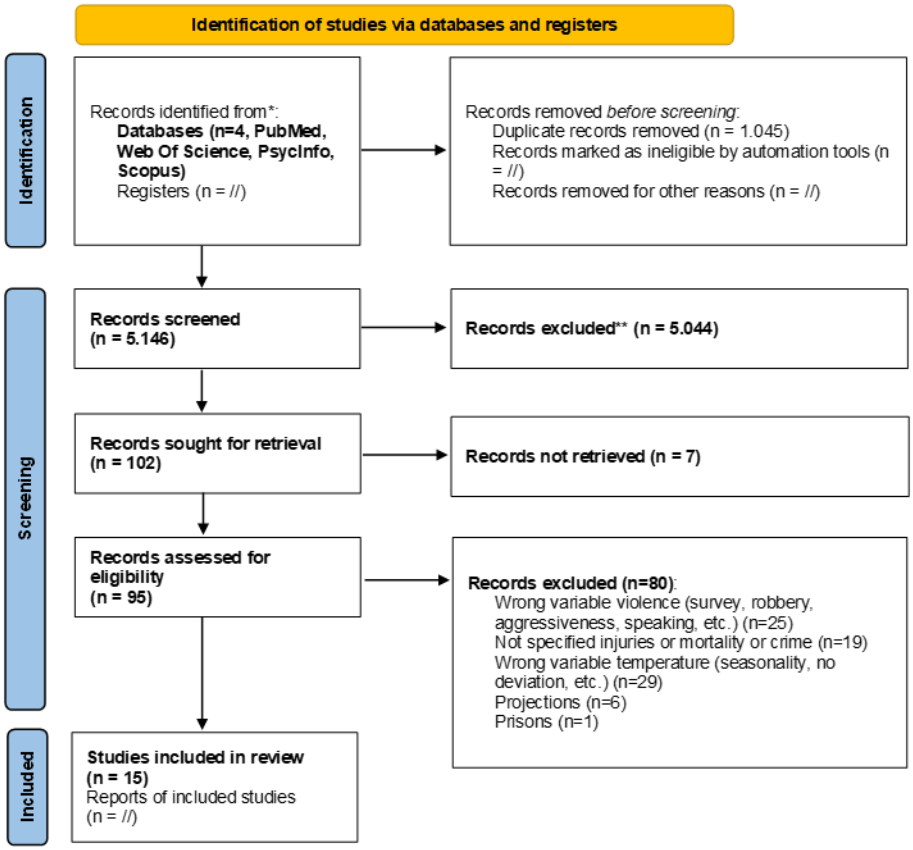
After 1,045 duplicates were removed, an initial screening was performed based on reading title and abstracts of the articles. Inclusion criteria: research article that explicitly referred to heatwaves or higher temperature than average and interpersonal violent behavior. Exclusion criteria: not research article (e.g., commentary) referred to different research topic (e.g., health problem), referred only to meteorological data unrelated to temperature (e.g., humidity), that it referred only to seasonal temperature differences (e.g., different homicide rated in winter and summer), and dealt with conflicts (e.g., mass shooting) and unintentional violence (e.g., injuries due to traffic accident or work-related accident). Other types of violence that are not related to the person but only to the property were not considered (e.g., robbery alone), as possible violent behaviour is considered a side effect of the main behaviour (e.g., attempted theft).

In addition, research articles in which injuries and violence were not described in detail were excluded: e.g. research in which injuries included different types of sources, such as road traffic and work, and in which it was not possible to identify the individual group of events (e.g. rape and robbery were considered 'crimes' without specific data). Research articles on violence that did not indicate whether it was murder or suicide were also excluded. In addition, as suggested by Hwong et al. [47], we excluded articles that met the following criteria: no collection and analysis of primary or secondary data; policy briefs, systematic reviews, or reviews without a substantial focus on data analysis (although these were used for background information).

After this first screening, the number of articles searched was reduced to 102. A second screening was then carried out, which included a full-text reading of the articles. In this second screening other exclusion criteria were added: e.g. temperature and violence variables out of interest. The final

number of studies included in this review was reduced to 15. Figure 1 shows the PRISMA flow diagram.

Figure 1. PRISMA flow diagram of study identification and selection.



Data analysis and study quality assessment

After selecting the studies, the necessary information was extracted into a form that summarized the included studies. The extracted data included: (i) source (first author and year of publication); (ii) setting (period and specific area considered) and main aim; (iii) main results; (iv) statistical methodology, temperature parameters and source of data; (v) other variables; (vi) positive relationship between temperature parameters and violent outcomes and (vii) description of the phenomenon in terms of heat and/or above-average temperature. To guide the development of the quality assessment criteria for this review, the authors used criteria suggested by other authors [48-50].

The criteria used included aspects of measurement and analysis. Further details can be found in Appendix A. Two authors (D.A.M., S.F.) independently assessed the quality of each relevant article. Overall, the assessment of the studies shows that the quality of all studies included in the scoping review was high.

RESULTS

Table 1 shows the main characteristics of the studies included.

Table 1. The main characteristics of the studies included in this review.

Study	Country, period of analysis and main aim	Main results	Statistical methodology, temperature parameters and source of data	Other variables	Positive relationship between temperature parameters and violent outcomes:	Heat/ AAT
Mares, 2013 [51]	USA – St. Louis (1990-2009) Study the link between climate change and neighborhood levels of violence in St Louis population.	- When a typical month is a single degree Fahrenheit warmer than the expected seasonal temperature, violence in St. Louis rises on average by 0.739 %. This citywide average appears to be associate to the disadvantage levels from the less socially disadvantaged neighborhood groups to the most (group 30 0.659, group 40 0.728, and group 5 01.070). - The most disadvantaged individuals typically experience an average 1% monthly increase in violent crimes for each degree increase in anomalous temperatures. - The least disadvantaged neighborhoods in the study display no significant correlation between violence and temperature anomalies.	Time-series analysis Regression models. Dependent variable: sum of reported aggravated assaults, rapes, homicides and so on occurring per month. Independent variable: monthly temperature anomalies, created by subtracting the monthly values of the long-term (30 years) mean from the actual monthly temperature Source of data: law enforcement agency (V); NOAA's National Climate Data Center (T); Census and Bureau of Labor Statistics (CV)	Control variables: census tracts (including poverty level, percent vacant homes, proportion of young Black males, female-headed households, high school dropouts, unemployment levels, and proportion of rental units); Monthly number of days, population number control, Consumer Price Index, seasonal temperature	YES	H/AAT
Williams et al., 2015 [52]	New Zealand (1994-2009) Investigation of the relationship between geographical, seasonal, and irregular variation in temperature and the incidence assault	- Geographical, seasonal, and irregular daily variation in temperature were all positively related to the incidence of assault, although only the effect of irregular variation in temperature was robust to controls for plausible confounds. - The estimated effect of irregular daily variation in temperature and recorded assaults was around 1.5 % more assaults for every 1 °C increase in temperature. - The estimated effect of irregular daily variation in temperature and assaults resulting in hospitalisation was about 1.7 % extra assaults for every 1 °C increase in temperature.	Generalised linear mixed model (GLMM) Predictor variable: the mean temperature on each of the 365 days of the calendar year as averaged across the entire study period within each region (i.e., the seasonal norm temperature). Response variable: the summed number of	Annual population estimates; deprivation index; seasonal temperature; relative humidity anomaly (%)	YES	AAT

			assaults occurring in a region across each of the 15 occurrences of each day of the calendar year over the study period. Source of data: law enforcement agency (V); public hospital admissions (V); Statistics New Zealand and University of Otago (OV); National Institute of Water and Atmospheric Research (T)			
Lemon et al., 2017 [53]	UK Dorset (2014-2016) Understanding the effects of climatic condition of assaults resulting in admission to emergency department	An increase of 1% in the assault rate for every degree increase in the maximum daily temperature (IRR = 1.01, P-value = 0.033). Analyzing the standard deviation from the mean temperature, the IRR relationship changes, initially increasing and then plateauing at unusually high temperatures (±1.5 SD above the mean).	Multivariable regression model (negative binomial model) Variables: Temperature deviation (distance from the average of maximum temperature range expressed in factors of standard deviation); Incident risk ratio. Daily data on admissions to emergency departments (ED) for assault injuries. Source of data: Clinical Commissioning Group (V); Hospitals (V); weather local Stations from UK meteorological office integrated data archive system (T)	Day of the week, alcohol consumed by the victim (self-report)	YES	AAT
Schinasi and Hamra, 2017 [54]	USA Philadelphia (2006–2015) The aim was to investigate the association between daily temperature and daily crime rates in Philadelphia, PA.	There is a linear relationship between the heat index deviation value and the rate of violent crime. The rate of violent crimes was 5% higher for days on which the mean daily heat index was 13° higher than the seasonal mean (95% CI 3%, 8%). On days that were 13 °C higher than the seasonal mean daily heat index, the rate of disorderly conduct crimes was 7% higher (95% CI−1%, 15%) relative to days on which the heat index was the same as the average for that season and year.	Generalized additive model with a quasi-Poisson distribution Variable: Heat index deviations from the yearly seasonal mean heat index value. Heat index (combination of hourly temperature and dew point calculated by a weather metrics package); daily counts for each category of crime (homicide, rape, aggravated assault, other sex	Day of the week, holidays, seasonality.	YES	H

			offenses, offenses against family and children, and so on). Source of data: law enforcement agency (V); National Centers for Environmental Information (T)			
Basu et al., 2018 [55]	USA -California (2005-2013) Study of the association between apparent temperature and emergency room (ER) visits for violent outcomes related to mental health	Heat-wave exposure was associated with increase in the risk for inflicted injury/homicide During the warm season, a 10°F (5.6°C) increase in mean apparent temperature was associated with a 7.9% (95% CI: 7.3, 8.4) increase in risk of inflicted injury/homicide. During the cold season, a mean apparent temperature increase of 10°F (5.6°C) was associated with a 10.6% (95%CI: 9.8, 11.4) increase in risk of inflicted injury/homicide visits.	2-stage time-series method with Poisson regression Variables: apparent temperature lags of 0–30 days for mean, maximum, and minimum apparent temperature; heatwaves (defined as 2 or more consecutive days of apparent temperature above the 95th percentile for each climate zone); ER visits, adjusting for holidays, day of the week, and seasonal/long-term trends. Source of data: National Office of Statewide Health Planning and Development (V); Environmental Protection Agency through the Air Quality System Data Mart (T), the National Irrigation Management Information System (T); the National Oceanic and Atmospheric Administration (T); Census population count (OV)	Day of the week, holiday, race/ethnicity, age group, sex, region (costal and non-costal). Overall mental health, and neurotic outcomes.	YES	H/AAT

Harp and Karnauskas, 2018 [56]	USA (North-east, Southeast, South Central, West, Midwest) (1979-2016) Examination of the observed covariability between interannual climate variability and the human response—criminal activity—over recent decades, garnering insight into the likely mechanisms	Across all five of the defined U.S. regions violent crime demonstrates a near universally positive monthly relationship with temperature anomalies. Results indicate large and statistically significant positive correlations between the interannual variability of wintertime air temperature and violent crime rates with negligible correlations emerging from summertime data.	Pearson correlation coefficient Variables: aggregated crime (murder, forcible rape, aggravated assault). and the local temperature **(**monthly temperature anomalies) Source of data: law enforcement agency (V); North American Regional Reanalysis (T)	Regional differences	YES	H/AAT
Chambru 2020 [57]	Francia, Savoy (1749-1792) Evaluation of the weather shocks on the increase of interpersonal conflicts	Results indicate that temperature shocks had a positive and significant effect on property crime rates and a negative impact on violent crime rates.	Correlation analysis Variables: the dependent variable is the log of total number of crimes (homicide, assault, insults and threats) per 100,000 Inhabitants; the independent variable Temperature is the seasonal temperature deviation from the long-term seasonal mean (1500–1600) Source of data: judicial archives (V); European Seasonal Temperature and Precipitation Reconstruction database (T); previous investigation (OV)	Drought, floods, migration data, prices data	NO	H
Henke and Hsu, 2020 [58]	USA (263 counties) (2006-2011) Analysis of theories supporting the role of local temperature variation and gender wage ratios at the county level on intimate partner violence (IPV)	If the maximum temperature increases by 1 °C (1.8 °F), reports of women being assaulted by their intimate partners increase by a factor of 1.008, or roughly 0.01 additional assaults per °C per county per day. Temperature deviation is associated with intimate partner violence (IPV) increase (Incidence rate ratio IRR = 1.023 ± 0.002 significative). Moreover, significant IRR (0.983±0.003) of the interaction term between temperature deviation and gender wage ratio was found supporting the hypothesis that an increase in the	Negative binomial regression Variables: the dependent variable is the daily count of simple and aggravated assaults (physical assault with grievous bodily harm or a lethal weapon) against female intimate partners. The independent variable is the temperature. Temperature	day-of-week, year, month, county, female race, male race, unemployment rate, income per capita, holiday , female population, female race-specific linear time trends, male race-specific linear time trends.	YES	H

		woman's relative wage protects her from violence resulted from weather shocks.	deviation (difference between the maximum temperature and the average of mean temperatures for the past week). Source of data: National Incident-Based Reporting System (V); Global Summary of the Day by the National Climatic Data Center at the National Oceanic and Atmospheric Administration (T); North America Land Data Assimilation System (T); Bureau of Economic Analysis (OV); Bureau of Labor Statistics (OV)			
Reeping and Hemenway, 2020 [59]	USA, (Chicago) (2012-2016) The aim was to measure the association between weather and the number of shootings in Chicago	The average high daily temperature was 15.3 °C, approximately a third degree warmer than historical readings. Difference in temperature from historical average, after adjusting for precipitation type, shown that every 10-degree higher temperature from the historical average, there were 33.8% more shootings [95%CI (29.1, 39.7)]. Warmer temperatures and a change in temperature from the historical average were both significantly associated with an increase in shootings in Chicago from 2012 to 2016.	Generalised linear model with negative binomial distribution; Generalized estimating equations Variables: daily temperature anomalies (difference between the maximum temperature and historical maximum average temperature 1930-2020); daily number of shooting victims. Source of data: Chicago Tribune website (V); Weather History (T); Chicago Public Schools yearly calendar (OV)	Weekend, holidays, other non-school days	YES	H/AAT

Xu et al., 2020 [60]	USA (Chicago, New York) (2007-2017) The aim was to evaluate the association between daily ambient temperature and intentional homicide	During the study period, 8.7% (95%CI: 4.3–12.7%) and 7.1% (95% CI: 1.4–12.0%) intentional homicide cases could be attributed to temperatures above city-specific median temperatures, in Chicago and New York, respectively.	Conditional logistic regression with distributed lag models Variables: daily temperature anomalies: temperatures above the city-specific median temperature during the study period in Chicago and New York. The dependent variable is a binary variable indicating the presence or not of cases (intentional homicide). Source of data: Crime Open Database (V); national meteorological Dataset (T); US Census Bureau (OV); the rank of state gun law (OV)The independent variable was the temperature.	Demographic (age, proportion of males, ethnic composition) and socioeconomic indicators (poverty rate, median household income, Gini index of income inequality, unemployment rate, educational attainment), gun.	YES	H/AAT
Corcoran and Zahnow 2021 [61]	Australia Brisbane (2010-2012) The aim was to examines the role of local weather conditions in explaining variations in assault	Higher daily mean temperatures are associated with an increased propensity for assault at the block group after controlling for the effects of season. Extreme temperature conditions were not a significant predictor of assault in the location examined (Brisbane) because it is warm year-round.	Negative binomial multilevel regression model Variables: the dependent variable is the dichotomous measure capturing the presence of assaults in neighborhood block groups. The independent variable captures weather, calendar events, land use, socioeconomic, and demographic neighborhood characteristics. Extreme temperature: dichotomous (days of the year greater than one standard deviation above or below the expected monthly temperature) Source of data: National Police Service crime data (V); Australian Bureau of Meteorology (T); Queensland	calendar events, land use, socioeconomic, demographic neighborhood characteristics	NO	H/AAT

			Valuation and Sales and Digital Cadastral DataBase (OV); Australian Bureau of Statistics (OV).			
Potgieter et al., 2022 [62]	South Africa, Khayelitsha (Cape Town) (2006-2016) The aim was to investigate the association between three weather parameters (temperature, relative humidity and rainfall) and three categories of crime	The risk of violent crime was found to increase with a rise in daily average temperatures, peaking at 30℃ (RR = 1.65; 95% CI = 1.13–2.42).	Distributed lag nonlinear Modelling Variables: daily temperature (percentile distribution of temperature); all crime, violent crime (assault, murder, attempted murder), sexual crime (rape, abduction and sexual assault). Source of data: law enforcement data (V); South African Weather Service (T)	/	YES	AAT
Thomas and Wolff, 2023 [63]	USA 28 cities (2015-2021) The aim was to explore the effects of temperature volatility (daily deviations - both upward and downward - from a 30-day moving average) on the incidence of violent crimes.	Significant positive association between upward departures in temperature and homicide, in which an unusually warm day is associated with an approximately 19.4% increase in homicides (Incidence rate ratio =1.194). Significant positive association between upward departures in temperature and assaults, in which an unusually warm day is associated with a 9.4% increase in assaults (IRR = 1.094).	Multivariable two-way fixed-effects negative binomial panel regression models Variables: dependent variable: daily counts of aggravated assault and homicide incidents were obtained from each city's police department. Independent variable: sudden upward and downward temperature anomalies. Source of data: National Incident-Based Reporting System (V); Visual Crossing Weather global database (from data of the National Oceanic and Atmospheric Administration's National Centers for Environmental Information) (T)	Other meteorological measures (humidity, precipitation, wind speed, percent cloud cover), holiday, day of week, dates after March 15, 2020 (because of changes in routine activities after the onset of the COVID-19 pandemic).	YES	H/AAT

Hu et al. 2024 [64]	USA- (Austin, San Francisco, Los Angeles, Memphis, New York City, Tucson, Seattle, Chicago (2007-2020) Evaluation of the correlation between temperature and crime taking in consideration the long-term trends and seasonal cycles.	Temperature residuals have a positive correlation with assault residual in all cities	Times series decomposition; box plot analysis; correlation analysis; linear regression Variables: mean and standard deviation for each type of crime (assault, dangerous acts, sexual violence); Temperature deviation: temperature residuals (difference between observed and estimated temperature); daily temperature . Source of data: Crime Open Database (V); global weather database (T).	/	YES	H/AAT
Stevens et al., 2024 [65]	Australia Greater Sydney Nation (2013-2018) Evaluation of the relationship between the number of daily violent crimes (inside or outside) and the average surface UHI (Urban Heat Island)	Surface UHI was positively associated with violent crimes that occurred outside ($p = 0.006$), with higher surface UHI having more impact on assault rates in winter versus summer ($p = 0.002$). No significant association was found between surface UHI and violent crime committed inside ($p = 0.072$).	Panelized negative binomial time series generalized additive models (GAMs); correlation analysis. Variables: daily frequency of assault (domestic assault, non-domestic assault, assault against police, sexual assault and murder), average maximum temperature, decile and percentage of grass, shrub and tree cover and all vegetation. Surface urban heat island (UHI): calculated by subtracting an estimate of nonurban baseline temperature from land surface temperature observations; average daily maximum temperature Source of data: Department of Justice, Bureau of Crime Statistics and Research (V); Australian Water Availability Project (T); Land surface temperature and urban heat island estimates for Australian urban centres (T); GSR urban vegetation	Seasonality, socio-economic disadvantage and household (such as income, unemployment, home ownership, disability and education), measures of green space	YES	H/AAT

			Cover (OV); Australian Bureau of Statistics (OV)			

Note: Heath = study in which the author/s use terms such as heatwaves, heat stress, unusual heat; AAT = study Heath = study in which the author/s use terms such as above average temperature, average maximum temperature, higher average temperatures.

Most of the included studies investigated the relationship between heat-waved and/or above-average temperature and violent behavior in the United States of America: 9 of 15, or 60% [51,54-56, 58-60,63,64]. The others focused in different World region: Australia [61,65], UK [53], France [57], New Zealand [52] and South Africa [62].

Regarding the periods considered, the average duration is 12.6 years, with a range spanning from two to 43 years: five studies (25% of the total) analyzed data collected over five years or less [53,58,59,61,65]; five studies (33.3%) considered observations between six to ten years [54,55,60,62,63]; three studies (16.7%) focused on periods with a range of 13-20 years [51,52,64] and two studies examined data collected over 30 years [56,57]. More in details, three studies evaluated the relationship between heatwaves/above-average temperature and violence by analysing data from late 1900s to early 2000s [51,52,56], nine publications assessed data from the period early 2000s-late 2010s [53-55,58-62,65], while only one paper examined historical data from 1700 [57] and only two included data until 2020-2021 [63,64].

It is interesting to note that most of the included studies describe the phenomenon in terms of heat (e.g. "hotter extreme heat events" [65]) and above-average temperatures (e.g. "average maximum temperature" [65]) [51,55,56,59-61,63-65], three studies describe the phenomenon in terms of heat [54,57,58] and three in terms of above-average temperatures [52,53,62].

Antecedents

The source of the data on heat waves and above-average temperatures was taken from national meteorological datasets [52,54,55,58,60-63,65]. Henke and Hau [58] and Corcoran and Zahnow [61] combined national and regional statistical data. Regional data were considered by Harp and Karnauskas [56], while Lemon et al. [53] considered data from local station. Chambru [57] used data from a European Database.

The main meteorological antecedents of the studies considered are temperature anomalies or differences between temperature measurements and their seasonal averages in a given period. For example, Williams et al. [52] describe that the irregular daily temperature fluctuations were recorded by calculating the difference between the temperature observed in a region on a particular day and the normal seasonal mean temperature.

Temperature measurements are reported as daily averages in ten of the reviewed studies (66.7%) [52-55,59,60,62-65], as monthly averages in three studies (20%) [51,56,61], as week averages in one study (6.7%) [58] and annual average in one study (6.7%) [57]. In the studies by Mares [51], Williams et al. [52], Lemon et al. [53], and Stevens et al. [65] also the season was taken into account. Williams et al. [49] considered also the relative humidity, while in the study by Thomas and Wollf [63] other meteorological conditions were also included (humidity, precipitation, wind speed, percent cloud cover). Schinasi and Hamra [54] considered the heath index deviations, which is a metric that combines temperature and dew point, developed to represent thermal comfort [54]. In the study by Stevens et al. [65], the urban heat island (UHI) effect—additional heat in built-up environments from hard surfaces that absorb, store, and radiate heat—as well as grass, shrub, and tree cover, were also considered.

Outcomes

The source of the data on violence varies in the different studies. Six studies (40%) considered police or law enforcement data [51,52,54,57,61,62]. Lemon et al. [53] considered only the hospital admission, while Williams et al. [52] considered also hospital admissions. Six studies (40%) considered data from national database for crime or health service [55, 58, 60, 63-65,], one judicial archive [57] and one journal news [59]. The acts of violence addressed are: homicide [51,54-57,60,62,63,65]; assaults [51-54,56-58,61-65]; rape [51,54,56,62]; assault or intentional injuries [55]; sexual assault or offence [54,62,64,65]; domestic violence [54,58,65]; shootings [59].

Summary of findings

The studies find a significant correlation between heatwaves and/or above-average temperatures and an increase in violent behavior, with the sole exception of Chambru [54] and

Corcoran and Zahnow [61]. The study by Chambru [57], which considers historical data from the XVIII Century in Savoy (France), showed that temperature deviation seems to have a negative and significant effect on violent crimes; while Corcoran and Zahnow [61] pointed out that extreme temperature conditions are not a significant predictor of assault in the examined location because it is warm year-round.

The main results of the studies examined are shown in Table 1. All studies included in the present review except two [62,64] analysed the effect of heatwaves/above-average temperature and violence considering also other variables, like demographic and socioeconomic variables, holidays and day-of-week, etc. It is important to take these aspects into account because of the complexity and multifactorial relationship between temperature and violence. In USA, Mares [51] found that violence increases on average by 0.739 when a typical month is a single degree Fahrenheit warmer than the expected seasonal temperature. This citywide average appears to be related to levels of deprivation, from the least deprived to the most deprived neighborhoods. In addition, the most deprived experience an average monthly increase in violent crime of 1 per degree of abnormal temperature. Henke and Hsu [58] found that when the maximum temperature increases by 1 °C (1.8 °F), reports of assaults on women by their intimate partners increase by a factor of 1.008.

Schinasi and Hamra [54] found a linear relationship between the deviation of the heat index and the rate of violent crime: the rate of violent crime was 5% higher on days when the mean daily heat index was 13°C above the seasonal mean. Interestingly, on days when the mean daily heat index was 13°C above the seasonal mean, the rate of behavioural crimes was 7% higher than on days when the heat index was equal to the average for that season and that year.

In the time series analysis conducted by Basu et al. [55], the authors found that exposure to heat waves was associated with an increased risk of inflicted injury/homicide. Specifically, during the warm season, a 10°F (5.6°C) increase in mean apparent temperature was associated with a 7.9% increased risk of assault/homicide. During the cold season, a 10°F (5.6°C) increase in mean apparent temperature was associated with a 10.6%increased risk of assault/homicide. The results of the study by Harp and Karnauskas [56] show a significant positive correlation between the interannual variability of air temperature in winter and the violent crime rate, while the correlations with the summer data are negligible. The results of the study by Reeping and Hemenway [59] show that both warmer temperatures and a change in temperature compared to the historical average are significantly associated with an increase in shootings: for every 10 degrees higher temperature compared to the historical average, there were 33.8% more shootings. It is interesting to note that in the same local area, Xu et al. [60] found that 8.7% and 7.1% of intentional homicides could be attributed to temperatures above the city-specific median temperatures in Chicago and New York respectively. In terms of homicide data, Thomas and Wollf [63] found a significant positive association between rising temperatures and homicide and assaults, with an unusually warm day being associated with an increase in homicide of about 19.4% and 9.4% for assaults. Similar results were found by Hu et al. [64], highlighting a positive correlation between temperature residuals and assault.

The studies conducted in Australia by Stevens et al. found that a high temperature in winter had a greater impact on the number of assaults than in summer. In their study conducted in New Zealand, Williams et al. [52] found that geographical, seasonal and irregular daily temperature variation were all positively related to the incidence of assault, although only the effect of irregular temperature variation was robust in controls for plausible confounders. The estimated effect of irregular daily temperature variation and recorded assaults was about 1.5% more assaults per 1 °C temperature rise, while the estimated effect of irregular daily temperature variation and assaults resulting in hospitalization was about 1.7% more assaults per 1°C temperature rise. Similarly, in UK Lemon et al. [53] found that a 1% increase in assault rate for each degree increase in daily maximum temperature. Finally, in South Africa, Potgieter et al. [62] found that the risk of violent crime increases with an increase in average daily temperatures, peaking at 30°C.

DISCUSSION

The literature proposed here aimed to investigate whether there is a relationship between the phenomenon of interpersonal violence and heatwaves and above-average temperatures in longitudinal studies. One of the difficulties in selecting studies is that in many cases it is not a question of examining the rise in temperature as an anomaly or deviation from the average, but in relation to seasonality (for example, winter vs. summer).

Furthermore, the definition of heatwave and temperatures is ambiguous in some cases. For example, in Helman and Zaitchik [8] reference is made to high temperatures, but not to differences from an average. Another difficulty is that some authors look at different data by adding them together and presenting the macro data (e.g. sexual assault and self-harm): this made it impossible to analyze the individual data on interpersonal violence [9]. The number of studies identified in an initial analysis seemed very promising in terms of the possibility of inclusion.

The analysis of the methodology used to determine anomalies revealed that in most papers (except this review) temperatures are analysed in relation to the seasonal trend. This means that theories such as routine activities can be applied to explain how violent behaviour is related to time spent outside the home, for example. About theories, most parts of the papers (80%) analyzed use a combination of Routine Activity Theory and/or the Temperature-Aggression Hypothesis and/or the Heat Hypothesis, and/or the General Aggression Model as the primary framework.

The study by Basu et al. [55], Williams et al. [52] and Reeping and Hemenway [59] do not mention a specific theory, even if Reeping and Hemenway [59] mention that warmer weather predicts aggression and violent behavior and Williams et al. [52] support the thermal discomfort theory. Xu et al. [60], Potgieter et al. [62], Thomas and Wollf [63] and Stevens et al. [65] mention the Temperature-Aggression Hypothesis or the Heat Hypothesis and the Routine Activity Theory. For example, Stevens et al. [65], describe as in warmer temperatures, people engage in more socialisation which fosters motivations and opportunities to act aggressively.

Mares [51], Schinasi and Hamra [54] and Chambru [57] mention the Routine Activity Theory. Lemon et al. [53] and Hu et al. [64] mention the Negative Affect Escape theory, while Corcoran and Zahnow [61] mention the Negative Affect Escape theory and the Routine Activity Theory. Harp and Karnauskas [53] mention the Routine Activity Theory and the Temperature-Aggression Hypothesis while Henke and Hsu [58] mention the Heat Hypothesis and the General Aggression Model. However, these studies do not explain whether heatwaves and the above-average temperature could actually have an effect on interpersonal violent behaviour. In contrast, the included studies that consider heatwaves and above-average temperatures show a link between temperature anomalies and interpersonal violent behaviour in most cases.

However, it is important to point out that most authors acknowledge their study's limitations, that the results should be viewed with caution, and that future research is needed to better understand the relationship between climate change and human health. Mares [51] and Thomas and Wolff [63] pointed out that the measurement of violent crime reported to police agencies may be inaccurate because it does not necessarily capture all incidents of violence. Another possible explanation for the increase in crime during peak temperatures is that people spend more time outdoors and may witness more crime. Harp and Karnauskas [56], who found solid and robust statistical correlations between the increase of temperature in the winter season and crime rates, suggest that future work should target long-term projections related to anthropogenic climate change.

Long-term data are very sensitive, as Lynch et al. [66] argue that the average of temperatures over long time periods (30 years or more) needs to be examined. Therefore, annual time series data are needed to assess whether a relationship between temperature and crime exists and is due to temperature differences. Authors such as Reeping and Hemenway [59] and Schinasi and Hamra [54] suggest that future research should collect information on the spatial heterogeneity of the relationship between temperature and crime: the authors argue that this information could provide insights into the mechanisms underlying the relationship and have implications for structural and

social prevention measures that can be taken to prevent crime. To better understand the relationship between heatwaves and above-average temperature and interpersonal violence, Xu et al. [60] suggest also collecting sociodemographic details about the individuals involved in crime and injuries, respectively, including alcohol consumption.

The results of the studies show that the relationship between temperature and violence is complex and that it is important to take other variables (see [67, 68]) and their role into account when analyzing it. For example, Mares [51] found that crime appears to be related to the level of deprivation. Poverty could be taken into account when examining the effects of temperature, as suggested by Heilmann et al. [69]: the monetary cost of heat-related crime in the highest poverty neighborhoods is five times higher than in more affluent areas.

As described above, most of the studies analyzed tended to associate an increase in interpersonal violence with increased temperatures. Attempts have been made to find an explanation based on theories that describe, for example, how behavior in routine activities changes when ambient temperatures rise. As suggested by Lynch et al. [66], understanding the phenomenon using multiple variables, such as perceptions of vulnerability and changes in social and economic conditions, could be useful to understand better what happens in human behavior when temperatures rise [70]. This understanding can be useful in identifying how to prevent and intervene in the phenomenon. The National Aeronautics and Space Administration (NASA) [71] indicates that the aim is to find strategies to adapt to and mitigate heatwaves and increased temperature.

Possible strategies are also mentioned in some of the studies examined. However, it should be noted that all the findings that emerge from the studies are useful indicators of the direction that policymakers in different countries need to take to address climate change and its impact on interpersonal violence. In particular, the study by Xu et al. [60] suggest that in cities where the relationship between temperature and homicide is significant, some preventative measures could be taken to deter criminals (e.g., increased patrols and camera activity). Other strategies relate to increasing hospital staffing levels [53] and improving thermal comfort and well-being in homes and built environments [59].

Overall, as described by Williams et al. [52], Basu et al. [55], Xu et al. [60], Stevens et al. [65] it is important to adopt various policy measures, such as accelerating low-carbon technology innovation, promoting technology innovation, improving capacity for vulnerability access and climate monitoring, diversifying land use and improving crop and water management, and minimizing inequality and resource scarcity.

The study's results contribute to policymakers' need to implement programs to promote health and prevent violent behavior. Such programs can be implemented both in terms of high temperature (related to climate change) adaptation and mitigation (e.g., promoting green spaces and reducing pollution) and at the level of individual city institutions, which can monitor the phenomenon and take action, such as increasing the presence of security personnel in anticipation of periods of high temperatures. For example, as suggested by Stevens et al. [65], green spaces can reduce stress and increase positive feelings. In addition to the psychological benefits, there are direct health benefits, such as increased life expectancy [64,65]. There are many ways in which green spaces can positively impact well-being and health. For example, living near a park can increase physical activity (see, for example, Slater et al. [72]). Interestingly, Engemann et al. [73] found in their study that green spaces can promote mental health and possibly reduce the risk of psychiatric disorders: children who grew up with the least amount of green space had up to 55% higher risk of developing a psychiatric disorder, independent of the effects of other known risk factors. In addition, Wicks et al. [74] have shown that negative emotions such as anger, mental exhaustion, or sadness decrease when spending time in nature.

At the same time, green spaces help to reduce the tendency towards violence in enclosed spaces [75]. Another benefit is that using green spaces for recreational activities can strengthen social cohesion and positive neighborhood relationships. In addition, the public use of green spaces can

make neighboring properties more visible and less likely to be targeted by potential criminals [76], which improves the surveillance of properties and people.

Implications for research and policymakers

Our study provides initial data that is crucial for understanding the complex relationship between heatwaves and above-average temperatures and interpersonal violence. This approach and perceptions of vulnerability and changes in social and economic conditions can clarify behavioral responses to rising temperatures and other climatic conditions such as air pollution [77]. Such insights are essential for the development of effective prevention and intervention strategies [78-82], including in indoor environments [83,84]. Adaptation and mitigation measures are crucial for dealing with climate change [85,86]. Policy recommendations include increasing police presence in high-risk areas, increasing staffing in hospitals, improving thermal comfort in buildings [87] and outdoors, for example increasing green spaces [76]. Promoting low-carbon technologies, improving climate monitoring and dealing with resource scarcity are also important strategies [88].

In summary, addressing high temperatures associated with climate change through targeted research and comprehensive policy action can significantly improve public health and safety, particularly for populations at risk from the twin threats of rising temperatures and violence.

Limitations of the review

The first limitation of this review is that we have not analyzed other forms of violence and have focused only on interpersonal violence. Other forms of violence could be part of a broader discourse on how heatwaves and higher temperatures than average affects violent behavior more broadly, including self-harm and collective violence. Future research could consider these phenomena to understand better how high temperature related to climate change influences violent behavior. In addition, we have not considered a specific setting in which interpersonal violence might be perpetrated, such as the workplace, where environmental conditions might exacerbate the effects of heat waves and above-average temperatures [89,90]. Further research could also consider the workplace and its characteristics in relation to temperature as a possible variable to explain interpersonal violence [91,92]. A second limitation is that the literature reviewed is longitudinal and quantitative.

However, qualitative studies could help explain the historical series of official data and provide a social perspective on the phenomenon and its perception. Future research could examine, for example, how and from when the study of heatwaves and/or higher temperature than average related to violent behavior began, how it was presented to large audiences, and whether this led to changes in legislative proposals or political discourse. We also did not consider whether descriptive elements of the type of interpersonal violence were considered or whether socio-demographic variables were present in the studies examined. As routine activity theory suggests, it could be that the highest temperature is causing people to spend more time indoors and thereby risk becoming targets of violent behavior [93], but staying at home may also lead to an increase in violent behavior within the family, as studies from the time of the pandemic have shown [94-97].

CONCLUSION

This scoping review shows a link between heatwaves and higher temperatures than average related to interpersonal violence, with rising temperatures presented as a predictor of interpersonal violence. The literature analysis conducted here shows how highest temperature affects people's well-being, mental health, and behavior. This leads to the conclusion that policymakers must implement programs to promote health and prevent violent behavior.

Supplementary Materials: see Appendix A -

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Appendix A. Studies' included quality assessment.

		Assessment for individual criteria							Summary assessment		
		Sample	Measurement				Analysis				
Title	**Author; Year of publication**	**1. Sampling**	**2. Variable description**	**3. Validity**	**4. Reliability**	**5. Standardised methods for data collection**	**6. Appropriate statistical methods**	**Sample (1)**	**Measurement (2-5)**	**Analysis (6)**	**Overall grade (1-6)**
Climate Change and Levels of Violence in Socially Disadvantaged Neighborhood Groups	Mares, 2013 [45]	Random probability, random in strata or oversampling, weighted (5)	Yes (4)	Yes (4)	Yes (4)	Yes (4)	Yes (4)	5	High	High	High
The relationship between temperature and assault in New Zealand	Williams et al., 2015 [46]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High
Is weather related to the number of assaults seen at emergency departments?	Lemon et al., 2017 [47]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High
A Time Series Analysis of Associations between Daily Temperature and Crime Events in	Schinasi and Hamra, 2017 [48]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High

Philadelphia, Pennsylvania											
Examining the Association Between Apparent Temperature and Mental Health-Related Emergency Room Visits in California	Basu et al. [52]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High
The Influence of Interannual Climate Variability on Regional Violent Crime Rates in the United States	Harp and Karnauskas, 2018 [49]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High
Weather shocks, poverty and crime in 18th-century Savoy	Chambru, 2020 [54]	Not random (2)	Yes (4)	Yes (4)	Yes (4)	Yes (4)	Yes (4)	2	High	High	High
The gender wage gap, weather, and intimate partner violence	Henke and Hsu, 2020 [55]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High
The association between weather and the number of daily shootings in Chicago (2012-2016)	Reeping and Hemenway, 2020 [56]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High

Ambient temperature and intentional homicide: A multi-city case-crossover study in the US	Xu et al., 2020 [57]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High
The Effect of Weather on Assault	Corcoran and Zahnow, 2021 [58]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High
The association between weather and crime in a township setting in South Africa	Potgieter et al., 2022 [59]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Partly (3)	2	High	High	High
Weird winter weather in the Anthropocene: How volatile temperatures shape violent crime	Thomas & Wollf 2023 [60]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High
Exploring the correlation between temperature and crime: A case-crossover study of eight cities in America	Hu et al., 2024 [n]	Not random (2)	Yes (4)	Yes (4)	Unclear (2)	Yes (4)	Yes (4)	2	High	High	High
Associations between violent crime inside and outside, air temperature, urban heat island magnitude and urban green space.	Stevens et al., 2024 [56]	Not random (2)	Yes (4)	Yes (4)	N/A	Yes (4)	Yes (4)	2	High	High	High

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Note: 1. Sampling: Random probability, random in strata or oversampling, weighted (5); Random in strata or oversampling, not weighted (4); Random within or whole population of selected group (3); Not random (2); Unclear/not reported (1); 2. Variable description: Is the material used (independent and dependent variables) well described? Yes (4); Partly (3); Unclear (2); No (1); 3. Validity: Have the measurements used been previously validated? Yes (4); Partly (3); Unclear (2); No (1); 4. Reliability: Was the reliability of the measurements in the study sample reported? Yes (4); Partly (3); Unclear (2); No (1); N/A; 5. Standardized methods for data collection: Were the methods standardized/identical with all respondents? Yes (4); Partly (3); Unclear (2); No (1); 6. Appropriate statistical methods: Were appropriate statistical methods used for analyzing predictors? Yes (4); Partly (3); Unclear (2); No (1).