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Review

Combined Effect of Hot Weather and Outdoor Air Pollution on Respiratory Health: Literature Review

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Abstract: Association between short-term exposure to ambient air pollution and respiratory health is well documented. At the same time, it is widely known that extreme weather events intrinsically exacerbate air pollution impact. Particularly, hot weather and extreme temperatures during heat waves (HW) significantly affect human health, increasing risks of respiratory mortality and morbidity. Concurrently, a synergistic effect of air pollution and high temperatures can be combined with weather–air pollution interaction during wildfires. The purpose of the current review is to summarize literature on interplay of hot weather, air pollution, and respiratory health consequences worldwide, with the ultimate goal of identifying the most dangerous pollution agents and vulnerable population groups. A literature search was conducted using electronic databases Web of Science, Pubmed, Science Direct, and Scopus, focusing only on peer-reviewed journal articles published in English from 2000 to 2021. The main findings demonstrate that the increased level of PM_{10} and O_3 results in significantly higher rates of respiratory and cardiopulmonary mortality. Increments in $PM_{2.5}$ and PM_{10}, O_3, CO, and NO_2 concentrations during high temperature episodes are dramatically associated with higher admissions to hospital in patients with chronic obstructive pulmonary disease, daily hospital emergency transports for asthma, acute and chronic bronchitis, and premature mortality caused by respiratory disease. Excessive respiratory health risk is more pronounced in elderly cohorts and small children. Both heat waves and outdoor air pollution are synergistically linked and are expected to be more serious in the future due to greater climate instability, being a crucial threat to global public health that requires the responsible involvement of researchers at all levels. Sustainable urban planning and smart city design could significantly reduce both urban heat islands effect and air pollution.

Keywords: air pollution; extremely hot weather; heat waves; combined effect; respiratory health; wildfires; urban heat island

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1. Introduction

The increase in respiratory health indicators, including allergic disease, is well-documented globally and, most harmfully, is more pronounced in those regions where it was previously low [1]. Studies conducted around the world show that both air pollution, on the one hand, and weather and climate conditions, on the other, have a negative impact on human respiratory health [1,2]. Endeavors to raise awareness and mitigate the health implications of air contamination are long-standing and successful. Extensive scientific assessments make a plausible argument for the theory of negative influence of air pollution on cardiac and pulmonary health, notwithstanding some whitespaces in scientific knowledge and, consequently, some lingering doubts [3]. Among them, less is known about the impact of the dangerously polluted air on health outcomes in various weather and climatic conditions, with the greatest interest being their potential synergy on respiratory tract during hot seasons and episodes with extremely high temperature [1,4–9]. Of special

interest are extreme events such as prolonged heat waves and wildfires, which cause air pollutants increase to dangerous levels, which affect respiratory health [10].

Outdoor air pollution is a major environmental threat to global public health that requires the liable involvement of researchers at all levels responsible for a number of health hazards and diseases. Air pollution and its health consequences reached severe levels, causing up to 7 million premature deaths each year with even more hospitalizations and sick leave days [11,12]. Epidemiological and toxicological studies show links between the main atmospheric pollutants such as sulfur dioxide (SO_2), carbon monoxide (CO), photochemical oxidants (such as ozone, O_3), nitrogen oxides (NO_x), and airborne particulate matter (PM) and human health. PM is all solid and liquid materials that, due to its small size, become suspended in the air [13–17]. Total suspended particles, inhalable particles (PM_{10}), fine inhalable particles ($PM_{2.5}$ and PM_1), and smoke are some types of PM, with PM_{10} and $PM_{2.5}$ being the two major pollutants currently controlled [18–20].

Evidence obtained from experimental and epidemiologic research supports the association between air pollution, its short- and long-term influence, and respiratory health [1,2,12,14,17,21–25]. Different indoor and outdoor exposures are associated with various acute and chronic respiratory health outcomes that range in severity, from allergies and general respiratory complaints to lung cancer and mortality, as air pollution is genotoxic and contributes to tumor development, causing persistent inflammation [24]. The high burden of pollution on respiratory diseases includes exacerbation of respiratory problems in individuals already suffering from chronic respiratory diseases, such as asthma, rhinosinusitis, bronchiolitis, decreased lung function, chronic obstructive pulmonary disease (COPD), and respiratory tract infections, leading to repeated hospitalizations and emergency room visits for the underlying disease, premature mortality, as well as the occurrence of new respiratory problems, such as new-onset asthma [1,17,26–28].

Environmental toxicants cause a wide range of effects on the respiratory system, from reversible local reactions to long-term chronic impact: local irritation, direct epithelium cells of the respiratory airways damage, allergic reactions (such as asthma), and cancer [1]. Although most recent epidemiological research focused on short-term (such as 24 h average) exposures to PM, O_3, NO_x, SO_2, CO, black smoke, and other pollutants [1,17,29–32], several studies suggest the long-term influence is more common in people with a predisposing disease—lung and cardiopulmonary diseases include COPD and asthma exacerbations, lung cancer mortality, etc. [19,33–39]—and may be more important from a general public health perspective [33,40–42].

Over the past few years, considerable advances were made in detecting the main biological mechanisms regarding how air contaminants affect human respiratory health [43,44]. The physiopathology of respiratory problems associated with atmospheric pollution can be explained by a cytotoxicity, which is said to be responsible for morphological and functional changes to the respiratory epithelium, as well as the induction of an inflammatory reaction, which may provoke a bronchial hyperresponsiveness and a possible interference with the immune system [45,46]. Epidemiological, clinical, and toxicological studies confirm the main pathway associated with oxidative systems. Particulate matter affects respiratory system depending on their size and penetrating activity: PM_{10} can be deposited in the respiratory tract, $PM_{2.5}$, in the alveoli [9]. PM interacts with the alveolar-capillary cells, induces oxidative stress reactions that can disrupt the integrity of lung endothelial cell barrier and inflammation, and leads to airway damage, lung dysfunction, and negative cardiopulmonary outcomes [14,25,47–49]. Ground-level ozone is a known lung irritant that affects the airway mucousa, other lung tissues, and respiratory function, causing oxidative injury to the respiratory epithelium and leading to lung inflammation, decreased lung function, worsening of airway symptoms, and excessive respiratory reactivity [9,50–52].

The higher temperatures and the increased heat waves (HW) frequency amplify exacerbation rate, morbidity, and mortality from weather-related respiratory diseases, especially in vulnerable populations [1,30,53–63]. Health impacts are determined by the level of exposure in terms of HW duration, severity, and frequency, as well as the susceptible population

and its sensitivity [64–66]. Studies illustrate that the implications of high temperature are generally intense on the same day or with a delay of one to four days [53,67,68].

The majority of surplus hospital admissions were shown to be caused by dehydration, heat stroke, and heat exhaustion among people with comorbidities. In addition, an excessive number of patients with secondary diagnoses of pneumonia and influenza-related respiratory problems, chronic obstructive pulmonary disease, chronic bronchitis, emphysema, and asthma were hospitalized [69]. A literature review conducted by Schlegel [68] highlighted the problems of individuals with chronic lower respiratory diseases on hot days as well as in heat waves. In the summer months, acute exacerbations in patients with chronic obstructive pulmonary disease (COPD), which is the main subtype of respiratory diseases, increase sharply during episodes of HW [70–73]. It was found that chronic respiratory diseases can be an important indicator of increased mortality risk among patients in hospitals on hot days [74,75]. The potential explanation may be that the health status of people with chronic respiratory diseases deteriorates rapidly during hot periods [1,54]. In these patients, it can be hypothesized that thermoregulatory responses to heat stress, especially those affecting the respiratory system, may be futile in dissipating excess heat, increasing risk of developing heat stress outcomes such as dehydration and heatstroke [1,76], which in turn leads to a risk of developing pulmonary vascular resistance secondary to peripheral blood accumulation or hypovolemia [30]. The physiologic effects of excess heat on the thermoregulatory system leads to an increase in cardiac output, elevating skin blood flow and respiratory rate [6]. High temperature raises heat loss through the cutaneous surface blood circulation, which may be associated with increased mortality [48,77].

It is well known that generation and dispersion of air contaminants depend on weather characteristics. High temperatures and sunshine cause the elevation in concentration of particulate matter, ozone, sulfate aerosols, and others, especially in hot summers and during heat waves episodes [1,8,9,20,78]. At the same time, the temperature rise is amplified by high levels of pollution, particularly PM and ozone [7,62,79]. Accumulated data show that pollutants, primarily soot (black carbon) and PM, can absorb heat, thereby enhancing local temperatures and affecting the climate [11,80]. Sunlight associated with high air temperatures increases local air pollution, even without additional emissions [79,81,82]. Excessive heat raises energy consumption and consequently affects air pollutants, their distributions, accumulation, changes in chemical composition of particulate matter, and even generation of more toxic pollutants [21,51,79,82–84].

Although many studies on the relationship between temperature, mortality, and morbidity took into account concentrations of air pollutant, only a few examined the potential synergistic effect of high temperature and air contaminants. Understanding the combined effects of both elevated temperature and air pollution, particularly PM and ozone, would allow us to better characterize the climate-related health outcomes under the changing climate [85]. The conclusions drawn from these findings would have compelling medical and social implication for public health, being important for the development of long-term prevention measures. When an episode of hot weather or even HW is predicted, additional measures may be required to reduce the concentrations of pollutant in the air at the beginning of emergency response [82].

The current review summarizes the scientific data on combined effect of air pollution and climate-related hazards, such as hot weather and heat waves, on respiratory health outcomes obtained from both climatological and epidemiological studies. In particular, we considered those climate events that could be most affected by climate change and for which climate conditions are related to air quality: temperature extremes, hot weather, or episodes of heat wave. Wildfires and urban heat island (UHI) effects, pathogenic mechanisms, vulnerable population subgroups, confounder of multiple environmental stressors, climate change impact, and policy implications are discussed.

2. Materials and Methods

A systematical literature search was conducted in November 2020–May 2021 using electronic databases Pubmed, Web of Science, Science Direct, and Scopus for papers published before 20 May 2021. Hand searching of the applicable literature was also performed in relevant journals and bibliographies of included studies. Three conceptual categories were used: "ambient/outdoor air pollution", "extremely hot weather", and "respiratory health outcomes", revealing a total of 253 records. We were seeking for key words "heat wave", "hot weather", "high temperature", "warm season", "air pollution'", "particulate matters", "fine particles", "ozone", "respiratory mortality", "respiratory disease", "asthma", or "COPD" and also looked for studies cited in the recognized articles. The search identified 40 studies that were selected for the review. The narrative synthesis included all original studies with time-series or case cross-over design, ambient air-pollution and weather exposure, and mortality and/or hospital admission/ambulance call outcomes. All included studies examined respiratory (8th or 9th revision of the International Classification of Diseases (ICD8) or (ICD9]): 460–519; or 10th revision of the International Classification of Diseases (ICD10): J00–J99) mortality or morbidity in all age groups. Study duplicates were removed, and abstracts were screened independently by two authors (E.G. and A.L.). Final selected studies were chosen based on the inclusion criteria that they attempted to feature recorded respiratory/pulmonary health outcomes (deaths and hospital admissions/emergency room visits), had air pollution, warm/hot weather, heat waves, and health outcomes recorded quantitatively, and controlled for the main confounding variables. We placed no restrictions on study design, however, only studies published in the English language were included.

The conceptual framework for these interactions is summarized in Figure 1.

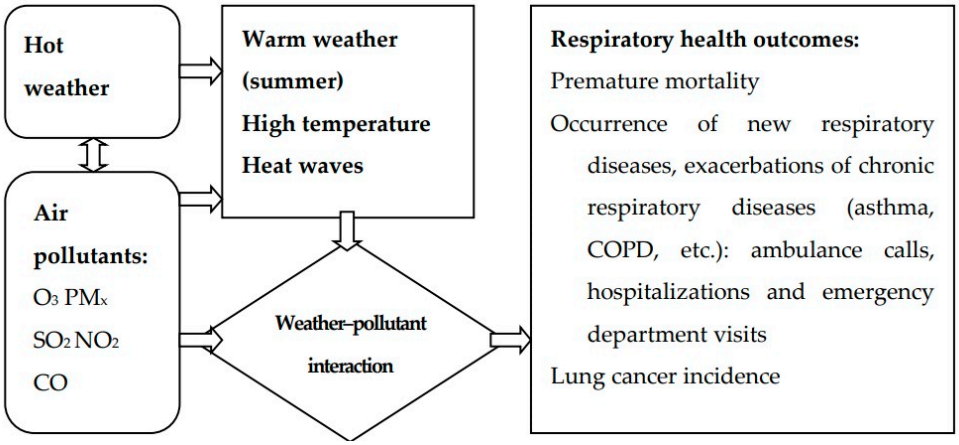

Figure 1. The conceptual framework for combining effect of hot temperatures and air pollution on respiratory health outcomes.

Warm and hot temperatures and heat waves combined with air-pollution (O_3, PM_x, SO_2, NO_2, CO) were shown to act consistently as risk factors for respiratory mortality, hospital admissions, and daily emergency transports, where respiratory health outcomes were taken from the main categories: premature mortality; general respiratory complaints, ambulance calls, hospitalizations, and emergency department visits for respiratory reasons; chronic respiratory diseases such as COPD, asthma, etc.; and lung cancer, as shown in Figure 1.

3. Results

We reviewed the titles and the abstracts of 153 studies, of which 40 met our prespecified inclusion criteria. Most (23) were from East Asia [37,41,73,86–105], 10 were from Europe [5,30,53,74,75,79,106–109], 5 were from USA and Canada [110–114], and far fewer were included from the Pacific region [115], Latin America, and the Caribbean [116].

The following characteristics of studies involved in the review were extracted: study; study area; study period; weather parameters such as air temperature and humidity, dew point temperature, wind speed and direction, air pressure, precipitation, hours of sunshine; hot weather description, including definition of HW or high temperature used in the study; air pollutants such as PM, O_3, NO_2, SO_2, CO; respiratory health indicators; exposure and confounders; statistical methods and study design; results with outcome and associated lag time. The role of effect modification was investigated in terms of gender and age. Respiratory health outcomes included daily mortality from respiratory causes, respiratory emergency department visits, hospital admissions, ambulance calls, and lung cancer incidence.

Hot weather descriptions were different among the studies. Almost all of them checked for health burden of high temperatures—those levels which exceed the specified percentile of the temperature distribution: 75th, 85th, 95th, 97th, 97.5th, or even 99th percentile for extremely hot weather. In a few papers, high temperature threshold was determined as temperature of minimum mortality [53,116] or temperature with the lowest frequency of ambulance calls [101]. Four studies focused on HW effect in European countries using different definitions of HW and counting for their intensity and duration [5,79,108,110]. Some papers looked at seasonal changes and warm air modifications during warm seasons [41,103,111,113] or in summer [102,104]. In some papers, hot weather influence was corrected by relative humidity expressed in apparent temperature (AT) [117,118] to analyze the perceived rather than the actual thermal load [5,30,41,53,74,79,91,109,110]. Two studies demonstrated the impact of polluted air on respiratory mortality and morbidity for different types of weather, where those with high temperature effects were referred to as dry tropical (DT) and moist tropical (MT) air masses [112,114].

Some studies examined effects of temperature changed by contaminants, and some observed the impact of pollutants modified by hot weather. For instance, a study by Breitner et al. [75] in Germany demonstrated modification in the temperature–mortality association by ozone. Park et al. [96] for South Korea notified the impact changed by temperature on the O_3 exposure, illustrating a pattern consistent with some modification of the effect. The potential interaction between air pollution health outcomes and high temperatures was tested mostly by means of a stratified analysis in time-series; few were tested by case-crossover analyses or through interaction terms. Statistical models used were mainly generalized additive models (GAM), generalized estimating equations (GEE), and generalized linear models (GLM). Almost all models were adjusted for time (seasonal and long-term trends), day of the week, public holidays, and influenza epidemics. Most of them had additional weather confounders such as relative humidity and barometric pressure.

Almost all studies provided consistent evidence of a synergy between the two exposures, with only two showing no evidence of interaction [5,106] and few of them reflecting that low temperature polluted air had a greater impact on respiratory health outcomes than hot air [73,87,101]. In addition, Anderson and Bell [110], for research in urban communities of the USA, showed heat effects on daily mortality from respiratory causes were slightly lower when models included ambient pollution (O_3 and PM_{10}) [110].

Most papers discussed all-cause and specific-cause mortality or morbidity, including respiratory outcomes. Of the identified papers, 24 discussed mortality from respiratory causes [5,53,73–75,79,86,88,90,92,93,95–98,100,106–110,114–116], 14 incorporated respiratory emergency department visits and hospital admissions [30,41,87,89,91,94,99,102–105,111–113], 1 was for ambulance calls for respiratory distress [101], and 1 was for lung cancer incidence [37]. The details of those studies are reported below, separately for respiratory morbidity and mortality and for heat wave episodes.

3.1. Heat, Air Pollution and Morbidity

Strong evidence was obtained for the synergistic impact of ambient air pollution with PM, CO, O_3, SO_2, and NO_2 and hot weather on triggering of health problems [78,119,120].

The magnitude of these effects on respiratory morbidity varies by diseases and individual characteristics; estimates seem to be higher among children and the elderly population. Illustrations of increasing number of daily emergency transports, hospital admissions, and ambulance calls for respiratory problems are summarized in this section. The effect was shown in European cities, especially for elderly aged ≥75 [30], in places with high levels of pollution in China, including Beijing and Nanjing [41,102,103,105], in Tokyo, Japan [104], etc. Increased asthma hospitalization was demonstrated to be extremely related with high levels of ozone in connection with hot weather in Indianapolis in the USA [111], for emergency department visits among children in St. Louis, USA [113] during warm seasons, as well as for cities in the USA such as North Carolina on hot, dry days [112]. Episodes of high $PM_{2.5}$ and O_3 and extremely hot temperatures (T > 27.9 °C) were demonstrated for hospital admissions with COPD exacerbations in Taiwan. Especially significant impact was detected in the elderly with odds ratio (OR) = 1.037 and greater lagged effect [89]. An increased rate for lung cancer incidence in association with high temperatures and PM_1 exposure was discussed by Guo with coauthors [37], who showed stronger incident rate for males. High daily ambulance calls for respiratory distress on extremely hot days (with temperature T > 99th percentile of distribution) with high concentrations of $PM_{2.5}$ and constituents were demonstrated for Kaohsiung in Taiwan [94]. Respiratory emergency transports during summer for episodes with high exposure of PM_{10} and NO_2 were shown to be greater for males than for females in Tokyo, Japan [104]. High temperatures in connection with particulate matter pollution were associated with increases in hospital emergency room visits for respiratory system diseases in Beijing, China, indicating the elderly (age ≥ 65) and women were the more vulnerable groups [105].

Children and adolescents were shown to be a sensitive age cohort. Increased hospitalization of acute bronchiolitis-related disease among children accompanied with high temperature and exposure to NO_2 and PM_{10} at different lag times was shown for Hong Kong [91]. Air pollution during hot weather raised asthma ED visits in St. Louis, USA by 9.45% (95% CI = 1.02, 1.17) among patients 11–17 years old [113].

Geography and type of climate were shown to be important. Michelozzi et al. [30], in a study for Europe, emphasized the raise in apparent temperature was more effective for Mediterranean cities with a +4.5% (95% CI: 1.9–7.3) increase in respiratory emergency visits compared with northern continental cities, where a +3.1% (95% CI: 0.8–5.5) increase in respiratory visits was demonstrated.

On the other hand, there was some polemical evidence for no statistically significant effect of air pollution on respiratory emergency department visits in moderately hot and hot days, for example, in Beijing [99]. Likewise, for ambulance calls with respiratory distress in Taiwan, exposure to the extreme level of $PM_{2.5}$ was more likely to occur at low temperatures [101].

3.2. Heat, Air Pollution and Mortality

The mean daily concentrations of some pollutants can be very high in East Asia; for instance, PM_{10} concentration in eight Chinese cities was found to range from 65 $\mu g/m^3$ to 124 $\mu g/m^3$, which is significantly higher than in Western countries [95]. Combined impacts of hot weather and ambient pollution on respiratory mortality are presented in many papers around the world, with more recent research being undertaken in East Asian countries, especially in China, than in Europe or other countries.

Hot weather was found to substantially strengthen the impact of air pollution on respiratory mortality, with PM_{10} and O_3 being the main pollutants, such as that shown by research in Japan [88]. Examples can be shown for heat effect during the excess PM_{10} exposure in Beijing, Tianjin, Guangzhou, Hefei, Wuhan, and other cities in China [92,93,95,97,98,100]. The higher mortality risk was shown for places in China with 0–1 days lag of PM_{10} exposure: 0.45% (95% CI: 0.13–0.78) for respiratory mortality in Beijing [100]; 0.74% (95% CI: −0.33, 1.82) for respiratory and cardiopulmonary mortality in Tianjin [92]; 6.09% (95% CI: 2.42, 9.89) in Guangzhou [93]; 4.6% (95% CI: 2.83–5.85%) for COPD excess mortality in

11 cities [73]; 1.79% (95% CI: 0.75–2.83) for 8 cities, with impact being higher in hotter locales [95]. High temperatures jeopardize the effect of PM_{10} pollution in South Korea [90]; in Christchurch, New Zealand [115]; in Sao-Paulo, Brazil, with rate ratio (RR) = 1.60% (95% CI: 0.74–2.46) [116]; in Italian cities, with RR = 2.54% (95% CI: 1.31–3.78) for 35+ age cohort [109]. High temperatures also impact exposure to O_3 pollution in Soul, South Korea [96], Germany [75], England, and Wales [107]. Besides, some studies discussed additional significant effects for SO_2 and NO_2, e.g., research in Hefei, China [98]. The combined effect of polluted air and weather was shown to be high during weather with tropical air masses, both dry and moist, for Canadian cities in summer [114]. The results highlighted that the synergistic effect varies across regions and countries depending on local climate peculiarities, activity patterns, and physical adjustments [1].

The studies demonstrated strong mortality growth on days with increases in concentration of air pollutants, with the effect being higher in older individuals ≥65 years [92], ≥75 years [53], and ≥85 years [75,96] old, in men [90] and women [97,98], in those who are illiterate [97,98], and in subjects in southern cities compared with northern ones [95]. It can be assumed the differences may arise due to personal behavioral and physiological dissimilarities to high temperature and pollution exposure [97].

Predictably, temperature extremes were found to create the greatest mortality burden, with studies in Wuhan, China, a highly polluted "oven" city [97,98], or cities in South Korea [96] as examples. Additionally, examples are presented for extremely high thermal exposure and pollution that resulted in excess mortality in subjects with chronic pulmonary disease in Italian cities (OR = 2.48 (95% CI: 1.50–4.09)) [74] and COPD for cities of Jiangsu province, China (OR = 4.6% (95% CI: 2.83–5.85%)) [73]. However, in contrast, no significant interaction between polluted air and extremely high temperatures was shown for Shanghai [86] and France [106], and a higher effect for low temperature exposure was demonstrated for locales in Jiangsu province, China [73].

3.3. Heat Wave Episodes

As frequency, intensity, and duration of heat waves are expected to increase with climate change, HW episodes are of special interest for public health [37,121]. While most of the studies cited above addressed joint effects of pollutants with high temperature, only four focused on heat wave episodes [5,70,108,110].

Heat waves in urban places of the USA were explored in detail by Anderson and Bell [110]. The joint effect of air pollution caused by elevated levels of PM_{10} and O_3 during the HW showed the higher estimates of exposure for respiratory disease compared with the total mortality [110].

European studies by Analitis et al. [5,79] focused on specific heat wave episodes, analyzing total and course-specific mortality, including respiratory disease, where they provided evidence of a significant interaction between high temperature and pollutants, mainly ozone, especially for the elderly [79].

A synergistic effect of heat and air pollution on mortality was shown for extremely long and intensive heat waves in European Russia accompanied with a disastrous wildfire in summer 2010, with Moscow as an example [108]. Main pollutants estimated were PM_{10} and O_3. The major HW lasted for 44 days, with 24 h average temperatures ranging from 24 °C to 31 °C and PM_{10} levels exceeding 300 $\mu g/m^3$ on several days [108]. An increase of 339 deaths in Moscow from respiratory diseases was found compared to the same period in summer 2009, with RR = 2.05 (95% CI: 1.80–2.39) 9 [108].

Although there was evidence of a synergetic effect of air pollution and high temperatures during HW episodes, a slight decrease in thermal effects was found when models included O_3 and PM_{10} [5,110], which should be analyzed in the future.

All results from 40 papers mentioned above are summarized in Table 1, where the papers are arranged alphabetically by the first author in the included studies.

Table 1. Characteristics of studies included in the review.

Study	Study Area	Study Period	Weather Parameter [1]	Hot Weather Description [2]	Air Pollutant [3]	Health Indicator [4]	Exposure and Confounders [5]	Statistical Methods and Study Design [6]	Results
Analitis et al. [79]	Europe: Athens, Barcelona, Budapest, London, Milan, Munich, Paris, Rome, Valencia	Summer months, 1990–2004	3-h T, Td, V, P	HW: period of at least 2 days with AT_{max} > 90th percentile of the monthly city-specific distribution, or a period of at least 2 days with T_{min} > 90th percentile of the minimum monthly distribution and AT_{max} > the median monthly value; intensity and duration of HW	PM_{10}, O_3, NO_2, SO_2, CO High pollution >75th percentile of the overall pollutant distribution	MRC (ICD9: 460–519)	HW—main exposure, adjusted for AP, confounders: P, V, calendar month, DOW, holiday, time trend	An interaction term between HW and each single pollutant; random effects meta-analysis for summarizing the city-specific results; time-series analysis	MRC increase during HW 54% higher on high O_3 days compared with low, among people age 75–84 years; significant positive interaction of HW and PM_{10} for MRC in Mediterranean cities (65–74 years); HW effect on MRC is larger than on other causes of death, although the effect modification was less evident for MRC
Analitis et al. [5]	Europe: Athens, Barcelona, Budapest, Helsinki, London, Paris, Rome, Stockholm, Valencia	2004–2010	1-h T, Td, RH, V, D, P	HW: (1) period of at least 2 days with AT > the 90th percentile of the monthly distribution; or (2) period of at least 2 days with T_{min} > the 90th percentile of its respective distribution and AT > median monthly value	PM_{10}, O_3, NO_2 High pollution >75th percentile of the city-specific pollutant distribution	MRC (ICD9: 460–519; ICD10: group J), age groups: 15–64, 65–74, >75 years and all ages	HW—main exposure, adjusted for pollutants, P, V, calendar month, day of the week, holiday, time trend	GEE modeling approach; Poisson regression for city-specific analysis; random effects meta-analysis to combine city-specific results; time-series of HW days	Synergistic effect between hot temperature and O_3, PM_{10}, and NO_2 on MRC No evidence for synergy for any of the pollutants and health endpoints analyzed during heat wave days [7]
Anderson and Bell [110]	USA: 107 urban communities	1987–2000	Daily T_{mean}, T_{max}, T_{min}, Td	HW, 6 types: periods of 2 or more or 4 or more days of continuous AT more than 98.5th, 99th, or 99.5th percentile of the community's temperature distribution	PM_{10} (lag 0–1), O_3	MRC (ICD9 codes 480–486, 490–497, or 507), age (<65, 65–74, ≥75 years)	T—main exposure, adjusted for pollutants; confounders: day of the week, Td; income, unemployment, education, public transportation, race, urbanicity, population	Bayesian hierarchical model used for community-specific estimates of absolute and relative heat and HW effects	Association between HW and MRC, although estimates are uncertain; somewhat higher estimates for respiratory, compared with total deaths. Heat effects slightly lowered when models included O_3 and PM_{10}
Baccini et al. [53]	Europe: Athens, Barcelona, Ljubljana, Milan, Rome, Turin, Valencia (Mediterranean), Budapest, Dublin, Helsinki, London, Paris, Prague, Stockholm, Zurich (north-continental)	1990–2000	3-h T, Td, V, P	High temperature: percent change in mortality associated with a 1 °C increase in AT_{max} above the city-specific threshold, defined as AT with the minimum mortality rate (lag 0–3)	NO_2 (lag 0–1)	MRC (ICD9: 460–519), age (15–64, 65–74, 75+ years)	AT—main exposure, adjusted for AP; confounders: holidays, DOW, day of calendar month, long-term time trend, P (lag 0–1), V	GEE, combined in a Bayesian random effects meta-analysis; distributed lag models for studying the delayed effect of exposure; time-varying coefficient models are used to check the assumption of a constant heat effect	Higher associations between heat and MRC, with estimated percent changes equal to 6.7 (2.4 to 11.3) and 6.1 (2.6 to 11.1) for Mediterranean and north continental cities, respectively; heat effect particularly large in the elderly (75+): 8.1% for the Mediterranean region and of 6.6% for the north-continental region; adjustment for AP changed the MRC increase with 1 °C rise in AT_{max} from 6.2% to 5.5% in Athens to a negligible effect in Stockholm

Table 1. *Cont.*

Study	Study Area	Study Period	Weather Parameter [1]	Hot Weather Description [2]	Air Pollutant [3]	Health Indicator [4]	Exposure and Confounders [5]	Statistical Methods and Study Design [6]	Results
Breitner et al. [75]	Germany: Munich, Nuremberg, Augsburg	1990–2006	Daily T, RH, P	High temperature: increase from the 90th (20.0 °C) to the 99th percentile (24.8 °C) of 2-day T_{mean} (lag 0–3)	PM_{10}, O_3	MRC (ICD9: 460–519; ICD10: J00-J99)	T—main exposure, adjusted for AP; confounders: long-term trend/seasonality, calendar effects, DOW, influenza, RH, P	Poisson regression models combined with distributed lag non-linear models; time-series analysis	High 2 day and 15 day T_{mean} and consistent MRC increases; 85+ most susceptible to heat effects; some effect modification by O_3 but not for PM_{10}
Byers et al. [111]	USA: Indianapolis	2007–2011	T, RH, P	Warm season (April–September)	$PM_{2.5}$, O_3, SO_2	Daily asthma-related EDV; ≥5 years old	AP—main exposure, adjusted for T; confounders: year, month, DOW, holidays; smoothing function of time	Poisson GLM to estimate the association between AP and asthma ED; RR for risk estimation, using interquartile range in single pollutant models, accounting for age group and season	O_3 and SO_2 increases associated with increased asthma morbidity
Chen and Kan [86]	China: Shanghai	January 2001–December 2004	T, RH	High temperature: T > 85th percentile of distribution	PM_{10}, O_3, NO_2, SO_2	MRC (ICD9: 460–519; ICD10: J00–J99)	AP—main exposure	GAM; time-series analysis	No significant interaction between air pollution and extremely high temperature for MRC
Chen et al. [87]	China: Guangzhou	January 2014–December 2017	T, RH	High temperature: T > 75% quartile, or 4th DTL defined as 27.4–31.1 °C	CO, $PM_{2.5}$, SO_2, NO_2, O_3	REDV	DTL—main exposure, adjusted for AP; confounders: DOW, holiday, RH	Quasi-Poisson varying coefficient regression models	Significant adverse effect on REDV of interactions between SO_2 and the 4th DTL (27.4–31.1 °C)
Chung et al. [88]	Taiwan: Taipei, Taichung, Kaohsiung; South Korea: Seoul, Incheon, Daejeon, Daegu, Gwangju, Busan; Japan: Sapporo, Sendai, Tokyo, Nagoya, Osaka, Kitakyush	Taiwan (1994–2007), South Korea (1992–2010), Japan (1972–2009)	Daily T_{mean}, T_{max}, T_{min}, RH, P	High temperature: T > 99th percentile; comparing the 90th and 99th percentiles of T_{mean} percentiles specific to each city	O_3, PM_{10}	MRC (ICD8 460–519; ICD9 460–519; ICD10 J00–J99), age (<65, 65–75, >75 years)	T—main exposure, adjusted for AP; confounders: DOW, influenza, RH, P	Generalized Poisson semiparametric regression model; city-specific effect estimates combined to generate an overall estimate for each country using Bayesian hierarchical modeling	Heat effects greater for cities in Korea and Japan; in all countries, heat effect increases with age and is higher for cardiorespiratory mortality than for non–cardiorespiratory mortality

Table 1. *Cont.*

Study	Study Area	Study Period	Weather Parameter [1]	Hot Weather Description [2]	Air Pollutant [3]	Health Indicator [4]	Exposure and Confounders [5]	Statistical Methods and Study Design [6]	Results
Ding et al. [89]	Taiwan: Taipei, New Taipei	2000–2013	Daily T, RH, P	High temperature: T > 27.9 °C	$PM_{2.5}$, O_3, SO_2, CO, NO_2	REDV COPD-associated, including: chronic bronchitis (ICD9 491), emphysema (492), chronic, airway obstruction (496); >40 years old (40–64, 65–79, >80)	AP—main exposure, adjusted for T, RH, P	Conditional logistic regression models with ORs and 95% CIs; case-crossover study design	$PM_{2.5}$ and O_3 have significantly greater impact on elderly COPD-associated EDV on hot days; greatest effect in the days with T > 27.9 °C (OR = 1.037 (95% CI 1.001–1.074)
Guo et al. [37]	China: 345 counties (districts)	2014–2015	Annual and monthly T, RH	High temperature: T > 75% percentile of distribution	PM_1	Lung cancer incidence (ICD10 C33–34)	T and RH—main exposure, adjusted for AP, confounders (smoking, education, economic status, occupation, employment, urban, population size)	Multivariable linear regression model for stratified and combined datasets	Strong association between PM_1 and the incidence rate of male lung cancer with high T
Hales et al. [115]	New Zealand: Christchurch	June 1988–December 1993	T_{max}	High temperature: T_{max} > 3rd quartile (20.5 °C)	PM_{10}	MRC (ICD9 460–519)	AP—main exposure, adjusted for T_{max}, controlling for season	GLM; interaction terms; time-series analysis	Increase of 1 °C on the day of death associated with a 3% MRC increase; increase in PM_{10} (lag 0–1)—4% MRC increase
Hanna et al. [112]	USA: 5 cities in North Carolina (Asheville, Charlotte, Greensboro, Raleigh, Wilmington)	1996–2004	Daily T_{max}, Td, V, D, P, CC, R	Weather types: DT (hot and dry), MT (hot and humid)	O_3 (lag 0–5)	HA for asthma (ICD9 493.x)	AP—main exposure, adjusted for DOW, seasonality, long-term trend, Td	GLM; time-series analysis	Increased asthma hospitalizations during episodes with high O_3 levels associated with DT and MT air masses
Kim et al. [90]	South Korea: seven cities	2000–2009	Daily T, RH, P	High temperature: T > 95–99th percentile of distribution	PM_{10}	MRC (ICD10 J00–J99)	AP—main exposure, adjusted for T; confounding factors: seasonal variation, DOW, RH, P	GAM; stratification; time-series analysis	Strong harmful effects from PM_{10} with the highest temperature range (>99th percentile) in men, with a very high temperature range (95–99th percentile) in women
Leung et al. [91]	Hong Kong	January 2008–December 2017	Daily T, RH, R, V	High temperature: high T and AT	PM_{10}, NO_2, SO_2, O_3	29,688 acute bronchiolitis-related HA (ICD9: 466.1 487.0, 487.1, 487.8), children ≤2 years old	T and AP—main exposure, adjusted for DOW, holiday	Quasi-Poisson GAM in conjunction with DLNMs; time-series analysis	Increased adjusted RR of acute bronchiolitis-related hospitalisation among children is associated with high T and exposure to NO_2 and PM_{10} at different lag times
Li et al. [92]	China: Tianjin	2007–2009	Daily T, RH	High temperature: T > 20 °C	PM_{10}, NO_2, SO_2	MRC: respiratory (ICD8 J00–99), cardiopulmonary (J00–99), age groups <65, ≥65	T—main exposure, adjusted for AP; confounders: days of calendar time, DOW, RH, holiday	Poisson GAM model natural logarithm of the expected daily death counts; time-series analysis	10 $\mu g/m^3$ increment of PM_{10} on T high for MRC (0.74% (95% CI: −0.33, 1.82), lag 0–1); PM_{10} effects on T high stronger on older (≥65 years)

Table 1. *Cont.*

Study	Study Area	Study Period	Weather Parameter [1]	Hot Weather Description [2]	Air Pollutant [3]	Health Indicator [4]	Exposure and Confounders [5]	Statistical Methods and Study Design [6]	Results
Li et al. [93]	China: Guangzhou	2005–2009	Daily T, RH	High temperature: T > 95th percentile of distribution	PM_{10}, NO_2, SO_2	MRC (ICD9: J00–99)	T—main exposure, adjusted for AP; confounders: days of calendar time, DOW, RH, holiday	GAM; time-series analysis	10 $\mu g/m^3$ increase in PM_{10} concentrations (lag 0–1) on high temperature days for MRC (6.09% (95% CI: 2.42, 9.89))
Lin et al. [94]	Taiwan: Kaohsiung	2006–2010	Daily T, RH, V	High temperature: T > 99th percentile of distribution	$PM_{2.5}$, EC, NO_x, SO_x	Daily AC of cases diagnosed with respiratory distress	T—main exposure, adjusted for AP, and vice-versa; confounders: time trend, seasonality, DOW, influenza, holiday, RH, V	Quasi-Poisson function and DLNM; time-series analysis	Significant association with T, $PM_{2.5,}$ and concentrations of constituents
Ma et al. [73]	China: Jiangsu, 11 cities	2014–2017	Daily T, RH, R, P, S	High temperature: T > 97.5th percentile of distribution	PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, O_3	MRC (ICD10 J00–J99), including COPD (J41–J44)	T—main exposure, adjusted for AP	1: DLNM combined with generalized linear model (GLM); 2: univariate random-effect meta-analysis for construction the overall cumulative exposure-response curves for all cities	Excess mortality for COPD (4.6% (95% CI: 2.83%–5.85%)) 20.58% (95% CI: 13.97%–24.96%) at cold exposure
Meng et al. [95]	China: Guangzhou, Hangzhou, Shanghai, Shenyang, Suzhou, Taiyuan, Tianjin, Wuhan	2001–2008	Daily T, RH	High temperature: T > 95th percentile of the distribution	PM_{10} (lag 0–1)	MRC (ICD10 J00–J98)	PM_{10}—main exposure, adjusted for T; confounders: DOW, RH	Poisson GAM; time-series analysis	10 $\mu g/m^3$ increment in PM_{10} during T high: increase for MRC (1.79% (95% CI: 0.75–2.83)); higher effect for southern cities
Michelozzi et al. [30]	Europe: Barcelona, Budapest, Dublin, Ljubljana, London, Milan, Paris, Rome, Stockholm, Turin, Valencia, Zurich	1990–2001	T, Td	High temperature: AT_{max} > 90th percentile of the distribution	NO_2 as an indicator of traffic-related pollution	REDV (ICD9 460–519); age groups: all ages, 65–74, 75+	T—main exposure, adjusted for NO_2 (lag 0–1); confounders: holidays, DOW, calendar month, P (lag 0–3), V	Semiparametric approach, which includes penalized cubic regression splines; time-series analysis	1 °C increase in AT_{max} gives increase in REDV by +4.5% (95% CI: 1.9–7.3) and +3.1% (95% CI: 0.8–5.5) in the 75+ age group in Mediterranean and North-Continental cities
Mohr et al. [113]	USA: St. Louis	1 June 2001–31 May 2003	T_{max}	Warm season: median seasonal T (86.5 °F = 30.3 °C)	EC, O_3, SO_2, NO_x	EDV for asthma (ICD9 J493), children aged 2–17 years	AP—main exposure, controlling for season (T), weekend, DOW, exposure, allergens	Poisson generalized estimating equations using a 1-day lag between exposure and ED visit; time-series analysis	0.10 $\mu g/m^3$ increase in EC gives 9.45% increase in asthma ED visits among 11–17-year-olds (95% CI = 1.02, 1.17); risk increased with increasing temperatur

Table 1. *Cont.*

Study	Study Area	Study Period	Weather Parameter [1]	Hot Weather Description [2]	Air Pollutant [3]	Health Indicator [4]	Exposure and Confounders [5]	Statistical Methods and Study Design [6]	Results
Park et al. [96]	South Korea: Seoul	June 1999–December 2007	1-hourly T, RH	High temperature: T $\geq$ 90th, 95th percentile of distribution	PM_{10},CO, NO_2, O_3, SO_2 (lag 0–1)	MRC (ICD10 J00–J99)	AP—main exposure, adjusted for T; confounders: long-term and seasonal trends, DOW, holiday, RH, influenza	GLM with natural cubic splines; temperature-stratified model; time-series analysis	O_3 effect stronger in summer; 85+ especially vulnerable to AP during extremely high T
Pascal et al. [106]	France: Bordeaux, Le Havre, Lille, Lyon, Marseille, Paris, Rouen, Strasbourg, Toulouse	2000–2006 (August 2003 excluded due to extreme HW)	T	High temperature: T > 97.5th percentile	PM_{10}, $PM_{10-2.5}$, $PM_{2.5}$, O_3	MRC (ICD10 J00–J99)	AP—main exposure, adjusted for T; confounders: long-term and seasonal trends, DOW, influenza, holiday	GAM; stratification; time-series analysis	Statistically non-significant results for MRC
Pattenden et al. [107]	England and Wales: 15 conurbations	May–September, 1993–2003	Daily T, RH	High temperature: 'Hot days'—2-day T > 95th percentile whole-year distribution	O_3, PM_{10}	MRC (ICD9 4600–5199, ICD-10 'J')	AP—main exposure, adjusted for T; confounders: DOW, holiday, seasonal and long-term time trends; time series analysis	Poisson regression GLM; time-series analysis	Independent association of heat with MRC, mean rate ratio 1.139 (95% CI: 1.079–1.202); adjusted for O_3 mean interaction rate ratio 1.008 (95% CI: 0.992–1.023); high heat and O_3 effect for aged <75
Pinheiro et al. [116]	Brazil: Sao Paulo	1998–2008	Daily T, T_{max}, RH_{min}	High temperature: T > temperature of the minimum mortality	PM_{10}	MRC (ICD10-X), >60 years old	T—main exposure, adjusted for AP; AP—main exposure, adjusted for T; controlled for seasonality, DOW, holidays	(1) Case-crossover approach with different types of case-control matching for isolated effects; (2) GAM, bidirectional case-crossover analysis matched by period, time-series analysis; (3) conditional logistic regression models to compare results (1) and (2)	10 $\mu g/m^3$ increase in PM_{10} for MRC (RR = 1.60% (95% CI: 0.74–2.46)); higher RR for MRC at high T and PM_{10} = 60 $\mu g/m^3$
Qian et al. [97]	China: Wuhan	1 July 2000–30 June 2004	T, RH	High temperature: T > 95th percentile distribution (31.7 °C)	PM_{10}, SO_2, NO_2, O_3	MRC (ICD9 460–519; ICD10 J00–J98)	AP—main exposure, adjusted for T; confounders: DOW, time trend, RH	GAM; stratification; time series analysis	Synergistic effects of PM_{10} and T high: 10 $\mu g/m^3$ increase in PM_{10} (lag 0–1) during T high gives increase in MRC 1.15% (CI: 3.54% to 6.07%)

Table 1. *Cont.*

Study	Study Area	Study Period	Weather Parameter [1]	Hot Weather Description [2]	Air Pollutant [3]	Health Indicator [4]	Exposure and Confounders [5]	Statistical Methods and Study Design [6]	Results
Qin et al. [98]	China: Hefei	January2008–December 2014	Daily T, RH, P	High temperature: T > 95th percentile distribution (30.25 °C)	PM_{10}, SO_2, NO_2	MRC (ICD10 J00–J98) stratified by gender, age (<75, 75–84, 85+)	AP—main exposure, adjusted for t; confounders: holiday, RH, P, age, gender, and educational levels	Quasi-Poisson regression GAM model with natural cubic splines; time series analysis	10 $\mu g/m^3$ at high temperatures was 7.18 (95% CI: 2.44 to 12.13) for PM_{10}, 28.23 (95% CI: 8.25 to 48.61) for SO_2, and 25.58 (95% CI: 3.66 to 47.99) for NO_2
Shaposh-nikov et al. [108]	Russia: Moscow	6 June–18 August 2010	Daily T, RH	HW: T > 97th percentile of the year-round distribution, duration >5 days	PM_{10}, O_3	MRC (ICD10 J00–J98)	T—main exposure, adjusted for AP; confounders: day number, DOW, RH	GLM; identity link and Gaussian errors; data for 2006–2010 used as a corresponding period; time series analysis	Added deaths due to interaction between HW and AP, elevated risks for MRC RR = 2.05 (95% CI: 1.80–2.39)
Song et al. [99]	China: Beijing	January 2009–December 2012	Daily T, RH, P, V, S	High temperature: moderately hot (50th–75th), hot > 75th percentile of distribution	PM_{10}, NO_2, and SO_2, API	REDV (ICD10 J00–J99)	AP—main exposure, adjusted for T	Quasi-Poisson GAM; bivariate response surface model and stratification model; time series analysis	No statistical significance of API effect on REDV on moderately hot days and hot days
Staffogia et al. [74]	Italian cities	1997–2004	Daily T, RH, P	High temperature: city-specific AT = 20–30 °C	PM_{10} (lag 0–1), O_3 (lag 0)	MRC, in-hospital chronic pulmonary diseases (ICD9 490–505), aged 65+	T—main exposure, adjusted for AP; confounders: DOW, RH, P, decrease in population during summer, holidays, influenza epidemics	Case-crossover approach; random-effects meta-analysis; pooled OR of dying on a day with AT = 30 °C compared to a day with AT = 20 °C	High mortality for patients with chronic pulmonary diseases OR = 2.48 (95% CI: 1.50–4.09)
Staffogia et al. [109]	Italian cities	1997–2004	Daily T, Td, P	High temperature: city-specific AT = 50th–75th percentiles and >75th percentile distributions	PM_{10} (lag 0–1)	MRC (ICD9 460–519), aged 35+	AP—main exposure, adjusted for AT(lag 0–1); confounders: DOW, RH, P, decrease in population during summer, holidays, influenza	Case-crossover approach to study the association between PM_{10}/AT and MRC; time-stratified approach to select control days	Higher PM_{10} effects on mortality during T high (lag 0–1 for PM_{10} and T): 10 $\mu g/m^3$ variation in PM_{10}: MRC, RR = 2.54% (95% CI: 1.31–3.78)
Tian et al. [100]	China: Beijing	January 2006–December 2009	Daily T, RH	High temperature: T > 15.9 °C	PM_{10}, NO_2, SO_2	MRC (ICD10: J00–J99), gender, age (<65 years and ≥65 years)	AP—main exposure, adjusted for T; confounders: RH, long-term trend, DOW, holidays, influenza epidemics	GAM; T-stratified parametric model	Strong adverse effects of PM_{10} on MRC at T high: 0.45% (95% CI: 0.13–0.78); stronger effect for elderly

Table 1. *Cont.*

Study	Study Area	Study Period	Weather Parameter [1]	Hot Weather Description [2]	Air Pollutant [3]	Health Indicator [4]	Exposure and Confounders [5]	Statistical Methods and Study Design [6]	Results
Vanos et al. [114]	Canada: 10 cities	1981–1999	4 hourly T, Td, V, R	Weather types: DT (hot and dry), MT (hot and humid)	CO, NO_2, SO_2, O_3	MRC (ICD9 460–519)	AP—main exposure	GLM stratified by season and each of six distinctive synoptic weather types; time-series analysis	Combined effect of weather and AP is greatest during DT and MT air masses in summer
Wang et al. [41]	China: Nanjing	2013–2016	Daily T, RH	Warm season, AT	$PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, O_3	REDV	AT—main exposure, adjusted for AP (lag 0–7); confounders: RH, time trends	Quasi-Poisson regression, GAM; DLNM to evaluate the cumulative and delayed effects of T on health; ER = percent increase with 95% CI in REDV per 10 $\mu g/m^3$ increase in AP concentration; time-series analysis	Warm season: 10 $\mu g/m^3$ increase in $PM_{2.5}$ and PM_{10} concentration on the current day of exposure (lag 0), increase in RESD ER = 0.35% (95% CI: 0.20–0.50); more serious impact than in cold season
Wang et al. [101]	Taiwan: 15 cities and counties (without Taipei)	2006–2014	Hourly T, T_{max}, T_{min}, RH, V, P	High temperature: T > 99th percentile of distribution relative to 25 °C (T with the lowest AC frequency)	PM_{10}, $PM_{2.5}$	AC for respiratory distress	T—main exposure, adjusted for AP; confounders: time trend, V, RH, DOW, holiday, pneumonia and influenza	DLNM with a quasi-Poisson function	Exposure to 99th percentile of $PM_{2.5}$ and T control: significant for respiratory distress events; more likely to occur in low temperatures
Wang et al. [102]	China: 18 sites	2014–2017	Daily T, RH, P	High temperature:T during summer (June to August)	$PM_{2.5}$ (lag 0–2), O_3, (lag 0–2), PM_{10}, CO, NO_2, SO_2	REDV (ICD10: J00–J9), divided by gender, age–groups (<17, 18–44, 45–59, 60–74, ≥75)	T—main exposure, adjusted for AP; confounders: RH, P, DOW, long-term trend	Quasi-Poisson GAM for each study site; time series analysis	High T exposure increased REDVs risks; patients >18 more vulnerable to T high
Wang et al. [103]	China: Beijing	January 2016–December 2017	Daily T, RH	Warm season: May to October	PM_1, $PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, O_3	REDV (ICD10: J00–J9), divided by gender, age–groups (<25, 25–65, ≥65)	AP—main exposure, adjusted for T; confounders: RH, DOW, long-term trend	GLMs; time series analysis	Stronger associations between PM exposure and EDVs during warm season
Ye et al. [104]	Japan: Tokyo	1980–1995, July and August	T_{max}, RH	High temperature:T_{max} during summer	NO_2, O_3, SO_2, CO, PM_{10} (lag 1–4)	REDV (ICD9: acute bronchitis 466, pneumonia 486, chronic bronchitis 491, asthma 493), gender, 65+	AP; T_{max}; confounders: annual trends, gender	GLMs; time series analysis	PM_{10} and NO_2 are associated with daily REDV; greater for males than for females, except for angina and acute bronchitis

Table 1. *Cont.*

Study	Study Area	Study Period	Weather Parameter [1]	Hot Weather Description [2]	Air Pollutant [3]	Health Indicator [4]	Exposure and Confounders [5]	Statistical Methods and Study Design [6]	Results
Zhang et al. [105]	China: Beijing	January 2009–December 2011	T, RH	High temperature: T > 28 °C	PM_{10}, $PM_{2.5}$ (lag 0–1)	REDV (ICD10: J00–J99)	AP—main exposure, adjusted for T; confounders: calendar day, DOW, holidays, RH, influenza	Three GAMs, including a bivariate response surface model, a non-stratification parametric model, and a stratification parametric model	Increase in REDVs per 10 μg/m^3 increase in $PM_{2.5}$ and PM_{10} at T high (>28 °C): 0.35% for $PM_{2.5}$, 0.08% for PM_{10}; elderly (age ≥ 65) and women are more vulnerable to PM at high temperatures

[1] T—air temperature (°C); Td—dew point temperature (°C); RH—relative humidity (%); V—wind speed (m/s); D—wind direction (degrees); P—barometric pressure (hPa); S—hours of sunshine (h); R—precipitation (mm); CC—cloud cover (points). [2] AT—apparent temperature calculated as a combination of T and Td [117,118]; DTL—daily temperature level; HW—heat wave; DT—dry tropical air mass; MT—moist tropical air mass. [3] API—air pollution index; PM_{10}—particulate matter with aerodynamic diameter <10 μm (μg/m^3); $PM_{2.5}$—particulate matter with aerodynamic diameter <2.5 μm (μg/m^3); PM_1—particulate matter with aerodynamic diameter <1 μm (μg/m^3); O_3—ozone (μg/m^3 or ppb); NO_2—nitrogen dioxide (μg/m^3); NO_x—total oxides of nitrogen (μg/m^3); SO_2—sulfur dioxide (μg/m^3); SO_x—total oxides of sulfur (μg/m^3); CO—carbon monoxide (μg/m^3); EC—elemental carbon particulate matter less than or equal to 2.5 μm in diameter (μg/m^3). [4] AC—ambulance call; ICD8, 9, 10—Primary International Classification of Disease, Eighth, Ninth, or Tenth Revision; COPD—chronic obstructive pulmonary disease; EDV—emergency department visits; MRC—daily mortality from respiratory causes; PEF—peak expiratory flow, used for lung function test (l/min); REDV—respiratory emergency department visits; HA—hospital admissions. [5] AP—air pollution; DOW—day of the week. [6] CI—confidence interval; DLNM—distributed lag non-linear model; DNN—deep neutral network; ER—excess risk; GAM—generalized additive model; GEE—generalized estimating equations; GLM—generalized linear model; OR—odds ratio; RR—rate ratio. [7] Controversial results are underlined.

4. Discussion

Episodes of hot weather and poor air quality pose significant consequences for public health. Numerous researchers revealed that both ambient temperature and air pollution are associated with human health. Although many studies on the association of temperature and mortality/morbidity adjusted for concentration of air pollutants, few of them considered the potential synergistic effects of temperature and air contaminants. In this review, we looked for relevant studies and summarized the findings to get a general understanding of this problem. We focused on the main air pollutants: sulphur dioxide, oxides of nitrogen, including nitrogen dioxide; carbon monoxide; particulate matter (PM) with PM_{10} and $PM_{2.5}$ being the main pollutants; and ozone. Most studies suggested that there were interactive effects between temperature and air pollution on human health, and the results varied among different geographic regions. The health consequences varied from premature death to decreases in lung function, new onset of diseases, exacerbation of chronic respiratory diseases, and lung cancer.

Much is known about the relation between high ambient temperature, air pollution, all-course and cardiovascular mortality [122], independent associations of hot weather, polluted air environment, and respiratory health [1,67,123], but the combined effect on disease-specific events, such as respiratory, is less clear. The current review shows the role of pollutants on respiratory health impacts may vary with hot weather conditions. The modifying effect of the high temperature on the air pollution–respiratory health indicators relationship was scarcely reported in recent years, although it is well known that high temperatures have an important action on the transport and the dispersion of pollutants in the air and vice versa [78], causing the plausible effect on respiration. Increased mortality and morbidity are associated with heat wave episodes; an interesting aspect is the role of air pollution in this relationship [1,67].

In the reviewed studies on effects of air pollution and temperature on human health, temperature was generally corrected to efficiently analyze the health impacts of ambient particles; otherwise, air pollutants were also adjusted when investigating the influence of temperature on mortality. Each identified a significantly enhanced mortality and morbidity effect for increasing values of both air contaminants and high temperature. However, a relatively small number of papers were found to confirm our hypothesis, which considerably limits the scientific significance of the current paper and is a great potential for further research. The large differences in the results obtained do not allow us to collect them in a meta-analysis and provide reliable, mathematically confirmed evidence with statistical weights about the jeopardized effect of exposure to both high temperature and air pollution on respiratory outcomes. Another problem identified is that the interaction between the temperature and the pollution continues to be vague, as some studies showed non-statistically significant coefficients for the interaction between air pollution, high temperature, and respiratory outcomes [57,86,99,106].

Many additional factors could shed more light on the confounding effect of interactions in the relationship of hot weather–air pollution–respiratory health and ways to mitigate these implications, which are discussed below.

4.1. Wildfires

A very significant consideration is the occurrence of wildfires caused by hot weather, which are associated with dangerous levels of pollutants and therefore affect respiratory health [9,63,108,124,125]. A vivid manifestation is the several large wildfires of unprecedented scale and duration that occurred recently, including wildfires in European Russia in 2010 [108,126], Australia in 2019 to 2020, the Amazon rainforest in Brazil in 2019 and 2020, the western United States in 2018 and 2020, and British Columbia, Canada in 2017 and 2018, with the huge impact on the population in terms of adverse effects on respiratory health [127].

The mechanisms that explain the respiratory effects of wildfires are mainly related to the air pollution associated with these events. Wildfire smoke is a complex mixture of

thousands of compounds, primarily $PM_{2.5}$, carbon dioxide, hydrocarbons, and nitrogen oxides, which contribute to increase air pollution locally and regionally. In multiple studies, air pollution from wildfire smoke was associated with more asthma exacerbations, ED visits, and hospitalizations for bronchitis, dyspnea, and COPD symptoms. Wood smoke particles can activate systemic and pulmonary inflammation, even in healthy human subjects [1,125,128–136].

Extreme events such as wildfires and prolonged heat waves and drought are causing increases in pollutants such as particulate matter and ground level ozone, often to dangerous levels. Due to high ambient temperature during wildfire, there is also a potential for interaction as evidenced by the combination of HW and wildfire conditions [1,108,126,137]. This mutual influence can be explained at the point of emissions by changes in smoke components caused by temperature, sunlight, water vapor, and interaction with other pollutants [138].

Next, a few more important points should be discussed. An in vivo experiment showed that the responses to wood smoke consist of higher inflammatory and cytotoxic reactions than those caused by urban particulate matter [139], suggesting that wildfire contamination is more dangerous than urban pollution. Another problem is that, although forest fires can only occur in certain regions, their smoke plumes can spread over long distances [130]. More research is needed to assess long-term health effects from wildfires [129]. The understanding of such factors is vital to ensuring that health care services are prepared for these events.

4.2. Urban Heat Island Effect

The problem of outdoor pollution is not new, but rapid urbanization is making the problem of air pollution more visible and its load on human health more noticeable [12,140,141]. Extreme heat events at urban centers in combination with air pollution pose a serious risk to human health. Studies showed the coupled interaction of urban heat island and air pollution increases hospital respiratory admissions and hospitalizations in the warm center of urban areas [141–143]. The prognostic doubling of urban population within the next two decades and the disproportionate growth of megacities make it critical to explore the synergism between urban heat and pollution [143].

Urban populations are likely to be particularly at risk, but the role of urban characteristics in changing the direct health effects of temperature is still debated due to a variety of modulating causes. For example, the impact of heat on mortality is higher in cities characterized by high population density, higher levels air pollution, fewer green spaces, and lower availability of health services [144].

4.3. Possible Biological Mechanisms

Several different explanations are proposed for the synergistic effects between ambient pollution and high temperature on human health [1,7,93,145]. Since the respiratory surface is a primary route by which air pollutants enter the body, prolonged heat exposure may activate three key mechanisms of thermoregulatory responses, which include: secretion of sweat glands, vasodilatation, and increase in ventilation rate and lung volumes, which in turn can directly or indirectly affect toxic substances entering the body and raise the total intake of airborne pollutants [1,7,145–147]. Next, high ambient temperature increases skin permeability, providing an easier way for air pollutants to be absorbed by the skin surface [145,148].

Pathophysiological mechanisms are discussed in detail in [55]. First, a combination of heat load and gaseous polluted environment leads to an inflammation of the bronchial mucosa and lowers the bronchoconstriction threshold; the accompanying fluid loss additionally contributes to subsequent changes in perfusion and ventilation, causing acute and chronic injury to lung tissue by gaseous particles in polluted air, such as greenhouse gases, nitrogen dioxide, sulfur dioxide, and ozone [149]. Secondly, fine PM of different size "destroys the integrity of endothelial cells via the signal transduction pathways that depend

on reactive oxygen derivates and p38-activated protein kinase and is involved in the pathogenesis of cardiopulmonary disorders", which is explained in detail in [47,50]. Moreover, the synergistic interaction of heat and concentrations of noxious/toxic substances in the air leads to exacerbations, especially of asthma and COPD [150,151]. Experiments on animals show the importance of hot air as a pathological substrate of bronchoconstriction and penetration of tissue-toxic elements [152,153]. Additionally, some evidence was found to demonstrate the increase in airway resistance during hot and humid days more rapidly than in cold air, triggering asthma symptoms, most likely by stimulating airway C-fiber nerves [130,154,155].

The delayed associations between exposure and outcome—or the "lagged" effect of air pollution, thermal exposure, or both—of different lengths (mostly 0–2 days) on respiratory mortality and morbidity were demonstrated in many studies [68,78,89,97,111,115]. It can be supposed that respiratory diseases are slower in their development and are therefore more lagged [29].

However, excess mortality may be followed by fewer deaths than expected during the next period of time, which is called a harvesting effect or mortality displacement [30,53,55,75,156–160]. A harvesting effect is found to partly or even fully balance the observed excess health outcomes due to heat. One more consideration can be shown for a sharp decrease in deaths to hospital admissions, with some suggestion of displacement or harvesting for respiratory admissions [159].

4.4. Virus and Bacteria Infections and Epidemics

Evidence supports a clear effect of air pollution on respiratory infections interacting to adversely affect the respiratory system, contributing to the recent coronavirus disease 2019 (COVID-19) pandemic. Most research indicated that chronic exposure to air pollutants leads to more severe and lethal forms of COVID-19, delaying and complicating the recovery period after the disease [161,162]. Areas with frequently high levels of air pollution—exceeding safe levels of ozone or particulate matter—had higher numbers of COVID-19 related infected individuals and deaths [163].

The biochemical and the physiological mechanisms behind this effect include a number of functional changes involving endothelial dysfunction, endothelial activation, and injury [44]. These local changes in the lung promote pulmonary responses, affecting airway function and resistance to viruses and bacteria, increasing the risk of infection, for example, upper respiratory tract infections, bronchitis, and pneumonia [44]. Moreover, high concentrations of nitrogen dioxide and particulate air pollutant induce serious damages to the immune system of people, weakening it to cope with infectious diseases of viral agents [164]. Knowing the associations between polluted environment and human respiratory infections in different temperature regimes may decrease turbulence and spread of a new COVID-19 pandemic and any other in the future.

4.5. Indoor Pollution

Indoor pollution obtained from a variety of sources such as ventilation and building materials, use of biomass fuels for heating and cooking, active indoor smoking, pesticides, incense, and biological pollutants such as dust, dandruff, furniture, and mold might be combined with high indoor temperatures [9,21,28,165,166]. In addition to ambient contaminants, exposure to poor indoor air quality is linked to many acute and chronic respiratory health outcomes such as general respiratory complaints, exacerbation of asthma symptoms and COPD, diminished lung function, lung cancer, and mortality, with women and young children being disproportionately affected due to time spent indoors [21,24,28,36,45,167,168].

4.6. Vulnerable or Susceptible Population Groups

Pre-existing respiratory diseases are important vulnerabilities to both thermal effect and air contamination. Since exposure factors are specific to each climate hazard and can vary by populations and over time, more research is needed, particularly for younger age cohorts and children as well as for other parts of the population, such as socioeconomic

groups with low income [46]. Vulnerable population subgroups were identified in regard to the effects of air pollution and/or heat, including: elderly; care homes' residents; young children; patients with cardio-respiratory disease asthma, renal diseases, and diabetes; people with obesity as well as those who takes certain drug therapy; and those who live in densely populated urban neighborhoods [1,5,40,46,75,95,107,169–171]. For example, some evidence was shown in England and Wales that ozone effects were worse on hot days, particularly for those aged <75 [107]. In addition, there were clear differences by sex: specifically, females showed higher mortality risk, and males showed higher hospitalization risk [172].

The elderly age cohort shows an increased sensitivity to exposure of both atmospheric pollution and thermal impact, which is probably explained by an excessive manifestation of concomitant diseases (diabetes, various acute heart disease such as congestive heart failure or myocardial infarction, etc.), by reduced respiratory and antioxidant capabilities, and by rise of inflammatory phenomena, even in healthy people [2,144,173]. The interacting effect between air contaminants and extremely high temperature is biologically plausible for the elderly, whose ability to thermo-regulate body temperatures is reduced, and sweating thresholds are generally elevated in comparison with younger people [95]. Inflammatory and immunological reactions in children are significantly contrasted compared to other age groups, which may possibly determine a higher degree of influence on children [120,174].

4.7. Confounder Effect of Multiple Environmental Stressors

Exposure to poor air quality and thermal load both already affect human health independently, but their combined occurrence poses an intensified threat to human life, especially as synergistic effects lead to a risk beyond the sum of their individual effects [4]. The idea of multiple environmental stressors supports the assumption that it is a scientific apparatus for organizing and evaluating relevant scientific data to identify and evaluate the cumulative effects of various environmental factors that negatively affect human health [175,176]. For instance, the Air Pollution Index assesses the combined effects of main air pollutants to determine whether their impacts on respiratory morbidity and mortality are affected by temperature, age, gender, pre-existing disease, as well as other confounders and effect modifiers, such as socioeconomic conditions, urbanicity, and central air conditioning [99]. Multiple air pollutants may be most responsible for increased impact on cardiopulmonary health, which would need to be taken into account in the future research [41]. Heterogeneity of the results of the joint effect of high temperature and air contamination on respiratory health may reflect the characteristics of the study sites, such as weather patterns, air pollution levels and components of pollution mixture, use of air-conditioning or heating systems, sensitivity of local residents to air pollution (e.g., gender, age, and smoking rate), and possibly other socioeconomic characteristics [79]. An important addition was proposed by Abed Al Ahad with coauthors [177] that the analysis of interaction between air pollution and weather stressors beyond specific limits and their effect on respiratory health should be supplemented by study of the major socio-demographics modifiers, such as ethnicity, occupational/educational/marital status, and others [177].

Other challenges may be specific parameters of the study area. For example, the impact on the population of outdoor temperature and air pollution may vary depending on social-economic status, use of air conditioners, local habits associated with opening windows, traditions in the house design, etc. Results from studies on the interaction of temperature and air pollution suggest that this topic cannot be ignored when detecting the effects of temperature or air pollution on respiratory causes, since the real scale of the relations may be understated. Overall, results differ depending on the pollutant under consideration and the study area, assuming that the original regularities are led by local conditions.

Many studies showed that, to explore the respiratory system status under environmental exposure, not only temperature is used but also air humidity [178,179] as well as special

indices such as apparent temperature, which determines the combined effect of weather parameters together with air pollutants [6,114,117,118]. It should be noted that, although absolute humidity correlates with air temperature, it can itself significantly change the impact of air pollutants on health outcomes [180].

Some results for mortality and hospital respiratory admissions showed the synergistic effects of long-term exposures to air pollution and temperature were associated with larger effects compared to short-term exposures; one possible explanation is the suggested evidence provided in studies on the effects of heat waves and air pollution on mortality that respiratory diseases are slower in their development and are therefore more lagged than, for example, cardiovascular diseases, which can initiate an acute body response [29,59,181].

Although there was evidence of a synergetic effect of air pollution and high temperatures during HW episodes, a slight decrease in thermal effects was found when models included O_3 and PM_{10} [5,110], which should be analyzed in future research.

4.8. Climate Change

Almost all climate events will worsen under climate change, as will the related disease burden. Climate and climate change are modifying air pollution effects on respiratory health in several ways: climate variations are predicted to increase frequency and intensity of heatwaves and wildfires, cause longer fire and pollen seasons, influence start, duration, and intensity of the pollen season, increase aero-allergenic plant pollen production, and raise long-term transport of air pollutants and allergens [1,9,84,121,182,183].

To better assess the potential impact of current climate change scenarios on human health, it is mandatory to comprehend not only the separate effects of temperature and other weather characteristics (adjusted for confounders, including air contamination) but also to understand any combined effect between meteorology and air pollution. It is proper to assume that the synergistic interactions between high ambient temperature and air pollution will become more important under extreme conditions that could occur in the future due to larger climate volatility [5,37,184]. Global climate models predict not only warmer temperatures on average but more frequent extreme weather events [6,185], which increase the threat of weather-related health outcomes [186].

Mitigation and age-specific adaptation strategies might greatly reduce the temperature-related mortality burden in the future climate change realm. If people cannot adapt to future climate change, heatwave-related excess mortality is expected to increase the most in tropical and subtropical countries/regions, while European countries and the United States will have smaller increases [37]. At the same time, considering future impacts on respiratory diseases, progressive population aging, growing spread of chronic diseases, and socioeconomic transformations that are currently taking place in a number of countries, especially in Europe and Northern America, will probably raise the portion of the population at risk [186,187]. This is crucial for individuals with impaired adaptation to weather variability, such as the elderly.

Another consideration is the increase in both urbanized and wildfire areas due to climate change. The risk of wildfire frequency is increasing in most areas of the world as climate change worsens [119], with projections of the fires to raise excess mortality and morbidity as well as mental health effects from burns and wildfire smoke [124,127,129]. Therefore, there is an urgent need to further understand the health effects and the public awareness of wildfires [108,183]. Due to climate change and other factors, such as the relatively rapid grow of urban population up to 5.2 billion in 2050 [188], the nature of pollution is changing in several urbanized areas worldwide, which has a significant impact on respiratory health, both separately and synergistically with weather state [1,188].

Another key research need for future studies is to compare the health burdens of future air quality under a changing climate with alterations in other risk factors. Warmer temperatures from climate change and increased amounts of carbon dioxide can cause increased growth of aero-allergenic plant pollen production, which leads to extension of pollen seasons with warmer springs and delays in first fall frost, therefore leading to increased production

of pollen [9,182,189]. Climate change may impact the incidence of bacterial, viral, fungal, and tick-borne respiratory infections in terms of incidence, total duration, and severity of these infectious diseases, increasing their overall incidence and geographical spread [9,17]. The only way to solve this problem is to inform the public using the multisectoral approach of the scientific community. National and international organizations must deal with the emergence of this threat and offer sustainable, viable decisions.

4.9. Prevention Policy

At last, decades-long periods of both high air temperature and air pollution, including wildfires, are becoming an important issue of global concern, exacerbating health outcomes and corresponding health-care expenditures. A significant impact of air pollution, including episodes of wildfires, on health-care costs related to respiratory diseases was identified [42,108,159,183,190,191]. Addressing these challenges requires the interdisciplinary cooperation of epidemiologists, climate scientists, respiratory and allergy physicians, policy makers, and public health professionals to jointly guide the world through the climate crisis, making the environment sustainable for future generations. Furthermore, the governments should strengthen environmental management, pay attention to the heterogeneity of the healthcare expenditure burden affected by both high temperatures and environmental pollution, ameliorate the medical insurance system, and improve the health of residents [65,66,137,159,192,193]. Moreover, policy makers should enhance the emission control of air pollution in high temperature days, especially to target pollutants produced by motor vehicles [78,91], and strengthen health education propaganda [89].

Taking into account the interrelationships between current and future climates and pollution challenges, adequate mitigation policy and public health actions are needed to face the two hazardous exposures. Considering the predicted increase in heat waves and stagnation events, it is time to enclose air pollution within public health heat prevention plans.

The prospect of global warming requires a more accurate assessment of how a hotter environment can affect the human response to toxic chemicals [192,193]. In climate change scenarios, the increase in extreme weather events and some air contaminants, particularly ozone, is likely to further exacerbate chronic respiratory disorders. Public health measures should aim to prevent this additional burden of illness in summer periods and especially during HW [30,65,193,194]. Identifying population groups that are more susceptible to weather variability is of paramount importance for the development of public health policies that protect them [5,195,196]. Recognizing the sources and the concentrations of air pollutants helps to establish the new regulations for control measures. This subsequently leads to the diminishing mortality of infants and children under the age of five [25], the elderly [196,197], and the low-income population [194,195]. Short-term public health activities to decrease heat-related morbidity should target sensitive population groups to assure access to air conditioning, evaporative coolers, fans, adequate fluid intake, etc. [194,195,197]. On the other hand, on hot days, emissions of pollutants may be further increased by behavioral changes when inhabitants of cities may choose to use their possibly air-conditioned car more often [79].

Long-term prevention efforts should aim to improve the general health condition of people at risk, implementing special prevention plans for cities [125,137,198,199] and conceptualizing special green and blue infrastructure in the built environment [199–201], with the paramount need to establish joint heat and air pollution warning systems [59,66,186,193,202]. Sustainable urban planning and smart city design developing integrated sustainability performance for innovative energy systems in smart cities could significantly reduce both UHIs and air pollution [203,204], enhance human thermal comfort, and decrease heat- and pollution-related mortality, thus saving lives [200].

It is also important to better comprehend the influence of climate characteristics on the direction and the spatio-temporal spread of wild fires [205]. The use of remote sensors

would help identify the components of pollution during fires and assess the temperature rise associated with fires [125,131,136].

5. Conclusions

Air-pollution and hot weather exposure beyond certain thresholds have serious effects on respiratory health, with the elderly and young children being the most vulnerable groups. However, there is a lack of information on broader perspectives, including the role of some exposure modifiers and the interaction between air pollution and weather characteristics. The purpose of this paper is to provide a holistic overview and descriptive synopsis of the literature on the association of air pollution and weather with mortality and hospitalization and to identify gaps in scientific knowledge that need further research. The final review included 40 articles, from which 24 involved mortality, 15 incorporated respiratory emergency transportations and hospital admissions, and 1 reviewed lung cancer incidence. Air-pollution was shown to act consistently as a risk factor for respiratory mortality and morbidity. Hot temperature was a risk factor for a wide range of respiratory disease. The role of effect modification in the included studies was investigated in terms of gender and age. These findings are important for public health, as the high spread of chronic diseases such as COPD is expected to increase, especially in developed countries as a result of an aging population. Effect alteration of important socio-demographics and the interaction between air pollution and weather is often missed in the literature. Climate and climate change are shifting, combining influences of hot weather and air pollution on respiratory health in several ways. Climate variations are predicted to increase frequency and intensity of heat waves and wildfires, raise long-range transport of air pollutants and allergens, and influence start, duration, and intensity of the pollen season. Moreover, with regard to climate changes, it is generally accepted that global warming increases the health effects of outdoor air pollution, resulting in more heat waves, during which levels of air pollutants raise and high temperatures and air contamination act in synergy, causing more serious health impacts than those estimated from heat or pollution alone.

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References

1. De Sario, M.; Katsouyanni, K.; Michelozzi, P. Climate change, extreme weather events, air pollution and respiratory health in Europe. *Eur. Respir. J.* **2013**, *42*, 826–843. [CrossRef] [PubMed]
2. Veremchuk, L.V.; Mineeva, E.E.; Vitkina, T.I.; Grigorieva, E.A.; Gvozdenko, T.A.; Golokhvast, K.S. The response ranges of pulmonary function and the impact criteria of weather and industrial influence on patients with asthma living in Vladivostok. *J. Environ. Health Sci. Eng.* **2020**, *18*, 235–242. [CrossRef] [PubMed]
3. Pope, C.A., III; Burnett, R.T.; Thun, M.J.; Calle, E.E.; Krewski, D.; Ito, K.; Thurston, G.D. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA* **2002**, *287*, 1132–1141. [CrossRef]
4. Katsouyanni, K.; Analitis, A. Investigating the Synergistic Effects between Meteorological Variables and Air Pollutants: Results from the European PHEWE, EUROHEAT and CIRCE Projects. *Epidemiology* **2009**, *20*, S264. [CrossRef]
5. Analitis, A.; Donato, F.D.; Scortichini, M.; Lanki, T.; Basagana, X.; Ballester, F.; Astrom, C.; Paldy, A.; Pascal, M.; Gasparrini, A.; et al. Synergistic Effects of Ambient Temperature and Air Pollution on Health in Europe: Results from the PHASE Project. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1856. [CrossRef]

6. Lepeule, J.; Litonjua, A.A.; Gasparrini, A.; Koutrakis, P.; Sparrow, D.; Vokonas, P.S.; Schwartz, J. Lung function association with outdoor temperature and relative humidity and its interaction with air pollution in the elderly. *Environ. Res.* **2018**, *165*, 110–117. [CrossRef] [PubMed]
7. Jiang, Y.; Chen, R.; Kan, H. The Interaction of Ambient Temperature and Air Pollution in China. In *Ambient Temperature and Health in China*; Springer Nature: Singapore, 2019; pp. 105–116.
8. Krug, A.; Fenner, D.; Holtmann, A.; Scherer, D. Occurrence and Coupling of Heat and Ozone Events and Their Relation to Mortality Rates in Berlin, Germany, between 2000 and 2014. *Atmosphere* **2019**, *10*, 348. [CrossRef]
9. Joshi, M.; Goraya, H.; Joshi, A.; Bartter, T. Climate change and respiratory diseases. *Curr. Opin. Pulm. Med.* **2020**, *26*, 119–127. [CrossRef] [PubMed]
10. The Intergovernmental Panel on Climate Change. Available online: https://www.ipcc.ch/ (accessed on 20 May 2021).
11. Orru, H.; Ebi, K.L.; Forsberg, B. The Interplay of Climate Change and Air Pollution on Health. *Curr. Environ. Health Rep.* **2017**, *4*, 504–513. [CrossRef]
12. Sweileh, W.M.; Al-Jabi, S.W.; Zyoud, S.H.; Sawalha, A.F. Outdoor air pollution and respiratory health: A bibliometric analysis of publications in peer-reviewed journals (1900–2017). *Multidiscip. Respir. Med.* **2018**, *13*, 1–12. [CrossRef]
13. Lelieveld, J.; Barlas, C.; Giannadaki, D.; Pozzer, A. Model calculated global, regional and megacity premature mortality due to air pollution. *Atmos. Chem. Phys. Discuss.* **2013**, *13*, 7023–7037. [CrossRef]
14. Karimi, B.; Shokrinezhad, B.; Samadi, S. Mortality and hospitalizations due to cardiovascular and respiratory diseases associated with air pollution in Iran: A systematic review and meta-analysis. *Atmos. Environ.* **2019**, *198*, 438–447. [CrossRef]
15. Sicard, P.; Khaniabadi, Y.O.; Perez, S.; Gualtieri, M.; De Marco, A. Effect of O3, PM10 and PM2.5 on cardiovascular and respiratory diseases in cities of France, Iran and Italy. *Environ. Sci. Pollut. Res.* **2019**, *26*, 32645–32665. [CrossRef]
16. Soleimani, Z.; Boloorani, A.D.; Khalifeh, R.; Teymouri, P.; Mesdaghinia, A.; Griffin, D.W. Air pollution and respiratory hospital admissions in Shiraz, Iran, 2009 to 2015. *Atmos. Environ.* **2019**, *209*, 233–239. [CrossRef]
17. Manisalidis, I.; Stavropoulou, E.; Stavropoulos, A.; Bezirtzoglou, E. Environmental and Health Impacts of Air Pollution: A Review. *Front. Public Health* **2020**, *8*, 14. [CrossRef]
18. Revuelta, M.A.; McIntosh, G.; Pey, J.; Pérez, N.; Querol, X.; Alastuey, A. Partitioning of magnetic particles in PM10, PM2.5 and PM1 aerosols in the urban atmosphere of Barcelona (Spain). *Environ. Pollut.* **2014**, *188*, 109–117. [CrossRef]
19. Chen, H.-L.; Li, C.-P.; Tang, C.-S.; Lung, S.-C.; Chuang, H.-C.; Chou, D.-W.; Chang, L.-T. Risk Assessment for People Exposed to $PM_{2.5}$ and Constituents at Different Vertical Heights in an Urban Area of Taiwan. *Atmosphere* **2020**, *11*, 1145. [CrossRef]
20. Nogarotto, D.C.; Pozza, S.A. A review of multivariate analysis: Is there a relationship between airborne particulate matter and meteorological variables? *Environ. Monit. Assess.* **2020**, *192*, 1–14. [CrossRef] [PubMed]
21. Abdo, N.; Khader, Y.S.; Abdelrahman, M.; Graboski-Bauer, A.; Malkawi, M.; Al-Sharif, M.; Elbetieha, A.M. Respiratory health outcomes and air pollution in the Eastern Mediterranean Region: A systematic review. *Rev. Environ. Health* **2016**, *31*, 259–280. [CrossRef] [PubMed]
22. Cohen, A.J.; Brauer, M.; Burnett, R.; Anderson, H.R.; Frostad, J.; Estep, K.; Balakrishnan, K.; Brunekreef, B.; Dandona, L.; Dandona, R.; et al. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: An analysis of data from the Global Burden of Diseases Study 2015. *Lancet* **2017**, *389*, 1907–1918. [CrossRef]
23. Newell, K.; Kartsonaki, C.; Lam, K.B.H.; Kurmi, O. Cardiorespiratory health effects of gaseous ambient air pollution exposure in low and middle income countries: A systematic review and meta-analysis. *Environ. Health* **2018**, *17*, 1–14. [CrossRef] [PubMed]
24. Amoatey, P.; Sicard, P.; De Marco, A.; Khaniabadi, Y.O. Long-term exposure to ambient PM2.5 and impacts on health in Rome, Italy. *Clin. Epidemiol. Glob. Health* **2020**, *8*, 531–535. [CrossRef]
25. Karimi, B.; Shokrinezhad, B. Air pollution and mortality among infant and children under five years: A systematic review and meta-analysis. *Atmos. Pollut. Res.* **2020**, *11*, 61–70. [CrossRef]
26. Jerrett, M.; Shankardass, K.; Berhane, K.; Gauderman, W.J.; Künzli, N.; Avol, E.; Gilliland, F.; Lurmann, F.; Molitor, J.N.; Molitor, J.T.; et al. Traffic-Related Air Pollution and Asthma Onset in Children: A Prospective Cohort Study with Individual Exposure Measurement. *Environ. Health Perspect.* **2008**, *116*, 1433–1438. [CrossRef]
27. Ren, C.; Tong, S. Health effects of ambient air pollution–recent research development and contemporary methodological challenges. *Environ. Health* **2008**, *7*, 56. [CrossRef]
28. Hogea, S.; Tudorache, E.; Fildan, A.P.; Fira-Mladinescu, O.; Marc, M.; Oancea, C.; Stanca, P.H. Risk factors of chronic obstructive pulmonary disease exacerbations. *Clin. Respir. J.* **2019**, *14*, 183–197. [CrossRef]
29. Zanobetti, A.; Schwartz, J.; Samoli, E.; Gryparis, A.; Touloumi, G.; Peacock, J.; Anderson, R.H.; Le Tertre, A.; Bobros, J.; Celko, M.; et al. The temporal pattern of respiratory and heart disease mortality in response to air pollution. *Environ. Health Perspect.* **2003**, *111*, 1188–1193. [CrossRef]
30. Michelozzi, P.; Accetta, G.; De Sario, M.; D'Ippoliti, D.; Marino, C.; Baccini, M.; Biggeri, A.; Anderson, H.R.; Katsouyanni, K.; Ballester, F.; et al. High Temperature and Hospitalizations for Cardiovascular and Respiratory Causes in 12 European Cities. *Am. J. Respir. Crit. Care Med.* **2009**, *179*, 383–389. [CrossRef] [PubMed]
31. Samoli, E.; Zanobetti, A.; Schwartz, J.; Atkinson, R.; Le Tertre, A.; Schindler, C.; Perez, L.; Cadum, E.; Pekkanen, J.; Paldy, A.; et al. The temporal pattern of mortality responses to ambient ozone in the APHEA project. *J. Epidemiol. Community Health* **2009**, *63*, 960–966. [CrossRef]

32. Nejjari, C.; Marfak, A.; Rguig, A.; Maaroufi, A.; El Marouani, I.; El Haloui, A.; El Johra, B.; Ouahabi, R.; Moulki, R.; Azami, A.I.; et al. Ambient air pollution and emergency department visits among children and adults in Casablanca, Morocco. *AIMS Public Health* **2021**, *8*, 285–302. [CrossRef]
33. Fuzzi, S.; Baltensperger, U.; Carslaw, K.; Decesari, S.; Van Der Gon, H.D.; Facchini, M.C.; Fowler, D.; Koren, I.; Langford, B.; Lohmann, U.; et al. Particulate matter, air quality and climate: Lessons learned and future needs. *Atmos. Chem. Phys. Discuss.* **2015**, *15*, 8217–8299. [CrossRef]
34. Jiang, X.-Q.; Mei, X.-D.; Feng, D. Air pollution and chronic airway diseases: What should people know and do? *J. Thorac. Dis.* **2016**, *8*, E31–E40. [CrossRef] [PubMed]
35. Chen, K.; Vicedo-Cabrera, A.M.; Dubrow, R. Projections of Ambient Temperature- and Air Pollution-Related Mortality Burden under Combined Climate Change and Population Aging Scenarios: A Review. *Curr. Environ. Health Rep.* **2020**, *7*, 243–255. [CrossRef] [PubMed]
36. Chatkin, J.; Correa, L.; Santos, U. External Environmental Pollution as a Risk Factor for Asthma. *Clin. Rev. Allergy Immunol.* **2021**, 1–18. [CrossRef]
37. Guo, Y.; Gasparrini, A.; Li, S.; Sera, F.; Vicedo-Cabrera, A.M.; Coelho, M.; Saldiva, P.; Lavigne, E.; Tawatsupa, B.; Punnasiri, K.; et al. Quantifying excess deaths related to heatwaves under climate change scenarios: A multicountry time series modelling study. *PLoS Med.* **2018**, *15*, e1002629. [CrossRef] [PubMed]
38. Sun, K.; Song, Y.; He, F.; Jing, M.; Tang, J.; Liu, R. A review of human and animals exposure to polycyclic aromatic hydrocarbons: Health risk and adverse effects, photo-induced toxicity and regulating effect of microplastics. *Sci. Total Environ.* **2021**, *773*, 145403. [CrossRef]
39. Wang, F.; Chen, T.; Chang, Q.; Kao, Y.-W.; Li, J.; Chen, M.; Li, Y.; Shia, B.-C. Respiratory diseases are positively associated with PM2.5 concentrations in different areas of Taiwan. *PLoS ONE* **2021**, *16*, e0249694. [CrossRef]
40. *Review of Evidence on Health Aspects of Air Pollution—REVIHAAP Project: Final Technical Report*; Technical Report; WHO: Geneva, Switzerland, 2013.
41. Wang, C.; Feng, L.; Chen, K. The impact of ambient particulate matter on hospital outpatient visits for respiratory and circulatory system disease in an urban Chinese population. *Sci. Total Environ.* **2019**, *666*, 672–679. [CrossRef]
42. Liu, J.; Yin, H.; Tang, X.; Zhu, T.; Zhang, Q.; Liu, Z.; Tang, X.; Yi, H. Transition in air pollution, disease burden and health cost in China: A comparative study of long-term and short-term exposure. *Environ. Pollut.* **2021**, *277*, 116770. [CrossRef]
43. Newby, D.E.; Mannucci, P.M.; Tell, G.S.; Baccarelli, A.A.; Brook, R.D.; Donaldson, K.; Forastiere, F.; Franchini, M.; Franco, O.H.; Graham, I.; et al. Expert position paper on air pollution and cardiovascular disease. *Eur. Hear. J.* **2015**, *36*, 83–93. [CrossRef]
44. Cascio, W.E. Wildland fire smoke and human health. *Sci. Total Environ.* **2018**, *624*, 586–595. [CrossRef] [PubMed]
45. Bravo-Linares, C.; Ovando-Fuentealba, L.; Orellana-Donoso, S.; Gatica, S.; Klerman, F.; Mudge, S.M.; Gallardo, W.; Pinaud, J.P.; Loyola-Sepulveda, R. Source identification, apportionment and toxicity of indoor and outdoor PM2.5airborne particulates in a region characterised by wood burning. *Environ. Sci. Process. Impacts* **2016**, *18*, 575–589. [CrossRef]
46. Collart, P.; Dramaix, M.; Levêque, A.; Mercier, G.; Coppieters, Y. Concentration–response curve and cumulative effects between ozone and daily mortality: An analysis in Wallonia, Belgium. *Int. J. Environ. Health Res.* **2018**, *28*, 147–158. [CrossRef]
47. Wang, T.; Chiang, E.T.; Moreno-Vinasco, L.; Lang, G.D.; Pendyala, S.; Samet, J.M.; Geyh, A.S.; Breysse, P.N.; Chillrud, S.N.; Natarajan, V.; et al. Particulate Matter Disrupts Human Lung Endothelial Barrier Integrity via ROS- and p38 MAPK–Dependent Pathways. *Am. J. Respir. Cell Mol. Biol.* **2010**, *42*, 442–449. [CrossRef] [PubMed]
48. Li, J.; Sun, S.; Tang, R.; Qiu, H.; Huang, Q.; Mason, T.G.; Tian, L. Major air pollutants and risk of COPD exacerbations: A systematic review and meta-analysis. *Int. J. Chronic Obstr. Pulm. Dis.* **2016**, *11*, 3079–3091. [CrossRef] [PubMed]
49. Ohlwein, S.; Kappeler, R.; Joss, M.K.; Künzli, N.; Hoffmann, B. Health effects of ultrafine particles: A systematic literature review update of epidemiological evidence. *Int. J. Public Health* **2019**, *64*, 547–559. [CrossRef]
50. Olivieri, D.; Scoditti, E. Impact of environmental factors on lung defences. *Eur. Respir. Rev.* **2005**, *14*, 51–56. [CrossRef]
51. Ebi, K.L.; McGregor, G. Climate Change, Tropospheric Ozone and Particulate Matter, and Health Impacts. *Environ. Health Perspect.* **2008**, *116*, 1449–1455. [CrossRef]
52. Turner, M.C.; Jerrett, M.; Pope, C.A.; Krewski, D.; Gapstur, S.M.; Diver, W.R.; Beckerman, B.S.; Marshall, J.D.; Su, J.; Crouse, D.; et al. Long-Term Ozone Exposure and Mortality in a Large Prospective Study. *Am. J. Respir. Crit. Care Med.* **2016**, *193*, 1134–1142. [CrossRef]
53. Baccini, M.; Biggeri, A.; Accetta, G.; Kosatsky, T.; Katsouyanni, K.; Analitis, A.; Anderson, H.R.; Bisanti, L.; D'Ippoliti, D.; Danova, J.; et al. Heat effects on mortality in 15 European cities. *Epidemiology* **2008**, *19*, 711–719. [CrossRef]
54. D'Ippoliti, D.; Michelozzi, P.; Marino, C.; De'Donato, F.; Menne, B.; Katsouyanni, K.; Kirchmayer, U.; Analitis, A.; Medina-Ramón, M.; Paldy, A.; et al. The impact of heat waves on mortality in 9 European cities: Results from the EuroHEAT project. *Environ. Health* **2010**, *9*, 37. [CrossRef]
55. Witt, C.; Schubert, J.A.; Jehn, M.; Holzgreve, A.; Liebers, U.; Endlicher, W.; Scherer, D. The Effects of Climate Change on Patients With Chronic Lung Disease. *Dtsch. Aerzteblatt Online* **2015**, *112*, 878. [CrossRef]
56. Lemmetyinen, R.E.; Karjalainen, J.V.; But, A.; Renkonen, R.L.; Pekkanen, J.R.; Toppila-Salmi, S.K.; Haukka, J. Higher mortality of adults with asthma: A 15-year follow-up of a population-based cohort. *Allergy* **2018**, *73*, 1479–1488. [CrossRef] [PubMed]
57. Achebak, H.; Devolder, D.; Ingole, V.; Ballester, J. Reversal of the seasonality of temperature-attributable mortality from respiratory diseases in Spain. *Nat. Commun.* **2020**, *11*, 2457. [CrossRef]

58. Hotz, I.C.; Hajat, S. The Effects of Temperature on Accident and Emergency Department Attendances in London: A Time-Series Regression Analysis. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1957. [CrossRef]
59. Pfeifer, K.; Åström, D.O.; Martinsone, Ž.; Kaļužnaja, D.; Oudin, A. Evaluating Mortality Response Associated with Two Different Nordic Heat Warning Systems in Riga, Latvia. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7719. [CrossRef]
60. Wang, Y.; Liu, Y.; Ye, D.; Li, N.; Bi, P.; Tong, S.; Wang, Y.; Cheng, Y.; Li, Y.; Yao, X. High temperatures and emergency department visits in 18 sites with different climatic characteristics in China: Risk assessment and attributable fraction identification. *Environ. Int.* **2020**, *136*, 105486. [CrossRef]
61. Basu, R. California and Climate Changes: An Update. In *Climate Change and Global Public Health*; Springer: Cham, Switzerland, 2021; pp. 237–251.
62. Jahn, S.; Hertig, E. Modeling and projecting health-relevant combined ozone and temperature events in present and future Central European climate. *Air Qual. Atmos. Health* **2021**, *14*, 563–580. [CrossRef]
63. Weilnhammer, V.; Schmid, J.; Mittermeier, I.; Schreiber, F.; Jiang, L.; Pastuhovic, V.; Herr, C.; Heinze, S. Extreme weather events in europe and their health consequences–A systematic review. *Int. J. Hyg. Environ. Health* **2021**, *233*, 113688. [CrossRef]
64. Matthies, F.; Bickler, G.; Marín, N.C. *Heat-Health Action Plans: Guidance*; World Health Organization: Copenhagen, Denmark, 2008.
65. Watts, N.; Adger, W.N.; Agnolucci, P.; Blackstock, J.; Byass, P.; Cai, W.; Chaytor, S.; Colbourn, T.; Collins, M.; Cooper, A.; et al. Health and climate change: Policy responses to protect public health. *Lancet* **2015**, *386*, 1861–1914. [CrossRef]
66. Revich, B.A.; Grigorieva, E.A. Health Risks to the Russian Population from Weather Extremes in the Beginning of the XXI Century. Part 1. Heat and Cold Waves. *Issues Risk Anal.* **2021**, *18*, 12–33. [CrossRef]
67. Analitis, A.; Katsouyanni, K.; Pedeli, X.; Kirchmayer, U.; Michelozzi, P.; Menne, B. Investigating the Independent and Synergistic Effects of Heat Waves and Air Pollution on Health: The EuroHEAT Project. *Epidemiology* **2008**, *19*, S214–S215. [CrossRef]
68. Schlegel, I.; Muthers, S.; Mücke, H.-G.; Matzarakis, A. Comparison of Respiratory and Ischemic Heart Mortalities and their Relationship to the Thermal Environment. *Atmosphere* **2020**, *11*, 826. [CrossRef]
69. Semenza, J. Excess hospital admissions during the July 1995 heat wave in Chicago. *Am. J. Prev. Med.* **1999**, *16*, 269–277. [CrossRef]
70. Gasparrini, A.; Armstrong, B.; Kovats, S.; Wilkinson, P. The effect of high temperatures on cause-specific mortality in England and Wales. *Occup. Environ. Med.* **2011**, *69*, 56–61. [CrossRef] [PubMed]
71. Harlan, S.L.; Chowell, G.; Yang, S.; Petitti, D.B.; Butler, E.J.M.; Ruddell, B.L.; Ruddell, D.M. Heat-Related Deaths in Hot Cities: Estimates of Human Tolerance to High Temperature Thresholds. *Int. J. Environ. Res. Public Health* **2014**, *11*, 3304–3326. [CrossRef]
72. Hoffmann, C.; Hanisch, M.; Heinsohn, J.B.; Dostal, V.; Jehn, M.; Liebers, U.; Pankow, W.; Donaldson, G.C.; Witt, C. Increased vulnerability of COPD patient groups to urban climate in view of global warming. *Int. J. Chronic Obstr. Pulm. Dis.* **2018**, *13*, 3493–3501. [CrossRef]
73. Ma, Y.; Zhou, L.; Chen, K. Burden of cause-specific mortality attributable to heat and cold: A multicity time-series study in Jiangsu Province, China. *Environ. Int.* **2020**, *144*, 105994. [CrossRef]
74. Stafoggia, M.; Forastiere, F.; Agostini, D.; Caranci, N.; De'Donato, F.; DeMaria, M.; Michelozzi, P.; Miglio, R.; Rognoni, M.; Russo, A.; et al. Factors affecting in-hospital heat-related mortality: A multi-city case-crossover analysis. *J. Epidemiol. Community Health* **2008**, *62*, 209–215. [CrossRef] [PubMed]
75. Breitner, S.; Wolf, K.; Devlin, R.B.; Diaz-Sanchez, D.; Peters, A.; Schneider, A. Short-term effects of air temperature on mortality and effect modification by air pollution in three cities of Bavaria, Germany: A time-series analysis. *Sci. Total Environ.* **2014**, *485-486*, 49–61. [CrossRef]
76. Liu, L.; Zhang, H.; Lu, X.; Li, Y. A differential Alamouti coding scheme for OFDM based asynchronous cooperative systems. In Proceedings of the 2011 IEEE 3rd International Conference on Communication Software and Networks, Xi'an, China, 27–29 May 2011; pp. 51–56. [CrossRef]
77. Basu, R.; Samet, J.M. Relation between elevated ambient temperature and mortality: A review of the epidemiologic evidence. *Epidemiol. Rev.* **2002**, *24*, 190–202. [CrossRef]
78. Chen, F.; Fan, Z.; Qiao, Z.; Cui, Y.; Zhang, M.; Zhao, X.; Li, X. Does temperature modify the effect of PM10 on mortality? A systematic review and meta-analysis. *Environ. Pollut.* **2017**, *224*, 326–335. [CrossRef] [PubMed]
79. Analitis, A.; Michelozzi, P.; D'Ippoliti, D.; De'Donato, F.; Menne, B.; Matthies, F.; Atkinson, R.; Iñiguez, C.; Basagaña, X.; Schneider, A.; et al. Effects of Heat Waves on Mortality. *Epidemiology* **2014**, *25*, 15–22. [CrossRef] [PubMed]
80. Bond, T.C.; Doherty, S.J.; Fahey, D.W.; Forster, P.; Berntsen, T.; DeAngelo, B.J.; Flanner, M.G.; Ghan, S.; Kaercher, B.; Koch, D.; et al. Bounding the role of black carbon in the climate system: A scientific assessment. *J. Geophys. Res. Atmos.* **2013**, *118*, 5380–5552. [CrossRef]
81. Fiore, A.M.; Naik, V.; Spracklen, D.V.; Steiner, A.; Unger, N.; Prather, M.; Bergmann, D.; Cameron-Smith, P.J.; Cionni, I.; Collins, W.J.; et al. Global air quality and climate. *Chem. Soc. Rev.* **2012**, *41*, 6663–6683. [CrossRef]
82. Kalisa, E.; Fadlallah, S.; Amani, M.; Nahayo, L.; Habiyaremye, G. Temperature and air pollution relationship during heatwaves in Birmingham, UK. *Sustain. Cities Soc.* **2018**, *43*, 111–120. [CrossRef]
83. Anderson, G.B.; Krall, J.R.; Peng, R.D.; Bell, M.L. Is the Relation between Ozone and Mortality Confounded by Chemical Components of Particulate Matter? Analysis of 7 Components in 57 US Communities. *Am. J. Epidemiol.* **2012**, *176*, 726–732. [CrossRef]
84. Meehl, G.A.; Tebaldi, C.; Tilmes, S.; Lamarque, J.-F.; Bates, S.; Pendergrass, A.; Lombardozzi, D. Future heat waves and surface ozone. *Environ. Res. Lett.* **2018**, *13*, 064004. [CrossRef]

85. Jhun, I.; Fann, N.; Zanobetti, A.; Hubbell, B. Effect modification of ozone-related mortality risks by temperature in 97 US cities. *Environ. Int.* **2014**, *73*, 128–134. [CrossRef]
86. Cheng, Y.; Kan, H. Effect of the Interaction between Outdoor Air Pollution and Extreme Temperature on Daily Mortality in Shanghai, China. *J. Epidemiol.* **2012**, *22*, 28–36. [CrossRef]
87. Chen, Y.; Zheng, M.; Lv, J.; Shi, T.; Liu, P.; Wu, Y.; Feng, W.; He, W.; Guo, P. Interactions between ambient air pollutants and temperature on emergency department visits: Analysis of varying-coefficient model in Guangzhou, China. *Sci. Total Environ.* **2019**, *668*, 825–834. [CrossRef] [PubMed]
88. Chung, Y.; Lim, Y.-H.; Honda, Y.; Guo, Y.-L.L.; Hashizume, M.; Bell, M.; Chen, B.-Y.; Kim, H. Mortality Related to Extreme Temperature for 15 Cities in Northeast Asia. *Epidemiology* **2015**, *26*, 255–262. [CrossRef] [PubMed]
89. Ding, P.-H.; Wang, G.-S.; Guo, Y.-L.; Chang, S.-C.; Wan, G.-H. Urban air pollution and meteorological factors affect emergency department visits of elderly patients with chronic obstructive pulmonary disease in Taiwan. *Environ. Pollut.* **2017**, *224*, 751–758. [CrossRef] [PubMed]
90. Kim, S.E.; Lim, Y.-H.; Kim, H. Temperature modifies the association between particulate air pollution and mortality: A multi-city study in South Korea. *Sci. Total Environ.* **2015**, *524–525*, 376–383. [CrossRef]
91. Leung, S.Y.; Lau, S.Y.F.; Kwok, K.L.; Mohammad, K.N.; Chan, P.K.S.; Chong, K.C. Short-term association among meteorological variation, outdoor air pollution and acute bronchiolitis in children in a subtropical setting. *Thorax* **2021**, *76*, 360–369. [CrossRef]
92. Li, G.; Zhou, M.; Cai, Y.; Zhang, Y.; Pan, X. Does temperature enhance acute mortality effects of ambient particle pollution in Tianjin City, China. *Sci. Total Environ.* **2011**, *409*, 1811–1817. [CrossRef]
93. Li, G.; Jiang, L.; Zhang, Y.; Cai, Y.; Pan, X.; Zhou, M. The Impact of Ambient Particle Pollution during Extreme-Temperature Days in Guangzhou City, China. *Asia Pac. J. Public Health* **2014**, *26*, 614–621. [CrossRef]
94. Lin, Y.-K.; Cheng, C.-P.; Kim, H.; Wang, Y.-C. Risk of ambulance services associated with ambient temperature, fine particulate and its constituents. *Sci. Rep.* **2021**, *11*, 1–10. [CrossRef]
95. Meng, X.; Zhang, Y.; Zhao, Z.; Duan, X.; Xu, X.; Kan, H. Temperature modifies the acute effect of particulate air pollution on mortality in eight Chinese cities. *Sci. Total Environ.* **2012**, *435–436*, 215–221. [CrossRef]
96. Park, A.K.; Hong, Y.C.; Kim, H. Effect of changes in season and temperature on mortality associated with air pollution in Seoul, Korea. *J. Epidemiol. Community Health* **2010**, *65*, 368–375. [CrossRef]
97. Qian, Z.; He, Q.; Lin, H.-M.; Kong, L.; Bentley, C.M.; Liu, W.; Zhou, D. High Temperatures Enhanced Acute Mortality Effects of Ambient Particle Pollution in the "Oven" City of Wuhan, China. *Environ. Health Perspect.* **2008**, *116*, 1172–1178. [CrossRef]
98. Qin, R.X.; Xiao, C.; Zhu, Y.; Li, J.; Yang, J.; Gu, S.; Xia, J.; Su, B.; Liu, Q.; Woodward, A. The interactive effects between high temperature and air pollution on mortality: A time-series analysis in Hefei, China. *Sci. Total Environ.* **2017**, *575*, 1530–1537. [CrossRef] [PubMed]
99. Song, X.; Jiang, L.; Wang, S.; Tian, J.; Yang, K.; Wang, X.; Guan, H.; Zhang, N. The impact of main air pollutants on respiratory emergency department visits and the modification effects of temperature in Beijing, China. *Environ. Sci. Pollut. Res.* **2021**, *28*, 6990–7000. [CrossRef]
100. Tian, L.; Liang, F.; Guo, Q.; Chen, S.; Xiao, S.; Wu, Z.; Jin, X.; Pan, X. The effects of interaction between particulate matter and temperature on mortality in Beijing, China. *Environ. Sci. Process. Impacts* **2018**, *20*, 395–405. [CrossRef] [PubMed]
101. Wang, Y.-C.; Lin, Y.-K.; Chen, Y.-J.; Hung, S.-C.; Zafirah, Y.; Sung, F.-C. Ambulance Services Associated with Extreme Temperatures and Fine Particles in a Subtropical Island. *Sci. Rep.* **2020**, *10*, 1–11. [CrossRef] [PubMed]
102. Wang, Y.-C.; Sung, F.-C.; Chen, Y.-J.; Cheng, C.-P.; Lin, Y.-K. Effects of extreme temperatures, fine particles and ozone on hourly ambulance dispatches. *Sci. Total Environ.* **2020**, *765*, 142706. [CrossRef] [PubMed]
103. Wang, H.; Lu, F.; Guo, M.; Fan, W.; Ji, W.; Dong, Z. Associations between PM1 exposure and daily emergency department visits in 19 hospitals, Beijing. *Sci. Total Environ.* **2021**, *755*, 142507. [CrossRef]
104. Ye, F.; Piver, W.T.; Ando, M.; Portier, C. Effects of temperature and air pollutants on cardiovascular and respiratory diseases for males and females older than 65 years of age in Tokyo, July and August 1980-1995. *Environ. Health Perspect.* **2001**, *109*, 355–359. [CrossRef]
105. Zhang, Y.; Wang, S.; Fan, X.; Ye, X. Temperature modulation of the health effects of particulate matter in Beijing, China. *Environ. Sci. Pollut. Res.* **2018**, *25*, 10857–10866. [CrossRef] [PubMed]
106. Pascal, M.; Falq, G.; Wagner, V.; Chatignoux, E.; Corso, M.; Blanchard, M.; Host, S.; Pascal, L.; Larrieu, S. Short-term impacts of particulate matter (PM10, PM10–2.5, PM2.5) on mortality in nine French cities. *Atmos. Environ.* **2014**, *95*, 175–184. [CrossRef]
107. Pattenden, S.; Armstrong, B.; Milojevic, A.; Heal, M.; Chalabi, Z.; Doherty, R.; Barratt, B.; Kovats, S.; Wilkinson, P. Ozone, heat and mortality: Acute effects in 15 British conurbations. *Occup. Environ. Med.* **2010**, *67*, 699–707. [CrossRef] [PubMed]
108. Shaposhnikov, D.; Revich, B.; Bellander, T.; Bedada, G.B.; Bottai, M.; Kharkova, T.; Kvasha, E.; Lezina, E.; Lind, T.; Semutnikova, E.; et al. Mortality Related to Air Pollution with the Moscow Heat Wave and Wildfire of 2010. *Epidemiology* **2014**, *25*, 359–364. [CrossRef] [PubMed]
109. Stafoggia, M.; Schwartz, J.; Forastiere, F.; Perucci, C.A. Does Temperature Modify the Association between Air Pollution and Mortality? A Multicity Case-Crossover Analysis in Italy. *Am. J. Epidemiol.* **2008**, *167*, 1476–1485. [CrossRef] [PubMed]
110. Anderson, B.G.; Bell, M.L. Weather-Related Mortality. *Epidemiology* **2009**, *20*, 205–213. [CrossRef]
111. Byers, N.; Ritchey, M.; Vaidyanathan, A.; Brandt, A.J.; Yip, F. Short-term effects of ambient air pollutants on asthma-related emergency department visits in Indianapolis, Indiana, 2007–2011. *J. Asthma* **2015**, *53*, 245–252. [CrossRef]

112. Hanna, A.F.; Yeatts, K.B.; Xiu, A.; Zhu, Z.; Smith, R.L.; Davis, N.N.; Talgo, K.D.; Arora, G.; Robinson, P.J.; Meng, Q.; et al. Associations between ozone and morbidity using the Spatial Synoptic Classification system. *Environ. Health* **2011**, *10*, 49. [CrossRef] [PubMed]
113. Mohr, L.B.; Luo, S.; Mathias, E.; Tobing, R.; Homan, S.; Sterling, D. Influence of Season and Temperature on the Relationship of Elemental Carbon Air Pollution to Pediatric Asthma Emergency Room Visits. *J. Asthma* **2008**, *45*, 936–943. [CrossRef]
114. Vanos, J.K.; Hebbern, C.; Cakmak, S. Risk assessment for cardiovascular and respiratory mortality due to air pollution and synoptic meteorology in 10 Canadian cities. *Environ. Pollut.* **2014**, *185*, 322–332. [CrossRef]
115. Hales, S.; Salmond, C.; Town, G.I.; Kjellstrom, T.; Woodward, A. Daily mortality in relation to weather and air pollution in Christchurch, New Zealand. *Aust. N. Z. J. Public Health* **2000**, *24*, 89–91. [CrossRef]
116. Pinheiro, S.D.L.L.D.A.; Saldiva, P.H.N.; Schwartz, J.; Zanobetti, A. Isolated and synergistic effects of PM10 and average temperature on cardiovascular and respiratory mortality. *Rev. Saúde Pública* **2014**, *48*, 881–888. [CrossRef]
117. Steadman, R.G. A universal scale of apparent temperature. *J. Clim. Appl. Meteor.* **1984**, *23*, 1674–1687. [CrossRef]
118. Kalkstein, L.S.; Valimont, K.M. An evaluation of summer discomfort in the United States using a relative climatological in-dex. *Am. Meteorol. Soc.* **1986**, *67*, 842–848. [CrossRef]
119. Sun, Q.; Miao, C.; Hanel, M.; Borthwick, A.G.; Duan, Q.; Ji, D.; Li, H. Global heat stress on health, wildfires, and agricultural crops under different levels of climate warming. *Environ. Int.* **2019**, *128*, 125–136. [CrossRef] [PubMed]
120. Bergmann, S.; Li, B.; Pilot, E.; Chen, R.; Wang, B.; Yang, J. Effect modification of the short-term effects of air pollution on morbidity by season: A systematic review and meta-analysis. *Sci. Total Environ.* **2020**, *716*, 136985. [CrossRef]
121. Meehl, G.A. More Intense, More Frequent, and Longer Lasting Heat Waves in the 21st Century. *Science* **2004**, *305*, 994–997. [CrossRef] [PubMed]
122. Stedman, J.R. The predicted number of air pollution related deaths in the UK during the August 2003 heatwave. *Atmos. Environ.* **2004**, *38*, 1087–1090. [CrossRef]
123. Thabethe, N.D.L.; Voyi, K.; Wichmann, J. Association between ambient air pollution and cause-specific mortality in Cape Town, Durban, and Johannesburg, South Africa: Any susceptible groups? *Environ. Sci. Pollut. Res.* **2021**, 1–9. [CrossRef]
124. Burke, M.; Driscoll, A.; Heft-Neal, S.; Xue, J.; Burney, J.; Wara, M. The changing risk and burden of wildfire in the United States. *Proc. Natl. Acad. Sci. USA* **2021**, *118*, 2011048118. [CrossRef]
125. Sorensen, C.; House, J.A.; O'Dell, K.; Brey, S.J.; Ford, B.; Pierce, J.R.; Fischer, E.V.; Lemery, J.; Crooks, J.L. Associations Between Wildfire-Related PM 2.5 and Intensive Care Unit Admissions in the United States, 2006–2015. *GeoHealth* **2021**, *5*, e2021GH000385. [CrossRef]
126. Grumm, R.H. The Central European and Russian Heat Event of July–August 2010. *Bull. Am. Meteorol. Soc.* **2011**, *92*, 1285–1296. [CrossRef]
127. Xu, R.; Yu, P.; Abramson, M.J.; Johnston, F.H.; Samet, J.M.; Bell, M.L.; Haines, A.; Ebi, K.L.; Li, S.; Guo, Y. Wildfires, Global Climate Change, and Human Health. *N. Engl. J. Med.* **2020**, *383*, 2173–2181. [CrossRef]
128. Henderson, S.B.; Brauer, M.; Macnab, Y.C.; Kennedy, S.M. Three Measures of Forest Fire Smoke Exposure and Their Associations with Respiratory and Cardiovascular Health Outcomes in a Population-Based Cohort. *Environ. Health Perspect.* **2011**, *119*, 1266–1271. [CrossRef]
129. Finlay, S.E.; Moffat, A.; Gazzard, R.; Baker, D.; Murray, V. Health Impacts of Wildfires. *PLoS Curr.* **2012**, *4*, e4f959951cce2c. [CrossRef] [PubMed]
130. Bernstein, A.S.; Rice, M.B. Lungs in a Warming World Climate Change and Respiratory Health. *Chest* **2013**, *143*, 1455–1459. [CrossRef] [PubMed]
131. Faustini, A.; Alessandrini, E.R.; Pey, J.; Perez, N.; Samoli, E.; Querol, X.; Cadum, E.; Perrino, C.; Ostro, B.; Ranzi, A.; et al. Short-term effects of particulate matter on mortality during forest fires in Southern Europe: Results of the MED-PARTICLES Project. *Occup. Environ. Med.* **2015**, *72*, 323–329. [CrossRef] [PubMed]
132. Williamson, G.J.; Bowman, D.M.J.S.; Price, O.F.; Henderson, S.B.; Johnston, F.H. A transdisciplinary approach to understanding the health effects of wildfire and prescribed fire smoke regimes. *Environ. Res. Lett.* **2016**, *11*, 125009. [CrossRef]
133. Black, C.; Tesfaigzi, Y.; Bassein, J.A.; Miller, L.A. Wildfire smoke exposure and human health: Significant gaps in research for a growing public health issue. *Environ. Toxicol. Pharmacol.* **2017**, *55*, 186–195. [CrossRef] [PubMed]
134. Gan, R.W.; Ford, B.; Lassman, W.; Pfister, G.; Vaidyanathan, A.; Fischer, E.; Volckens, J.; Pierce, J.; Magzamen, S. Comparison of wildfire smoke estimation methods and associations with cardiopulmonary-related hospital admissions. *GeoHealth* **2017**, *1*, 122–136. [CrossRef]
135. Lipner, E.M.; O'Dell, K.; Brey, S.J.; Ford, B.; Pierce, J.R.; Fischer, E.V.; Crooks, J.L. The Associations between Clinical Respiratory Outcomes and Ambient Wildfire Smoke Exposure among Pediatric Asthma Patients at National Jewish Health, 2012–2015. *GeoHealth* **2019**, *3*, 146–159. [CrossRef]
136. Karanasiou, A.; Alastuey, A.; Amato, F.; Renzi, M.; Stafoggia, M.; Tobias, A.; Reche, C.; Forastiere, F.; Gumy, S.; Mudu, P.; et al. Short-term health effects from outdoor exposure to biomass burning emissions: A review. *Sci. Total Environ.* **2021**, *781*, 146739. [CrossRef]
137. Revich, B.; Avaliani, S.; Simons, G. Air pollution and public health in a megalopolis: A case study of Moscow. *Econ. Reg.* **2016**, *12*, 1069–1078. [CrossRef]

138. Naeher, L.P.; Brauer, M.; Lipsett, M.; Zelikoff, J.T.; Simpson, C.D.; Koenig, J.Q.; Smith, K.R. Woodsmoke Health Effects: A Review. *Inhal. Toxicol.* **2007**, *19*, 67–106. [CrossRef] [PubMed]
139. Jalava, P.I.; Salonen, R.O.; Hälinen, A.I.; Penttinen, P.; Pennanen, A.; Sillanpää, M.; Sandell, E.; Hillamo, R.; Hirvonen, M.-R. In vitro inflammatory and cytotoxic effects of size-segregated particulate samples collected during long-range transport of wildfire smoke to Helsinki. *Toxicol. Appl. Pharmacol.* **2006**, *215*, 341–353. [CrossRef]
140. Xu, Y.; Dadvand, P.; Barrera-Gómez, J.; Sartini, C.; Marí-Dell'Olmo, M.; Borrell, C.; Medina-Ramón, M.; Sunyer, J.; Basagaña, X. Differences on the effect of heat waves on mortality by sociodemographic and urban landscape characteristics. *J. Epidemiol. Community Health* **2013**, *67*, 519–525. [CrossRef] [PubMed]
141. Sabrin, S.; Karimi, M.; Nazari, R. Developing Vulnerability Index to Quantify Urban Heat Islands Effects Coupled with Air Pollution: A Case Study of Camden, NJ. *ISPRS Int. J. Geo-Inf.* **2020**, *9*, 349. [CrossRef]
142. Lai, L.-W.; Cheng, W.-L. Air quality influenced by urban heat island coupled with synoptic weather patterns. *Sci. Total Environ.* **2009**, *407*, 2724–2733. [CrossRef]
143. Ulpiani, G. On the linkage between urban heat island and urban pollution island: Three-decade literature review towards a conceptual framework. *Sci. Total Environ.* **2021**, *751*, 141727. [CrossRef]
144. Sera, F.; Armstrong, B.; Tobias, A.; Vicedo-Cabrera, A.M.; Åström, C.; Bell, M.L.; Chen, B.-Y.; Coelho, M.D.S.Z.S.; Correa, P.M.; Cruz, J.C.; et al. How urban characteristics affect vulnerability to heat and cold: A multi-country analysis. *Int. J. Epidemiol.* **2019**, *48*, 1101–1112. [CrossRef]
145. Jung, J.; Lee, J.Y.; Lee, H.; Kim, H. Predicted Future Mortality Attributed to Increases in Temperature and PM10 Concentration under Representative Concentration Pathway Scenarios. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2600. [CrossRef]
146. Gordon, C.J. Role of environmental stress in the physiological response to chemical toxicants. *Environ. Res.* **2003**, *92*, 1–7. [CrossRef]
147. Leon, L.R. Thermoregulatory responses to environmental toxicants: The interaction of thermal stress and toxicant exposure. *Toxicol. Appl. Pharmacol.* **2008**, *233*, 146–161. [CrossRef]
148. Li, L.; Yang, J.; Guo, C.; Chen, P.-Y.; Ou, C.-Q.; Guo, Y. Particulate matter modifies the magnitude and time course of the non-linear temperature-mortality association. *Environ. Pollut.* **2015**, *196*, 423–430. [CrossRef] [PubMed]
149. Monteiro, A.; Carvalho, V.; Oliveira, T.; Sousa, C. Excess mortality and morbidity during the July 2006 heat wave in Porto, Portugal. *Int. J. Biometeorol.* **2013**, *57*, 155–167. [CrossRef] [PubMed]
150. Maier, K.L.; Alessandrini, F.; Beck-Speier, I.; Hofer, T.P.J.; Diabaté, S.; Bitterle, E.; Stöger, T.; Jakob, T.; Behrendt, H.; Horsch, M.; et al. Health Effects of Ambient Particulate Matter—Biological Mechanisms and Inflammatory Responses to In Vitro and In Vivo Particle Exposures. *Inhal. Toxicol.* **2008**, *20*, 319–337. [CrossRef] [PubMed]
151. Health Protection Agency. Public Health Adaptation Strategies to Extreme Weather Events (PHASE). Available online: http://www.phaseclimatehealth.eu/ (accessed on 20 May 2021).
152. Ruan, T.; Gu, Q.; Kou, Y.R.; Lee, L.-Y. Hyperthermia increases sensitivity of pulmonary C-fibre afferents in rats. *J. Physiol.* **2005**, *565*, 295–308. [CrossRef] [PubMed]
153. Ni, D.; Gu, Q.; Hu, H.-Z.; Gao, N.; Zhu, M.X.; Lee, L.-Y. Thermal sensitivity of isolated vagal pulmonary sensory neurons: Role of transient receptor potential vanilloid receptors. *Am. J. Physiol. Integr. Comp. Physiol.* **2006**, *291*, R541–R550. [CrossRef] [PubMed]
154. Aitken, M.L.; Marini, J.J. Effect of heat delivery and extraction on airway conductance in normal and in asthmatic subjects. *Am. Rev. Respir. Dis.* **1985**, *131*, 357–361. [CrossRef]
155. Hayes, D., Jr.; Collins, P.B.; Khosravi, M.; Lin, R.-L.; Lee, L.-Y. Bronchoconstriction triggered by breathing hot humid air in patients with asthma: Role of cholinergic reflex. *Am. J. Respir. Crit. Care Med.* **2012**, *185*, 1190–1196. [CrossRef]
156. Wang, P.; Zhang, X.; Hashizume, M.; Goggins, W.B.; Luo, C. A systematic review on lagged associations in climate–health studies. *Int. J. Epidemiol.* **2021**, dyaa286. [CrossRef] [PubMed]
157. Hajat, S.; Armstrong, B.G.; Gouveia, N.; Wilkinson, P. Mortality Displacement of Heat-Related Deaths. *Epidemiology* **2005**, *16*, 613–620. [CrossRef]
158. Gasparrini, A.; Armstrong, B. The Impact of Heat Waves on Mortality. *Epidemiology* **2011**, *22*, 68–73. [CrossRef]
159. Iñiguez, C.; Royé, D.; Tobías, A. Contrasting patterns of temperature related mortality and hospitalization by cardiovascular and respiratory diseases in 52 Spanish cities. *Environ. Res.* **2021**, *192*, 110191. [CrossRef] [PubMed]
160. Zafeiratou, S.; Samoli, E.; Dimakopoulou, K.; Rodopoulou, S.; Analitis, A.; Gasparrini, A.; Stafoggia, M.; Donato, F.D.; Rao, S.; Monteiro, A.; et al. A systematic review on the association between total and cardiopulmonary mortality/morbidity or cardiovascular risk factors with long-term exposure to increased or decreased ambient temperature. *Sci. Total Environ.* **2021**, *772*, 145383. [CrossRef]
161. Tzampoglou, P.; Loukidis, D. Investigation of the Importance of Climatic Factors in COVID-19 Worldwide Intensity. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7730. [CrossRef] [PubMed]
162. Bourdrel, T.; Annesi-Maesano, I.; Alahmad, B.; Maesano, C.N.; Bind, M.-A. The impact of outdoor air pollution on COVID-19: A review of evidence from in vitro, animal, and human studies. *Eur. Respir. Rev.* **2021**, *30*, 200242. [CrossRef]
163. Coccia, M. Factors determining the diffusion of COVID-19 and suggested strategy to prevent future accelerated viral infectivity similar to COVID. *Sci. Total Environ.* **2020**, *729*, 138474. [CrossRef] [PubMed]
164. Glencross, D.A.; Ho, T.-R.; Camiña, N.; Hawrylowicz, C.M.; Pfeffer, P.E. Air pollution and its effects on the immune system. *Free. Radic. Biol. Med.* **2020**, *151*, 56–68. [CrossRef]

165. Tiotiu, A.I.; Novakova, P.; Nedeva, D.; Chong-Neto, H.J.; Novakova, S.; Steiropoulos, P.; Kowal, K. Impact of Air Pollution on Asthma Outcomes. *Int. J. Environ. Res. Public Health* **2020**, *17*, 6212. [CrossRef]
166. Stone, B.; Mallen, E.; Rajput, M.; Broadbent, A.; Krayenhoff, E.S.; Augenbroe, G.; Georgescu, M. Climate change and infrastructure risk: Indoor heat exposure during a concurrent heat wave and blackout event in Phoenix, Arizona. *Urban Clim.* **2021**, *36*, 100787. [CrossRef]
167. Hansel, N.N.; McCormack, M.C.; Belli, A.J.; Matsui, E.C.; Peng, R.D.; Aloe, C.; Paulin, L.; Williams, D.L.; Diette, G.B.; Breysse, P.N. In-Home Air Pollution Is Linked to Respiratory Morbidity in Former Smokers with Chronic Obstructive Pulmonary Disease. *Am. J. Respir. Crit. Care Med.* **2013**, *187*, 1085–1090. [CrossRef]
168. Gayle, A.V.; Quint, J.K.; Fuertes, E.I. Understanding the relationships between environmental factors and exacerbations of COPD. *Expert Rev. Respir. Med.* **2021**, *15*, 39–50. [CrossRef] [PubMed]
169. Katsouyanni, K.; Trichopoulos, D.; Zavitsanos, X.; Touloumi, G. THE 1987 ATHENS HEATWAVE. *Lancet* **1988**, *332*, 573. [CrossRef]
170. Chen, S.; Wu, S. Deep learning for identifying environmental risk factors of acute respiratory diseases in Beijing, China: Implications for population with different age and gender. *Int. J. Environ. Health Res.* **2020**, *30*, 435–446. [CrossRef] [PubMed]
171. Wang, L.; Luo, D.; Liu, X.; Zhu, J.; Wang, F.; Li, B.; Li, L. Effects of PM2.5 exposure on reproductive system and its mechanisms. *Chemosphere* **2021**, *264*, 128436. [CrossRef] [PubMed]
172. Shin, H.H.; Gogna, P.; Maquiling, A.; Parajuli, R.P.; Haque, L.; Burr, B. Comparison of hospitalization and mortality associated with short-term exposure to ambient ozone and PM2.5 in Canada. *Chemosphere* **2021**, *265*, 128683. [CrossRef]
173. Zanobetti, A.; Schwartz, J.; Gold, D. Are there sensitive subgroups for the effects of airborne particles? *Environ. Health Perspect.* **2000**, *108*, 841–845. [CrossRef]
174. Ko, F.W.S.; Tam, W.; Wong, T.W.; Lai, C.K.W.; Wong, G.W.K.; Leung, T.-F.; Ng, S.; Hui, D.S.C. Effects of air pollution on asthma hospitalization rates in different age groups in Hong Kong. *Clin. Exp. Allergy* **2007**, *37*, 1312–1319. [CrossRef] [PubMed]
175. Sexton, K.; Hattis, D. Assessing Cumulative Health Risks from Exposure to Environmental Mixtures—Three Fundamental Questions. *Environ. Health Perspect.* **2007**, *115*, 825–832. [CrossRef]
176. Sexton, K. Cumulative Risk Assessment: An Overview of Methodological Approaches for Evaluating Combined Health Effects from Exposure to Multiple Environmental Stressors. *Int. J. Environ. Res. Public Health* **2012**, *9*, 370–390. [CrossRef]
177. Al Ahad, M.A.; Sullivan, F.; Demšar, U.; Melhem, M.; Kulu, H. The effect of air-pollution and weather exposure on mortality and hospital admission and implications for further research: A systematic scoping review. *PLoS ONE* **2020**, *15*, e0241415. [CrossRef]
178. Leitte, A.M.; Petrescu, C.; Franck, U.; Richter, M.; Suciu, O.; Ionovici, R.; Herbarth, O.; Schlink, U. Respiratory health, effects of ambient air pollution and its modification by air humidity in Drobeta-Turnu Severin, Romania. *Sci. Total Environ.* **2009**, *407*, 4004–4011. [CrossRef] [PubMed]
179. Davis, R.E.; McGregor, G.R.; Enfield, K.B. Humidity: A review and primer on atmospheric moisture and human health. *Environ. Res.* **2016**, *144*, 106–116. [CrossRef] [PubMed]
180. Katsouyanni, K.; Touloumi, G.; Samoli, E.; Gryparis, A.; Le Tertre, A.; Monopolis, Y.; Rossi, G.; Zmirou, D.; Ballester, F.; Boumghar, A.; et al. Confounding and Effect Modification in the Short-Term Effects of Ambient Particles on Total Mortality: Results from 29 European Cities within the APHEA2 Project. *Epidemiology* **2001**, *12*, 521–531. [CrossRef]
181. Yitshak-Sade, M.; Bobb, J.F.; Schwartz, J.D.; Kloog, I.; Zanobetti, A. The association between short and long-term exposure to PM2.5 and temperature and hospital admissions in New England and the synergistic effect of the short-term exposures. *Sci. Total Environ.* **2018**, *639*, 868–875. [CrossRef]
182. Eguiluz-Gracia, I.; Mathioudakis, A.G.; Bartel, S.; Vijverberg, S.J.H.; Fuertes, E.; Comberiati, P.; Cai, Y.S.; Tomazic, P.V.; Diamant, Z.; Vestbo, J.; et al. The need for clean air: The way air pollution and climate change affect allergic rhinitis and asthma. *Allergy* **2020**, *75*, 2170–2184. [CrossRef]
183. Johnston, F.H.; Borchers-Arriagada, N.; Morgan, G.G.; Jalaludin, B.; Palmer, A.J.; Williamson, G.J.; Bowman, D.M.J.S. Unprecedented health costs of smoke-related PM2.5 from the 2019–20 Australian megafires. *Nat. Sustain.* **2021**, *4*, 42–47. [CrossRef]
184. Viegi, G.; Maio, S.; Fasola, S.; Baldacci, S. Global Burden of Chronic Respiratory Diseases. *J. Aerosol Med. Pulm. Drug Deliv.* **2020**, *33*, 171–177. [CrossRef]
185. McMichael, A.J.; Lindgren, E. Climate change: Present and future risks to health, and necessary responses. *J. Intern. Med.* **2011**, *270*, 401–413. [CrossRef]
186. Ebi, K.L.; Vanos, J.; Baldwin, J.W.; Bell, J.E.; Hondula, D.M.; Errett, N.A.; Hayes, K.; Reid, C.E.; Saha, S.; Spector, J.; et al. Extreme Weather and Climate Change: Population Health and Health System Implications. *Annu. Rev. Public Health* **2021**, *42*, 293–315. [CrossRef]
187. Rai, M.; Breitner, S.; Wolf, K.; Peters, A.; Schneider, A.; Chen, K. Impact of climate and population change on temperature-related mortality burden in Bavaria, Germany. *Environ. Res. Lett.* **2019**, *14*, 124080. [CrossRef]
188. Lelieveld, J.; Evans, J.S.; Fnais, M.; Giannadaki, D.; Pozzer, A. The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nat. Cell Biol.* **2015**, *525*, 367–371. [CrossRef]
189. Glick, S.; Gehrig, R.; Eeftens, M. Multi-decade changes in pollen season onset, duration, and intensity: A concern for public health? *Sci. Total Environ.* **2021**, *781*, 146382. [CrossRef]
190. Fann, N.; Alman, B.; Broome, R.A.; Morgan, G.; Johnston, F.H.; Pouliot, G.; Rappold, A.G. The health impacts and economic value of wildland fire episodes in the U.S.: 2008–2012. *Sci. Total Environ.* **2018**, *610–611*, 802–809. [CrossRef]

191. Li, L.; Du, T.; Zhang, C. The Impact of Air Pollution on Healthcare Expenditure for Respiratory Diseases: Evidence from the People's Republic of China. *Health Policy Politi sante* **2020**, *13*, 1723–1738. [CrossRef]
192. Bikomeye, J.; Rublee, C.; Beyer, K. Positive Externalities of Climate Change Mitigation and Adaptation for Human Health: A Review and Conceptual Framework for Public Health Research. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2481. [CrossRef]
193. Pascal, M.; Wagner, V.; Alari, A.; Corso, M.; Le Tertre, A. Extreme heat and acute air pollution episodes: A need for joint public health warnings? *Atmos. Environ.* **2021**, *249*, 118249. [CrossRef]
194. Chen, B.; Xie, M.; Feng, Q.; Li, Z.; Chu, L.; Liu, Q. Heat risk of residents in different types of communities from urban heat-exposed areas. *Sci. Total Environ.* **2021**, *768*, 145052. [CrossRef]
195. Ehsan, S.; Abbas, F.; Ibrahim, M.; Ahmad, B.; Farooque, A. Thermal Discomfort Levels, Building Design Concepts, and Some Heat Mitigation Strategies in Low-Income Communities of a South Asian City. *Int. J. Environ. Res. Public Health* **2021**, *18*, 2535. [CrossRef]
196. Yang, H.; Yoon, H. Revealing an Integrative Mechanism of Cognition, Emotion, and Heat-Protective Action of Older Adults. *Sustainability* **2021**, *13*, 3534. [CrossRef]
197. Lou, J.; Ban, J.; Zhang, T.; Wang, P.; Wu, Y.; Huang, L.; Li, T.; Bi, J. An intervention study of the rural elderly for improving exposure, risk perception and behavioral responses under high temperature. *Environ. Res. Lett.* **2021**, *16*, 055029. [CrossRef]
198. Public Health England. *Heatwave Plan for England*; Public Health England: London, UK. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/888668/Heatwave_plan_for_England_2020.pdf (accessed on 20 May 2021).
199. Degirmenci, K.; Desouza, K.C.; Fieuw, W.; Watson, R.T.; Yigitcanlar, T. Understanding policy and technology responses in mitigating urban heat islands: A literature review and directions for future research. *Sustain. Cities Soc.* **2021**, *70*, 102873. [CrossRef]
200. Jandaghian, Z.; Akbari, H. Increasing urban albedo to reduce heat-related mortality in Toronto and Montreal, Canada. *Energy Build.* **2021**, *237*, 110697. [CrossRef]
201. Semeraro, T.; Scarano, A.; Buccolieri, R.; Santino, A.; Aarrevaara, E. Planning of Urban Green Spaces: An Ecological Perspective on Human Benefits. *Land* **2021**, *10*, 105. [CrossRef]
202. McGregor, G.R.; Bessemoulin, P.; Ebi, K.L.; Menne, B. Heatwaves and health: Guidance on Warning-System Development: World Meteorological Organization. 2015. Available online: http://www.who.int/globalchange/publications/WMO_WHO_Heat_Health_Guidance_2015.pdf (accessed on 20 May 2021).
203. Abu-Rayash, A.; Dincer, I. Development of integrated sustainability performance indicators for better management of smart cities. *Sustain. Cities Soc.* **2021**, *67*, 102704. [CrossRef]
204. Shamsuzzoha, A.; Nieminen, J.; Piya, S.; Rutledge, K. Smart city for sustainable environment: A comparison of participatory strategies from Helsinki, Singapore and London. *Cities* **2021**, *114*, 103194. [CrossRef]
205. Glagolev, V.A.; Zubareva, A.M.; Grigorieva, E.A. Grassfire forecast at agricultural lands in Jewish Autonomous Region. *Reg. Probl.* **2018**, *21*, 93–97. [CrossRef]