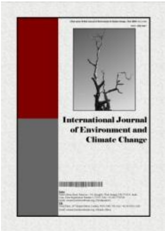

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A Systematic Review and Meta-Analysis on the Relationships between Extreme Ambient Temperature and All-Cause Mortality Risk: A Time Series Approach

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Authors' contributions

This work was carried out in collaboration among all authors. Author OOE designed the study and participated in editing. Author ODS took part in writing and editing the study. Author EI outlined the analysis and took part in analysis. Author NC extracted data, entered and analyzed the data. All the authors participated in final drafting and scrutinizing of the entire study. All authors read and approved the final manuscript.

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Systematic Review Article

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ABSTRACT

Background: Exposure to extreme low or high ambient temperatures is associated with cardiovascular, respiratory and endocrine diseases and other complications, thereby causing death. This article is a synthesis of the relationships between ambient temperature and mortality from time series studies.
Methods: This systematic review and meta-analysis used the PICO search strategy and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. On 14th February to 21st of May 2020, PubMed, Springer and Science direct databases were systematically

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searched to obtain original studies published during the period of (2010 to 2019). The systematic review incorporated 23 studies, with sixteen (16) of these articles used for the meta-analysis and the remaining seven (7) articles were included in the narrative synthesis. Twelve of 16 studies used for meta-analysis were conducted in countries in Asia particularly in China, while three (3) of the remaining in Europe (Sweden, Spain and Portugal) and only one (1) study in Africa (South Africa). The meta-analysis was sub-grouped into (cold and warm) temperatures.

Results: The result of the meta-analysis indicated a pooled relative risk (RR) for cold temperature of 1.632, while pooled RR for the warm temperature of 1.287 and the RR for the whole data (cold and warm) temperature of 1.430. The Meta-analysis indicated a statistical significance ($p < 0.01$) of the pooled estimate which signified that exposure to cold or extreme low temperature 1.632 (95% CI 1.262–2.110) have greater mortality risk than exposure to extreme high temperature 1.287 (95% CI 1.030–1.606).

Conclusion: The RRs for extreme low and high temperatures associated with temperature attributable deaths differs in populations and locality. Government, Decision Makers, Social Actors and Health Administrators should make adequate planning and set up public health interventions to prevent and control the health impact of exposure to extreme ambient temperatures in vulnerable subpopulation particularly Africa.

Keywords: Systematic review; meta-analysis; temperature; relative risk; all-cause mortality; time series.

ABBREVIATIONS

ATmax : Maximum Atmospheric Temperature
CI : Confidence Interval
DLNLM : Distributed Lag Non-Linear Models
MMT : Minimum Mortality Temperature
PICO : Patient/Population, Intervention, Comparison and Outcomes
PRISMA : Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines
RR : Relative Risk

1. INTRODUCTION

Global climate change is a continuous event that is accompanied with changes in ambient temperature and other weather parameters [1]. The climate changes in the different regions of the world affect the health of human [2]. Over five decades, global climate change has had pervasive impacts such as increased occurrence of life-threatening weather events (e.g., heat waves, cold spells, drought and flood) [3]. The occurrence, intensity, and extent of extreme temperature events are likely to increase in the future and double the associated health risks to human beings [4]. Climate change is now known as the main threat to human health in the 21st century all over the world [4].

The impacts of climate change on human health are of increasing public health concern 3. Health impacts of climate change in countries have been reported. These include heat-related deaths, health effects of air pollution, flood and drought, water- and foodborne diseases, vector and rodent borne diseases [1, 2]. Increase in atmospheric temperature alongside changes in the Earth's climatic patterns has been predicted [1]. Much as it has been acknowledged that rising temperatures will have deleterious effects on the planetary ecosystem, more directly, the atmospheric temperature has been shown to influence the occurrence of mortality in human populations [1]. This means that temperature associated deaths will mirror climate change, aging population, and high level of urbanization [5].

There is an evidence that climate change is associated with extreme temperatures and mortality [6]. Elevated temperatures with significant impacts on daily mortality incidence in many cities have been documented [1]. Increasingly, investigators are exploring the simultaneous relationships between temperature and mortality [6]. While most studies suggest pooled effect of cold and hot temperatures on mortality, others have yielded inconsistent mortality estimates [6].

1.1 Reference Ambient Temperatures

The ambient temperature is referred to as the average air temperature inside or outside the environment5. It is regarded as the normal temperature or the standard temperature, commonly expressed in degrees Centigrade (°C) or degrees Fahrenheit (°F). The reference human body-temperature ranges of 36.5–37°C (98.6°F). However, reference ambient temperature is considered as the standard temperature range which differs in various continents of the world [4]. Reference temperatures may be measured in percentiles such as 90th percentile and 10th percentile for extreme high temperature effect and extreme low temperature effect respectively [7]. The reference temperatures have been applied in Distributed Lag Non-linear Models (DLNM) analysis to produce RRs for extreme low and high temperature effects [8].

1.2 Effects of Ambient Temperature on Human Health

The effect of extreme temperatures on human health has been established and reported in several studies [4,2]. Extreme high and low had short and long-term effects on all-cause mortality [4]. Ambient temperature, particularly extreme cold or hot temperatures have been linked to many health conditions (such as cardiovascular diseases, respiratory diseases, endocrine diseases and cancers etc) which in turn lead to death. However, impacts of extreme high temperatures are more implicated in cardiovascular diseases [5]. However, the relationship between extreme ambient temperature and cardiovascular mortality differs in populations, regions and climates [2]. It is estimated that extreme temperature greatly contribute to about 3.7 million people who died of cardiovascular disease annually, leading to high of the burden of the disease [2,7].

1.3 Pathophysiology of Effect of Extreme Temperatures on Human Organ-System

The human body tolerates certain level of low and high temperatures [7]. This is achieved through the thermoregulatory system governed by the negative feedback loop that maintains the body temperature within small limits. This regulator system is similar to other control systems in the body. The thermoregulatory center control the temperature changes through integrated afferent impulses from temperature-sensitive cells in the brain, spinal cord, central core tissues (i.e., brain, heart, lungs, liver, kidneys, and endocrine glands), respiratory tract, gastrointestinal tract, and skin [9].

During extreme low and high temperatures the thermoregulatory system is altered thereby exacerbating the impacts of existing diseases and complications in different system of the body, particularly the cardiovascular, respiratory and cerebrovascular system [10]. Studies reported that variations in ambient temperature cause constriction of blood vessels in the human body which leads to fluctuations in blood pressure, thereby increasing afterload of the heart and worsening symptoms of previous cardiovascular disease [1,2]. It is documented that rapid alterations in blood pressure may result in cardiovascular disease [1,2].

Studies reported that cold temperatures cause physiological changes such as changes in cholesterol levels, platelet aggregation, fibrinogen concentrations and blood sugar [11]. Fibrinogen has a vital role in acute myocardial infarction, life-threatening arrhythmia and coronary artery thrombosis [11]. Increase in heart rate, blood pressure, and blood viscosity has been linked to exposure to cold. Also, during winter (cold weather) higher levels of blood lipids, fibrinogen was observed in the elderly [12]. The fluctuations in these indicators, and atherosclerosis can affect the incidence of cardiovascular disease and complications [12]. Also, cold temperature can cause complications in respiratory infections and affects the cardiovascular function indirectly. High temperature exposure increases the risk of short-term cardiovascular death, resulting from rise in platelet counts, red blood cell, level of serum cholesterol and level of plasma viscosity [12]. Exposure to hot ambient temperature lead to high body temperature which causes short-term cardiovascular death caused by ‘harvest effect’. Hot atmospheric temperature increases body temperature of humans and rearranged distribution of blood flow, thereby worsening the stress on the cardiovascular system [13].

1.4 Relative Risk

Relative risk is also called risk ratio, it is the ratio of the probability of an outcome in an exposed group to the probability of an outcome in an unexposed group [14]. Relative risk is calculated by dividing the likelihood of an event taking place (group A) to the ratio of possibility of another event happening (group B) [14]. In this context of this review, the relative risk was considered as the effect of cold or hot (low or high) temperature on the exposed to the ratio of effect of cold or hot (low or high) temperature on the unexposed [14]. Tobias et al. [15] reported that, relative risks varied across the climatic zones, and was higher in cities with cooler climates compare to hot weather [15]. Relative risk can be influenced or affected by individual features, social and environmental factors such as urbanizations rates and central heating. Similarly, [2] reported that relative risks were affected by gender, age, and specific cardiovascular disease. In males, there was a higher relative risks of and effect of cold temperature than in females [16]. Individuals, at the age of ≥75 years had a higher estimate of temperature-related cardiovascular mortality risk [16].

1.5 Relationship between Temperature and Mortality Risk

The short-term exposure to extreme temperatures has been linked to mortality and this is similar in various geographical regions with different climatic conditions in the world [17]. Epidemiological studies conducted on relationship between ambient temperature and mortality, revealed that association differs across study settings, illustrated as J, U, or V-shaped [2]. Relationship between extreme temperatures and all-cause mortality risk were reported as temperature-based RRs and some as percentile-based RR estimates [18]. The temperature-based RRs and percentile-based RR estimates is linked to the reference temperature points and RR estimates associated with every one degree change in reference point. The extreme high temperature had acute and short term effects decreases rapidly along the lag days, with a great risk at 0-day exposure [19].

Conversely, extreme low temperature effect persists longer and drops more slowly but worsen health condition that result to death causing more. However, effects of extreme temperatures on mortality pattern varies by individual features such as gender, age, type of cardiovascular diseases [2]. In a study by [2], indicated that minimum mortality temperature (24.7°C) and defined (-1.8°C) as extreme cold and (26.3°C) as extreme hot. Generally, cardiovascular mortality risk by temperature was estimated as a non-linear. Zhai et al. [2,16] posited that temperature is associated with cardiovascular mortality risk, and has a greater relative risk at cooler temperatures, with attainment of the maximum risk at -11.5°C.

The RR of 2.05 at -4.8 °C caused cardiovascular death, nevertheless, as temperature decreases, the risk of cardiovascular mortality slowly increases. This was noticed in rapid increasing temperature below -4.8°C [16]. This implies that cold ambient temperature has a higher effect on cardiovascular mortality than the hot temperature particularly in older people [18]. This is because there is a decrease in regulating body temperature with increasing age [18]. In another study conducted in Portugal, revealed that raised temperatures have a significant impact on daily mortality occurrence in the most urbanized areas in the country [1]. However, bearing in mind the enormous indication that global climate is likely to become hotter, there is a genuine concern that imminent climate changes will have a substantial health effect in comings years. As the relationship between extreme temperature and human health are intricate and specific in a particular locality, there is a need to identify population that are most vulnerable and susceptible to extreme temperature at the local level [1].

In many countries there have been an increase in premature deaths associated with extreme temperatures. It is has been reported that environmentally-determined mortality will double by 2050 globally if no serious action is taken to reduced factors that influence mortality caused by temperature [20,21]. Though, evidence that extreme temperatures (cold and hot) lead to increase in mortality has been reported by [1], but consistent effect of extreme temperatures (cold and hot) has not yet been elucidated. This is because impacts of extreme temperatures on human health and mortality is influenced by several environmental factors such as air quality, global warming, and climate change [22].

Also, enough public health preparedness efforts for adaptation of climate change have not been done [23]. Hence, it is essential to review and analyze the relationships between extreme ambient temperatures and all-cause mortality risk in a time series approach. This time series approach was applied to undertake specific way of analyzing the sequence of data collected over an interval of time (within 10 years interval (2010-2019)). The time series approach enabled recording of the data at a consistent intervals over 10 years period of time instead of intermittent or random recording the data.

Review Questions; what is the relationship between ambient temperature change and all-cause mortality?

2. MATERIALS AND METHODS

This systematic review was conducted based on Preferred Reporting Items for Systematic

Reviews and Meta-Analyses (PRISMA) guidelines [24], and time-series studies.

Data sources and search strategy: Online databases (PubMed, Springer and Science Direct) were systematically searched to find articles that documented on the relationships between temperature and mortality pattern. Date restriction was applied in the search, only related articles published between 2010 and 2020 were used. The following search terms were used in the search for related titles and ((temperature OR "atmospheric temperature" OR "ambient temperature") AND ("daily mortality" OR "all-cause mortality" OR "daily mortality risk" OR "mortality" and "death")).

2.1 Eligibility

Inclusion Criteria: (1) Original articles published in English (2) time-series studies (3) Human studies which used actual instrumental measurements or modelled levels of temperature measurements and relate these with mortality (4) Articles published within 10 years interval (2010-2019). Ten 10 years interval was adopted to obtain reliable information and data that reflect the current situation.

Exclusion Criteria: (1) Article published in any native language (2) Studies that used animals (3) All reviews articles (4) Documentaries (5) article in which full study that were not available (6) Studies that did not mention or are not specific to time-series studies.

PICO Framework:

Inclusion / Exclusion Participants: Studies included the whole population (children, youths, adults and elderly) who were defined as healthy or did not have significant co-morbidities. Exposure: Individuals who were exposed to daily minimum, mean or average, and maximum temperatures, extreme temperatures (cold and hot).

Compare / Control: Extreme low temperature (cold) and extreme high temperature (warm), low confidence interval of cold temperature and low confidence interval of warm temperature, high confidence interval of cold temperature and high confidence interval of warm temperature, relative risk of cold temperature and relative risk of warm temperature.

Outcomes: Daily mortality from all causes.

Effect estimate: Data using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and random-effects model was applied to measure effect estimate from the pool of data on relative risk of cold temperature which ranged from 1.006 to 4.08, relative risk of warm temperature which ranged from 0.67 to 5.6. The low confidence interval of cold temperature ranged from 0.86 to 3.63, high confidence interval of cold temperature ranged from 1.01 to 6.29, the low confidence interval of warn temperature ranged from −2.44 to 4.6 and high confidence interval of warn temperature ranged from 1.038 to 6.6. Most of the studies reported unable to control for confounders [3,13,16].

2.2 Data Selection

Duplicate records were deleted, after which other remaining articles were reviewed and collated to ascertain their suitability for inclusion. Titles and abstracts of articles were first screened, and publications that did not meet the written criteria were removed. There was always re-assessment the full texts of the remaining articles for eligibility when necessary. Using a constructed data extraction table, which consists of author's last name, air quality parameter, temperature, and number of death, experimental model, duration years/months / week /days of studied, month of peak of mortality, year of peak of mortality, mortality rate and experimental summary after which relevant data for the study were extracted.

2.3 Data Analysis

The data extracted were entered into Microsoft Excel 2016. A random-effects meta-analysis analysis was performed using Microsoft Excel 2016. The heterogeneity of the data was managed by ensuring that data from articles that reported relative risk, 1 degree Celsius rise in temperature and percentiles were extracted and used for the meta-analysis. Also, test of sub-group or heterogeneity was conducted using random-effects model, and the results of the meta-analysis were presented in forest plots.

3. RESULTS

3.1 Data Selection

Initially, we searched three databases (PubMed, Springer and Science direct) using the keywords, without date restriction and 1706 articles (546 PubMed, 665 Springer and 495 Science direct) were identified. A subsequent search with date restriction of (2010-2019) gave 973 records (333 from PubMed, 424 from Springer and 216 Science direct). After screening of the titles and removal of abstracts, and removal duplicates from each of the journals, 123 records (36 PubMed, 34 Springer and 23 Science direct) were left. Furthermore, screening full article for relevance and removal of inaccessible articles gave a total of 23 records (18 PubMed, 3 Springer and 2 Science direct). Hence, 23 of the records were downloaded for full text screening, sixteen (16) of the articles were used for the meta-analysis and the remaining seven (7) articles were included in the narrative synthesis.

3.2 Statistical Analysis

Fig. 2 Meta-analysis and forest plot of the effect of the pooled RR. The meta-analysis was sub-grouped by (cold and warm) temperatures. The pooled RR for cold temperature is 1.632 while pooled RR for the warm temperature is 1.287 and the overall RR for the whole data (cold and warm) temperature is 1.430. The Meta-analysis indicated a statistical significance ($p < 0.01$) of the pooled estimate. This signify that exposure to cold temperature has greater risk of causing death than warm temperature. Also, it shows that 11 studies out of 13 studies used for the meta-analysis of the cold temperature were conducted in Asia, while only 1 article out of the 13 articles were carried out in Africa and Europe respectively. For the meta-analysis of the warm temperature, 12 studies were conducted in Asia, 3 Europe and 1 Africa.

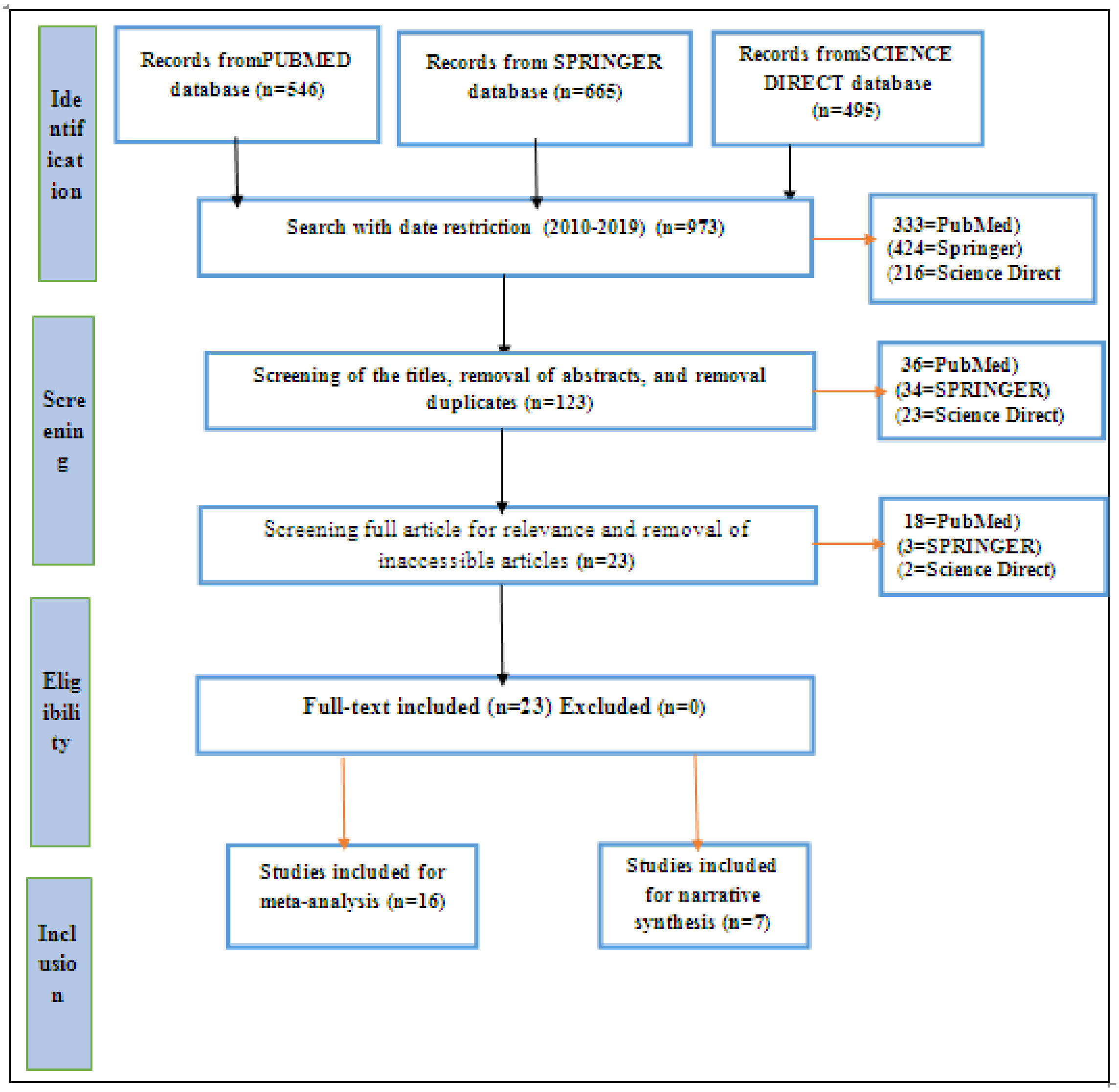

Fig. 1. Flowchart of data selection process

Table 1. Extracted data on temperatures, RR, time lag of the studies included in the quantitative and qualitative synthesis

Time lag	Author, year	Continent	Study site	Daily average death/mortality	Low temp/min	Moderate temp/average	Maximum temperature	Relative Risk
1981-2012	Yang ,2015	Asia	China/Shanghai	5	−8.0°C	14.2°C	31°C	1.01
1990–2002	Rocklöv,2010	Europe	Sweden/Stockholm	10.21	3.2°C	16.1°C	34.6°C	1.024
1990-2006	Breitner,2014	Europe	Southern Germany/Augsburg	8	−15.3°C	9.1°C	27.1°C	1.06
1995-2004	Tobias,2012	Europe	Spain/Teruel	165	11.7	20	28.6	1.24
1996-2013	Ferreira,2019	South America	Brazil/ Rio de Janeiro	45	13.8	23.3	31.3	1.24
1997-2013	Scovronick, 2018	Africa	South Africa	50	15.8 °C	25.3 °C	30.6 °C	1.06
1999–2008	Guo/2012	Asia	Thailand	35	13.3	26.24°C	33.5	1.1
2000–2004	Almeida,2013	Europe	Portugal/Lisbon	53.4		21.3◦C	29.3◦C	5.6
2000-2009	Cheng,2017	Asia	Australia/Sydney	66.4	8.3°C	18.4°C	33.1°C	1.16
2000–2009	Kim,2015	Asia	South Korea	25.01	−15.72°C	14.46°C	30.43°C	4.13
2003 -2005	Liu,2011	Asia	China/Beijing	29	6.9°C	22.6°C	32.1°C	1.098
2004-2010	Li,2014	Asia	China/Shenzhen	14.4	21.8°C	31.4°C	37.9°C	1.319
2005-2008	Wang,2014	Asia	China/Suzhou	34.2	−2.8°C	17.2°C	33.8°C	1.43
2007-2013	Ding,2015	Asia	Southwest China/Yuxi	14	−0.9°C	16.9°C	24.6°C	1.03
2008–2011	Bao,2016	Asia	China/Wuhan		–2.7	17.15	35.3	1.35
2008-2012	Bai ,2014	Asia	China/ Jiangzi	3.8	−12.2°C	6.7°C	16.4°C	2.251
2009–2012	Zhang,2017	Asia	China/ Hubei	9.1	−0.5	16.6 °C,	32.4	1.097
2009-2016	Deng, 2019	Asia	southwest China	33	−3.3°C	16.1°C	25.6°C	0.67
2009-2016	Singh,2019	Asia	India/Varanasi city	22.15	20.05	25.81	31.56	1.13
2009-2017	Zhai,2020	Asia	China/Qingdao	67	24.7°C	14.5°C	26.3°C	3.73
2010 - 2016	Alahmad,2019	Asia	Kuwait	35	6.86°C	28.7°C	44.65°C	1.65
2011–2014	Han,2017	Asia	China/Jinan	104.1	−9.4°C	14.7°C	34°C	1.02
2000–2014	Ruuhela,2019	Europe	Finland	-	−20 °C	24 °C	-	1.16

Table 2. Data showing extreme temperatures, RR, confidence interval, time lag of the studies included in the meta-analysis

Time lag	Author, year	Continent	Study site	Relative risk/cold	Low confidence-interval/cold	High confi /Cold	Relative risk/warm	Low confidence interval /warm	High confi/warm	Environmental impact
1990-2002	Rocklov, 2010	Europe	Sweden /Stockholm	1.006	1.001	1.01	1.024	1.01	1.038	For every 1◦C elevation in ATmax above the city-specific threshold, all-cause mortality rate rose
1995-2004	Tobias,2012	Europe	Spain /Teruel	1.24			1.24	1.19	1.3	Maximum and minimum temperatures were simultaneously below the 50th percentile.
1997-2013	Scovronick,	Africa	South Africa	1.14	1.1	1.17	1.06	1.03	1.09	1st percentile and the 99th percentile relative to the optimum temperature
1999-2008	Guo, 2012	Asia	Thailand	1.29	1.16	1.44	1.11	1	1.24	1st percentile and the 99th percentile relative to the optimum temperature
2000-2004	Almeida, 2013	Europe	Portugal/ Lisbon	-	-		5.6	4.6	6.6	For every 1◦C elevation in ATmax above the city-specific threshold, all-cause mortality rate rose
2000-2009	Cheng, 2014	Asia	Australia /Sydney	1.68	1.57	1.81	1.16	1.12	1.21	Deaths associated with each 1 °C rise in temperature variability elevated
2005-2008	Wang, 2014	Asia	China /Suzh	1.75	1.43	2.14	1.43	1.31	1.56	1st percentile and the 99th percentile relative to the optimum temperature
2007-2013	Ding, 2005	Asia	Southwest China/Yuxi	2.05	1.25	3.36	0.84	0.46	1.53	25th percentile and the 75th percentile relative to the optimum /increase in daily temp
2008-2011	Bao,2016	Asia	China /Wuhan	4.78	3.63	6.29	1.35	1.18	1.55	Extreme cold temperatures at a lag of 21 days, extreme hot temperatures, at a lag of 3 days.

Time lag	Author, year	Continent	Study site	Relative risk/cold	Low confidence-interval/cold	High confi /Cold	Relative risk/warm	Low confidence interval /warm	High confi/warm	Environmental impact
2008-2012	Bai,2014	Asia	China /Jiangzi	2.251	1.054	4.849	1.215	0.658	2.246	1st percentile and the 99th percentile relative to the optimum temperature
2009-2012	Zhang, 2017	Asia	China/ Hubei	1.828	1.468	2.277	1.097	1.044	1.153	1st percentile and the 99th percentile relative to the optimum temperature
2009-2016	Deng, 2019	Asia	Southwest China	4.08	0.86	7.12	0.67	-2.44	3.64	At 2.5th and 97.5th percentiles of the distribution of mean temperature
2009-2016	Singh, 2019	Asia	India/Varan asi city	1.06	0.98	1.14	1.13	1.04	1.22	For every 1◦C elevation in ATmax above the city-specific threshold, all-cause mortality rate rose
2010-2014	Alahmad, 2019	Asia	Kuwait	1.67	1.02	2.73	1.65	1.09	2.48	1st percentile and the 99th percentile relative to the optimum temperature
2011-2014	Han, 2017	Asia	China/Jinan	1.08	1.06	1.11	1.02	1	1.05	5th percentile and the 95th percentile relative to the optimum temperature
2014-2010	Li,2014	Asia	China/Shen zhen	-	-	-	1.04	1.014	1.067	For every 1◦C elevation in ATmax above the city-specific threshold, all-cause mortality rate rose

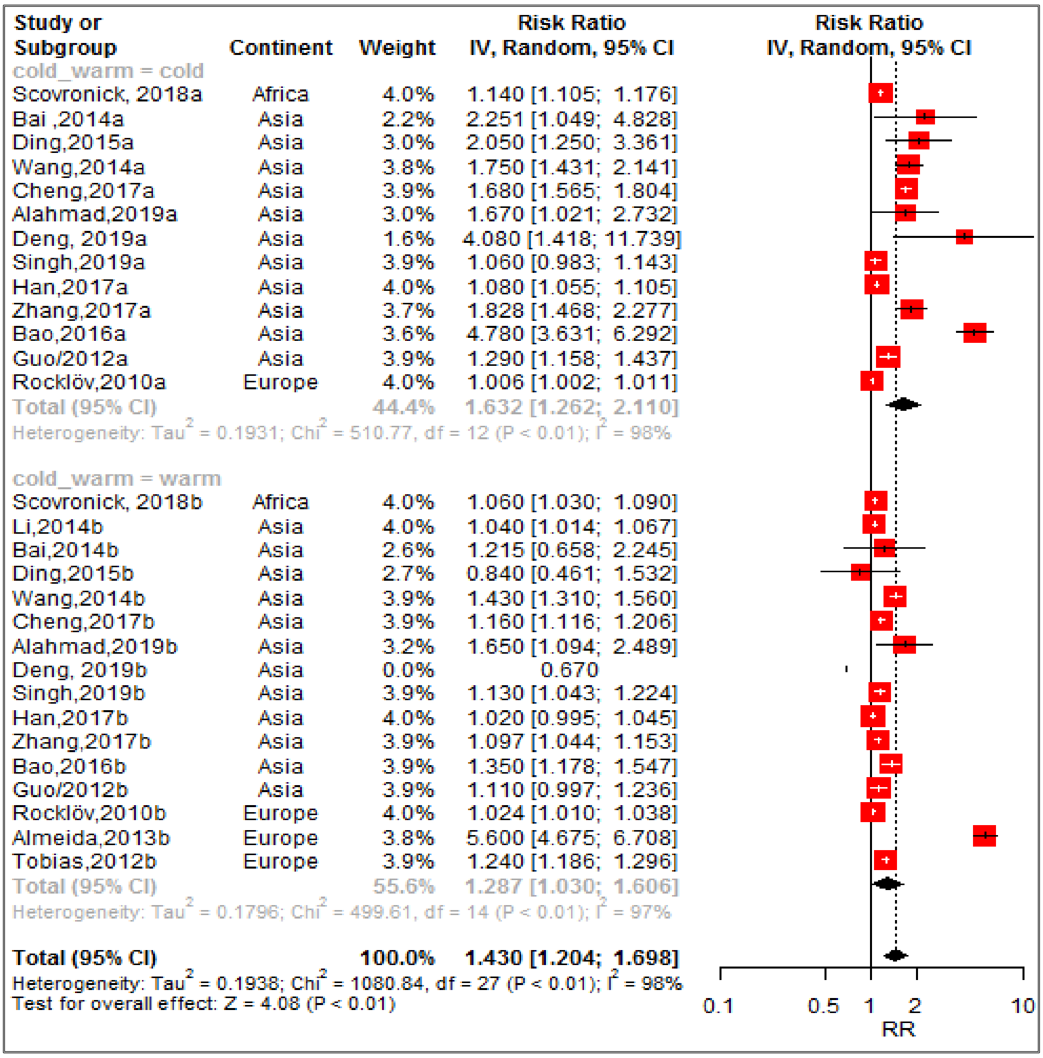

Fig. 2. Meta-analysis and forest plot of effect of RR for cold and warm temperatures

Table 3. Relative risks, confidence intervals and temperature subgroups (cold and warm)

RR	95%-CI	%W (random)	Cold_Warm
Bai ,2014a	2.2510 [1.0495; 4.8281]	2.2	cold
Rocklöv,2010a	1.0060 [1.0015; 1.0105]	4.0	cold
Ding,2015a	2.0500 [1.2504; 3.3610]	3.0	cold
Wang,2014a	1.7500[1.4305; 2.1408]	3.8	cold
Cheng,2017a	1.6800 [1.5647; 1.8038]	3.9	cold
Alahmad,2019a	1.6700 [1.0208; 2.7321]	3.0	cold
Scovronick, 2018a	1.1400 [1.1054; 1.1757]	4.0	cold
Deng, 2019a	4.0800 [1.4180; 11.7393]	1.6	cold
Singh,2019a	1.0600 [0.9828; 1.1433]	3.9	cold
Han,2017a	1.0800 [1.0554; 1.1052]	4.0	cold
Zhang,2017a	1.8280 [1.4678; 2.2766]	3.7	cold
Bao,2016a	4.7800 [3.6313; 6.2921]	3.6	cold
Guo/2012a	1.2900 [1.1578; 1.4373]	3.9	cold
Li,2014b	1.0400 [1.0138; 1.0668]	4.0	warm
Bai,2014b	1.2150 [0.6576; 2.2447]	2.6	warm
Rocklöv,2010b	1.0240 [1.0101; 1.0381]	4.0	Warm
Rocklöv,2010b	1.0240 [1.0101; 1.0381]	4.0	warm
Almeida,2013b	5.6000 [4.6752; 6.7078]	3.8	warm
Ding,2015b	0.8400 [0.4606; 1.5319]	2.7	Warm

RR	95%-CI	%W (random)	Cold_Warm
Wang,2014b	1.4300 [1.3104; 1.5605]	3.9	warm
Cheng,2017b	1.1600 [1.1160; 1.2057]	3.9	warm
Alahmad,2019b	1.6500 [1.0939; 2.4888]	3.2	warm
Scovronick, 2018b	1.0600 [1.0304; 1.0904]	4.0	warm
Deng, 2019b	0.6700	0.0	warm
Singh,2019b	1.1300 [1.0433; 1.2239]	3.9	warm
Han,2017b	1.0200 [0.9954; 1.0452]	4.0	**warm**
Zhang,2017b	1.0970 [1.0439; 1.1528]	3.9	warm
Tobias,2012b	1.2400 [1.1864; 1.2960]	3.9	warm
Bao,2016b	1.3500 [1.1779; 1.5472]	3.9	warm
Guo/2012b	1.1100 [0.9968; 1.2360]	3.9	warm

This table indicates the various RR for all-cause mortality reported by the each of the studies included in the meta-analysis.

4. DISCUSSION

The key finding in this systematic review is that 16 out of the 23 articles established that there is a direct or indirect relationships between temperatures particularly extreme low and high (cold and hot) and mortality in different populations. Concerning population samples, majority of the articles included in this systematic review considered all population (children, youths, adults and elderly). In most of the studies, the children and elderly were the major part of the population reported to experience more temperature related illness and deaths. It is essential to understand how the children and elderly respond and handle the effects of extremely low or high (cold and hot) temperatures.

Over the time, there has been significant increase in publications on this topic in the last 6 years, with 12 publications between 2014 and 2020 included in this review (Table 2). This review shows that thirteen out of sixteen studies used for meta-analysis were conducted in countries in Asia particularly in China, three out of the sixteen studies were conducted in Europe (Sweden, Spain and Portugal), while only one study out of the sixteen studies was carried out in Africa (South Africa) (Fig. 2). The dissimilarity in the study locations as reported by some authors may be due to the fact that those studies did not look at the extreme ambient temperatures as their key study terms rather heat wave. Thus, distribution of studies on this topic is linked to the level of concern for low and high (cold and hot), related illness and deaths in different populations and regions. This review identified that most of the temperature attributable deaths in elderly were due cardiovascular and respiratory complications resulting from increased exposure to hot temperature. In several studies, mortality was predicted by using the average, maximum or minimum daily temperatures.

On the other hand, such exposure variables may not adequately define the collective effects of temperature and other weather parameters such as humidity. Some of the studies reviewed reported that variation in temperature is associated with global warming and other climate events in addition to air pollution. There are several suggestions on the likelihood that extreme raised temperatures increase the health hazards on exposure to air pollution. Hence, there is increasing interest on relationships between temperature, air pollution, and health.

Scovronick et al. [25] found that changes in climatic factors and diverse mortality profiles (cause/age of death) and age distributions cause difference in relationship between ambient temperature and mortality in Africa and other developed areas. They reported that many people reside in places where they are not adequately protected from cold and hot temperatures. This review serves as a litmus test of poor information and lack of existing data on this topic in other continents of the world particularly Africa. Studies conducted in Europe and Africa, reported that extreme low and high temperatures were linked to risk of death and deaths [15,16,25]. The only study conducted in Africa included in this review reported an association between daily maximum temperature and mortality, and relative risk of very cold and hot days (1.14) and (1.06) for all age all-cause mortality significantly increased per day of the extended heat exposure [25]. This affirms the finding of the present review that pooled relative risks (1.632) for cold temperature have stronger effect on mortality than the pooled relative risk (1.287) for the warm.

Findings by Bao et al. [26] revealed that the effects of extremely high temperatures (warm) usually continued for 3 days, while the risk of extremely low temperatures (cold) could persist for 21 days. Bao et al. [26] reported that the relative risks (95% confidence interval) of extreme cold temperatures in four cities in China were 4.78, 2.38, 2.62 and 2.62, while the relative risks extreme hot temperatures were 1.35, 1.19, 1.22 and 2.47. This implies that relative risks of low temperatures (cold) has greater effect on mortality than the relative risks of high temperatures (hot). Similarly, finding in this present review indicated that pooled relative risks (1.632) for cold temperature has stronger effect on all-cause mortality than the pooled relative risk (1.287) for the warm or high temperature.

In course of this review, we found that vulnerability to extremely low and high temperatures varies by cause of death, place of occurrence of death, demographic and socioeconomic features [27-30]. Also, exposures to different extremes of temperatures, particularly hot temperatures lead to increase in cause-specific cardiovascular mortality which is associated with arrhythmias, heart failure, and cerebrovascular diseases [5,31-34]. Effects of temperature were more evident in the elderly, and there was an increase in all-cause mortality rate for every 1◦C elevation in ambient temperature above the city-specific threshold [30,35-39].

Similarly, findings by Song et al. [40] showed that exposure to hot temperature increased risk of mortality. These reports are in line with the findings in the present review, the pooled estimate for the relative risk (RR) of mortality for cold temperature was 1.632 (95% CI 1.262–2.110) with reference at 1◦C rise in temperature. However, low temperature (cold) is more likely to cause death, than high temperature (warm) at every 1◦C change in temperature.

4.1 Strengths

Reviews have been conducted on "systematic review and meta-analysis on extreme ambient temperature and mortality. However, to the best of our knowledge none of the reviews used time series approach. The main benefit of this time series analysis is that specific way of analyzing the sequence of data collected over a period of time such as 10 years interval. The time series approach enabled recording of the data at a consistent intervals over 10 years period of time instead of intermittent or random recording the data. This is an important aspect of this study that have not been applied in any other review on this topic. This review included the children, youths, adults and elderly who were defined as healthy or did not have significant co-morbidities. We choose a prolonged timeframe that allowed the authors to gather a substantial number of original studies on the topic, then adopted a method of re-assessment the full texts of the articles for eligibility when necessary.

5. CONCLUSION

The review found a range of relative risks that is associated with temperature attributable deaths that is applicable in different populations and locality. The results of the analysis support the findings that temperature (extreme cold and hot temperatures) have a deleterious effect on human health and cause death direct or indirectly. These assertions may require additional verification, particularly in regions with different weather patterns as this will offer substantial understanding of impact of extreme temperature and climate change on the mortality pattern of general populations. Also, an extensive range of ideas and factors linked to extreme temperatures with mortality pattern was considered. Hence, direct relationship between temperatures and death with several specific features was identified in most articles.

The impacts of temperatures changes on the health of an individual and communities have been broadly studied, to the point of identifying relative risk relationships. Consequently, it is possible to state the range of relative risks of extreme temperature exposure that can lead to death. From aspect of epidemiological studies, it is vital to understand whether people are aware of the impacts of extreme temperatures and how it can affect their health. This is important for interpreting the existing data in terms of reducing risk, thereby preventing temperature attributable death. The effects of extreme temperature on mortality should be understood in the relative context of the local temperatures and the level of adaptation of a population. Studies have documented that exposure to extreme temperatures especially the warm temperature increases chances of being a victim of cardiovascular and respiratory deaths. This mortality associated extreme temperature is seen in all ages particularly in older population compare to other age groups. Most studies reported that increased exposure to very low temperatures (cold) cause more death than warm temperature.

Therefore, we conclude that, there is a relationship between increased and decreased ambient temperatures and mortality. Cold temperature has a strong cumulative effect on mortality, than hot temperature which has acute and short-term effects. Finally, based on the findings in this review, it can be stated that exposure to 1◦C change in temperature, the relative risks associated with low temperatures (cold) 1.632 (95% CI 1.262–2.110) have a greater danger of causing death compared to that of high temperatures (warm) at 1.287 (95% CI 1.030–1.606).

6. RECOMMENDATIONS

This review found that quality of decisions and actions towards solving health problems associated with extreme temperature is dependent on sharing of information among scientific community and policy makers. Hence, information and data on effects of extreme temperature on human health should be gathered and used by government, policy makers and health administrators to prevent and manage temperature attributable deaths. Original studies and reviews should carry out socio-demographic characteristics (such as sex, age occupation, monthly income etc) to assess the effects of extreme temperature on human health. This will enable scholars ascertain disease of extreme temperature and the vulnerable populations. Also, stratified analyses on sex, age occupation and more should be performed, as this will allow health administrators to get correct evidence. This review found that exposure to cold temperature has greater risk of causing death than warm temperature. This finding should be used to plan for environmental health intervention that will prevent health impact of exposure to extreme temperatures in vulnerable subpopulations particularly in Africa. Finally the future lines of research should conduct studies on the relationships between temperature, current widespread of the Covid-19 pandemic and mortality patterns.

7. LIMITATIONS

Based on the scope of this topic, we acknowledge the limitations of this systematic review, mainly inability to obtain all available original articles on this subject matter. These limitations include choice of keywords, and exclusion of some scientific databases. Even though, we have confidence in the greater qualitative reliability of this review, we are aware that the period or duration of years selected and rejection of some scientific materials of other forms may limit the completeness of this review. Nevertheless, most systematic reviews with similar objectives producing new and adding to existing knowledge in a suitable period of time with only a few articles are characterized with all these limitations. Irrespective of these limitations, we have confidence that our paper will be of great importance to researchers as it will offer valuable evidence for prospective studies related to temperature and mortality pattern.

8. CONTRIBUTION TO KNOWLEDGE

This review contributes to understanding the risk of exposure to particular range of temperatures. It also affirms that there is a relationships between extreme temperature (cold and hot or low and high) and mortality risk. The review establishes that at 1◦C change in temperature tilting to extreme low temperature (cold) having a greater effect on mortality risk compared to that of extreme high temperatures (warm or hot). This review ascertains that level of the mortality risk associated with the changes in temperature is influenced by individual characteristics such as age, gender and preexisting health conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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