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Review article

A systematic review assessing the association between extreme temperature exposure and cardiovascular health outcomes in Africa

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ABSTRACT

The African continent is grappling with a rising prevalence of cardiovascular diseases (CVDs) in conjunction with the growing threat of climate change and its associated extreme temperatures. This systematic review aims to assess the relationship between extreme temperature exposures (heat and cold exposure) and cardiovascular health outcomes in African populations. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed in compiling this evidence. A comprehensive literature search was performed on PubMed-Medline, Scopus, Web of Science, and Google Scholar as the primary databases to identify relevant studies published from January 1990 to October 2024. Both hot and cold temperature extremes were linked to detrimental cardiovascular outcomes related to stroke. Exposure to sudden drops in minimum temperature exceeding 2.4 °C was linked with a 43 % higher risk of stroke. Elderly women (≥65-years) exposed to cold had the highest mortality rates and were more vulnerable to air pollution interactions during moderate temperatures (20–23 °C). Exposure to high temperatures (>37 °C) was associated with increased rates of heart failure and stroke. Hypertension was identified as a significant risk factor, with 37.6 % of stroke patients having pre-existing hypertension; notably, 86.2 % of these cases were linked to heat exposure. The highest CVD vulnerability was observed among females, older adults, and rural dwellers. The evidence presented in this systematic review suggests that exposure to both extreme cold and heat significantly contributes to the development of cardiovascular diseases. However, further studies are needed to validate and strengthen these findings.

1. Introduction

Cardiovascular diseases (CVD) are among the leading cause of morbidity and mortality globally (Bunker et al., 2016a; Mendis et al., 2022). In sub-Saharan Africa, CVD cases more than doubled between 1990 and 2019, while age-standardized mortality declined by 14.4 %; yet CVD now accounts for 38.3 % of all NCD deaths and 22.9 million DALYs, making it the second leading cause of death in the region (Minja et al., 2022a; Alhuneafat et al., 2024). This growing burden is largely driven by unequal access to healthcare and limited awareness of preventive and early intervention programmes [5; 6; 7]. The African continent is currently grappling with a rising prevalence of CVDs in conjunction with the growing threat of climate change and its associated extreme weather conditions, including extreme temperatures (Keir et al., 2022; Minja et al., 2022b). Temperature extremes including cold, ambient, and heat conditions have been identified as major

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environmental stressors contributing to detrimental cardiovascular health outcomes, particularly in vulnerable populations (Mendis et al., 2022; Kengne and Mayosi, 2013; Alahmad et al., 2023a; Liu et al., 2022). This relationship is further influenced by various risk factors such as age, existing comorbidities, socioeconomic status, and access to healthcare services (Kengne and Mayosi, 2013; Fomonyuy Yuyun et al., 2020). Existing literature indicates that the human body depends on thermoregulatory mechanisms to maintain homeostasis; however, exposure to extreme temperatures can impair these processes, resulting in adverse health effects linked to cardiovascular complications.

Exposure to cold temperatures triggers vasoconstriction, which increases blood pressure and cardiac workload, placing significant strain on the heart, particularly in individuals with pre-existing cardiovascular conditions. This can trigger ischemic events like heart attacks and strokes and may lead to fatal outcomes (Gasparrini et al., 2015; Ikäheimo et al., 2020; Ryti et al., 2017). In addition, cold exposure also alters blood composition, increasing haemo-concentration and fibrinogen levels, which promotes coagulation and raises the risk of thrombosis (De Vita et al., 2024). This response is also driven by the cold-related autonomous nervous system activation, occasionally leading to arrhythmias (Cleland et al., 2023). Conversely, heat exposure induces vasodilation and stimulates sweating, which can result in hypotension, dehydration, and reduced blood volume. These changes compromise cardiovascular function, especially in vulnerable individuals, potentially causing dizziness, arrhythmias, and severe cardiac events (Miles et al., 2022). When cardiac output fails to adequately compensate, this heat intolerance may lead to detrimental cardiovascular events.

The relationship between cold- and heat-related CVD mechanisms is supported by numerous studies, predominantly conducted in high-income countries, demonstrating strong associations between extreme temperatures and elevated cardiovascular morbidity and mortality (De Vita et al., 2024; Cleland et al., 2023; Bunker et al., 2016b; Hundessa et al., 2024; Masselot et al., 2023; Rai et al., 2023; Zanasi and Conte Keivabu, 2024). For instance, a large multi-country analysis by Gasparrini et al. (2015) (Gasparrini et al., 2015), encompassing data from 384 locations across 13 countries, revealed that both cold and heat significantly contributed to excess mortality, with cardiovascular-related deaths being among the most prominent (De Vita et al., 2024). Similarly, studies in Europe and North America have consistently reported V- or U-shaped relationships between temperature extremes and cardiovascular mortality, especially among older adults and individuals with underlying health conditions (De Vita et al., 2024; Cleland et al., 2023; Zanasi and Conte Keivabu, 2024; Analitis et al., 2008). This evidence indicates that both cold and hot temperature extremes are linked with increased cardiovascular mortality, with the lowest mortality risk occurring at moderate temperatures. Highlighting a well-established link between temperature variability and cardiovascular outcomes in high-income settings.

In contrast, such comprehensive epidemiological evidence remains limited in Africa, where diverse climatic conditions and underdeveloped health surveillance systems contribute to persistent knowledge gaps. To address this, the present systematic review aims to comprehensively assess the available evidence on the relationship between extreme temperature exposure and cardiovascular health outcomes across Africa. By synthesizing findings from various regions, this review seeks to offer a clearer understanding of how climate change-driven temperature extremes associated with cardiovascular health on the continent. In addition, it identifies key gaps in the literature, such as the lack of region-specific data and limited policy-oriented research, thus providing valuable insights for public health interventions and future research directions.

2. Methodology

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Cumpston et al., 2019). However, we did not conduct a meta-analysis due to including a diversity of research work with varying study designs. Although the outcomes of the included studies were comparable and could be pooled purposefully, the temperature extremes and comparators across the studies differed, which further limited the execution of a meta-analysis. The protocol for the current systematic review was not registered with the International Prospective Register for Systematic Reviews (PROSPERO). However, we followed a predefined methodology and adhered to PRISMA 2020 reporting guidelines throughout the review.

2.1. Literature search strategy

A comprehensive literature search was performed using PubMed-Medline, Scopus, Web of Science, and Google Scholar as the primary electronic databases to identify relevant studies published from January 1990 to October 2024. We included studies published from 1990 to 2024 to capture the emergence and evolution of research on temperature extremes and cardiovascular health in Africa. This period aligns with the growing global recognition of climate-related health risks, which gained momentum following the IPCC's First Assessment Report in 1990 (IPCC, 1990). The search strategy employed a combination of medical subject headings (MeSH) and relevant keyword terms related to: "Extreme temperatures," "Cardiovascular health outcomes," and "African countries," including their most relevant synonyms (supplementary file 1). Articles deemed eligible for inclusion were used to identify electronic databases that suggested similar articles, in addition to screening their reference list for any relevant studies. Furthermore, a manual search using key terms was conducted to identify additional studies not indexed in the selected primary database. A detailed search strategy of key terms and MeSH is provided in Supplementary File 1. The retrieved articles were imported into Rayyan and Zotero for screening, reference management, and duplicate removal. The Population-Exposure-Comparators-Outcomes (PECO) framework (Morgan et al., 2018) for this study encompassed the following:

2.2. Population (P)

This systematic review focuses on African populations of varying ethnicities with CVD health outcomes related to extreme temperature exposure.

2.3. Exposure (E)

This component of the study considered extreme temperature events, including ambient temperature, high- and low-apparent temperatures, temperature variability, and nonoptimal temperatures.

2.4. Comparators (C)

The study examines periods of normal and moderate temperatures, different levels of temperature extremes (e.g., moderate vs. severe heat exposures), and comparisons between hot and cold seasons in relation to CVDs in Africa.

2.5. Outcomes (O)

Outcomes of interest were cardiovascular health outcomes, which include hospital admissions for CVD, incidence and prevalence of cardiovascular events, and their associated risk factors.

2.6. Review design

Although the available literature on extreme temperature exposure and cardiovascular outcomes in Africa is limited and heterogeneous, we

deliberately employed a systematic review methodology to ensure a rigorous, transparent, and replicable process in identifying, appraising, and synthesizing the evidence. This review was conducted in accordance with the PRISMA 2020 guidelines. A systematic approach was selected to answer a focused research question using predefined eligibility criteria, comprehensive database searches, risk of bias assessment, and structured data synthesis. While some elements may resemble those of a scoping review due to the emerging nature of the evidence, our primary objective was to critically appraise and quantify the association between extreme temperature exposure and cardiovascular outcomes, justifying a systematic review framework over a scoping review.

2.7. Study eligibility criteria

Inclusion and exclusion criteria are outlined in Table 1. The eligibility assessment was conducted in two stages: first, titles and abstracts retrieved from electronic databases were screened to identify potentially relevant studies. Articles that met the inclusion criteria or lacked sufficient information were advanced to the full-text screening stage. The eligibility assessment was conducted independently by two reviewers to ensure reliability and minimize bias, with discrepancies resolved through discussion or consultation with a third reviewer when necessary.

2.8. Data extraction and quality assessment of studies

Two authors independently extracted data. Where disagreements existed, a third reviewer was assigned to validate the quality of evidence and risk of bias reported by the included studies. Extracted information from studies deemed eligible included author details, publication year, study region and timeframe, population size with gender distribution and participant age, primary temperature exposure variable, and key findings. Additional factors such as ethnicity and rural/urban study settings were also extracted when available. The quality of evidence and risk of bias were assessed by two independent authors using the NIH quality assessment tool for observational, cohort, and cross-sectional studies (NIH (National Institute of Health), 2021). Briefly, this tool evaluates the quality and risk of bias of the evidence reported in the included studies using four domains, including reporting bias, external validity, internal validity, and selection bias. Unlike other quality assessment tools, the NIH tool expresses these four domains as questions scored out of fourteen possible scores (Supplementary File 1). Interrater agreement between the two independent authors was determined using the International Business Machine Statistical Package for the Social Sciences (IBM SPSS) version 29.0.

Table 1
Inclusion and exclusion criteria for systematic literature review.

Inclusion	Exclusion
Observational studies (cohort, case-control, time-series, ecological time series, case-crossover, or case series study designs or cross-sectional designs).	Case reports or case series, opinion pieces, editorials or commentaries, unpublished studies, conference abstracts, or dissertations.
Studies conducted in African countries.	Global studies that did not provide separate data for African populations.
Studies examining the association between extreme temperature exposures and cardiovascular health outcomes.	Studies that did not focus on temperature exposures.
Studies published from 1990 up to the search date in 2024.	Studies examining other environmental exposures without considering temperature (e.g., air pollution alone).
Original studies published in English or can be translated into English.	Studies focusing solely on non-cardiovascular health effects of temperature.
Full-text articles.	Non-Human Subject Research.
Human subject research.	Non-English language publications.
	Duplicate publications of the same study.

2.9. Data synthesis

To synthesize the data for this systematic review, studies meeting the inclusion criteria were first categorized based on their year of publication. This allowed us to track existing evidence and ongoing developments linking temperature extremes and CVD. Because of heterogeneity in the methodological designs among the identified studies, we could not purposefully pool and group data on the duration of exposure, statistical model employed in each study, temperature extreme exposure type, and geographical location within Africa. Thus, the heterogeneity in study designs, temperature measurement techniques, and outcome definitions necessitated a narrative synthesis approach, as statistical pooling was not feasible in all cases due to methodological differences. Both observational and case-crossover studies were included, with data spanning diverse African regions, within Sub-Saharan countries. To purposefully present our data, we first described the characteristic attributes of the included studies. Taking into consideration the demographic characteristics (age, sex, and ethnicity) of the enrolled participants, and study design. We then gave a generalised link between extreme temperature exposure and the manifestation of CVD. This was followed by looking at the independent link between hot or cold temperature extremes with CVD development. Where applicable, we highlighted patterns or gaps in the evidence base.

2.10. Definition for extreme temperature

In this systematic review temperature extremes were defined using definitions presented by the included studies. These included computed daily temperature exposure, heat or cold indices, ambient temperatures, apparent, mean monthly, Wet-Bulb globe, and seasonal temperatures. For example, Northern Africa and sub-Saharan Africa, defined daily temperature exposure as 24.03 °C and 24.5 °C, respectively, by averaging daily minimum and maximum temperatures. Temperatures exceeding these thresholds were categorized as 'heat' exposures, while those falling below were classified as 'cold' exposures. This standardized definition allows for consistent comparison across studies by contextualizing temperature extremes relative to local climatic norms, thereby facilitating a more accurate assessment of temperature-related cardiovascular risks in differing African climatic zones.

3. Results

3.1. Characteristic attributes of the included studies

A total of 3000 studies published from January 1990 to October 2024 were identified in various scientific databases. After screening for article type and quality, only 16 studies met the eligibility criteria and were included, as illustrated in Fig. 1. Sample sizes ranged from 83 to 215632 participants. Five studies reported a mean age of 47 years among the enrolled participants, (Kengne and Mayosi, 2013; Ikäheimo et al., 2020; Heunis et al., 1995; Ibrahim et al., 2022), while eleven studies did not explicitly report the mean age of their enrolled participants. Seven studies reported on gender (Ibrahim et al., 2022; Gomes et al., 2015; Koch et al., 2023; Kunutsor and Powles, 2010; Chang et al., 2004; Lokotola et al., 2020; Matzke et al., 2024), with a predominance of female participants in five studies. Ethnic groups were reported in eight studies, with the prevalent ethnic group being Sub-Saharan African in seven studies, and both European and Sub-Saharan African participants in one study (Table 2).

By country/region, South Africa had the highest number of studies (n = 5), followed by Burkina Faso (n = 3), Mozambique (n = 2), Niger (n = 1), the Democratic Republic of Congo (n = 1), Ghana (n = 1) and Kenya (n = 1). Two studies were global or multi-country studies incorporating data from Africa, including Kenya, Zambia, Zimbabwe,

Table 2
Characteristic key findings on the association between extreme temperature exposure and cardiovascular health outcomes.

Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
Hundessa et al., 2024, (Hundessa et al., 2024)	Ecological observational study	Quasi-Poisson regression, distributed lag nonlinear model, 21-day lag	5 continents including Africa	19 years (2000–2019).	215632	Not reported	Not reported.	Average daily mean temperature (°C). Northern Africa: Heat: >24.03 °C; Cold: <24.03 °C. Sub Saharan Africa: Heat: >24.5 °C °C; Cold: <24.5 °C.	Long-term trends and seasonality, day-of-week effects	Not clearly specified; implied seasonal blood pressure variation.	Participants exposed to cold temperatures accounted for 196,411 CVD deaths annually, driven by ischemic heart disease and hypertension from vasoconstriction and increased cardiac demand. Key CVD risk factors in this population included inadequate public health infrastructure. Participants in regions with inadequate public health infrastructure were disproportionately affected.
Matzke et al., 2024, (Matzke et al., 2024)	Observational Case study	Unadjusted linear regression, multilinear regression analyses, 21-day lag	Rural Siaya, Kenya	1 year (2021–2022).	83	43 females and 41 males Mean age of 33-years.	Sub-Saharan African	Wet Bulb Globe Temperature (WBGT) and heat index of 20 °C and 22.1 °C, respectively.	Gender, age, and BMI	Self-reported data and observational symptoms; limited clinical validation.	Participants exposed to high heat index conditions experienced significant health impacts, with 95.1 % of study days exceeding caution-level heat thresholds (≥26.67 °C), however, cardiovascular outcomes and temperature results were inconclusive due to incompleteness of data. Key CVD risk factors in this population included aging and gender. Key CVD risk factors in this population included aging and other pre-existing CVDs. Older adults and females showed heightened vulnerability.

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Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
Koch et al., 2023, (Koch et al., 2023)	Observational panel study	Linear mixed-effects models, lag period unspecified	Rural Nouna Burkina Faso,	1 year (2021–2022).	143	76 males and 71 females Mean age of 43-years.	Sub-Saharan African	Wet-bulb globe temperature (WBGT) and heat index (HI) of ≥30 °C, and ≥25 °C respectively.	Not reported	Panel study: biometric and physiological assessments in occupational settings.	Participants exposed to high heat index conditions faced substantial environmental health risks, with 95.1 % of study days exceeding caution-level heat thresholds (≥26.67 °C). Participants exposed to unsafe wet bulb globe temperature (WBGT) levels for high-intensity labor on 96.6 % of days, increasing cardiovascular strain during essential activities like farming. Elevated Heart rate as a risk factor for CVD showed no significant correlation with heat exposure. Key CVD risk factors in this population included aging and other pre-existing CVDs.
Olutola et al., 2023, (Olutola et al., 2023)	Case-crossover study	Conditional logistic regression models, 0–1,0-6-day lag	Cape Town South Africa,	9 years (2006–2015).	54356	28134 males and 26166 females Age ranges of 15–44 (n = 20166) and 65-years and above (n = 34189).	Not reported.	Apparent temperature (Tapp), defined as low at (12.6 °C); moderate at 12.6 °C and ≤20.3 °C; and high at (>20.3 °C).	Public holidays and apparent temperature (Tapp) lag0-1	Hospital admissions and mortality records (linked with air pollution data).	Participants exposed to moderate and high (Tapp) combined with air pollution, faced significant cardiovascular risks. Participants exposed to NO_2 at moderate Tapp (20.3 °C) had the highest CVD mortality risk (4.7 % increase per 10 μg/m^3), driven by ischemic heart disease (31 % of deaths) and cerebrovascular events (27 %). Key CVD risk factors in this population

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Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
											included aging and gender. Elderly (≥65 years) faced a 7.0 % mortality increase from NO_2 at moderate Tapp. Females had higher susceptibility, with a 7.5 % risk increase in two-pollutant models (NO_2 + PM_{10}) at moderate Tapp.
Bühler et al., 2022 (Bühler et al., 2022)	Longitudinal study	Distributed lag non-linear model with negative binomial regression, 21-day lag	Limpopo Province, South Africa	7 years (2009–2016).	3124	1611 males and 1513 females Age ranges of <45 (n = 658) and ≥45 (n = 2466) years	Not reported.	Apparent temperature (T app), defined as cold (6–25 °C) and hot (27–32 °C) temperatures.	Humidity	Hospital records and mortality data from health surveillance systems.	Participants exposed to nonoptimal apparent temperatures (Tapp) showed significant cardiovascular disease (CVD) hospitalization risks, with 8.5 % of total CVD admissions attributable to cold temperatures and 1.1 % to warm temperatures. The highest risk of CVD admissions occurred at 16 °C, with a 23 % increased risk compared to the optimal temperature of 26 °C. Key CVD risk factors in this population included poverty and aging. Participants exposed to poverty (55 % below USD 73/ month) lacked heating/cooling infrastructure, exacerbating cold-related risks. Older adults (≥45 years) comprised 79 % of admissions, with heightened thermoregulatory strain.

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Table 2 (*continued*)

Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
Ibrahim et al., 2022, (Ibrahim et al., 2022)	Prospective study	Not clearly specified	Niger	4 months	258	121 females and 37 males Mean age of 55.17-years.	Sub-Saharan African	Seasonal temperature variations. Cold season: (21.4 °C, −34 °C). Hot season: (30.8 °C.-43. 5 °C)	Not reported	Not clearly specified	Participants exposed to hot-season temperatures (37–38 °C) faced higher rates of heart failure (56.55 % vs. 43.45 % in cold season) and stroke (38 vs. 24 cases). Ischemic strokes dominated (74.20 % of cases), occurring three times more frequently than haemorrhagic strokes. Participants exposed to heat had a 16.43 % mortality rate (24 deaths), significantly higher than the 11.60 % rate (13 deaths) in the cold season. Cardiovascular deaths accounted for 44.58 % of total mortality, with 64.87 % occurring during the hot season. Key CVD risk factors in this population included aging and modifiable factors. Older adults (≥60 years) comprised 54.25 % of admissions, with heightened thermoregulatory strain. Sedentary lifestyle (62.79 %) and hypertension (37.60 %) were leading modifiable risk factors.
Lokotola et al., 2020, (Lokotola et al., 2020)	Case-crossover epidemiological study	Conditional regression models, lag0–7, 0–14 and 0–21days	Cape Town, South Africa,	5 years (2011–2016)	54818	31904 males and 22913 females Age ranges of 15–44 (n = 27244)	Not reported.	Apparent temperature, defined as cold (<12.3 °C), normal (12.3 °C–20.3 °C), and warm (>20.3 °C)	Matched exposure data to individual characteristics that vary slowly over short periods,	Vital registration systems and hospital-based mortality statistics.	Participants exposed to air pollution and temperature extremes demonstrated significant cardiovascular

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Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
						and ≥65 (n = 27573).			such as comorbidities		disease (CVD) risks. Participants exposed to warm-day PM_{10} saw a 6.3 % increase in CVD admissions per 10 μg/m^3 rise (95 % CI: 3.4–9.3 %). Warm-day exposure (>20.3 °C) caused a 12.5 % higher risk of admissions (95 % CI: 5.3–20.2 %), peaking at 16.4 % for ages 15–64. SO_2 and Cold-day (<12.3 °C) exposure elevated admissions by 11.9 % (95 % CI: 1.8–23.0 %) for younger adults. Key risk factors for CVD in this population included age and gender. Ages 15–64 faced 2–3 times higher risks vs. ≥65 group, likely due to outdoor activity. Females had 7.6 % higher PM_{10}-related admissions vs. males.
Scovronick et al., 2018, (Scovronick et al., 2018)	Longitudinal study	Distributed lag non-linear models, 21-day lag	South Africa	16 years (1997–2013)	7576674 s	Not clearly specified Age range of 25–44-years (n = 2665473).	Not reported.	Mean daily maximum temperature ranging between 15.8 and 30.6 °C.	Location-specific average maximum temperature and temperature range.	Mortality and hospital discharge records.	Participants exposed to nonoptimal temperatures faced significant cardiovascular disease (CVD) outcomes, with 3.4 % of all deaths attributable to temperature extremes. Participants exposed to cold temperatures accounted for 3.0 % of deaths (RR 1.14, 95 % CI: 1.10–1.17). Cardiovascular deaths showed even stronger cold-associated risks (RR

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Table 2 (*continued*)

Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
											1.33, 95 % CI: 1.24–1.42). Participants exposed to heat experienced a smaller but significant mortality burden (0.4 % of deaths, RR 1.06, 95 % CI: 1.03–1.09), with immediate but short-lived impacts. Key risk factors for CVD in this population included age. Participants exposed to cold had the highest mortality rates among older adults (≥65 years) while children under 5 showed heat vulnerability.
(Bunker et al., 2017) (Bunker et al., 2017a)	Longitudinal study	Distributed lag non-linear models, quasi-Poisson distribution of years of life lost (YLL),14-day lag	Kossi Province, Rural Burkina Faso	10 Years (2000–2010).	472	Not clearly specified	Not reported.	Daily maximum temperature (°C). The median (50th percentile) maximum daily temperature was 36.4 °C, while the 75th percentile was 38.9 °C.	Season and long-term time trends	Health registry and hospital admission data.	Participants exposed to temperatures ≥41.7 °C (95th percentile) faced 0.81 excess daily NCD-YLL (95 % CI: 0.13–1.59) on the day of exposure (lag 0), decreasing after 4 days. A change from the 36.4 °C–42.8 °C resulted in 4.07 (95 % CI -2.73 to 35.66) mean daily YLL from all NCDs (including CVD) over lags 0–14 days. Exposure to extreme heat (42.8 °C) over 4 days increased excess daily mean NCD-YLL for all ages to 7.39 (95 % CI 0.32 to 24.62). Key risk factors for CVD in this population included gender. Men had 3.6 × higher heat-related CVD YLL than

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Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
											women at extreme heat (99th percentile: 42.8 °C), with 8.65 excess daily YLL (95 % CI: 1.07–32.73) versus 0.12 for women.
Gomes et al., 2015, (Gomes et al., 2015)	Case-crossover study	Conditional logistic regression, 0–7, 14–21 and 21–28-day lags	Maputo, Mozambique	1 year (2005–2006).	593	311 females and 282 males Mean age of 58.8-years.	Sub-Saharan African	Maximum decrease in minimum temperature, specifically declines higher than 2.4 °C in any two consecutive days in the previous week.	Mean relative daily humidity and mean precipitation	Hospital records of stroke admissions linked with heat exposure.	Participants exposed to cold temperature drops (≥2.4 °C decline in minimum temperature) had 43 % higher odds of stroke (adjusted OR = 1.43, 95 % CI: 1.15–1.76). The effect was strongest for haemorrhagic strokes (adjusted OR = 1.50, 95 % CI: 1.07–2.09) compared to ischemic strokes. Haemorrhagic stroke dominated temperature-related risks, with 1.5 times higher odds than ischemic strokes. Key risk factors for CVD in this population included pre-existing health conditions and healthcare delays. Participants exposed to cold without smoking, high cholesterol, or atrial fibrillation faced higher stroke odds (OR = 1.53 for no high cholesterol vs. 0.79 with high cholesterol). Stronger associations were seen in participants arriving >24 h post-stroke (OR = 1.62) versus <24 h (OR = 1.24).

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Table 2 (*continued*)

Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
Gomes et al., 2014, (Koch et al., 2023)	Retrospective cohort	Poisson regression model, 3, 5, 10, and 15-day lag	Maputo, Mozambique	1 year (2005–2006).	651	Not clearly specified	Not reported.	Daily minimum and maximum temperatures ranging from 5.1 to 5.1 °C minimum and 15.0–16.3 °C maximum	Humidity and precipitation	Stroke admissions and hospital record linkage.	Participants exposed to sudden declines in minimum temperatures (≥3.0 °C over 2 consecutive days), faced a 31 % higher incidence of stroke hospitalizations (adjusted IRR = 1.31, 95 % CI: 1.09–1.57) during the 10 days following exposure. Haemorrhagic stroke dominated temperature-related risks, though ischemic strokes were more common overall (74.2 % of cases). 86.2 % of participants had hypertension, but temperature effects were stronger in those without traditional risk factors (e.g., smoking, high cholesterol). Key risk factors for CVD in this population included health care delays. Participants arriving >24 h post-stroke had higher temperature-related risks.
Kunutsor and Powles, 2010, (Kunutsor and Powles, 2010)	Cross-sectional study	Pearson's linear correlation, bivariate regression analyses, lag period unspecified	Rural Kassena–Nankana District of northern Ghana	2 months (2010).	574	367 females and 207 males Mean age of 37.8-years.	Sub-Saharan African	Ambient temperature (°C), with daily mean temperatures ranging between 20 and 45 °C.	Age, gender, body mass index, waist circumference and blood pressure measurement time	Biometric blood pressure measurements.	Participants exposed to higher ambient temperatures (39–43 °C) during daytime measurements had lower mean SBP (120.9 mmHg vs. 123.1 mmHg at 28–34 °C) and diastolic blood pressure (DBP: 70.6 vs. 71.9 mmHg). Ambient

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Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
											temperature was inversely linked with both systolic (SBP) and diastolic blood pressure (DBP). SBP decreased by 5 mmHg per 10 °C increase in temperature. Higher ambient temperatures are associated with lower blood pressures. Key risk factors for CVD in this population included older age and larger waist circumference which independently increased SBP.
Kynast-Wolf et al., 2010, (Kynast-Wolf et al., 2010)	Retrospective cohort study	Poisson regression model, lag period unspecified	Rural/semi-urban Kossi province Burkina Faso	4 years (1999–2003).	11174 ps	Not clearly specified Age ranges of 40–64 (n = 8402) and 65-years and above (n = 2771.)	Not reported.	Mean monthly temperature ranging between 24 and 33 °C.	Age group	Mortality statistics and surveillance data.	Participants exposed to peak hot-dry season temperatures (32°-33 °C) (March–April) faced the highest CVD mortality, accounting for 7.4 % of deaths in adults aged 65+. Key risk factors for CVD in this population included age. Adults aged 65+ faced 5 × higher CVD mortality rates than those aged 40–64.
Hightower, 2009, (Hightower, 2009)	Cross-sectional study	Unpaired t-test or a correlation analysis, lag period unspecified	Kinshasa, Democratic Republic of Congo	1 year (2008–2009).	525	Not clearly specified	Sub-Saharan African	Average monthly temperatures: August 2008 (22.7 °C) and April 2009 (30.0 °C)	Exclusion of diabetes, hypertension, malaria, pregnancy, lactation, smoking, and recent major surgery cases	Seasonal biometric data; unclear if medical records were used.	Participants exposed to cooler temperatures (August, avg. 22.7 °C) had higher Hct levels compared to warmer months (April, avg. 30.0 °C). MAP decreased in females during cooler months (82.3 ± 7.3 mmHg vs. 87.9 ± 6.6 mmHg in

(*continued on next page*)

Table 2 (*continued*)

Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
											April), while males showed no seasonal MAP difference. Key risk factors for CVD in this population included gender. Females demonstrated stronger inverse Hct-MAP relationships. Males exhibited unchanged MAP despite higher Hct, implying reduced vascular adaptability and potential long-term hypertension risk.
Chang et al., 2004, (Chang et al., 2004)	Case–control study	Negative binomial regression model, 1 to 3 Months lags	17 different countries including Kenya, Zambia and Zimbabwe	6 years (1989–1995).	168	All 168 participants were females, = Age range of 15–29-years.	Sub-Saharan African	Monthly mean air temperature ranging between 15.3 and 19.0 °C, 16.3–24.5 °C and 13.4–21.1 °C in Kenya, Zambia and Zimbabwe respectively.	Excluded countries with a standard deviation in temperature of less than 1.5 C	Not clearly specified	Participants exposed to a 5 °C temperature drop faced a non-significant 11 % increase in hospitalization risk (IRR = 0.89, 95 % CI: 0.64–1.24). Zimbabwe showed the strongest inverse trend (IRR = 0.91, 95 % CI: 0.62–1.34). Limited data revealed no significant temperature association (IRR = 0.96, 95 % CI: 0.04–21.2) due to sparse cases (e.g., only 3 AMI cases in Kenya). Zimbabwe reported 146 stroke cases vs. 94 VTE cases, reflecting higher cerebrovascular burden. Key risk factors for CVD in this population included gender. Younger women (<35 years) showed marginally stronger

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Table 2 (*continued*)

Source	Study design	Statistical methods	Country/Location	Study period	Population size	Gender & Age	Ethnic group	Main temperature exposure variable (s)	Confounder control	Outcome Assessment Method	Key findings
											temperature-stroke links.
Heunis et al., 1995, (Heunis et al., 1995)	Retrospective study	T-test, Lag periods of 1, 2, 3 and 4 days	Cape Town, South Africa,	7 years (1978–1985).	11367	Gender not clearly specified Age range 65-years and above.	Restricted to European and Sub-Saharan African	Daily minimum and maximum temperatures. T_{min} of 4 °C and T_{max} of 25 °C were considered as extreme cold and hot conditions respectively.	Not reported	Vital statistics and cause-specific mortality records.	Participants exposed to minimum temperatures <4 °C experienced a lagged mortality peak 2 days post-exposure (average CDM: 10.00 deaths/day vs. 8.8 deaths/day on milder days). Participants exposed to sudden hot, dry winds >25 °C faced a 17 % rise in CDM 2 days later (10.30 deaths/day vs. 8.72 baseline). Participants exposed to large diurnal temperature ranges (21–25 °C) had the highest CDM (10.3 deaths/day), while small ranges (1–5 °C) also elevated risks (9.1 deaths/day) due to prolonged cold stress. Average daily mortality was 8.72 deaths among the elderly during winter. Key Risk Factors in this population included age. Elderly participants (60+) were disproportionately affected.

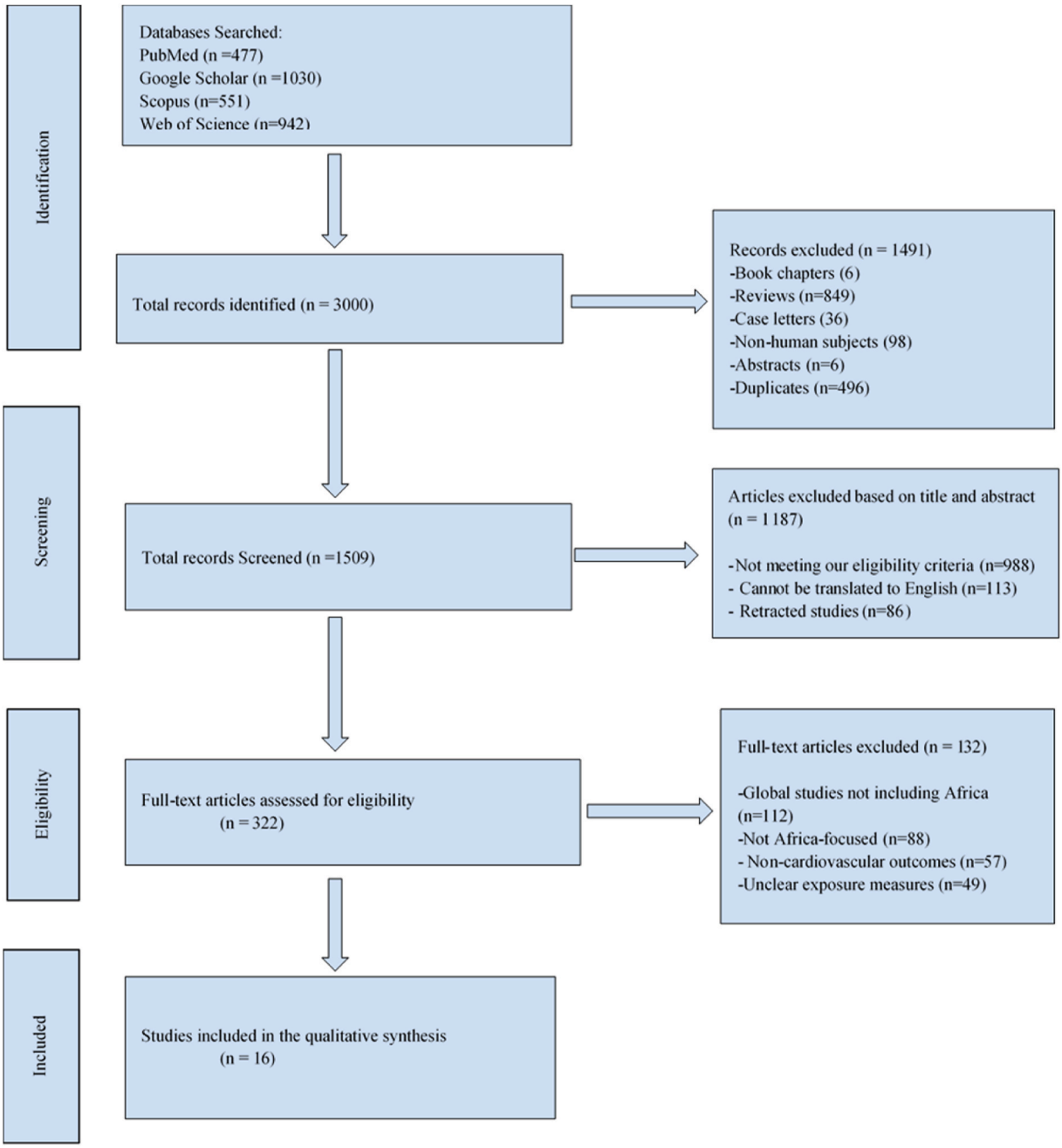

Fig. 1. The PRISMA flow diagram shows the study selection guided by the inclusion and exclusion criteria and the steps taken in the present systematic review to identify, assess, and include relevant studies.

and South Africa, as presented in Table 2. The included studies employed a variety of study designs and demonstrated methodological variation across several key aspects. These designs included case-crossover (n = 3), longitudinal (n = 3), retrospective cohort (n = 3), cross-sectional (n = 2), prospective cohort (n = 1), case-control (n = 1), observational panel (n = 1), ecological observational (n = 1), and observational case study (n = 1) designs. Statistical modelling approaches included unpaired t-tests (n = 2) with lag periods of 1–4 days; negative binomial regression within distributed lag nonlinear models (n = 4), with lag periods of 21days and 1–3 months; distributed lag nonlinear models (n = 5), with a 14-day lag, and 21-day lag; conditional logistic regression (n = 4) with lag periods of 0–6 days, 0–28 days, 0–7, 0–14, and 0–21 days (Alahmad et al., 2023b; Bunker et al., 2017a). One study (n = 1) did not specify statistical methods used.

Confounder control strategies varied across the 16 studies reviewed. Several studies (n = 4) adjusted for individual-level demographic and health characteristics to reduce confounding. These included controlling for gender, age, body mass index (BMI), waist circumference, and comorbidities such as diabetes, hypertension, malaria, pregnancy, lactation, smoking, and recent major surgery. Most (n = 9) studies accounted for environmental confounding by controlling for weather-related factors such as temperature, humidity, precipitation, seasonality, and long-term trends. Some (n = 3) studies did not report any confounder control, which poses challenges for interpreting their findings due to potential residual confounding. Most of the studies (n = 6) used mean daily temperature as the main exposure variable, followed by mean monthly air temperature (n = 4), apparent temperature (n = 3), seasonal temperature variations (n = 1), and wet bulb globe temperature (n = 2). The main outcome measures included hospital admissions for cardiovascular events (n = 5) such as myocardial infarction (MI),

ischemic heart diseases, acute myocardial infarction (AMI), heart failure, stroke, hypertension, and Venous thromboembolism (VTE). Other key outcomes included cardiovascular disease mortality (n = 4), stroke incidence (n = 2), years of life lost from CVD diseases (n = 1), blood pressure (n = 2), and increased heart rate (n = 2).

3.2. Quality of evidence and risk of bias

Using the NIH quality assessment tool to assess the quality of evidence and risk of bias for the included studies, the results indicate that the majority of the included studies reported fair (n = 10) quality of evidence and risk of bias after scoring 8–9 points out of 14 possible scores. A few (n = 5) studies reported good quality of evidence and risk of bias after scoring 10–11 points, with only two studies reporting poor quality of evidence after scoring 7 points and below. The interrater agreement between the three independent authors was determined using the Intraclass Correlation Coefficient (ICC). The results indicate that rater-1 gave the highest rating score for the included studies, with a mean (±SD) of 9.471 ± 0.894. This was followed by rater-3, with a mean (±SD) of 9.235 ± 0.831. Rater 2 gave the lowest rating score with a mean (±SD) of 8.177 ± 1.811. The overall ICC value for the three raters was 0.553 at p = 0.007, indicative of a moderate agreement and a reliable quality of evidence reported by the included studies.

3.3. Temperature extremes and cardiovascular health outcomes

Most of the studies (n = 10) examined the association between CVD morbidity and mortality together with extreme temperature exposure. Five of these studies (Gomes et al., 2015; Koch et al., 2023; Chang et al., 2004; Jonah Kunda et al., 2024; Kynast-Wolf et al., 2010) focused specifically on cardiovascular-related mortality while five investigated CVD morbidities attributed to extreme temperature exposure. Both a decrease and an increase in temperature to levels considered as extreme have been associated with inducing or accelerating CVD outcomes in African populations, particularly among the elderly (≥65-years of age).

3.4. Association between cold temperature exposure and cardiovascular diseases morbidity and mortality

Among the included studies, seven revealed a significant association between cold temperature exposure and CVDs (Heunis et al., 1995; Gomes et al., 2014, 2015; Chang et al., 2004; Bühler et al., 2022; Hightower, 2009). Participants exposed to cold temperatures across the Southern and Northern African countries accounted for 196,411 CVD deaths annually. Participants with inadequate infrastructure in both Sub-Saharan African and Northern African countries demonstrated an increased risk of cold-related CVD mortality. In South Africa, participants exposed to nonoptimal apparent temperatures (6–25 °C) showed significant CVD hospitalization risks, with 8.5 % of total CVD admissions attributable to cold temperatures. Additionally, South African participants exposed to low temperatures throughout the day and the temperature drops below cold thresholds had an increased risk of cardiovascular mortality. Elderly participants above 65-years exposed to cold had the highest mortality rates and were more vulnerable to air pollution interactions during moderate temperatures (20–23 °C), with a 7.0 % mortality increase from NO_2 exposure. Young women also had an increased risk of hospitalization for stroke and acute myocardial infarction compared to other demographic groups when exposed to lower ambient temperatures. Socioeconomic factors substantially amplified temperature-related cardiovascular risks in the South African populations. Among participants exposed to severe poverty (defined as income below USD 73/month), inadequate housing infrastructure and insufficient heating capabilities were among those with heightened vulnerability to cold temperature extremes.

Stroke emerged as a prominent cardiovascular outcome associated with cold temperatures among participants (n = 4) (Gomes et al., 2015; Koch et al., 2023; Chang et al., 2004; Bunker et al., 2017b). In Mozambique, exposure to sudden drops in minimum temperature exceeding 2.4 °C was associated with a 43 % higher risk of stroke among participants. Similarly, abrupt declines in minimum temperatures exceeding 3.0 °C sustained for more than two consecutive days were linked to a 31 % increase in stroke-related hospitalizations. Temperature effects on stroke risk were occasionally stronger in individuals without traditional risk factors, including smoking or high cholesterol. However, individuals with high cholesterol exhibited a greater susceptibility to stroke under cold conditions compared to those with lower cholesterol levels.

Participants exposed to a 5 °C temperature drop within the ranges of 15.3–19.0 °C, 16.3–24.5 °C, and 13.4–21.1 °C in Kenya, Zambia, and Zimbabwe, respectively, experienced a 11 % increase in hospitalization risk for stroke and acute myocardial infarction. However, this increase was not statistically significant. Individuals exposed to minimum temperatures below 4 °C exhibited a delayed mortality peak two days after exposure, accounting for 3.0 % of all deaths. Cardiovascular-related deaths demonstrated even more pronounced cold-associated risks. Men in these countries faced disproportionately higher heat-related impacts, losing 3.6 times more years of life due to cardiovascular disease (CVD) at extreme temperatures (42.8 °C) compared to women.

In Congo, participants exposed to cooler temperatures in August (22.7 °C) displayed elevated haematocrit levels compared to those exposed to warmer temperatures in April (30.0 °C). Gender differences were observed in mean arterial pressure responses to seasonal changes. Females exposed to cooler temperatures exhibited a stronger inverse relationship between haematocrit levels and mean arterial pressure, suggesting reduced vascular adaptability and a potential long-term risk of hypertension. In contrast, males showed unchanged mean arterial pressure despite higher haematocrit levels under similar conditions.

3.5. Association between hot temperature exposure and cardiovascular diseases morbidity and mortality

Heat exposure had substantial impacts on cardiovascular health outcomes in several studies (n = 12) (Heunis et al., 1995; Ibrahim et al., 2022; Koch et al., 2023; Kunutsor and Powles, 2010; Lokotola et al., 2020; Matzke et al., 2024; Kynast-Wolf et al., 2010; Bunker et al., 2017b; Olutola et al., 2023). In regions experiencing extreme heat, such as Niger, exposure to high temperatures (37–38 °C) was associated with increased rates of heart failure and stroke. Heat exposure among participants in Niger led to a 16.4 % mortality rate, significantly higher than the 11.6 % observed during colder seasons. Cardiovascular-related deaths accounted for 44.6 % of total mortality, with 64.9 % occurring during the hot season. Older adults over the age of 60-years in Niger represented 54.3 % of temperature-related CVD admissions, highlighting heightened thermoregulatory strain under hot conditions. Hypertension was identified as a significant risk factor, with 37.6 % of stroke patients having pre-existing hypertension; notably, 86.2 % of these cases were linked to heat exposure. Additionally, modifiable lifestyle factors played a critical role in influencing temperature-related cardiovascular vulnerability. A sedentary lifestyle emerged as a leading risk factor among heat-exposed populations, with 62.79 % of affected individuals reporting limited physical activity.

Similarly, in Burkina Faso, exposure to peak hot-dry season temperatures (32–33 °C) from March to April was associated with the highest cardiovascular disease (CVD) mortality, accounting for 7.4 % of adult deaths. Vulnerable populations included adults aged 65-years and older, who experienced CVD mortality rates five times higher than those aged 40–64-years, particularly during these extreme temperature periods. In South Africa, a 17 % rise in cardiovascular mortality was observed among individuals exposed to sudden hot, dry winds with temperatures exceeding 25 °C for two consecutive days. Women demonstrated greater susceptibility to elevated apparent temperatures, with a 7.5 % increase in non-pollution-related mortality (NO_2 + PM_{10})

at moderate temperatures and a 7.6 % higher rate of PM_{10}-related hospital admissions compared to men. These findings highlight the critical need for targeted interventions to address gender and age-related vulnerabilities during extreme weather conditions.

In rural Burkina Faso, heat exposure among participants accounted for 6.2 % of YLL from CVDs, quantitatively measuring the burden of heat-related cardiovascular mortality in this region. Two studies in Burkina Faso and Kenya observed elevated heart rate as a risk factor for CVDs under a heat index ranging from 22.1 °C to ≥25 °C. However, no significant association was found between temperature and cardiovascular stress in these studies due to incomplete data. Adults above 65 years faced five times higher CVD mortality rates than those aged 40–64 years, particularly during peak hot-dry season temperatures (32–35 °C). Additionally, participants engaged in high-intensity labor faced substantial cardiovascular strain during essential activities like farming, particularly when exposed to unsafe wet bulb globe temperature (WBGT) levels.

Exposure to higher ambient temperatures in Ghana was associated with hypotension. Participants exposed to temperatures between 39 and 43 °C exhibited reduced mean systolic blood pressure (SBP: 120.9 mmHg vs. 123.1 mmHg at 28–34 °C) and diastolic blood pressure (DBP: 70.6 mmHg vs. 71.9 mmHg), particularly among adults. Furthermore, systolic blood pressure decreased by approximately 5 mmHg for every 10 °C rise in temperature. However, among older adults and individuals with a larger waist circumference, systolic blood pressure tended to increase under higher ambient temperatures, indicating potential variations in thermoregulatory responses within the population. These findings underscore the importance of considering demographic and physiological factors when assessing the impact of temperature on cardiovascular health.

4. Discussion

Existing evidence shows a growing trend in CVDs linked to both hot and cold extreme temperatures, with notable differences between Western and African countries (Gasparrini et al., 2015; Alahmad et al., 2023b; Bunker et al., 2017b; Scovronick et al., 2018). In Western nations, such as the United States and those in Europe, prolonged exposure to extreme temperatures exacerbated by climate change, has been associated with increased hospital admissions and mortality from heart attacks, strokes, and other cardiovascular complications (Liu et al., 2022; Moslehi and Dowlati, 2021; Brooke Anderson and Bell, 2011; Phung et al., 2016; Wang et al., 2016). In contrast, African countries face a more complex and often underreported burden (Zhang et al., 2023; Opoku et al., 2021). While extreme heat is more prevalent and increasing in frequency across the continent. Countries such as Niger, Mali, and Chad, have seen some of the most significant increases in extremely hot days, with temperatures regularly exceeding 40 °C during the dry season (Jonah Kunda et al., 2024; Wright et al., 2024; Pattnayak et al., 2019). In East Africa, countries like Ethiopia and Kenya are experiencing a gradual warming trend, though the impact is often compounded by erratic rainfall and drought, contributing indirectly to CVDs through malnutrition and water scarcity (Climate Change over West Africa, 2016; Siddiqui et al., 2025; Grace et al., 2015; Manyuchi et al., 2022). Southern African nations, such as Mozambique, Zambia, and Zimbabwe, are also experiencing more frequent and intense hot temperatures, which have been associated with increased hypertension, heart attacks, and stroke incidents (Gomes et al., 2015; Chang et al., 2004; Gomes et al., 2014; Climate Change over West Africa, 2016). Cold temperatures, although less common, still pose a threat in highland regions or during unexpected weather shifts, and the lack of protective housing and clothing increases vulnerability.

In the present systematic review, we report that both cold and heat exposure are significant contributors to increased cardiovascular morbidity and mortality. Cold exposure has been linked to a 5.76 % increase in cardiovascular deaths annually across various African regions (De Vita et al., 2024; Gasparrini et al., 2015; Heunis et al., 1995; Chang et al., 2004; Jonah Kunda et al., 2024; Gomes et al., 2014; Teku and Eshetu, 2024), with sharp temperature drops (2.4 °C) in countries such as Mozambique contributing to higher risks of stroke and myocardial infarction (Analitis et al., 2008). These findings align with global evidence, including that reported by Gasparrini et al. (2015), who indicated that exposure to cold contributed more to mortality (7.29 %) than heat across 13 countries. The sustained cardiovascular strain from cold temperatures is particularly pronounced among older adults and impoverished populations lacking adequate heating systems. This aligns with findings from Analitis et al. (De Vita et al., 2024) and Hong et al. (Doku et al., 2024), who observed increased cold-related cardiovascular mortality among the elderly, and from Medina-Ramón et al. (Gasparrini et al., 2015) and Barnett et al. (Gomes et al., 2014), who also noted similar prolonged health impacts in the U.S. following cold exposure. These results suggest that cold temperature exposure poses a substantial and sustained threat to cardiovascular health.

Similarly, heat exposure also presents a significant risk, with studies showing an association between high temperatures and increased rates of heart failure, stroke, and cardiovascular deaths, particularly in countries like Niger (Gomes et al., 2015), Burkina Faso (Teku and Eshetu, 2024), and South Africa (Heunis et al., 1995). Consequently, the impact of heat on cardiovascular health is compounded by rising ambient temperatures and extreme weather events, which exacerbate cardiovascular strain and mortality. Several studies support the link between heat exposure and increased cardiovascular mortality and morbidity. Masselot et al. (Bunker et al., 2016b) found that heat exposure significantly contributed to cardiovascular deaths in 854 cities in Europe. Bunker et al. (2017b) observed higher cardiovascular mortality with elevated temperatures, particularly among the elderly. In Finland, Sohail et al. (Mendis et al., 2022) found that heatwaves led to increased hospital admissions for cardiovascular conditions, with more pronounced effects in warmer cities. Barnett et al. (Keir et al., 2022) highlighted that the impact of heat on cardiovascular diseases in the U.S. persisted for weeks after exposure. These results suggest that temperature extremes, particularly heat exposure, significantly heighten cardiovascular morbidity and mortality, likely through physiological mechanisms such as heat-induced vasodilation and altered blood composition that affects blood pressure and thrombosis risk, and heat-induced vasodilation that lowers blood pressure and strains the cardiovascular system, especially among vulnerable populations in African regions.

Taken together, findings from our systematic review also highlight how age, sex, pre-existing health conditions, and socioeconomic factors significantly influence cardiovascular vulnerability to temperature extremes. Older adults, women, rural residents, and individuals with conditions like hypertension are especially at risk, with lifestyle and occupational factors further increasing their susceptibility. These studies reinforce the importance of addressing temperature-related cardiovascular risks, particularly for vulnerable groups such as the elderly, those with pre-existing health conditions, and underserved rural populations.

Previous systematic reviews, including Zafeiratou et al. (2021) and Siddiqui et al. (2025), have predominantly focused on global or high-income country contexts, with limited representation of African data. Zafeiratou et al. (2021), systematically assessed the effects of long-term exposure to ambient temperature on mortality and hospital admissions but concentrated mainly on Europe and North America. Similarly, Bunker et al. (2017b), and Siddiqui et al. (2025), conducted a global synthesis on temperature-related mortality, highlighting regional disparities but still underreporting African evidence (Amini et al., 2021). Our review is the first to comprehensively synthesize data on the cardiovascular effects of extreme temperature exposure in African settings, encompassing both heat and cold extremes. We provide new insights into context-specific vulnerabilities, such as poverty, age, gender, and lack of access to health infrastructure, which are often overlooked in global assessments. In addition, our review captures acute and

short-term exposure impacts and identifies methodological heterogeneity in exposure definitions, outcome measures, and confounder adjustment. This African-focused synthesis offers critical evidence for regional adaptation strategies and public health planning, filling a major gap in the environmental epidemiology literature.

4.1. Study strengths and limitations

This is the first comprehensive review to appraise available evidence outlining the potential effects of both cold and heat extreme temperature exposure on cardiovascular health outcomes, particularly in the African context. Illuminating the intricate interplay between temperature exposure and cardiovascular health in African populations. The present study provides a balanced perspective on temperature-related cardiovascular risks, identifying critical knowledge gaps and research priorities, giving effective directives for future studies and interventions in this field. To ensure quality, reliability, and minimum bias of our reporting, the included studies were selected based on a systematic review approach, which provides a validated methodological approach to select studies and critically discuss them based on their findings in relation to cold and heat temperature exposure linked with the manifestation of detrimental cardiovascular outcomes. Despite the strengths of this systematic review, it also holds several limitations worth noting. A significant concern was the varying study designs of the included research reports, which may affect the reliability of our reporting. In addition, some of the included studies had missing critical information, such as participants' gender, ethnicity, and age, further affecting our reporting. We also observed the limited geographical coverage, with most studies focused on South Africa, presenting a challenge to the generalizability of results across the diverse continent. The included studies had inconsistent methodologies and definitions of extreme temperatures, which made it challenging to purposefully categorise the included studies to run statistical tests, including a meta-analysis. Moreover, the included studies demonstrated wide methodological variability, employing designs with differing approaches to exposure measurement and confounder adjustment. These variations, including the limited use of advanced statistical models and inconsistent consideration of delayed effects, may partially explain the heterogeneity observed across findings. Lastly, the absence of long-term studies examining the cumulative effects of temperature exposure on cardiovascular health signifies a substantial gap in the evidence base, underscoring the need for more comprehensive longitudinal research in this area.

5. Conclusion

This systematic review highlights the importance and multifaceted impact of both cold and heat exposure on cardiovascular morbidity and mortality across African regions. The synthesised evidence indicates that temperature extremes, whether sharp drops in cold or sustained heat exposure, are associated with increased cardiovascular events such as stroke, myocardial infarction, and heart failure in the African population. These effects are amplified among vulnerable populations, including the elderly, individuals with pre-existing conditions, and those living in rural areas with limited access to healthcare and temperature-mitigating infrastructure. The findings align with global patterns observed in Europe, the U.S., and Asia, reinforcing the universal relevance of this issue while highlighting the heightened burden in African settings. Thus, there is an urgent need for region-specific public health strategies, improved surveillance systems, and adaptive interventions to mitigate temperature-related cardiovascular risks, particularly in the face of ongoing climate change. Seasonal variations, present higher CVD incidences, particularly in colder months, further highlighting the need for season-specific public health interventions.

CRediT authorship contribution statement

Mamakase G. Sello: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Sihle E. Mabhida:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Conceptualization. **Bevan Esterhuizen:** Writing – review & editing, Methodology. **Musawenkosi Ndlovu:** Writing – review & editing. **Jemimah Kyeyune:** Writing – review & editing. **Hellen Kgatla:** Writing – review & editing. **André P. Kengne:** Writing – review & editing, Validation. **Zandile J. Mchiza:** Writing – review & editing, Validation. **Haskly Mokoena:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Conceptualization.

Availability of data and materials

All data generated or analysed during this study are included in this published article.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2025.122812.

Data availability

All the data used in this study is as presented in the main body of the manuscript.

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