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Method and process towards developing a Health Vulnerability Index (HVI) for Extreme Weather Events (EWEs) for local residents in South Africa

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A R T I C L E   I N F O

Method name:
Development of a Health Vulnerability Index (HVI) for local South African residents

Keywords:
Climate
Index
Review
Diseases
Water-borne
Water-washed
Water-related
Extreme weather event
Health
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Indicators

A B S T R A C T

An increase in incidence and amplitude of extreme weather events (EWEs) linked to climate change, has resulted in greater human exposure and vulnerability to weather-related health effects. Increases in the occurrence of EWEs, including storms, flooding, extreme heat and wildfires, will impact health globally, with poor and vulnerable populations disproportionately affected. Vulnerability to EWEs, and the ability to adapt to these weather shocks, are influenced by existing physical, social and political limitations of a given region. As such, developing context-specific health vulnerability indices to inform planning and decision-making for policy makers and citizens alike, should be prioritized. The existence and development of health vulnerability indices in South Africa are limited, therefore, this study provides a foundation from which future indices can build. Mixed methods approaches including evidence and data analysis/synthesis and focus groups are used to understand the interconnections between extreme weather events and human health, including citizens' understanding of emergent vulnerabilities linked to these events. The methods employed in this study include:

- A rapid evidence review (RER) including data extraction identifying health impacts and indicators.
- Development of a draft health vulnerability index (HVI) framework.
- Focus groups and individual interviews testing the draft HVI for citizen input and framework refinement.

Specifications Table

Subject area:	Environmental Science
More specific subject area:	Climate change and the associated public health implications
Name of your method:	Development of a Health Vulnerability Index (HVI) for local South African residents
Reference of related method:	Cutter, S.L., Emrich, C.T., Webb, J. J., Morath, D. 2009. Social vulnerability to climate variability hazards: A review of the literature., in Final Report. Oxfam America, 1–44. DOI e0708976f51536074aba4cf7fd5375d9c8f58c2b https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=e0708976f51536074aba4cf7fd5375d9c8f58c2b
Resource availability:	N.A

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Method details

Introduction

Extreme weather events (EWEs) such as floods, storms, droughts and heatwaves are increasing in frequency and intensity, largely due to the impacts of climate change [1]. Anthropogenically-induced climate change has increased temperatures over the last century, increasing the frequency and intensity of heatwaves. Climate change is expected to increase the frequency and severity of floods [2]. The health impacts associated with these EWEs include heat exhaustion, heat stroke, exposure to water- and vector-borne diseases, physical injuries, malnutrition, mental health problems, and the worsening of chronic conditions such as cardiovascular and respiratory diseases, which can lead to death [2–5]. Health effects attributable in some way to climate change can occur through various routes, ranging from direct contact with flood waters to limited access to health care facilities, damaged infrastructure (including healthcare facilities) and power outages, challenges in accessing sites of care or necessary supplies, and longer-term impacts such as carbon monoxide/gasoline poisoning from improper use of carbon-based fuels [6].

Extreme weather events will have health impacts globally, with poor and vulnerable populations disproportionately affected [7]. In the public health sector, vulnerability is defined by the degree to which an entity is susceptible to harm, injury or damage [8]. At the same time, the Third National Climate Assessment – a report that explores climate change impacts in the United States - defines vulnerability as a function of exposure, sensitivity and adaptive capacity to climate variations [9]. The assessment of climate vulnerability relies on the identification of the existence of health susceptibilities due to climate change [10], but little research has been done in sub-Saharan Africa to understand the links between health trends, associated risks, and climate patterns [11–14]. To manage these health risks appropriately, an understanding of the health-related risks associated with EWEs needs to be developed with the specific context in mind. All too often, risk assessments of climate events are too narrowly focused and only based on the hazards to which populations are exposed during events and the corresponding coping mechanisms instead of longer-term impacts, and/or cascading issues (i.e., the lived experience in context) [15].

Existing vulnerability research, specific to EWEs, employs various ways to measure climate-related vulnerability. A wide range of climate risk and vulnerability assessments (CRVAs) exist at global and regional levels, and in context specific settings (e.g. post mine closure) [16], but these seldom target health specifically. For example, in Ethiopia and Nigeria, Nwaka and Akadiri (2020) highlighted that across countries, there were major gendered differences in food insecurity post-drought or flood [17]. In Lwasa's (2018) research, a survey and resident input was paired with GIS spatial analysis to understand drought and flood risk, impacts and adaptation options in rural Uganda [18]. In Burkina Faso, Dos Santos et al. (2019) analysed factors associated with becoming a 'disaster victim' for Ougadougo residents [19]. Yankson et al's (2017) research in Ghana, focused on flood vulnerability, and drew on seven indicators, but none referenced health [20].

In comparison to CRVAs, health vulnerability indices are an emergent area of research, most notably in Brazil [21,22], with less research available in India [23] and the U.S [24]. On the African continent, these types of analysis are limited, but available, for example, in Sudan [25] and Ethiopia [26]. In general, these indices tend to consider exposure, adaptive capacity, and sensitivity in various permutations to determine a number from 0 – 1 that indicates level of vulnerability. This relies on complex permutations, and weightings that are not easily usable for laypersons with limited-to-no training. Abbas and Routray (2014) [25] suggests that key indicators for health vulnerability should be simplified, and should include: 1. Access to facilities; 2. Interruption of healthcare services; 3. Ownership/use of bednets; 4. Sanitation situation (latrines, sewered, etc.); 5. Water access; and 6. Consideration of vulnerable groups (double burden). While more generalized methods adopted by Abbas and Routray (2014) are potentially more user friendly, they might prioritize aspects that have no relevance in other contexts. There are pros and cons to the available methods discussed above for assessing health vulnerability, and this research has been integrated into the methodology of this paper. This study has drawn on Cutter et al's (2009) [27] approach that indicators are necessarily developed over time, and that a process of identifying indicators can become more precise (with weighting), however, in the beginning, an exploration of relevant indicators is necessary. In this way, the study has developed on Cutter's method and initial categories (exposure, sensitivity and adaptation) while drawing on the knowledge base (from an evidence review) that is locally relevant to guide the methodology.

South Africa, with its diverse climatic zones and wide range of existing challenges, provides a relevant case study for understanding health vulnerabilities in the face of rapid climate change (and sometimes, cascading EWEs). In line with contemporary understandings of health and climate vulnerability indices, this research project aimed to develop a framework that drew on the evidence base of health outcomes associated with EWEs as a starting point, to offer a method by which localities and regions can develop their own health vulnerability indices that are locally relevant, context specific and aimed at being usable by local persons. This was done through the following project aims.

Project aims

1. To develop an understanding of the drivers and patterns of vulnerability and risk during extreme weather events, and working backwards from the evidence, to explore which health outcomes result from EWEs.
2. To determine how these risks specifically affect human health, including short-term and long-term considerations (communicable and non-communicable diseases, as well as healthcare accessibility, human capacity, and related healthcare provision resource demands).
3. To provide a health vulnerability index (HVI)framework that can assist at the local level for the development of context specific health vulnerability indicators.

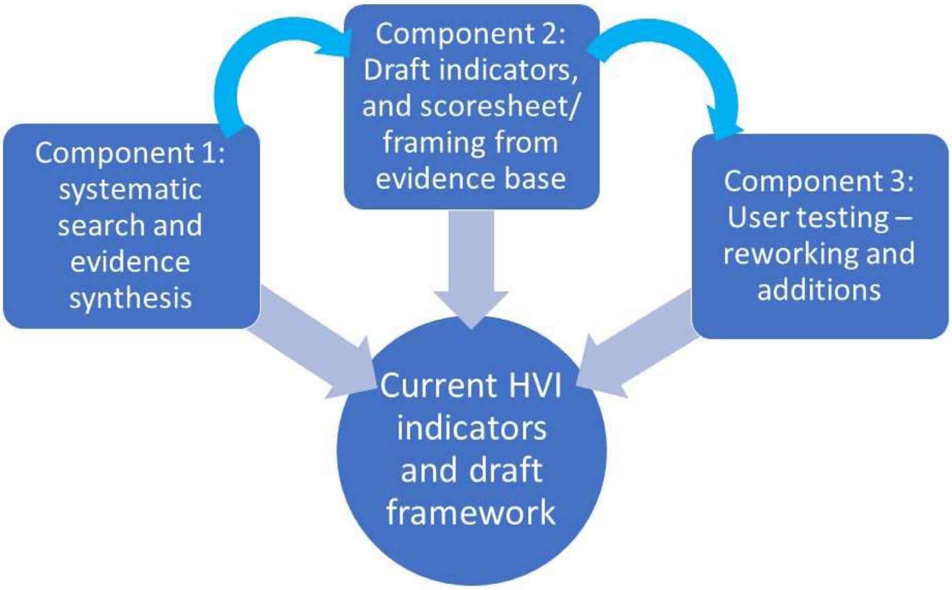

Fig. 1. A 'methods flow' for the project.

Methods

The study process included three separate methodological components: development of an extensive literature review to understand and synthesize the evidence base for the association between EWEs and health vulnerabilities, including health impacts (component 1); development of a framework for assessing health vulnerability (component 2); and user testing of the framework in a number of localities (component 3), as seen in Fig. 1 below. As a brief overview, the literature review/evidence synthesis (component 1) served as the evidence-based foundation from which health outcomes associated with EWEs could be identified, extrapolated and used to build the HVI. Once the health outcomes were identified in workshop teams, researchers who had screened the articles engaged in a process of developing questions pertinent to the vulnerabilities related to each health outcome. This approach attempted to unpack the 'pathways' to these health outcomes, which were understood to be indicators of vulnerability. Using this pathways approach, a framework for health vulnerability was developed (component 2), which was then tested in several settings (component 3). It is important to note that the timing of this research, in South Africa, coincided with the onset of the COVID-19 pandemic and, therefore, due to COVID restrictions, the ability to hold focus groups and engage with publics during the funding timeline was restricted (i.e., the research team was only legally allowed to meet in the last month of project funding). Further testing and workshopping is necessary and encouraged; thus, a framework such as this should be understood as a living document that is always under construction. The methodological process is unpacked in more detail below.

Rapid evidence reviews (RERs) (component 1)

Component 1 included the development of an extensive and systematic review process to understand the evidence available linking health outcomes with EWEs. Guided by Cochrane systematic review process to provide a comprehensive and in-depth framework for the systematic review process [28] but, due to the time-intensive process of Cochrane reviews and the expansive nature of the literatures available on this topic (health effects associated with numerous EWEs), a Rapid Evidence Review (RER) process was used [29]. A minimum of two authors reviewed and screened each study for inclusion and data extraction. A structured and rigorous search and data extraction process was maintained while casting a wide net to scope and understand what data is available on the topic of EWEs in relation to human health [29], what research is being done, and where gaps in the evidence base exist while providing specific endpoints and outcomes related to human health in EWEs to inform the development of a community-usable HVI for EWEs [30].

Development of search strategies

The development of a feasible search strategy required directed questions to retrieve articles that were relevant to the study objectives. Three study variables that needed to be defined were the exposures, outcomes and geographic locations that the study would cover. According to Godsmark and Irlam (2020) [31] and Godsmark et al. (2019) [32], the main EWEs occurring in South Africa include extreme heat/heat stress, drought, wildfires (and associated smoke inhalation), flooding and storms, which are often inter-related [10]. Given the limited timeframe available, the exposures, as developed by Godsmark and Irlam (2020), as seen in Fig. 2, were grouped together (Fig. 3).

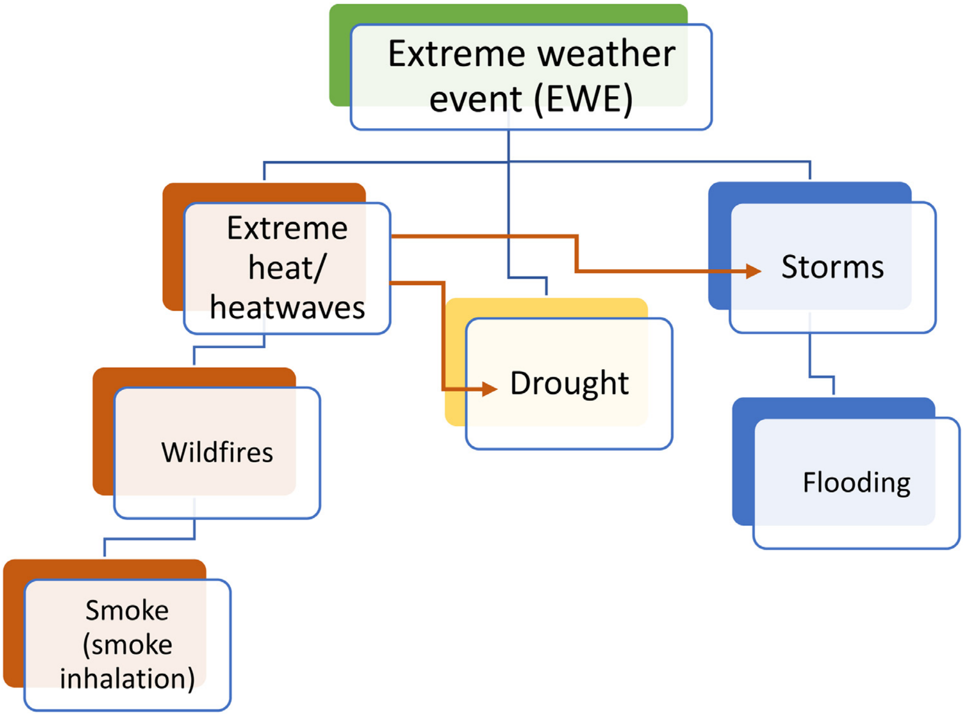

Fig. 2. The inter-relationship between the most commonly occurring extreme weather events in South Africa.

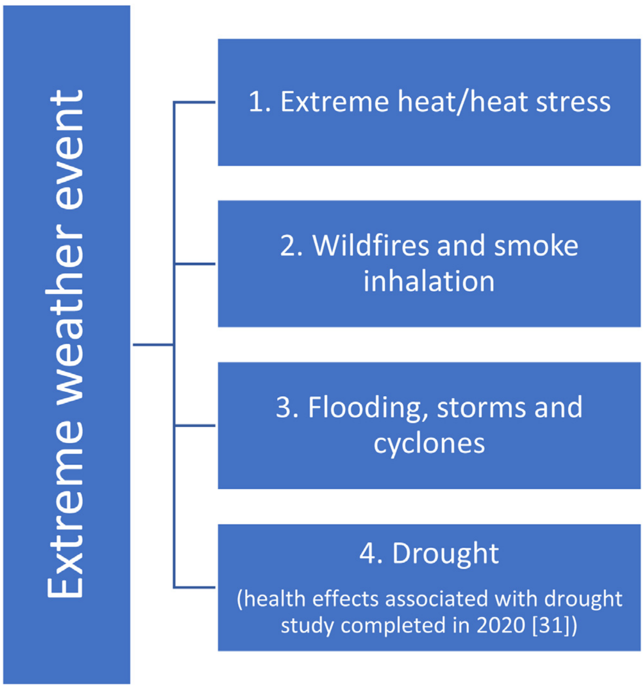

Fig. 3. Categorization of extreme weather events common in South Africa and the EWE categories used to guide the development of search strategies for this study.

The health effects associated with each EWE category - (1) Extreme heat/heat stress; (2) Wildfires and smoke inhalation; and (3) Flooding, storms and cyclones - were explored in-depth between April and December 2021. Research on the adverse health effects associated with drought (category 4), was completed in 2020 [see 33]. In order to obtain relevant information on the health-related impacts of extreme weather events, separate searches for each EWEs were developed, i.e., three separate search strategies 1. extreme heat/heat stress/heat waves; 2. wildfires/smoke inhalation; and 3. flooding/floods/storms and cyclones. To avoid duplication of results, each strategy had a different timeframe based on the most recently published reviews for each EWE category: for flooding and storms, articles published from 2016 to 2021 were included; for heatwaves and wildfires articles published from 2007 to 2021 and 2015 to 2021 respectively, were included (see inclusion criteria below). The outcome, i.e., health effects, were kept non-specific to avoid limiting the results obtained. While the objective of this project was to develop a framework for locally relevant HVI creation in South Africa, articles published throughout Africa were included to understand the wider context, and to address gaps where South African data on specific topics may be limited. The final search strategies are attached in Appendix 1.

Databases used

Once the search strategies were developed, an extensive electronic literature search was undertaken for studies published in peer-reviewed journals. Articles were searched using a combination of keywords, Medical Subject Heading (MeSH) terms and free text words across Pubmed, Scopus, Web of Science and Africa Wide databases.

Defining exposure variables

To comprehensively define the three study variables, a mini-literature search was conducted prior to the systematic search, in which approximately 200 published articles collectively, were reviewed. These articles included existing systematic review papers and original studies. Thereafter, a list on each exposure variable was collated. The list below, while substantial, may not have included other methods used to define the exposure variables. Owing to this, the authors discussed the eligibility of individual studies when faced with cases of ambiguity.

Existing reviews on heatwaves/extreme heat, wildfires, flooding, storms and cyclones do not adhere to strict definitions of these variables and tend to use different methods to classify exposure. However, where possible, these variables were broadly classified as follows:

Heat waves and extreme heat

- Summer temperatures which were higher/hotter than the normal average per given location[1]
- The Bureau of Meteorology criteria:
    - ≥5 consecutive days with Tmax ≥ 35 °C or
    - ≥3 consecutive days with Tmax ≥ 40 °C
    - >3 consecutive days of dry-moderate or moist-tropical plus type weather.
- Approximately 3 days when maximum temperatures were > 30.0 °C.
- Assessment of individual studies based on maximum temperature (Tmax), mean temperature (Tmean), thermal indices that consider additional atmospheric variables such as humidity, wind speed, and solar exposure.

Wildfires

- An uncontrolled fire that burned in the wildlands, forests, grasslands, savannas, and other ecosystems.
- Fires referred to as bushfires, forest fires, woodland fires, grassfires, and peat fires that are caused by climatic factors such as lightning.
- Identification of fire affected areas using Moderate Resolution Imaging Spectroradiometers (MODIS) or other imaging techniques.
- Studies that measured $PM_{2.5}$ due to smoke events AND were able to ascribe this to wildfires specifically.

Flooding, storms and cyclones

- A flood was defined as an overflow of a natural stream/water body which includes fluvial, pluvial, flash, urban and coastal floods due to climatic factors such as continuous rainfall.
- Flooding defined as an unusual inundation of areas with water, due to climate related factors such as storms.
- Storms defined as an atmospheric disturbance resulting in rain showers, snowstorms, thunderstorms, gales, tornadoes and tropical cyclones.
- A storm occurring due to low-pressure, strong wind cyclones (>119 km/hr) with heavy precipitation.
- Rotating storm system occurring over water, with a wind speed of >62.968 km/hr.
- Classification of an area as a “disaster area” based on the Centre for Research on the Epidemiology of Disasters (Brussels, Belgium) International Disaster Database guidelines criteria:

[1] The authors did not specify, at the outset, the number of degrees above average temperature as part of the inclusion criteria. The World Meteorological Organization (WMO) defines a heat wave as a period during which the daily maximum temperature exceeds for more than five consecutive days the maximum normal temperature by 9 degrees Fahrenheit (5 degrees Celsius). However, the authors found inconsistencies in the definitions used for heatwaves in the screened studies and in casting a wide net, if the paper asserted a heat wave had occurred the study was included.

- 10 or more people reported killed.
- 100 or more people reported affected.
- A declaration of a state of emergency or call for international assistance.

Drought

As mentioned previously, a study on the adverse health effects associated with drought in Africa was completed in 2020 and published in 2021 [33]. In this study, drought was defined by common definitions used by ecologists and summarised in Slette et al. (2019) [34]. Drought was defined as:

- Dry conditions which represented reduced water availability and absent or deficient rainfall.
- Precipitation events which differed from the normal (below 25%) for a given site.
- Negative Standardized Precipitation Evapotranspiration Index (SPEI).
- Low water flow and low soil moisture for a given site.

It is important to note that the above-mentioned criteria do not have a specified time period due to the ambiguity associated with the start and/or end points of a drought episode.

Inclusion criteria

A study was eligible if it complied with the inclusion criteria below:

- Based on the most recent published review of the effects of heatwaves on health [35], articles published from 2007 onwards for this category were included.
- Based on the most recent published review on the effects of flooding and storms on health [6], articles published from 2016 onwards for this category were included.
- Based on the most recent published review on the effects of wildfires on health [36], articles published from 2015 onwards for this category were included.
- Fires which were described as “natural” fires and result from climate change only, e.g., wildfires caused by extreme heat or drought were included.
- Flooding caused by climatic factors only, such as cyclones, typhoons, heavy rains and tropical storms were included.
- Studies published in English.
- Studies which deal with a clear association between one or more of the study’s climatic extremes and adverse health effects in humans.
- Studies with comparative and non-comparative study designs.
- Observational studies.
- Studies performed in any region and any subgroup in Africa; and
- Participants of all ages and sex.

Exclusion criteria

A study was not eligible if it met any of the exclusion criteria listed below:

- Studies published in a language other than English.
- Studies which addressed the effects of climatic extremes on other species such as microorganism growth without being linked to an adverse human health effect.
- Studies with a systematic or review study design.
- Studies on controlled prescribed fires or fires caused by human negligence.
- Studies on occupational exposures to fires (e.g., fire fighters’ exposures), and the subsequent health effects, were excluded as the overall health outcomes cannot be attributed solely to climate-induced wildfire exposures (i.e., EWEs).
- Studies on the exposure to indoor or outdoor fuel burning for household purposes; and
- Studies without an objective measure of the exposure variables.

Study selection

Articles were identified, screened, assessed for eligibility and included according to the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocol (PRISMA-P) guidelines [37]. The titles and abstracts of articles were first screened by two authors who assessed whether they met the inclusion criteria. Articles not meeting the inclusion criteria were removed. Following this, full-text articles were screened by two authors and articles that did not meet the inclusion criteria were removed. Data was extracted from the included articles. The Covidence system was used by all authors to screen titles, abstracts and full texts.

Data extraction and management

Extracted data was added to summary tables which included author name(s) and year of publication, article title, methods, climatic exposure(s), health outcome(s) investigated, additional study findings including vulnerabilities identified within the study itself and relevance of the study to HVIs. With the outlined inclusion criteria parameters, quantitative meta-analysis was not conducted due to the heterogeneity of the studies identified. However, quantitative results from individual studies were summarised in the systematic RER scoping process (forthcoming) [31].

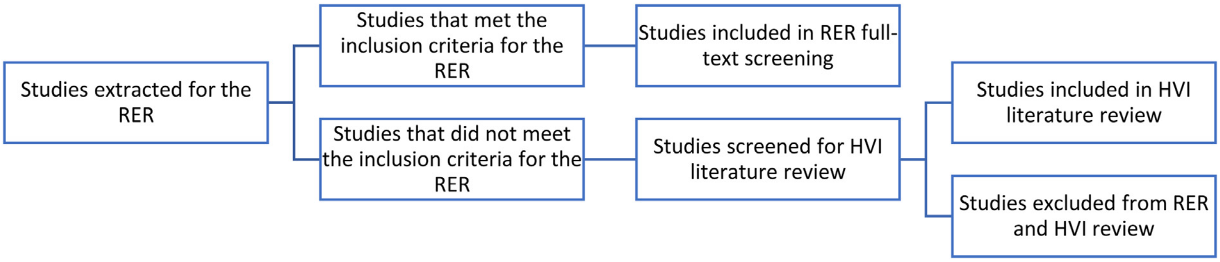

Fig. 4. Literature sources for HVI review.

Health vulnerability index literature review and indicator exploration methods (towards component 2)

Concurrent with the systematic scoping RER for component 1, the study drew from the systematic search to identify and include studies for an HVI literature review, i.e., those studies that did not fit the inclusion criteria for the RER but, were relevant to the project's larger aim of developing an HVI for EWEs, were included in the HVI review (Fig. 4).

The HVI literature review - a second part of this multi-layered approach to developing the draft framework - focused heavily on African resources and research but also drew on some research from other regions – particularly where research was unavailable on a topic in the African continent/region. The multi-disciplinary research team engaged with these literatures as part of the initial pathways workshopping process to iteratively develop the framework. In these workshops, the team began by brainstorming what was the best way to create an adaptive HVI that could comprehensively assess an individual's vulnerability to adverse health effects associated with EWEs. The workshops allowed for the teams to critically discuss current HVI frameworks, methods of assessing vulnerability across different disciplines, locations and weather-related extremes to tailor an HVI framework that could work across diverse South(ern) African contexts.

Indicator methods for proposed HVI framework draft

After considering the literatures on HVIs and the health outcomes extracted from the scoping RER, the need for context specificity (and thus adaptive frameworks) that made use of indicators developed with consideration across a wide range of disciplines and knowledge regimes was understood. In this study, all indicators were equally weighted across the three draft frameworks, following the logic of Cutter et al. (2007) [27] in that enough information is not available to weigh them otherwise [22]. The study approach used multiple indicators to engage with a range of impacts.

Specific indicators identified through the studies in the literature review were drawn on to create a composite set of indicators for each EWE. These indicators were developed by drawing on research such as Hahn et al. (2009) [38], which developed several indicators to assess the impacts of climate change and variability in Mozambique, including a specific focus on health, food, water and natural disasters – as well as that of Yankson et al. (2017) [20] (discussed in the introduction), Tyubee (2014) [39] and Dintwa et al. (2019) [40]; studies which highlighted the importance of considering for example, pinch points, cascading impacts and the reality that social vulnerability is driven by many variables, different across contexts. The HVI framework thus included the gathering of key demographic vulnerability indicators; this we suggest is necessary, while acknowledging the complexity given the dynamic nature of these variables. This work made use of a human-environment place-based approach following Cutter et al. (2007) [27], where social vulnerability is independent of hazard type [22], although health vulnerability is not; an approach that accounts for both a general social vulnerability, and more context-specific health vulnerabilities in relation to hazard type (i.e., an extreme weather event).

Health outcomes as pathways to exploring indicators were workshopped to develop a framework for unpacking the emergent vulnerabilities during and after an EWE. For example, diarrhoea was identified as a health outcome associated with flooding. The study team then developed questions related to experiences of diarrhoea following a flood episode. See supplementary materials, appendix2, for details on the question flow approach.

The workshops mapped out each health outcome alongside a set of questions and these questions were used as the basis for individual EWE framework. The typed (word doc) framework draft was developed with an aligned score sheet and testing began to determine the ease of use among people who had experienced each EWE. In total, there were three EWE frameworks (one for heat, flooding and drought) which were collated to form the draft HVI framework.

Methods and process for developing draft frameworks

The process undertaken to develop the frameworks was as follows:

1. All data from the studies in the scoping RER were extracted and cleaned.
2. All studies that were relevant to the topic but did not provide EWE-health data were added to the HVI literature review.
3. The cleaned data was further extracted for specific health outcomes relevant to each EWE.
4. Tables were created for each EWE and related health outcomes.
5. Team meetings, where the frameworks were developed and workshopped, were held 2 – 3 times per week over the course of five weeks i.e., the final week of January 2022 through to the end of February 2022.

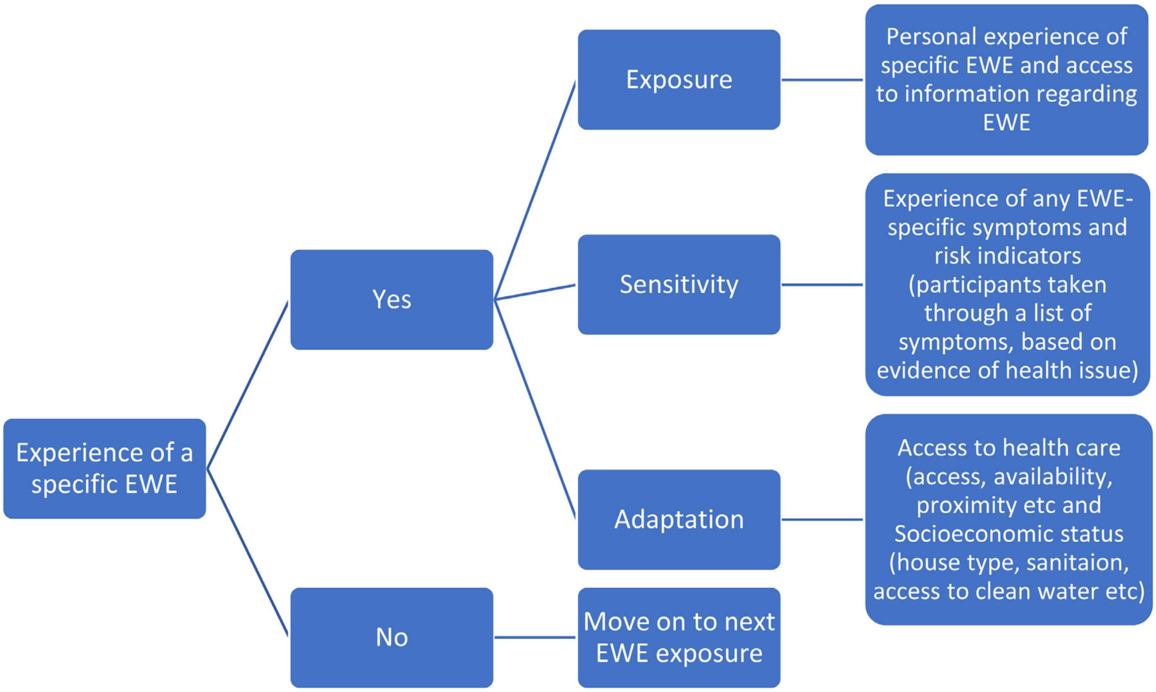

Fig. 5. General EWE framework approach.

6. Framework drafts emerged from working backwards from extracted health outcomes emergent from the RER (see section 3.3 below).
7. Once a health outcome was identified, a pathways approach was used to imagine how an outcome was reached and a series of questions was developed to explore how those specific outcomes were reached – i.e., the research team developed a series of indicators using these pathways [41,42,43] that related to the emergent health outcomes drawn from the evidence base.
8. The research team was split into smaller groups, with more senior researchers each convening a group, to workshop these questions. Project members with the following training were involved in this phase of the project: AA (env/medical anthropology; public health), SH (climate science, gender), TA (MPH environmental public health), student researchers LM (MPH), RP (Honours/Masters social anthropology), MD (MPH), NT (medical school graduate). Three groups of three researchers were tasked to work through potential questions that could address the specific health outcomes raised in the scoping RER.
9. Each of the research sub-teams then presented their draft frameworks in plenary to the larger team virtually, where the frameworks were further edited and developed.
10. Simultaneously, demographic questions relevant to social vulnerability were developed and cross-checked against EWEs to reduce repetition.
11. Frameworks were refined, simplified and printed in large format for user-testing workshops.
12. Workshops and interviews with residents who had experienced various EWEs took place from 1 – 22 March 2022.
13. Feedback from workshops was reviewed, framework scores were consolidated, and frameworks were edited.

The HVI draft framework (component 2)[2]

Framework drafts were developed by working backwards from extracted health outcomes emergent from the RER. When a health outcome, e.g., diarrhoea, was found to be associated with an EWE, the team worked to develop questions on diarrhoea and related symptoms. Questions were laid out in a pathways flow diagram for visual aid and tabulated in a word document to allow participants to answer these questions. The question framing for each health outcome is shown in Fig. 5 below:

User-testing and validation of HVI framework draft- Resident Workshop details (component 3)

The research team conducted workshops and individual interviews with members of the public who had experienced an EWE to test the user-friendliness of the frameworks and score sheets that were developed, and explore the extent to which the review

[2] Further details about the HVI framework can be found in the Water Research Commission technical report (available upon request from the corresponding author) and a forthcoming manuscript. See supplementary materials for an example of the final draft framework.

of available evidence covered residents' experiences. The sites chosen for this phase of the project were based on established research networks available to the lead authors during the COVID period and where participants had experiences with the relevant EWE.

The focus groups and interviews assessed the useability, coherence and existence of possible gaps in the framework to explore both the feasibility of the application of the framework and unpack the validity (validity testing) of the pathways approach and underlying evidence base gleaned from the systematic review process that addressed individual EWEs and potential health concerns. Workshop participants ranged in age from 20 – 60 years and were invited through processes of first purposeful sampling using existent research contacts (given the COVID context) and the need to engage with people who had experiences of EWEs, and then snowball sampling through those networks. In total, there were 8 participants from Sweet Home Farm, 5 from Muizenberg, 6 from Brooklyn, 6 from Craneborne and Chitungwiza, and 5 from Northdale. All participants volunteered and provided written consent. In all focus groups, aside from the one held in Muizenberg (which was all female), the gender balance was skewed towards women but men were present. Details of the workshops, emergent themes, and ways in which the workshops validated the systematic review and pathways process can be found in supplementary materials, Appendix 3.

With each focus group, the materials for scoring and the indicators themselves were further refined. Each focus group addressed a single EWE. Having completed five focus groups to refine the draft indicator framework, we submitted it to our funders (technical report available upon request) and have since explored opportunities to secure funds to continue this research and further refine the indicator frameworks. Recent events in Cape Town and Durban have highlighted that in unpacking health vulnerability, consideration should include cases where populations move from one EWE (drought) to another (flooding), or where these events are concomitant (drought, erosion, new flooded areas). Future research would aim to further streamline the indicator framework and allow for attention to explore the ways in which cascading EWEs might magnify vulnerability and how that could best be captured within the indicator framework.

Discussion

Drawing from Cutter et al.'s (2009) [27] initial exploration of HVIs without relying on weighting indicators, this mixed methods approach relied on layers of data gathering. The process undertaken drew strongly on first developing an evidence-base, and then working backwards to understand experiences linked to the evidence base. Despite efforts to cast a wide net, focus groups identified experiences that fell outside of the evidence base, and this highlights the value of pairing the quantitative analysis of evidence with qualitative inquiry. For example, in multiple focus groups, 'fever' was identified as a health outcome associated with a number of EWEs, but generally did not appear in the evidence base. Similarly, the details and nuance emerging from focus groups highlighted the importance of including demographic questions (for general vulnerability context) alongside EWE experience specific indicators (for health vulnerability specific to EWE information). Focus groups highlighted ways to improve the score sheets for user-friendliness and adjustments necessary in the frameworks. The entire process illuminated the importance of treating indicator frameworks as living documents, always in progress, and under development.

While the study attempted to follow stringent guidelines, limitations to the study methodology are acknowledged. These include but are not limited to: (1) flexible inclusion criteria, owing to the inconsistencies noted for the identification of EWEs and the parameters for defining each across studies; (2) the absence of grading/evaluation processes for each paper included in the RER; and, relatedly, (3) the absence of quality assessments and risk of bias. The timing of this grant within the COVID restrictions limited the process of validation and refinement. Despite the limitations listed, the study aimed to cast a wide net and explore potential pathways to health vulnerabilities. The study therefore chose to take an approach similar to ethnographic data collection – if an experience of an EWE had a particular outcome, we did not require confirmation of its relevance through the frequency of others having the same/similar experience, but rather considered all experiences regardless of frequency as important and included. While our research can highlight health events that are more likely to occur, this way of approaching all experiences as important, prioritizes lived experiences over correlation.

Conclusion

This paper recounts a process of developing a Health Vulnerability Indicator framework for extreme weather events for use by local residents in South Africa during COVID restrictions. We offer insights into the development of a draft HVI framework, grounded in an evidence review of health impacts from EWEs that takes into account the already robust Climate Risk and Vulnerability Assessments (CRVA) in place and validated for South Africa [see Greenbook; https://greenbook.co.za/about-the-green-book.html]. As such, the draft HVI frameworks generated from this research project worked to incorporate local engagement as well as the evidence from the scoping review. The study strove to gather data on vulnerabilities of EWEs from lived experiences, highlighting some areas not otherwise available in the evidence base. The process highlights that in order to ensure that HVIs are locally relevant, existent research (like CRVAs) and available evidence are required to be integrated alongside indicators; at the same time these indicators and the framework itself need to be considered a living document, open to change and engagement; ready to adapt and take on a case-by-case basis. This study provides the methods used to achieve draft frameworks; these drafts were developed after one phase of engagement and further engagement and refinement is, therefore, required. Key to this process has been the layering of methods that draw not only on the evidence base, but also on the lived realities and experiences of people vulnerable to EWEs.

Ethics statements

UCT EBE faculty approval. Informed consent was obtained from those who wished to participate in the study. Consent forms were distributed once participants were welcomed and the aim of the study explained. The consent forms included information regarding the study title, procedure, the study aims and objectives, benefits, risks and/or harms associated with participation, confidentiality, cost of participating (none), remuneration (none), rights of the participants, point-person for follow-up questions and consent (Appendix 4).

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.

CRediT authorship contribution statement

Amber Abrams: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Taherah Asmall:** Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Funding acquisition. **Sithabile Hlahla:** Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Kirsty Carden:** Writing – review & editing. **Mohamed Aqiel Dalvie:** Writing – review & editing.

Data availability

Data will be made available on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.mex.2024.102725.

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