

Enhancing primary healthcare nurses' preparedness for climate-induced extreme weather events

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ABSTRACT

Background: Climate Change is causing frequent and severe extreme weather events globally, impacting human health and well-being. Primary healthcare (PHC) nurses' are at the forefront of addressing these challenges and must be prepared.

Purpose: This scoping review explored literature on the preparedness of the PHC nursing workforce for extreme weather events and identify gaps in knowledge and practice.

Methods: Using Arksey and O'Malley's framework, a comprehensive search was conducted across PubMed, Scopus, CINAHL, Web of Sciences, and ProQuest, on studies from 2014–2024, addressing PHC nurses' preparedness.

Discussion: Nine studies were identified and highlighted a need for preparedness training and facility-based preparedness plans. Key themes included prioritizing regional networks, clinical leadership, service delivery, health information, health workforce, medical products and technologies, and financing.

Conclusion: Strengthening PHC nurses' resilience against extreme weather requires targeted professional development, mental health support, comprehensive planning, and collaborative efforts. Future strategies should enhance PHC nurses' capacity through training, support, and policy development.

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Introduction

Climate change presents an urgent and imminent worldwide risk to human health, both now and increasingly in the decades to come (Seneviratne and Zhang, 2023; WHO, 2024). Extreme weather events have escalated in both frequency and severity since preindustrial times, and it is expected that this trend will continue with the predicted incremental increases in global temperature (Seneviratne and Zhang, 2023). As such, nurses, the largest healthcare workforce, must be prepared and fully equipped to respond to extreme weather events (Richards et al., 2023). This is particularly important for

nurses practising in primary healthcare (PHC) settings, where their roles extend beyond traditional clinical care settings.

Our study specifically focused on extreme weather events, which are also categorized as disasters due to their significant impacts to communities and infrastructure (Lahsen & Ribot, 2021). While the term “disaster” is broadly used in the literature to describe various natural and human-made catastrophic events, our research narrowed this focus on weather-related disasters to align with our objectives. Extreme weather events, as defined by the Intergovernmental Panel on Climate Change's (IPCC's) sixth report (Seneviratne et al., 2023), include events such as heatwaves, heavy precipitation, severe storms such as cyclones and hurricanes, and various forms of flooding such as pluvial, riverine floods. Consequently, when we refer to “disasters” in our study, we are specifically referring to extreme weather events, in line with our focus on climate-related disasters.

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In the nursing literature, disaster management inclusive of extreme weather events, typically involved three key phases: planning, response, and recovery. The planning phase focuses on risk assessment, resource allocation, and the development of emergency plans to prepare for potential disasters (Bell et al., 2021; Kako & Hutton, 2023). This phase ends when a disaster is imminent or detected. The response phase begins with the occurrence of the disaster and includes immediate actions such as emergency medical response, search and rescue, and provision of shelter (Kako & Hutton, 2023; Menegat & Witt, 2018). The response phase lasts until immediate threats are mitigated. The recovery phase focuses on rebuilding and returning communities to normalcy, addressing both physical and emotional impacts, and can last from several months to years, depending on the disaster's severity (Menegat & Witt, 2018).

PHC is health care that occurs outside of hospitals, such as in aged care or community care settings (Australian Primary Health Care Nurses Association [APNA], 2024). PHC plays an important role in prevention, early intervention and minimizing hospitalizations, and providing care for vulnerable populations, including older people, those with disabilities and/or chronic conditions, children, and pregnant people (APNA, 2024; van Weel & Kidd, 2018). It is well-documented that vulnerable populations are at increased risk during extreme weather events (Filiberto et al., 2015; Ha, 2022; Lindsay et al., 2023; Rylander et al., 2013).

The evolving challenge of climate change and extreme weather events imposes unprecedented demands on the PHC system, necessitating an adaptive approach to nursing practice (Curtis et al., 2017; Richards et al., 2023). These pressures are likely to intensify, adding to the already-significant workforce challenges faced by the PHC nursing workforce (Sayre et al., 2010). These challenges are reflective of the strains experienced during the COVID-19 pandemic, which exacerbated PHC nurses' work-related stressors, including workload, workplace instability, concerns related to health impacts on their families and themselves, and feeling unsupported by their workplaces (Falatah, 2021). Such conditions within the PHC sector adversely impact mental health, leading to burnout, increased attrition rates, and a desire to leave the profession altogether (Falatah, 2021; Galanis et al., 2021; Ulupinar & Erden, 2024).

To address PHC nurses' and healthcare sector resilience and adaptation to extreme weather events, it is imperative to acknowledge and prepare for the complex impacts of climate change on PHC nurses and their work. Recognizing the critical role of PHC in ensuring delivery and continuity of care during climate-induced emergencies, the aim of this scoping review is to explore the peer-reviewed literature on the preparedness of the PHC nursing workforce in responding to the impacts of extreme weather on service delivery.

Methods

This review utilized the five-stage methodological approach based on the framework developed by Arksey and O'Malley (2005), which involves identifying the research question, identifying relevant studies, study selection, charting the data, and collating, summarizing, and reporting the results.

Review Questions

This review addressed the following questions:

1. What is the current state of preparedness of the PHC nursing workforce to address impacts of extreme weather on service delivery?
2. What are the key challenges faced by the PHC nursing workforce in responding to impacts of extreme weather?

3. What strategies or interventions have been proposed or implemented to enhance the preparedness of the PHC nursing workforce in addressing the impacts of extreme weather?

Identifying Relevant Studies

The search strategy was developed to identify relevant scientific articles with key concepts pertaining to the preparedness of the primary healthcare nursing workforce in responding to the impacts of extreme weather on service delivery, worldwide. Researchers identified subject terms relevant to concepts, and then mapped Medical Subject Headings (MeSH) subject headings. One researcher (SM) conducted preliminary test searches, resulting in the refinement of search terms. Terms like "adapt*," "primary healthcare nurs*," and "severe weather" were utilized for article retrieval. An experienced research librarian then assisted in testing and refining the terms used for the search, which is summarized in Table 1. The search was conducted in January 2024 by one researcher (IW) across five databases: PubMed, Scopus, CINAHL (via EBSCO), Web of Sciences, and ProQuest.

Study Selection

To be included, studies required a clear focus on the preparedness of the PHC nursing workforce for extreme weather events. Peer-reviewed, empirical, contemporary (2014–2024), and English language texts were all included. If papers produced a mixed sample of nurses, findings on PHC nurses had to be identifiable and able to be parsed, or the paper would be excluded. Similarly, if papers produced a mixed sample of natural disasters, extreme weather events had to be identifiable and able to be parsed or they would be excluded. These criteria were applied to facilitate the discretionary stratification of findings and enable contextualized analyses of specific PHC and disaster settings.

Extreme weather events were defined in alignment with the IPCC's sixth report (Seneviratne et al., 2023). This included temperature extremes (e.g., heatwaves), heavy precipitation, flooding (e.g., pluvial, river), and storms (e.g., hurricanes, cyclones) (Seneviratne et al., 2023). Compound events, which combine multiple hazardous weather conditions (Seneviratne et al., 2023), were also included. A notable compound event was fire weather, consisting of hot, windy, and dry conditions (Seneviratne et al., 2023). Other types of natural disasters, such as earthquakes and tsunamis, were excluded, as they were not covered under the IPCC's extreme weather definition (Seneviratne et al., 2023).

Nursing within the PHC setting was defined as "any medical service that is provided outside of the four walls of a hospital, including aged care, community health, general practice, custodial, schools, and many other primary health care settings." (APNA, 2024).

Screening was conducted in Covidence (Covidence systematic review software). After duplicate removal, title, abstract, and full-text screening were completed independently by two researchers (IW and SM). Conflicts were settled by a senior researcher (AW).

Charting the Data

Data were charted by two researchers (SM, IW) and included author/s, year of publication, geographic location, sample size, and key findings.

Thematic Analysis

Themes and subthemes were identified with deductive thematic analysis, which facilitated data extraction aligned with the review's objectives. Themes and subthemes were reviewed by the entire research team to ensure a high quality of analysis.

Table 1
PubMed Search Strategy

Text Type	Preparedness	Primary Healthcare Nursing Workforce	Severe Weather
Free Text	adapt* mitigat* prepar* respon* strateg* interven* respon* recover* capacit* readiness ready mobili* challeng* anticipat* recover* obstacle* difficult* adversit* opportunit* barrier limitation* constrain* enable* facilitat* effect*	"primary healthcare nurs*" "primary health care nurs*" "primary health-care nurs*" "Primary healthcare" "Health Workforce" "health care workforce" "disaster response" "health-care system" "healthcare system" "health workforce governance" "healthcare management" "health-care management" "healthcare capacity" "health-care capacity" "human resources for health" "Rural nurs*" "Public health nurs*" "community nurs*" "community health nurs*"	"severe weather" "climate change" "global warming" "extreme weather" "extreme temperature*" heatwave* natural disaster* flood* "heatwave*" drought* fire* bushfire* wildfire* "sea level rise" storm* lightning "saltwater intrusion" "saltwater inundation" cyclone* thunder thunderstorms storm* wind* rain* hail "disaster response*" hurricane snowstorm Blizzard "Climate crisis" disaster* "Disaster management"
PubMed MeSH	"Disaster planning"	Nurses	"Climate change" "Natural disasters"

Results

Screening and study selection, including reasons for exclusion (Figure 1), following Page et al. (2021). Nine studies remained for inclusion in the review. Studies were conducted in America ($n = 3$), Indonesia ($n = 3$), Brazil ($n = 2$), and Japan ($n = 1$), using qualitative ($n = 3$), quantitative ($n = 5$), and mixed-methods ($n = 1$) designs (Table 2). The sample size ranged from 20 to 570. Data were collected through surveys ($n = 2$), questionnaires ($n = 2$), interviews ($n = 2$), retrospective payroll data ($n = 2$), focus groups ($n = 1$), and a mixture of surveys and interviews ($n = 1$) (Table 2). Studies examined nursing response to specific extreme weather events ($n = 6$), and general preparedness for disasters ($n = 3$) (Table 2). Nurses tended to work with vulnerable populations such as the elderly, those with chronic diseases, low socioeconomic status, and pregnancy (Bell et al., 2021; Jester et al., 2021, 2022; Menegat & Witt, 2018, 2019). Extreme weather events included hurricanes ($n = 3$) and floods ($n = 3$) (Table 2).

Thematic Analysis

Clinical Leadership

PHC nurses sometimes assumed key leadership roles throughout disaster responses (Menegat & Witt, 2018, 2019) with core responsibilities, including adapting and implementing disaster plans, managing nonhealthcare volunteers, and communicating with various individuals, particularly about health hazards (Menegat & Witt, 2018, 2019). One article described how, although there was an existing volunteer nurse deployment system in place, it did not include PHC nurses (Kako & Hutton, 2023). Thus, PHC nurses need to join existing infrastructure as leaders to strengthen PHC nurse co-ordination (Kako & Hutton, 2023). A key challenge was limited prior leadership experience resulting in requests for training (Menegat & Witt, 2018, 2019).

Service Delivery

Patient and Household Preparedness. PHC nurses helped clients and households prepare, either well in advance, or as the disaster approached, sometimes through in-person home visits (Bell et al., 2021; Kako & Hutton, 2023; Menegat & Witt, 2019). The nurses would also follow up after the extreme weather event to check on their clients' status and provide pertinent health education (Menegat & Witt, 2019). Advanced planning occurred through comprehensive, personalized emergency plans, when patients went through admission to the nursing service (Bell et al., 2021; Kako & Hutton, 2023). Implementation provided challenges, such as financial concerns, belief that the disaster would not impact them, forgetting the plan, and mobility and transportation issues ... *I don't know that we could do any better just because of the way the world works ...* (Bell et al., 2021).

Nurses experienced additional challenges in the recovery phase, where limited understanding of health and safety led to further health problems among their clients, despite thorough preparation (Bell et al., 2021). One nurse stated, *"If you have floodwaters in your house, you can't be walking around with your bandaged foot, and there's so many people doing that ..."* (Bell et al., 2021).

Continuity of Care. Despite disruptive and challenging weather events, PHC nurses demonstrated considerable preparedness and determination to ensure service provision throughout disaster preparation, response, and recovery phases, and despite limited resources (Bell et al., 2021; Kako & Hutton, 2023; Menegat & Witt, 2018). Nurses faced challenges such as client hesitation to evacuate despite prior agreement (Bell et al., 2021), lost medication or prescriptions (Menegat & Witt, 2018), or critical medical devices like oxygen tanks with dysfunction potential (Kako & Hutton, 2023). Nurses needed a thorough knowledge of their clients' personalities,

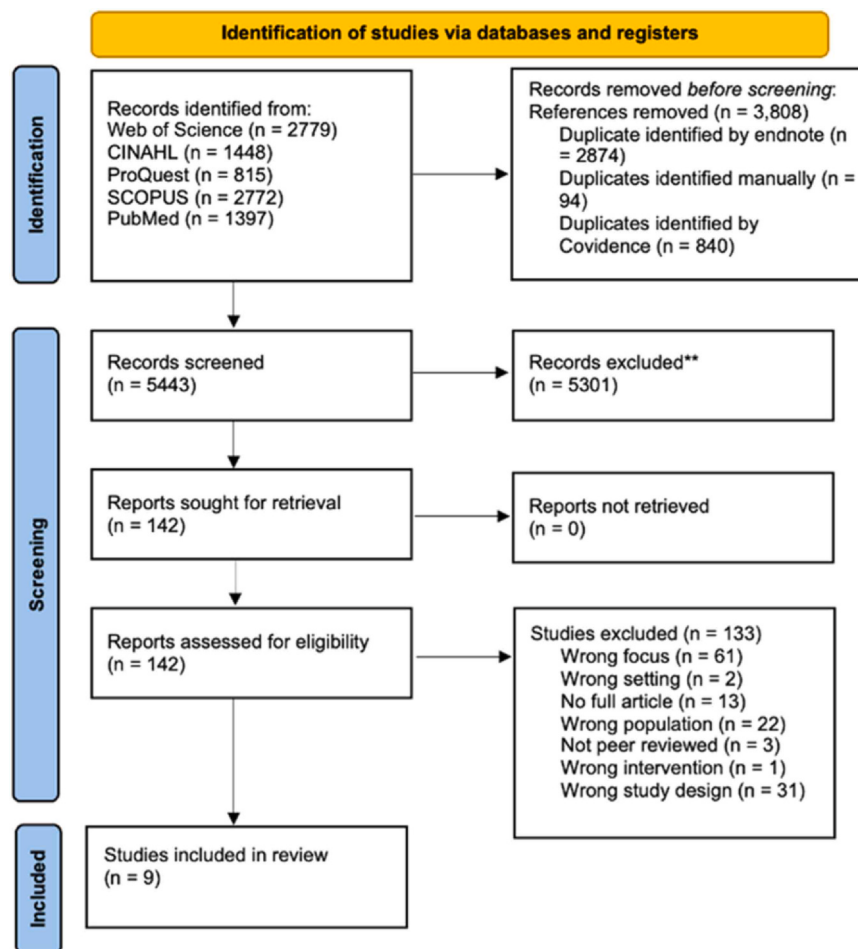


Figure 1. Study selection flow diagram.

emergency plans, medications, medical devices, and conditions (Bell et al., 2021; Kako & Hutton, 2023; Menegat & Witt, 2018).

Integration of Services. Nurses took on extra duties dependent on the phase of the disaster (Menegat & Witt, 2018, 2019). During the response phase, nurses provided critical services, such as first aid, immunizations, psychological care, and referrals to either a primary or tertiary center where necessary (Menegat & Witt, 2018, 2019). The nurses also tried to ensure access to basic needs, such as shelter, water, and food (Menegat & Witt, 2019). In the recovery phase, nurses provided additional support to the community through education on pertinent topics, such as negative health impacts from flood water (Menegat & Witt, 2018). A challenge to integrating emergency care into their existing role was the need to sometimes work outside of their usual environment, and potentially outside their scope of practice (Menegat & Witt, 2018, 2019).

Extra duties were primarily noted during the response phase. They included helping with disaster aid, insurance applications, and acting as intermediaries between home health agencies and their patients (Bell et al., 2021). These tasks were taken on due to support scarcity, and the trusting relationship that nurses developed with their clients (Bell et al., 2021). One participant described going to the grocery store and buying adult diapers with her own money because she was not sure if their client had remembered to take them when evacuating (Bell et al., 2021).

Health Information

Vulnerability Assessment. Nurses were an invaluable source of information for risk mapping and assessment, which contributed

to the overall preparedness of their communities (Menegat & Witt, 2018, 2019). PHC nurses already knew where vulnerable populations lived, including pregnant people, older people, and those with chronic diseases (Menegat & Witt, 2018, 2019).

Incident Response Plan. Some PHC nurses' workplaces did not have emergency response plans or guidelines in place (Kako & Hutton, 2023; Menegat & Witt, 2019), demonstrating a lack of preparedness. Challenges to preparing plans included time constraints and lack of emergency planning education (Kako & Hutton, 2023). Additionally, it was noted that for-profit healthcare centers appeared to tend to deprioritize emergency response plans (Kako & Hutton, 2023).

Health Workforce

Multidisciplinary Team. Multidisciplinary teams involving nurses conducted critical work, such as distributing necessities, conducting vulnerability assessments, and maintaining continuity of care (Kako & Hutton, 2023; Menegat & Witt, 2018, 2019). However, nurses consistently commented on the challenges associated with multidisciplinary teams working in disaster response and recovery. These included communication barriers due to differing terminologies (Kako & Hutton, 2023), coordination difficulties arising from conflicting priorities among team members (Menegat & Witt, 2018), and disputes over the allocation of limited resources (Kako & Hutton, 2023). Having solid relationships already formed ensured strong teams that could communicate under pressure, and that those facing disasters had a network to call upon for help when needed (Kako & Hutton, 2023; Menegat & Witt, 2018, 2019).

Table 2
Summary of Included Studies

Authors	Year	Aims	Methodology	Location	Sample Size	Study Population	Key Findings
Bell, S., Dickey, S., Rosenberg, M.	2021	To qualitatively understand the barriers and facilitators of both patients and providers that influence the provision of home-based care activities in two hurricane-affected communities.	Qualitative description	Michigan, America	25	Nurses providing home-based care	Nurses were prepping at home patients by giving them individualized care plans for disasters. Nurses took on social work duties for clients.
Emaliyawati, E., Ibrahim, K., Trisyani, Y., Mirwanti, R., Ilhami, F.M., Arifin, H.	2021	To determine the factors associated with disaster management preparedness among community health nurses in coastal areas.	Quantitative, observational, analytical, and cross-sectional	Indonesia	142	Community health nurses	Almost half (45%) were poorly prepared for disasters. Practical experience as a nurse (~6–10 years), and disaster volunteering were effective for a high level of preparedness.
Jester, D., Thomas, K., Peterson, L., Dosa, D., Andel, R., Hyer, K.	2021	To examine the effect of Hurricane Irma on staff-related financial expenditures and daily direct-care nurse staffing levels.	Quantitative, observational, and retrospective cohort study	Florida, America	653	Nursing homes	Staffing increases associated with hurricane Irma were significant and represent considerable costs to the nursing homes.
Jester, D., Peterson, L., Thomas, K., Dosa, D., Andel, R.	2021	To examine whether the nursing homes that compare overall star rating were associated with direct-care nurse staffing levels in Florida Nursing Homes during Hurricane Irma.	Quantitative, retrospective, and longitudinal cohort study	Florida, America	570	Nursing homes	Lower-rated nursing homes had significantly smaller increases in staffing during/after hurricanes, compared with higher-rated nursing homes.
Kako, M., Hutton, A.	2023	To understand the overview of disaster preparedness and its experience in the targeted area.	Mixed methods, sequential or explanatory	Hiroshima, Japan	89	Community nurses	Healthcare providers that neglected to have disaster preparedness plans did so due to time scarcity or not knowing how. Nurses were often impacted by the disasters, which could make staffing appropriately difficult.
Menegat, R., Witt, R.	2019	To identify critical requirements for nursing practice when responding to hydrological disasters in the rural area.	Qualitative description	Brazil	20	Rural primary healthcare nurses	Emergent care was taken on by PHC nurses, such as wound care and immunizations. Afterward, nurses went to homes, checking in on at-risk families and providing continual education on health risks such as waterborne diseases.
Menegat, R., Witt, R.	2018	To identify primary healthcare nurses' competencies when responding to hydrological disasters in rural areas.	Qualitative description	Brazil	20	Rural public health nurses	PHC nurses knew where the vulnerable populations were and what they would need. Nurse leadership was critical for disaster response.
Putra, A., Petpichetchian, W., Maneewat, K.	2021	To examine the level of public health nurses' (PHNs) knowledge regarding disaster management.	Quantitative, descriptive, and cross-sectional	Indonesia	252	Public health nurses	More than half of the respondents had no experience or training responding to disasters. Most nurses did not have knowledge around basic life support, disaster triage, sorting and screening disaster victims, or strategies to increase community awareness following a disaster.
Sangkala, M., Gerdzt, M.	2018	To identify the current levels of knowledge, skills, and preparedness for managing natural disasters as perceived by CHN coordinators, working in community health settings in South Sulawesi.	Quantitative, descriptive, and cross-sectional	South Sulawesi, Indonesia	214	Community health nurses	Most nurses perceived their disaster preparedness to be "moderate." One "weak" area was disaster preparedness specific to their community's needs. Areas that tended to be stronger were evacuation routes for themselves and their families.

Training and Education. Education and training were the most widely mentioned topics and discussed in six of the nine papers (Emaliyawati et al., 2021; Kako & Hutton, 2023; Menegat & Witt, 2018, 2019; Putra et al., 2021; Sangkala & Gerdtz, 2018). Studies conducted with large samples found that, overall, nurses were low to moderately prepared, with only a few nurses reporting that they felt highly prepared (Emaliyawati et al., 2021; Putra et al., 2021; Sangkala & Gerdtz, 2018). Being highly prepared was positively correlated with time in the workforce (6–10 years) and previous disaster experiences (Emaliyawati et al., 2021; Kako & Hutton, 2023). However, poor or inadequate training was described as leading to poor preparedness, highlighting the importance of contextually appropriate and relevant training accompanied by regular drills (Emaliyawati et al., 2021; Kako & Hutton, 2023).

Key challenges to implementing adequate disaster preparedness training for PHC nurses included provision of consistent and specific information across healthcare providers (Kako & Hutton, 2023; Menegat & Witt, 2018, 2019). Content needed to be tailored to the clients' and nurses' needs, and probable disasters (Kako & Hutton, 2023). Menegat and Witt (2018, 2019) found that when nurses were adequately trained and empowered to take on leadership roles during disasters, they also contributed effectively to the development of disaster education programs for healthcare professionals.

Workforce Safety and Well-being. Nurses responded to disasters that had occurred in their communities, which impacted on them, their families, and their clients (Bell et al., 2021; Kako & Hutton, 2023; Menegat & Witt, 2018, 2019). This presented challenges to their own safety, and mental and physical well-being (Bell et al., 2021; Kako & Hutton, 2023).

A key strategy for mental health preparedness was having a personal disaster plan, organized with family in advance, which enabled PHC nurses to be present with their clients (Bell et al., 2021). A strategy to ensure nurses' safety was for the clinic manager or the nurses' direct supervisor to regularly contact staff to assess if they could safely report to work the next day (Kako & Hutton, 2023).

Surge Capacity. A surge of presenting patients and/or clients was not identified in the literature. Despite this, increased staffing was still requisite in some situations, like residential aged care facilities before and after extreme weather events (Jester et al., 2021, 2022; Kako & Hutton, 2023).

Inadequate staffing levels led to worse continuity of care and increased risk of poor health outcomes (Jester et al., 2022). Additional nurses were needed to prepare and care for clients during the disaster, and further nurses were needed for evacuation (Jester et al., 2021, 2022). However, securing extra staff was challenging, as all healthcare providers were drawing from the same local pool of nurses, thereby leading to inequalities in care (Jester et al., 2021, 2022). These inequalities often impacted those with a low socioeconomic status, and Black and Hispanic/Latino residents (Jester et al., 2022).

Medical Products and Technologies

Adequate Medical/Laboratory Equipment and Supplies, and Appropriate Infrastructure and Technology. Having access to appropriate medical supplies and infrastructure was mentioned as challenging (Kako & Hutton, 2023; Menegat & Witt, 2018, 2019). Some nurses in rural areas noted that work was conditional upon availability of medical supplies like bandages (Menegat & Witt, 2018, 2019). Nurses sometimes worked with medical devices without access to electricity, which then created a need to either know or have hard copies of device instructions (Kako & Hutton, 2023). Last, nurses described road inaccessibility, which presented a challenge for commuting, and in-home visits (Kako & Hutton, 2023). Healthcare providers would call nurses to see who was available to work, and if

they could cover clients who lived on accessible roads (Kako & Hutton, 2023).

Financing

Financial Resources. Disasters had an economic impact on residential aged care facilities as they were required to hire extra staff before, during, and after hurricane landfall (Jester et al., 2021, 2022). These costs were borne by the facilities, and presented a challenge when they were faced with a potential increase in intensity and frequency of hurricanes (Jester et al., 2021).

Discussion

The aim of this literature review was to examine the peer-reviewed literature pertaining to the preparedness of PHC nurses in responding to extreme weather events. It is evident from this exploration that the PHC nursing workforce faces unprecedented challenges in the wake of increasing extreme weather events. Grounded on a comprehensive review of the contemporary literature, analyses identified that preparedness must focus on effective guidelines that assure continuity of service delivery, the strategic implementation of health information and vulnerability assessment, targeted education and training to prepare PHC nurses to work within a multidisciplinary, multisectoral response, and leadership and governance (Kako & Hutton, 2023).

Policy

Despite the integral role that PHC nurses play in the frontline delivery of healthcare services, particularly during extreme weather events, their involvement in policy development and planning remains markedly insufficient (Veenema et al., 2016). This gap in policy participation and leadership restricts the ability of the healthcare system to fully leverage the insights and experiences of PHC nurses, who often have an intimate understanding of community needs and vulnerabilities (Veenema et al., 2016).

Current healthcare policies often overlook the direct contributions of PHC nurses, focusing instead on higher-level organizational strategies that may not address the operational challenges faced on the ground in maintaining patient care, continuity in service delivery, resource allocation, and health workforce management (Lamberti-Castronuovo et al., 2022; Veenema et al., 2016). Empowering nurses to provide valuable insights and leadership in policy design and implementation, can lead to more robust and adaptable policies, capable of addressing the multifaceted challenges faced by the demands of healthcare delivery during extreme weather events (Veenema et al., 2016).

Clinical Leadership

The emphasis on pre-disaster networking and coordination among multidisciplinary healthcare providers and community organizations form an important component of preparedness. PHC nurses often act as the linchpin in these networks, facilitating communication and collaboration that are essential for a cohesive response to extreme weather events (Kako & Hutton, 2023). Nurses' comprehensive understanding of community health dynamics and needs, ensures that PHC nurses can facilitate the seamless integration of emergency services within routine care, therefore ensuring that the healthcare system can adapt in the face of adversity (Smolowitz et al., 2015).

Vulnerability Assessment

Clinical leadership in PHC involves nurses coordinating and conducting vulnerability assessments to manage patients with complex

conditions and other vulnerable groups effectively. PHC nurses are essential in co-designing risk stratification models that categorize patients based on their health status and other risk factors, facilitating targeted care management and vulnerability mapping (Dera, 2019; Girwar et al., 2021). Although there is limited research evidence on population health management data, infrastructure, systems, and governance within Primary Health Services, such information is crucial for nurses to prevent, manage, and plan clinical interventions to reduce complications and hospital admissions.

PHC nurses are pivotal in vulnerability mapping, often knowing the locations of many vulnerable individuals through historical service provision (Menegat & Witt, 2018, 2019). This intimate knowledge of their client base could significantly enhance the effectiveness of vulnerability assessments. Moreover, it is vital to include nurses from Indigenous communities in these assessments, this group frequently faces disproportionate impacts from climate change (Smith et al., 2022). Their involvement ensures that vulnerability mapping is inclusive and addresses the specific needs of all community members.

Continuing Service Delivery During Extreme Weather Events

The healthcare system, inclusive of nurses, must remain prepared and responsive during extreme weather events to ensure continuity of care amidst the chaos that often ensues during an event (Sorensen & Fried, 2024). Obstacles to continuity of care that arise from extreme weather events, include disrupted communication channels, suboptimal staffing distribution, accessibility issues, and the urgent need for medical supplies and resources that were not always available (Richards et al., 2023).

A primary function of PHC facilities is to support and enhance hospital services during surge events by expanding their roles (Lamberti-Castronuovo et al., 2022). Literature indicates that, as is common in PHC settings, PHC nurses frequently take on responsibilities beyond their traditional scope during extreme weather events, including tasks such as social work, and facilities management and maintenance during extreme weather events (Richards et al., 2023). Clear state and local strategies outlining how to maintain staffing across health organizations (including PHCs), may better equip PHC nurses for the changes in their role, and additional challenges placed on them to continue service delivery in extenuating circumstances (Lamberti-Castronuovo et al., 2022).

The importance of client and household preparedness has been demonstrated to be effective in response to extreme weather events (Menegat & Witt, 2019). Through targeted education and planning with community members within their healthcare service, PHC nurses can equip clients and their loved ones with the knowledge and resources needed to navigate the complexities of extreme weather events. This planning can include development of a personalized emergency plan, education on basic first aid, and ensuring people with chronic conditions have an adequate supply of medications and a plan if their health deteriorates (Menegat & Witt, 2019).

Education and Training

This review has revealed a landscape where the level of preparedness education varies significantly across regions and facilities, with many PHC nurses receiving minimal formal education and training in extreme weather event preparedness, response, and/or management (Putra et al., 2021). This poses a significant challenge, as the effectiveness of PHC nurses during such events heavily depends on their knowledge and preparedness.

Globally, there is a notable deficiency in the integration of climate change content within undergraduate and prelicensure nursing programs, which exacerbates this gap in knowledge (Martin et al., 2024). All nurses, regardless of context of practice, require a

foundational level of knowledge and skills related to the impacts of climate on health (Martin et al., 2024). This foundational education should be expanded upon through postgraduate programs tailored specifically for PHC nurses, designed to address the unique challenges and needs of the communities they serve.

Following this foundational education, targeted training programs should be implemented to incorporate advanced training in extreme weather event preparation and response, psychological first aid, and leadership during crisis. Importantly, these training programs need to be context-specific and tailored to the geographical and population variations of communities, which influence the diversity of potential extreme weather events and the vulnerabilities of populations (Menegat & Witt, 2018, 2019).

Additionally, integrating simulation-based learning (SBL) and practical exercises into these training programs could significantly enhance PHC nurses' ability to apply theoretical knowledge to real-world scenarios, improving decision-making and response times during extreme weather events. SBL provides a safe and realistic learning environment where PHC nurses can hone their skills, practise emergency procedures, and make critical decisions under pressure, mirroring the conditions they may face during extreme weather events (Glauber et al., 2020).

Strengthening the Resilience of PHC Nurses

The dual role of a PHC nurse, as both a responder and victim of extreme weather events, exacerbates stress, psychological distress, and burnout (Bell et al., 2021; Kako & Hutton, 2023). Parallels can be drawn from the PHC nursing workforce during the COVID-19 pandemic (Richards et al., 2023). Burnout and high attrition rates, with many more PHC nurses considering changing careers, were symptoms of the significant personal and professional stress that nurses faced during COVID (Ashley et al., 2021).

To address these challenges and to support the workforce to respond in a way that prioritizes nurses' own health and well-being, it is imperative to embed multifaceted strategies that encompass pre-extreme weather event preparedness, active disaster response, and post-disaster recovery. Pre-disaster initiatives focused on comprehensive training programs, including psychological first aid, stress management during crisis, and strategies for self-care, can equip nurses with the skills and resources needed to manage their well-being and that of their patients (Putra et al., 2021). During extreme weather events, ensuring adequate support systems, accessible mental health resources, and clear communication channels can mitigate the immediate impacts on nurses' mental health (King et al., 2015). Equally important, post-disaster support should include debriefing sessions and ongoing psychological support to address long-term effects and prevent burnout (Ranse & Lenson, 2012).

Organizations and facilities also play a vital role in facilitating the health and well-being of PHC nurses. Strong facility-based preparedness plans, reinforced by policy support and intersectoral collaboration, can enhance nurse's capacity to navigate these challenges (Kako & Hutton, 2023). Flexible work schedules or the provision of additional leave post disaster to accommodate the personal needs of nurses, such as repairing homes, caring for family members, volunteering in community recovery efforts, or for mental health breaks can also assist in alleviating psychological distress (Xue et al., 2020). Additionally, recognizing the extraordinary efforts of PHC nurses during such crises, healthcare organizations could offer additional financial compensation in the form of hazard pay or bonus payments for additional hours worked (Franzosa et al., 2022).

Conclusion

The increasing impact of climate change highlights the urgent need for PHC nurses to be effectively prepared for extreme weather

events. This scoping review of the peer-reviewed literature highlights the necessity for robust professional development, mental health support, detailed planning, and regional collaboration to enhance the resilience of PHC nurses. By focusing on comprehensive education and training, integrated policy support, and collaborative efforts, we can ensure that the PHC nurses are well-prepared to manage both personal and professional challenges during such events. Future strategies should aim at strengthening nurse preparedness through practical education, training, and policy improvements, ensuring that the largest healthcare professional workforce is prepared in the face of these increasing threats.

Credit Statement

Aletha Ward: Conceptualisation, project administration, writing (original draft), writing (review and editing), supervision. **Sophia Martin:** Formal analysis, investigation, writing (original draft), writing (review and editing), supervision. **Catelyn Richards:** Writing (review and editing), supervision. **Isabella Ward:** Data curation, investigation, writing (review and editing). Tracey Tulleners: Conceptualisation, writing (review and editing), supervision. **Danny Hills:** Conceptualisation, writing (original draft), writing (review and editing). **Hylda Wapau:** Writing (original draft), writing (review and editing). **Tracey Levett-Jones:** Conceptualisation, writing (original draft), writing (review and editing). **Odette Best:** Conceptualisation, writing (original draft), writing (review and editing).

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Ethics statement

This project required no ethics clearance.

Declaration of Competing Interest

The authors declare no conflicts of interest.

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