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Preparedness of Primary Health Nurses for Biological Disaster Management: A Review of Knowledge, Competencies, Resources, and Institutional Support

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Abstract

This research analyzed the capacity of primary health nurses (PHNs) to manage biological disasters by synthesizing literature on four major domains: knowledge and awareness, clinical competence, resource availability, and institutional support. A thorough search of research published between 2018 and 2024 was conducted across major databases, with suitable publications evaluated using predetermined inclusion criteria. The findings revealed that PHNs had intermediate levels of basic knowledge on pathogen biology and outbreak protocols, but lacked depth in emerging zoonotic threats and bioterrorism agents. Targeted drills improved technical abilities, including personal protective equipment use and infection control, but adaptive decision-making and critical thinking in crisis situations remained underdeveloped. Health systems should build resilient supply chains, such as regional stockpiles and quick distribution networks, and integrate PHN representation into disaster management frameworks. On-site counselling and peer support programs are important for maintaining workforce resilience. By addressing these multidimensional deficiencies, the analysis concluded that health systems might transform moderate preparedness into robust, long-term response capacity, thereby bolstering primary healthcare infrastructure against future biological threats.

Keywords

Preparedness, Primary Health Nurses, Biological Disaster Management

1. Background of the Study

Biological disasters, including natural disasters as well as accidental or intentional

acts, constitute some of the greatest risks to the global population [1]. Such disasters, characterized by their unpredictability along with the ability to escalate quickly, pose a significant burden to health systems [2]. In these systems, primary health nurses are at the forefront as they participate in the provision of preventive care, the identification of cases, intervention, and the assurance of follow-up after cases have been addressed [3].

The global health landscape has seen a dramatic increase in the frequency and severity of biological disasters over the past two decades. The instances like severe acute respiratory syndrome (SARS), Swine flu (H1N1), Ebola, and now Coronavirus disease (COVID-19) have brought the vulnerabilities of healthcare systems into the limelight [4].

Nurses in primary health care need to be prepared by having knowledge about the basics of biological agents, the features of outbreaks, methods of infection control, and collaboration with other organizations [5].

Best practices in disaster preparedness involve knowledge and awareness; however, findings indicate that there is a lack of knowledge among primary health nurses [6]. Particularly, an effective response to disaster involves expertise in aspects like triage, infection prevention and control, and personnel communication as well as psychological support for patients and their families [6]. However, these competencies are achieved through certain professional training, which is not always accessible to nurses [5]. This reliance on theoretical knowledge without practical infusions exposes many nurses to inadequate skills and competencies in dealing with biological disasters in practice [7].

Proper availability, sufficiency, and access to resources are pertinent for disaster response. Personal protective equipment, diagnostic equipment, vaccines, medications, training programs, and other items that may be deemed essential are frequently available in limited quantities [8].

Leadership, policies within organizations, and culture comprise the main components of institutional support, which is indispensable to nurse preparation [7]. Practical and concise disaster management policies offer structures in which nurses can function successfully, while continuous recommendations from the leadership offer authoritative guidance [9].

Primary health nurses involved in the management of disasters demonstrate commitment despite experiencing various challenges [10]. Thus, their experiences underscore a critical lesson of improving their preparedness levels and emphasize a holistic preparedness approach that integrates knowledge and skills, resources, and institutional support [11]. This review aimed to explore and synthesize existing literature on the preparedness of (PHNs) for biological disaster management, with a specific focus on their knowledge, competencies, access to resources, and institutional support.

The goal is to identify gaps and best practices to inform future training programs, policy development, and capacity-building efforts, particularly in contexts vulnerable to biological threats such as Saudi Arabia.

2. Statement of the Problem

Saudi Arabia's strategic location, global religious gatherings, and history of zoonotic outbreaks make it highly susceptible to biological disasters [10]. Despite this vulnerability, research indicates low levels of preparedness among PHNs, who are vital to frontline response efforts [12]. Past events such as the MERS outbreak and the COVID-19 pandemic have demonstrated gaps in training, resource provision, and institutional support [13].

With ongoing threats like H5N1 and Rift Valley Fever, as well as the looming risk of bioterrorism, a comprehensive assessment of PHNs' readiness is essential. Disparities in preparedness, particularly between rural and urban healthcare settings, further exacerbate the problem [13]. This study seeks to evaluate the preparedness of PHNs in Saudi Arabia with a focus on knowledge, skills, resources, and institutional backing, contributing to national and global strategies for effective disaster response.

3. Definition of Terms

- **Biological Disaster:** Refers to events caused by the outbreak of infectious diseases, bioterrorism, or accidental release of biological agents that pose significant threats to public health and safety [1].
- **Preparedness:** The state of readiness and ability to effectively plan for, respond to, and recover from biological disasters, including having the necessary knowledge, skills, resources, and institutional support [14].
- **Primary Health Nurses (PHNs):** Nurses who work in primary healthcare settings and serve as the first point of contact for patients. They play a crucial role in community health management, including disease surveillance, prevention, and disaster response [3].
- **Protocols and Guidelines:** Standardized procedures and policies established by healthcare organizations or governing bodies to guide responses during biological disasters and ensure consistency in care and safety [7].
- **Competencies:** The practical skills, abilities, and professional attributes required by nurses to perform effectively in managing biological disaster scenarios, including infection control, triage, communication, and ethical decision-making [6].
- **Resources:** Tools, equipment, training programs, medications, and other materials necessary for effective disaster preparedness and response. These include PPE, testing kits, vaccines, and ongoing professional education [8].
- **Disaster Management:** A systematic process involving planning, organizing, and implementing measures to prevent, prepare for, respond to, and recover from disasters, including both natural and human-made biological threats [15].
- **Institutional Support and Policies:** Institutional Support and Policies as an independent variable encompasses multiple critical components that collectively influence the preparedness of primary health nurses (PHNs) for biological disaster management. These components include:

A. **Formal Protocols:** Established and documented procedures, guidelines, and frameworks that clearly define roles, responsibilities, and operational steps during biological disasters. These protocols provide consistency and guidance, ensuring that PHNs understand their specific tasks and the overall disaster response structure [7].

B. **Leadership and Organizational Engagement:** The active involvement of healthcare leadership in disaster preparedness planning, policy development, and implementation. Effective leadership fosters a culture of readiness by ensuring regular training, emergency drills, and clear communication channels within healthcare settings [9]. Leadership engagement also promotes accountability and resource allocation to support disaster management efforts.

C. **Psychosocial Support:** Mental health resources and services provided to nurses to address stress, anxiety, and burnout associated with disaster response. This includes access to counseling, peer support programs, and resilience training to maintain the psychological well-being and functional capacity of PHNs during crises [14].

4. Methods

This study aimed to evaluate and synthesize existing literature on the preparedness of Primary Health Nurses (PHNs) for biological disaster management, focusing on knowledge, competencies, resources, and institutional support. A systematic review methodology was employed, following established protocols for evidence synthesis. The review was based on peer-reviewed research studies published between 2018 and 2024.

4.1. Literature Search Strategy

A comprehensive search was conducted across several major academic databases to ensure the inclusion of a broad spectrum of studies. The databases used in this search included PubMed, CINAHL, Google Scholar, Scopus, and Web of Science. The literature search was designed to capture a wide array of research articles, including those that focus on biological disaster preparedness, primary health care nursing, and disaster management competencies. The search was restricted to studies published between January 2018 and December 2024, ensuring that the findings reflect the most recent evidence in the field.

4.2. Keywords and Search Terms

To maximize the search's comprehensiveness, specific keywords were chosen to target the relevant themes of the study. The primary terms included "Primary Health Nurses" or "Primary Care Nurses" combined with terms like "Biological Disaster Management," "Biological Threats," "Infectious Disease Outbreaks," and "Preparedness." Additional terms such as "Competence," "Training," "Institutional Support," and "Response Strategies" were incorporated to ensure that all

relevant articles were identified. The search terms were connected using Boolean operators like "AND" to filter for studies that addressed both the role of PHNs and biological disaster preparedness. For more precise results, Medical Subject Headings (MeSH) terms were employed where applicable.

4.3. Inclusion and Exclusion Criteria

To ensure the relevance and quality of the studies included in the review, strict inclusion and exclusion criteria were applied. The inclusion criteria were as follows: studies published between 2018 and 2024, peer-reviewed articles (including systematic reviews and empirical research), and research focusing specifically on PHNs' preparedness for biological disasters. This included studies that discussed PHN knowledge, competencies, resources, and institutional support related to disaster management. Studies were excluded if they were not available in English, did not provide full-text access, or focused solely on healthcare settings other than primary health care. Additionally, research that did not address biological disasters or lacked empirical data was excluded to maintain the integrity and focus of the review.

4.4. Data Extraction and Synthesis

The data from the selected articles were extracted using a structured template, which ensured that critical elements were captured consistently across studies. This included information about the study design (e.g., qualitative, quantitative, mixed-methods), study population (PHNs involved in biological disaster preparedness), and the specific interventions or training programs explored in the research. Key outcomes measured across studies were also extracted, such as knowledge levels, skill acquisition, resource availability, and institutional policies. The data were then synthesized thematically, with findings categorized under the following four main domains: 1) Knowledge and Awareness, 2) Clinical Competence, 3) Resource Availability, and 4) Institutional Support. This thematic synthesis allowed for a comprehensive understanding of the factors influencing PHNs' preparedness for biological disasters.

4.5. Quality Assessment

To ensure the methodological rigor of the studies included in the review, quality assessments were conducted using well-established tools. For qualitative studies, the Critical Appraisal Skills Programme (CASP) checklist was applied to evaluate the reliability and validity of the findings. For quantitative studies, the Newcastle-Ottawa Scale (NOS) was used to assess study quality. These tools helped to ensure that the studies included in the review met the necessary standards for credibility, methodological quality, and the robustness of their findings. This quality assessment process was integral to maintaining the integrity of the review and ensuring that the conclusions drawn were based on high-quality evidence.

4.6. Data Analysis

The data extracted from the studies were analyzed using a narrative synthesis approach. This approach allowed for a broad description of the findings while identifying key trends and patterns across studies. Descriptive summaries provided an overview of PHNs' preparedness levels, highlighting strengths and weaknesses in knowledge, competencies, resource availability, and institutional support. A thematic analysis was conducted to uncover recurring themes, particularly gaps in knowledge or challenges faced by PHNs during biological disasters. Additionally, the Disaster Management Cycle Framework and Betty Neuman's Systems Model were used to frame the findings and provide a theoretical context for interpreting the results. These frameworks helped to organize the data and identify areas of weakness in PHN preparedness, while also offering practical recommendations for improvement.

5. Theoretical Framework

5.1. Betty Neuman's Systems Model

The System model developed by Betty Neuman is a theoretical model that acknowledges people and systems as open systems that exist and function within the environment [16]. It underlines the need for knowledge of how various outside and inside forces affect the overall equilibrium and performance of the system [16]. This model is important for this study because it illustrates how the nurses, as members of the healthcare system, address biological emergencies. The special focus of the model on prevention is crucial in this study. In the context of the management of biological disasters, primary prevention implies the development of training, education, and other preparatory activities aimed at enhancing the readiness of nurses to deal with possible threats. This is very important, as it helps to prevent the dangers of biological disasters. Secondary prevention and management of disasters entail activities such as identification, isolation, treatment, and stabilization during a disaster. These activities are very necessary in order to reduce the impact and prevent any biological events from getting out of hand.

Lastly, the tertiary prevention is aimed at the recovery processes and rehabilitation, such as counselling of affected individuals and healthcare staff. This is in line with Neuman's systems thinking since the preparedness of the nurses in biological disasters depends on aspects like institutional policy, resource availability, and collaboration among professionals. In this way, the model is useful in pinpointing specific areas of readiness that are lacking or in which resources and support systems are insufficient. As a theoretical framework, this perspective allows the current study to assess nurses' readiness holistically while suggesting tangible ways to improve their performance in addressing biological catastrophes.

5.2. Disaster Management Cycle Framework

This framework provides a structured and systematic approach to disaster preparedness, response, and recovery, making it particularly relevant to the current

study on nurses' readiness for biological disaster management [15]. This framework outlines four key phases: mitigation, preparedness, response, and recovery, which tackle different sections of the disaster management process [17]. The mitigation phase stresses the aspect of preventing biological catastrophes from occurring in the first place. These may involve contributing to the formulation of infection control policies, supporting calls for vaccines, and carrying out other tasks to raise awareness of infections. All these activities help to reduce the threats as well as the severity of any possible biological risks, as they are deemed essential. Preparedness involves the engagement in various exercises like disaster training, simulations, and the development of response plans. This phase is consistent with the goal of the study of determining how well-prepared nurses are in handling biological risks.

The response phase focuses on what takes place during a disaster: early identification, containment, and care for the vulnerable population. A nurse is usually involved in these events, hence the need to ensure that an adequate response is made in order to minimize the mortality and morbidity. The final phase is the recovery phase, where things are brought to normalcy, psychological support is offered, and finally, information gained from the incident is shared to improve the next response. In this phase, it focuses on the continuous involvement of nurses in disaster management, not only in the area of disaster but also afterward. By providing a clear roadmap for evaluating disaster preparedness, the Disaster Management Cycle Framework ensures a comprehensive analysis of nurses' readiness across all stages of a biological disaster. It supplements Neuman's model by focusing on the application and systems approaches to enhance disaster preparedness and response.

6. Conceptual Framework

The conceptual framework for this study centers on the relationship between the independent and dependent variables, with an emphasis on their interaction and combined impacts on the biological disaster preparedness of primary health nurses (PHNs). The revised framework now includes **Resources** as one of the core domains, ensuring consistency with the rest of the manuscript. This framework helps to understand how knowledge, skills, resources, and institutional support interact to influence the preparedness of PHNs in managing biological disasters (**Figure 1**).

6.1. Dependent Variable: Preparedness for Biological Disaster Management

Preparedness for biological disaster management encompasses the knowledge, skills, and application of disaster management protocols by primary health nurses. This variable represents the ability of nurses to effectively respond to biological disasters through their awareness, technical expertise, and adherence to established guidelines. It reflects how well nurses can prevent, identify, manage, and recover from biological threats, focusing on the integration of competencies, resources, and institutional frameworks.

6.2. Independent Variables

The independent variables, which influence the preparedness of PHNs in biological disaster management, include the following four key domains:

- **Knowledge and Awareness of Biological Disaster Management:** This refers to nurses' understanding of biological disaster protocols, including emergency response measures, prevention strategies, and adherence to global and institutional standards. It encompasses both basic knowledge and specialized understanding of biological agents, disease outbreaks, and disaster management frameworks.
- **Skills and Competencies:** This domain includes the technical and practical abilities that are essential for implementing effective responses during biological disasters. These include infection control, triage, stabilization techniques, and the ability to make sound decisions under pressure. Nurses' competencies are vital for mitigating the impact of disasters and ensuring patient care and safety during emergencies.
- **Resources:** Resources refer to the availability and sufficiency of essential tools, equipment, and materials needed to manage biological disasters effectively. These resources include personal protective equipment (PPE), diagnostic equipment, vaccines, medications, training programs, and logistical support. Adequate resources are crucial for ensuring that nurses can respond promptly and efficiently to disaster situations.
- **Institutional Support and Policies:** This includes the role of organizational frameworks, leadership, and policy support in equipping nurses with the tools, training, and mental preparedness necessary for managing biological disasters effectively. Institutional support also involves ensuring nurses have access to disaster response plans, training opportunities, and mental health resources during and after a disaster.

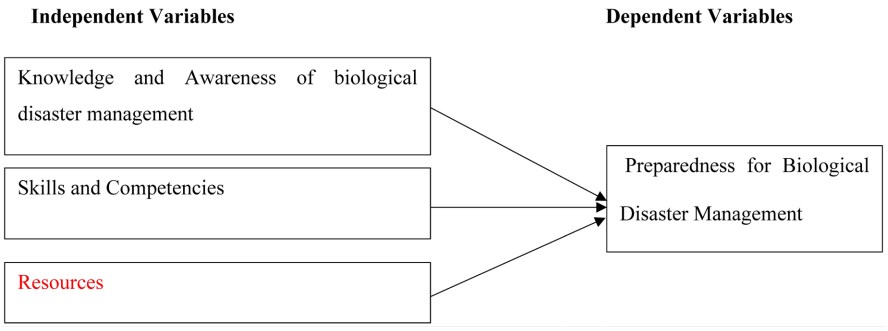

Figure 1. Conceptual framework

7. Discussion

This review examined Primary Health Nurses (PHNs) preparedness for biological crisis management in four critical domains: knowledge and awareness, clinical competencies, resource access, and institutional support. PHNs exhibit intermediate levels of preparedness both globally and in Saudi Arabia, but substantial gaps

persist in their readiness to manage biological disasters effectively.

Knowledge Gaps and the Disaster Management Cycle

The most significant gap lies in the knowledge and awareness of PHNs. While they possess foundational knowledge of biological hazards, many lack familiarity with emerging zoonotic diseases and new pathogens [1]. This gap in knowledge hinders their ability to detect outbreaks early and provide accurate public education. According to the Disaster Management Cycle, this deficiency corresponds to the Mitigation and Preparedness phases. PHNs are tasked with prevention strategies such as surveillance and public awareness, but insufficient knowledge limits their ability to mitigate biological risks effectively. As the Disaster Management Cycle emphasizes, preparedness for future outbreaks can be strengthened by focusing on knowledge-building during non-crisis periods.

The Knowledge and Awareness deficits also hinder PHNs' ability to execute early identification and containment measures during the Response phase, as seen during COVID-19 and past outbreaks. Regular, updated training, including awareness of emerging diseases like H5N8, would bridge this gap, aligning with Betty Neuman's Systems Model of primary prevention. Primary prevention entails developing robust educational programs to equip nurses with up-to-date knowledge on emerging biological threats, fostering resilience before a disaster occurs [16].

Clinical Competence and Decision-Making in the Response Phase

While PHNs demonstrate satisfactory technical abilities (e.g., personal protective equipment [PPE] usage and infection control), they often struggle with adaptive decision-making under pressure. This lack of adaptive problem-solving relates to deficiencies in the Response phase of the Disaster Management Cycle, particularly in terms of resource allocation, protocol adjustments, and ethical decision-making. During the Ebola outbreak, for example, PHNs struggled with decisions related to resource scarcity and changing protocols under pressure [7]. This can be connected to secondary prevention in Neuman's Systems Model, which focuses on intervention during a disaster to reduce its impact. Secondary prevention requires PHNs to make quick, adaptive decisions about how to use limited resources, emphasizing the need for scenario-based training exercises that incorporate decision-making, communication, and triage [5]. By simulating crisis scenarios, nurses can be better prepared for real-world situations, improving their decision-making skills in both procedural and cognitive areas.

Resource Access and the Mitigation/Preparedness Phases

The lack of resources, particularly PPE, diagnostic tools, and vaccines, exacerbates the challenges faced by PHNs in crisis situations. The Disaster Management Cycle identifies resource availability as a key factor in both the Preparedness and Response phases. Inadequate resources can undermine PHNs' ability to respond effectively, as demonstrated by Anyebe *et al.* (2021), who note recurrent shortages in low-resource settings. The Mitigation phase of the cycle requires building resilient supply chains, including regional stockpiles, to ensure that PPE, diagnostic kits, and vaccines are available in emergencies. In addition, the Preparedness phase

includes the establishment of logistical frameworks that ensure the efficient distribution of resources during a disaster [18].

Institutional Support and the Recovery Phase

Institutional support plays a crucial role in the effectiveness of PHNs during biological crises. Defined policies, strong leadership, and active communication channels ensure a cohesive response during disasters. The absence of formal disaster protocols and catastrophe committees in many primary care settings directly impacts PHNs' ability to effectively navigate biological emergencies [7]. Institutional weaknesses hinder recovery, as seen during COVID-19 when a lack of mental-health support led to burnout among nurses [12]. These deficiencies align with the Tertiary Prevention phase in Neuman's Systems Model, which involves rehabilitation and support after a crisis. Providing adequate psychological services and peer support can mitigate the adverse effects of stress and burnout, enabling nurses to remain resilient through long-term recovery phases.

A study by Baker (2021) found that institutions with active leadership, disaster committees, and policy reviews scored higher on disaster preparedness assessments. Such systems embody the Preparedness and Recovery phases of the Disaster Management Cycle, as they focus on long-term organizational readiness and the mental well-being of healthcare workers [19].

Linking Findings to Neuman's Model of Prevention

Through the lens of Neuman's Systems Model, the gaps identified in this review, knowledge deficits, resource shortages, and insufficient institutional support are critical in each of the three levels of prevention: primary, secondary, and tertiary.

- Primary Prevention: Strengthening knowledge and awareness of biological hazards through continuous training, focusing on emerging pathogens, and improving communication about prevention strategies.
- Secondary Prevention: Enhancing clinical competence and adaptive decision-making through scenario-based simulations and real-time crisis drills, helping PHNs respond effectively during a disaster.
- Tertiary Prevention: Providing psychosocial support, mental health services, and post-crisis recovery programs to mitigate burnout and ensure the workforce remains resilient.

8. Recommendations

To enhance primary health nurses' preparedness for biological disasters, several targeted actions must be implemented.

First, nursing education programs should develop specialized training modules focusing on emerging zoonotic diseases and bioterrorism agents, ensuring nurses stay up-to-date on the identification, prevention, and management of these threats. This training should cover the biology of new pathogens, diagnostic techniques, quarantine protocols, and specific responses to bioterrorism. Additionally, there should be a focus on emerging zoonotic threats such as H5N8 and Ebola, as well

as bioterrorism risks like anthrax and ricin. These theoretical updates should be complemented by simulation-based drills, which challenge nurses to apply both technical methods and critical thinking under pressure. Such exercises should include ethical decision-making scenarios, like resource allocation during shortages and managing ethical dilemmas, to prepare nurses for complex, real-world situations.

Furthermore, institutions must develop resilient supply chains by creating regional stockpiles of personal protective equipment (PPE), diagnostic tools, vaccines, and medications, ensuring that these resources are regularly maintained and replenished. The creation of rapid-response distribution networks is also essential, particularly in underserved or remote areas, to guarantee that resources can reach healthcare facilities without delay. Another key area for improvement is the mental health and well-being of primary health nurses. Institutions should implement comprehensive psychosocial support programs, offering peer support and counseling services to help nurses manage stress and reduce burnout, which can negatively impact response effectiveness. Additionally, resilience-building programs focusing on stress management should be incorporated into professional development for PHNs to equip them with the tools to cope with the psychological pressures of biological disaster management.

In terms of institutional support, it is essential that formal biological disaster protocols are established and reviewed regularly. These protocols should clearly outline the roles and responsibilities of primary health nurses during a biological disaster, with an emphasis on emergency preparedness drills. These drills should be based on real-life scenarios, such as pandemics and bioterrorism events, and must involve all healthcare personnel, from frontline nurses to leadership. Clear policies and active leadership are also critical, as catastrophe committees and policy reviews have been shown to improve disaster preparedness. In addition, collaboration with local and national health agencies, as well as public-private partnerships, should be prioritized to ensure the availability and distribution of resources, as well as the sharing of critical information during emergencies.

Lastly, a continuous monitoring system must be implemented to assess the effectiveness of PHN preparedness regularly. This should include readiness evaluations, feedback mechanisms, and data-driven assessments of training programs and response efforts. By regularly evaluating preparedness and identifying gaps, health institutions can adapt their strategies to ensure that PHNs are consistently ready for biological threats, both emerging and ongoing.

These recommendations, when implemented, will address the identified gaps in knowledge, skills, resources, and institutional support, ultimately improving the preparedness and resilience of primary health nurses in managing biological disasters. By strengthening these areas, healthcare systems can better respond to both emerging infectious diseases and bioterrorism threats, improving overall public health outcomes and ensuring more effective disaster management in the future.

9. Conclusion

This review indicated that primary health nurses have the necessary knowledge and abilities to manage biological disasters, but there are gaps in adaptive decision-making, consistent resource availability, and institutional support. To transform moderate preparedness into a robust, sustainable response capacity, health systems should integrate up-to-date pathogen education with realistic simulation exercises, strengthen supply chain resilience, embed clear disaster protocols into everyday practice, and prioritize nurses' psychological well-being. Finally, empowering nurses through these multidimensional techniques will not only protect communities from biological dangers, but will also develop a more resilient primary healthcare infrastructure ready to address future problems.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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