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Pediatric emergency disaster preparedness: a narrative review of global disparities, challenges, and policy solutions

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Abstract

Background Disasters, whether natural or man-made, pose significant challenges to healthcare systems, with children being among the most vulnerable populations. Pediatric Emergency Departments (PEDs) require specialized protocols to address children's distinct physiological, psychological, and developmental needs in other to respond adequately to disasters. While international guidelines for disaster preparedness exist, significant disparities persist across different healthcare settings, particularly in low-resource regions where preparedness measures remain inadequate. This review examines the current state of pediatric disaster preparedness, analyzing insights from past disasters to highlight key challenges, gaps, and opportunities for improvement. Special attention is given to global frameworks, existing protocols, and how lessons from successful disaster responses can inform future strategies, particularly in resource-limited settings.

Aims This review aims to assess the readiness of PEDs for disaster scenarios by identifying deficiencies and proposing strategies to enhance preparedness. It explores infrastructure requirements, workforce training, triage protocols, and mental health considerations specific to pediatric populations. Additionally, it assesses international frameworks and best practices to inform policy recommendations for strengthening pediatric-focused disaster response globally.

Conclusion Pediatric disaster preparedness remains inadequate across global healthcare systems, particularly in resource-limited settings. While international protocols exist, their implementation varies widely, leaving gaps in staff training, resource allocation, and mental health support. Addressing these gaps requires a multi-faceted approach that includes enhanced training programs, improved resource allocation, and integration of mental health services into disaster protocols. By adopting evidence-based strategies and fostering interdisciplinary collaborations, healthcare systems can develop more resilient and child-focused emergency response frameworks. Strengthening disaster preparedness in PEDs is essential to ensuring equal opportunities for care and effective treatment for children in times of crisis.

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Introduction

Disasters, both natural and man-made, pose significant challenges to healthcare systems worldwide. Among the most vulnerable populations affected are children, whose unique physiological, psychological, and developmental characteristics demand specialized consideration during emergencies. Pediatric Emergency Departments (PEDs) serve as critical frontline facilities, tasked with addressing the immediate and long-term needs of children during disasters [1]. However, the readiness of these departments to respond effectively to such crises remains unexplored.

The importance of disaster preparedness in PEDs cannot be overstated. Disasters disrupt essential healthcare services, overburden emergency systems, and escalate risks of morbidity and mortality, particularly among pediatric populations. For children, the physiological differences—such as smaller circulating blood volumes and higher metabolic rates—exacerbate their vulnerability to injuries, infections, and rapid deterioration during crises [2]. Additionally, their reliance on caregivers for communication and emotional support complicates disaster responses [3]. The psychological toll of disasters on children, manifesting as acute stress, anxiety, and post-traumatic stress disorder (PTSD), further underscores the need for tailored interventions [2].

Global crises, such as the Yemen conflict and the COVID-19 pandemic, illustrate the compounded vulnerabilities faced by children in disaster settings. In Yemen, years of armed conflict have led to widespread displacement, malnutrition, and outbreaks of preventable diseases such as cholera, disproportionately affecting children [4]. Healthcare systems in conflict zones are often ill-equipped to meet the unique needs of pediatric populations, highlighting systemic gaps in preparedness and response frameworks. The COVID-19 pandemic introduced additional complexities, straining already limited resources and emphasizing the critical role of PEDs in adapting to evolving challenges [4, 5].

This review aims to evaluate the current state of disaster preparedness in PEDs, with a focus on identifying gaps and proposing actionable strategies to enhance resilience. By examining key areas such as infrastructure readiness, staff training, resource allocation, and psychosocial support, this paper seeks to provide a comprehensive understanding of how PEDs can better serve children during emergencies. It also draws on lessons from past disasters to inform policy recommendations and future directions.

Addressing the unique vulnerabilities of children in disaster scenarios is not merely a healthcare imperative but a moral responsibility. By prioritizing pediatric-specific preparedness measures, healthcare systems can mitigate the disproportionate impact of disasters on this fragile population. There is need for a multi-faceted approach, integrating clinical expertise, community engagement, and policy advocacy, to safeguard the health and well-being of children in the face of adversity.

Main body

Defining disasters and types relevant to peds

Disasters pertain to their effect on the environment and healthcare and are divided into two major groups: natural and man-made. Natural disasters further include volcanoes, hurricanes, earthquakes, and floods, while man-made disasters include wars, pollution, fires, explosions, and exposure to hazardous materials. These disasters lead to the destruction of infrastructure, the spread of communicable diseases, and an increase in the rate of mortality [1].

The post-disaster phase plays a crucialrole in healthcare response, particularly in disease control, resource allocation, and staff training. Effective disaster preparedness is essential for managing crises, ensuring the availability of adequate equipment, and implementing structured emergency protocols [6].

Children are affected significantly in a disaster owing to their smaller bodies, higher respiratory rate, less subcutaneous fat, and inability to effectively verbalize their needs [3]. A study by Dyregrov A et al. highlighted the dual physical and emotional toll disasters impose on children. For example, the eruption of Eyjafjallajökull in 2010 led to respiratory diseases and an earthquake in China in 2008 led to increased cases of depression and post-traumatic stress disorder (PTSD) among children. Consequently, highlighting the need to prepare to effectively manage and reduce the impact of disasters on the children [7].

Unique needs of children in disasters

Children make up about 25–30% of those hurt in disasters. During disasters, pediatric care is especially challenging due to differing biological, social, and ethical factors, requiring specific approaches to disaster handling and preparedness [2]. The Federal Emergency Management Agency (FEMA) divides these points of vulnerability into three categories: psychological, anatomy and physiology, and educational vulnerabilities [2].

Anatomical and physiological traits of children significantly influence their care during disasters. Children's smaller circulating blood volume, thin skin, and limited body fat increase their susceptibility to fluid and heat loss compared to adults [2]. Their smaller body mass results in greater energy absorption per square inch, leading to unique injury patterns [2].

Skeletal immaturity and ligamentous laxity make children prone to different injuries. Their shorter stature and higher body surface area-to-mass ratio heighten the risk of toxin absorption and inhalation of heavy gases such as

sarin and chlorine [2]. Additionally, their higher metabolic rates increase the risk of hypothermia and susceptibility to toxins [2].

Healthcare professionals who are not experienced in pediatric care may have difficulties providing adequate care to children in disasters. Due to variances in normal vital signs and dosages, it is essential to have quick access to pediatric-specific references [2]. Children were more impacted by gastrointestinal diseases than injuries, after hurricanes Katrina, Rita, and Tropical Storm Allison highlighting their vulnerability to infectious diseases in disasters [2]. Gastroenteritis can lead to srapid dehydration, shock and death. In addition, children who experience disrupted services face increased mortality from diarrheal diseases and respiratory infections, both of which are two of the leading causes of death for children under five [2].

Children's psychological and developmental responses to disasters differ from adults, posing challenges for healthcare providers. For communication and emotional support, infants and young children rely entirely on caregivers for communication and emotional support [2]. Separation or loss of caregivers during disasters further complicates care and increases staffing demands [2].

Disasters can bewilder children, impacting their ability to cooperate with evaluations and treatments. Stress often results in developmental regression. Also, children are particularly vulnerable to an acute stress disorder, which if left without treatment can develop into PTSD. Symptoms such as withdrawal and emotional instability often go unrecognized increasing risk for mental health problems in adulthood, highlighting the necessity for pediatric tailored interventions in disaster response [2].

Children's dependency on carers for physical and emotional needs complicates disaster response. Since they cannot care for themselves, infants and young children need safe age-appropriate resources and safe housing [2]. communication and care get interrupted when caregivers are separated from them due to injury, death, or logistical challenges [2]. Unfamiliar surroundings further distress children, hindering effective medical intervention [2].

Educational vulnerability is often overlooked in disaster response. Children's education is severely disrupted, with many changing schools' multiple times within months after a disaster. These disruptions negatively impact academic performance and recovery [2].

Addressing children's unique needs in disaster preparedness and response is critical to reducing morbidity and mortality. Failure to do so exacerbates the challenges faced by this vulnerable population [2].

Pediatric disaster preparedness frameworks

International guidelines for pediatric disaster preparedness

International organizations such as UNICEF and WHO have developed frameworks to safeguard children's health and well being during disasters. The 1990 Convention on the Rights of the Child, for instance, establishes the right of children to development, protection, and survival. International initiatives, such as the Anti-war Agenda (UNICEF, 1996), have been driven by this legal framework to advocate for the inclusion of children's concerns in peace talks [8]. The removal of child soldiers, vaccinations during ceasefires, and the promotion of children as (zones of peace) in conflict zones are all measures central to UNICEF's child protection strategies [8]. Child protection principles are further solidified by International Labour Organization (ILO) Convention No. 182 which forbids the use of minors under 18 in armed conflict [8]. Pediatric disaster preparedness implies that systems are in place to ensure the rapid triage and emergency management of children as patients in event of a disaster [9].

The United States has developed pediatric-specific disaster response guidelines, known as the *Guidelines for Care of Children in the Emergency Department*. These guidelines outline the necessary pediatric-specific equipments, medications, supplies, and readily available experienced staff, to help emergency departments (EDs) assess their readiness for disasters involving children [10]. Since their introduction in 2009, there has been a significant improvement in the number of EDs meeting these requirements and demonstrating increased preparedness [11].

Although not specifically designed for children, the World Health Organization (WHO) has developed the *Health System Capacity Toolkit*, which allows countries to assess their health systems' ability to respond to various threats and identify gaps in preparedness [12, 13]. When applied in the European Union, this tool has shown that while the region's preparedness is at an acceptable level, there remains considerable room for improvement [14].

Currently, the U.S. protocol is the only pediatric-specific tool available for assessing disaster readiness and is being adopted globally. However, a survey of EDs in Europe using these guidelines revealed that they lag behind the U.S. in pediatric disaster preparedness [15]. Studies from Europe continue to emphasize the need for national programs and pediatric-specific guidelines to enhance readiness [16–18].

During disasters, the needs of pediatric patients should be addressed through specialized disaster response practices. Triage systems and emergency responder training should be developed which consider the physiological and psychological features of children [8, 19]. For

instance, during the 2009 H1N1 pandemic, regional variation in mortality estimates highlighted the importance of pediatric-specific response frameworks [19]. Furthermore, child-focused critical care interventions, such as oxygen concentrators and low-cost ventilation systems, have proven effective in improving pediatric outcomes in resource-limited settings, as evidenced by Papua New Guinea's 35% reduction in pneumonia fatalities [19].

The stark differences between high and low-income nations about preparedness stand out when available tools and resources are compared. High-income countries make use of technology and initiate advanced-level instructors, while poor countries lack even the basic resources, such as staff, supplies, and basic infrastructure. Discrepancies are sought to be remedied through WHO-funded programs that build on affordable care in critical areas and include it in the disaster prevention action plan [19].

Challenges in implementing Pediatric-Specific frameworks

Resource limitations, training gaps, and ethical dilemmas remain barriers to adopting comprehensive pediatric disaster frameworks. The worldwide shortage of health workers (4.3 million doctors and nurses below requirements) worsens these challenges, particularly in resource-limited settings [19]. Most regions lack specialized pediatric care providers, including intensivists and respiratory therapists, which compromises disaster response efforts [19].

Although material resources, such as intravenous fluids and oxygen, are often available, a lack of trained personnel frequently prohibits their utilization, as was seen during the Ebola outbreak in West Africa [19]. Financial constraints also limit the application of pediatric-specific frameworks. In some cases, the daily costs of ICU in low-income settings are similar to those in high-income countries, which makes critical care appear cost-prohibitive [19]. However, short-term ICU interventions for acute but curable diseases in children can reduce mortality rates significantly, thus justifying their cost-effectiveness [19].

Ethical issues, however, further complicate pediatric disaster preparedness. Resource allocation decisions and those regarding local cultural values of global justice need to strike a balance between immediate needs and long-term goals. The child-focused framework will be further enhanced by systematically incorporating pediatric considerations in peace accords, deployment of child protection advisers, and robust monitoring mechanisms of violations against children [8, 19].

Infrastructure, training, and crisis response in pediatric emergency departments (PEDs)

Infrastructure and resource readiness

Disaster response is based on PEDs' infrastructure and physical readiness. A spike in pediatric patients during disasters calls for more beds, adaptable treatment spaces, and specialized equipment. Reconverting non-clinical facilities into temporary patient care areas, for example, is a popular tactic, but it requires careful planning to prevent lowering the standard of treatment [20].

Equipment designed specifically for children presents special difficulties. PEDs need specialized equipment, such as ventilators that are the right size, infusion pumps, and monitoring made for babies and kids, in contrast to regular emergency rooms. In a similar vein, the accessibility of pharmaceuticals in child-friendly quantities is still a major worry during emergencies. Due to financial limitations and a lack of storage space, many PEDs struggle to accumulate these items. Patient outcomes may worsen if care is delayed due to a lack of readiness in this area [21].

PEDs frequently struggle to maintain basic operation, let al.one being disaster ready, making resource-constrained environments face substantial challenges in disaster preparedness. These difficulties include a lack of pediatric-focused training, limited personnel, and inadequate infrastructure. During emergencies, when the already constrained systems are under tremendous strain, the differences in resource distribution are most noticeable [21].

Novel adaptations have been developed to lessen these difficulties. Among the strategies used to increase capacity include mobile clinics, telemedicine platforms, and task-shifting models, in which non-specialized healthcare professionals are taught to provide critical pediatric care. In order to augment local resources, collaborations with foreign assistance groups are also essential. These modifications demonstrate the adaptability and ingenuity of healthcare professionals in environments with limited resources, but systemic investments are still necessary for long-term progress [22].

Sudden, overwhelming patient surges brought on by disasters frequently put a strain on PED staffing and resources. Three key components have being identified as necessary for efficient surge capacity management: system-wide coordination, resource mobilization, and flexible personnel. A tried-and-true method of increasing the workforce during emergencies is to cross-train medical personnel to manage pediatric situations. Establishing catastrophe response procedures and conducting frequent simulation exercises also guarantees that teams can react effectively [23].

During catastrophes, regional and interdepartmental cooperation is frequently required for resource

mobilization. For example, quick resource allocation is made possible by establishing digital inventory systems, utilizing regional supply networks, and hoarding essential commodities. In order to offer comprehensive treatment in the midst of turmoil, crisis management also includes psychological support for patients and medical staff [24].

Effective crisis response by PEDs necessitates a multipronged strategy. It is crucial to address equipment and space requirements, enhance resource allocation in settings with limited funding, and fortify surge capacity through effective crisis management techniques. Even if there has been improvement, there are still large gaps, especially in areas with limited resources. Building robust PED systems that can protect juvenile populations during catastrophes would need sustained funding along with creative modifications [24].

Staff training and simulation programs

Pediatric disaster preparedness involves systems for the swift triage and emergency management of children in natural, human-made, or terrorist-related disasters. Disaster preparedness is crucial for healthcare workers, as demonstrated by Boston's healthcare workers' effective response to the Boston Marathon bombing [25–27]. Physicians, particularly PEPs who are expected to provide care for disaster victims, must be prepared for these situations. Physicians should consider their potential roles in disasters and prepare accordingly. Physicians in all specialties should consider their potential roles in a disaster and attempt to prepare for these roles.

Nevertheless, workforce readiness remains a challenge. Most emergency medical responders lack specific training in pediatric disaster care, particularly in triage protocols like JumpSTART [28]. When it comes to treating the primary causes of pediatric death during catastrophes, this training gap frequently leads to uneven use of pediatric assessment and airway management abilities. Systemic shortcomings in readiness are evident in the fact that less than 20% of U.S. emergency services questioned said they have strategies specifically for pediatric emergencies [28, 29].

One of the primary concerns during disasters is surge capacity ability to manage and handle a rapid influx of patients more than the usual patient load [30]. Disaster protocols simulating training programs should ensure bed surge capacity by marking areas for patient expansion, like waiting rooms and hallways. Training should contain both staff surge capacity involving cross-training hospital staff for emergency care, and resource surge capacity including medical supplies and equipment, emphasizing rationing during prolonged disasters [25].

Communication and coordination systems

Disaster preparedness involves a crucial step of communicating the care between the hospitals for exchange of information, coordination of care and allocation of resources. Triage is the initial step for classifying the patients by their means of needs of care. It is conducted by qualified healthcare professionals and relies on effective communication to deliver essential care to critical patients [6]. Telemedicine is another means that could be used for triaging in pediatric emergency situations to direct care to patients who need immediate care and limit unnecessary visit to optimize the use of manpower. However, this can only be achieved with a healthcare professionals trained in the care of children [31].

The study by Torab-Miandoab A et al. explains how interoperability proves to provide the effective communication and efficient care to the patients. The word itself refers to the sharing of information between the healthcare to provide care for the patients by providing thorough information about the patient data. It further highlights how interoperability is the solution for delayed care due to inaccessible health records [32]. The study by Chaichotjinda K et al. found the incidence of 22% in adverse effects when transporting critically ill patients, which could have been avoided to some extent by effective communication, inappropriate escrot and lack of equipment [33].

Communication with the families is another aspect of effective communication as families rely on the healthcare professionals to support for their children's care. In addition, it is needed for a two-way communication as a pre-disaster preparation to equip families with necessary information of how and where to access care. This can be made possible with the help of primary care patient medical home, information regarding continuity of care and rehabilitation services to serve as a medium for disaster planning [34].

Psychosocial support and mental health considerations

Disasters expose children to traumatic experiences that can lead to anxiety, depression, or post-traumatic stress disorder (PTSD). Events like the Haiti earthquake and the Gaza conflict demonstrate the profound psychological impacts on children, including separation from caregivers, exposure to violence, and loss of community support [35–37]. These challenges often lead to developmental regression and hinder their ability to cooperate with medical evaluations [37, 38].

Integrating mental health care into Pediatric Emergency Departments (PEDs) is essential for mitigating these effects. Psychological first aid, combined with access to child psychologists, ensures early intervention. Establishing child-friendly spaces and delivering long-term follow-up care are critical to addressing both

immediate and prolonged psychological impacts on pediatric patients [37, 38].

PED staff play a crucial role in providing not only medical care but also emotional and logistical support to families during disasters. Clear communication helps caregivers manage their child's needs and navigate the complex disaster environment [37, 38]. Structured programs, such as family reunification protocols, caregiver education on trauma responses, and access to counseling, help families remain resilient during crises [37, 38]. UNICEF's guidelines on child protection emphasize the importance of caregiver inclusion as a cornerstone of effective pediatric disaster response [35].

Lessons from past disasters

Responses to pediatric disasters are intricate and multidimensional, requiring a customized strategy to address children's particular vulnerabilities. Many historical and modern occurrences highlight the difficulties pediatric emergency rooms face during disasters. To identify existing gaps in emergency disaster preparedness, this section looks at case studies from previous disasters, highlighting the problems encountered and the lessons learned.

Case studies from pediatric disaster responses

Haiti earthquake, 2010

Pediatric emergency care faced several difficulties because of the Haiti earthquake, which killed over 220,000 people and left millions more homeless. Children made up about half of the impacted population and were particularly vulnerable to psychological trauma, infectious infections, and starvation [39]. Emergency medical personnel sometimes lacked the pediatric knowledge and resources necessary to treat pediatric illnesses and injuries, including respiratory infections, malnourishment, and dehydration [39]. International and local agencies' coordination was frequently disjointed, which delayed the efficient distribution of resources and made post-disaster care for the unique needs of children more difficult [39].

Gaza conflict, 2008–2009

Significant pediatric casualties resulted during the fighting in Gaza, which was characterized by heavy military incursions [39]. There were thousands of injuries, many of which required emergency care, and more than 400 kid fatalities, according to reports [39]. The issue was made worse by the devastation of clinics and hospitals. Limited resources, including kid-specific equipment and drugs, presented challenges for pediatric emergency teams [39]. Furthermore, children's psychological distress—which expressed as anxiety, sadness, and post-traumatic stress disorder (PTSD)—presented further difficulties for caregivers who were unprepared to manage mental health emergencies in a conflict area [39].

The "tripledemic" in the united States, 2022

During the "tripledemic" of COVID-19, RSV, and influenza in 2022, pediatric emergency departments in community hospitals were overwhelmed by patient surges [40]. Many community hospitals lacked pediatric ICUs, forcing them to manage critically ill children with insufficient space, staff, and specialized equipment [40]. Despite implementing contingency strategies, such as utilizing adult ICUs and deploying additional pediatric staff, hospitals faced challenges in transferring patients to tertiary care centers due to a lack of available ICU beds [40]. These difficulties highlighted the systemic inadequacies in disaster planning for pediatric care.

Yemen conflict, 2010

The Yemen conflict, marked by intense fighting and widespread displacement, exposed children to severe vulnerabilities. Many were separated from their families, leaving them without critical support networks [39]. Shelters lacked necessities, leading to high rates of malnutrition and outbreaks of infectious diseases such as cholera [39]. Child protection assessments revealed alarming levels of physical and psychological abuse, exacerbated by the breakdown of community structures [39]. Emergency responders often struggled with inadequate resources and the lack of interagency coordination to address both immediate medical needs and longer-term mental health challenges. This conflict underscored the urgent need for robust systems to safeguard displaced children and ensure comprehensive pediatric disaster care [39].

Specific issues faced by pediatric emergency departments

Resource limitations

Pediatric departments often face shortages of essential supplies, such as age-appropriate medications, equipment, and beds, during disasters. This was evident during the "tripledemic," where the lack of high-flow nasal cannulas and other respiratory devices impeded effective care [40].

Coordination challenges

Fragmented coordination between local, national, and international agencies frequently delays critical responses. For instance, during the Haiti earthquake, the absence of integrated communication systems hindered the timely delivery of pediatric-focused care [41].

Training and preparedness

Many healthcare providers lack training in pediatric-specific disaster response protocols, resulting in suboptimal care. The Georgian conflict highlighted the need for

standardized training in child protection and emergency medical care for children [39].

Psychosocial impact

Children in disaster zones often suffer from PTSD, anxiety, and other mental health disorders, yet mental health services are seldom prioritized in emergency responses. Both the Gaza conflict and the Haiti earthquake underscored the absence of adequate psychosocial support for children [39, 41].

Current gaps in emergency disaster preparedness

Pediatric-Specific disaster plans

Less than half of U.S. hospitals have disaster policies explicitly addressing pediatric populations. This gap underscores the need for comprehensive plans tailored to children's unique physiological and psychological needs [42].

Mental health integration

Despite the growing recognition of mental health needs in disasters, few response frameworks adequately integrate psychosocial support into pediatric disaster care [42].

Training and education

Emergency responders and healthcare providers require more robust training in pediatric disaster care, including triage systems, resource management, and mental health support [42].

Technological adaptation

The use of telehealth and other technological innovations remains underutilized in disaster responses, particularly in low-resource settings. Expanding access to these tools could bridge critical gaps in pediatric care [42].

The lessons from past disasters underline the critical need for pediatric-specific disaster preparedness and response strategies. Addressing resource limitations, enhancing coordination, and integrating mental health services are essential steps toward improving outcomes for children in future emergencies. By learning from these experiences, healthcare systems can build more resilient frameworks to protect and care for the most vulnerable populations during disasters.

Innovations and future directions for pediatric emergency preparedness

Pediatric emergency disaster preparedness must change because of the growing frequency and complexity of disasters by implementing creative fixes and progressive tactics. Improving outcomes for children during emergencies mostly depends on evidence-based approaches, interdisciplinary collaborations, and emerging technologies.

Leveraging artificial intelligence and data analytics

A game-changing technology for improving pediatric catastrophe preparedness is artificial intelligence (AI). By combining real-time data from several sources, including weather systems, epidemiology databases, and healthcare infrastructure, AI-powered systems improve early warning systems [43]. For pediatric populations, these systems can anticipate resource allocation requirements and optimize response tactics. Machine learning algorithms, for example, can predict pediatric emergency department (PED) surge capabilities during mass casualty situations, effectively directing staffing and resource allocation [43].

AI also makes it easier to communicate effectively in emergency situations. To ensure inclusivity in disaster response, automated tools that use natural language processing can translate medical protocols into many languages [43]. By customizing treatments for each child's distinct physiological and developmental traits, AI algorithms also make precision medicine possible. Algorithms that incorporate patient data, for instance, can forecast pediatric drug dosage needs and track treatment results in real-time, reducing the chance of prescription errors [43].

Innovations in training and workforce development

Simulation-based training programs have become integral to equipping healthcare professionals with the skills needed for pediatric disaster response. Advanced simulations replicate high-stress environments, such as mass casualty incidents, allowing providers to practice triage, airway management, and pediatric resuscitation [44]. These exercises improve readiness and highlight gaps in system workflows. Initiatives like the Pediatric Emergency Preparedness Fellowship Program have introduced comprehensive curricula that blend education, research, and policy development, preparing future leaders in pediatric disaster medicine [44].

Additionally, telehealth platforms play a crucial role in bridging workforce shortages. By enabling remote consultations and decision support, telehealth ensures that expertise is accessible even in resource-constrained settings. Such platforms also facilitate mental health interventions for children, addressing the psychological aftermath of disasters [44].

Integrating community and global efforts

Community-based approaches are essential for enhancing pediatric disaster resilience. Initiatives like Region V for Kids in the United States demonstrate the value of coordinated regional networks [45]. These programs integrate local, state, and national resources to bolster

pediatric surge capacities and ensure seamless communication among stakeholders. Globally, collaborations between governments, non-governmental organizations, and academic institutions drive the development of scalable solutions tailored to diverse cultural and infrastructural contexts [45].

Future directions and policy implications

As pediatric disaster preparedness advances, there is an urgent need to address existing gaps through policy reforms. Governments must prioritize funding for pediatric-specific equipment and infrastructure, such as neonatal ventilators and specialized shelters. Furthermore, ethical considerations surrounding the use of AI and big data in disaster response must be addressed to ensure equity and protect patient privacy [43, 44].

Recovery science also holds promise for shaping long-term outcomes. Research on resilience-building interventions, such as community-based mental health programs, can mitigate the enduring impacts of disasters on children's development. By fostering partnerships among healthcare providers, policymakers, and technologists, pediatric emergency disaster preparedness can evolve into a more robust and equitable framework [29, 45].

The future of pediatric disaster preparedness lies in leveraging technological innovations, enhancing workforce capabilities, and fostering global collaborations. By addressing systemic challenges and integrating cutting-edge solutions, we can build a resilient infrastructure that safeguards children's health and well-being in the face of disasters.

Global perspectives on pediatric disaster preparedness

Evaluation of High-Resource and Low-Resource environments

Frameworks for pediatric disaster preparedness in high-resource and low-resource environments differ significantly. Regions with advanced systems, procedures, and staff that provide specialized care for children during disasters are referred to as high-resource regions. Dedicated PICUs provide specialized support for children with multisystem illnesses or severe trauma, guided by standardized admission criteria and appropriate resource availability [2, 19]. Advantages associated with these settings are the existence of previously established frameworks of disaster response, well-structured and wide-ranging training programs, and advanced equipment that raises their capacity to manage complicated emergencies easily [19].

In contrast, low-resource settings are characterized by substantial shortfalls in infrastructure, human resources, and disaster-specific pediatric protocols. The inability to access PICUs and dependence on general pediatricians and senior nurses frequently restrict the capacity to treat pediatric cases in disasters [19]. In addition, cultural and economic obstacles in these areas enhance the difficulty of providing pediatric-specific interventions [2, 19]. In such contexts, triage criteria, resource allocation, and care delivery often require modifications to suit resource constraints, such as prioritizing basic, cost-effective interventions [19].

While resource-poor settings often have to focus on immediate survival needs, resource-rich settings can afford to be better prepared, with extensive prevention and early intervention. Innovations such as the introduction of oxygen concentrators and reasonably priced ventilators in resource-poor settings have contributed to a significant reduction in pediatric mortality even during emergencies [19].

Success stories from LMICs

Against this background, some LMICs have nonetheless realized remarkable successes in disaster preparedness for children through creative, resource-sensitive approaches. One outstanding example of creativity in disaster preparedness within low-income settings is illustrated during the 2014 Ebola virus disease outbreak in West Africa, where limited-resource approaches to case definitions and strong epidemiological tracking served to keep the disease under reasonable control [19]. Such clear and data-driven interventions proved decisive in the effective management of health crises within resource-limited settings [19].

The concept of "zones of peace" has been effective in facilitating temporary ceasefires during conflicts, allowing children in war zones to receive vaccinations and essential medical supplies. This is a method followed by agencies such as Save the Children and UNICEF, which concentrate on embedding child-specific initiatives within general disaster response operations [8]. Commitment from around the world to pediatric disaster resilience has also been emphasized through programs incorporating DDR for child soldiers. Such programs have taken into consideration the unique needs of children affected by disasters through the development of child-specific policies and the appointment of qualified child protection advisors [8].

In addition, the incorporation of disaster preparedness into more expansive pediatric care frameworks has been successful at LMICs. For example, the development of low-cost, locally manufactured medical devices and training of health care workers has enhanced the survival of a child during an emergency [2, 19]. For example, the low-cost scale-up of oxygen therapy and oximetry monitoring reduced the mortality from pneumonia in Papua New Guinea remarkably, which showed the potential

lifesaving, low-technology therapies adapted to resource constraints [19].

Ethical considerations in pediatric disaster response

The paradigm for disaster response in pediatric emergency departments (PEDs) is heavily influenced by ethical issues. Due to financial constraints and the particular vulnerability of juvenile patients, numerous ethical quandaries arise during catastrophes that must be carefully navigated in order to provide fair, efficient, and compassionate care.

Prioritization of care and resource allocation

The distribution of limited resources is one of the most important ethical issues in pediatric disaster response. The ideals of justice, beneficence, and non-maleficence must be balanced in triage procedures, which establish the order of priority for care. Since children are frequently seen as a group with the potential to make a substantial contribution in the future, the challenge is more acute in pediatric care, where prioritizing is necessary. To prevent biases that might result in injustices, such as giving preference to younger children over teenagers, such prioritizing must be weighed against objective clinical criteria [20].

When deciding how to allocate scarce resources, like ventilators or prescription drugs, the proportionality principle is also essential. In order to free up resources for essential cases, strategies like "reverse triage," in which stable patients are moved or dismissed, are frequently used. However, this presents moral dilemmas regarding the long-term effects on those who are released too soon [22].

Informed consent and Pediatric Autonomy

Ensuring informed consent and upholding pediatric autonomy are important ethical considerations in disaster response. Parents or guardians frequently make choices for pediatric patients in emergency situations. However, in chaotic crisis scenarios, caregivers may be unavailable or disabled, leaving healthcare practitioners to make judgments in the child's best interest [23].

Additionally, as older pediatric patients are able to make decisions, their wishes must to be taken into account, striking a balance between their growing independence and parental control. In high-stakes situations where prompt interventions are necessary, this can be very difficult [24].

Equity and vulnerable populations

The disproportionate impact on vulnerable pediatric groups, such as children with disabilities, chronic diseases, or those from socioeconomically challenged homes, must be taken into consideration while responding to disasters. Such populations must not be excluded from the distribution of resources or care access, according to ethical norms. Addressing these gaps requires policies that put equality first, such as culturally sensitive practices, language-accessible care, and community outreach [46].

Provider well-being and moral distress

Lastly, healthcare professionals are also subject to ethical issues; when faced with tough decisions due to resource constraints, they may feel morally distressed. To preserve ethical integrity, it is essential to assist responders' mental health and wellbeing through debriefing sessions, ethical consultations, and institutional support networks [47].

Policy recommendations

Strategies to Improve Pediatric Disaster Preparedness at Institutional, National, and International Levels.

1. Institutional level

- Hospitals should develop pediatric-specific disaster protocols, emphasizing simulation-based training for staff to address children's unique needs during emergencies [38].
- Investments in infrastructure, such as child-sized ventilators, pediatric-friendly pharmaceuticals, and flexible surge capacity, can help PEDs manage a sudden influx of pediatric patient [35, 38].
- Partnering with mental health organizations ensures that psychosocial support is integrated into disaster preparedness frameworks [35, 36].

2. National level

- Governments must adopt national guidelines requiring pediatric-specific considerations in disaster preparedness plans. Lessons from the H1N1 pandemic underscore the importance of ensuring children's access to tailored care during public health crises [5].
- Centralized systems for resource allocation, including medications and equipment designed for pediatric patients, are essential for equitable healthcare delivery during emergencies [35, 37].
- Increased funding for pediatric disaster research is critical to identifying and addressing systemic gaps in readiness and response [35, 38].

3. International level

- Global organizations, such as UNICEF and WHO, should lead collaborative efforts to implement child-focused disaster preparedness programs [38].
- Cross-border coordination during pandemics and other crises ensures resource sharing and equitable care for children.
- Frameworks like UNICEF's Anti-War Agenda stress the need for international policies that prioritize pediatric welfare in conflict and disaster scenarios.

Conclusion

Pediatric disaster preparedness requires a multi-faceted and interdisciplinary approach to address the unique vulnerabilities of children during emergencies. From the physical challenges of providing age-appropriate care to the psychological needs arising from trauma, effective disaster response frameworks must integrate both clinical expertise and psychosocial support. The inclusion of simulation-based training, resource optimization strategies, and technological innovations such as telehealth and AI can significantly enhance the readiness of Pediatric Emergency Departments (PEDs).

Lessons from global and localized disasters, such as the response to the COVID-19 pandemic and conflicts in regions like Yemen, highlight critical gaps in preparedness, particularly in low-resource settings. These gaps include inadequate infrastructure, insufficient pediatric-specific equipment, and fragmented coordination among agencies. To bridge these gaps, global collaborations led by organizations like WHO and UNICEF must complement national-level policies to ensure equitable access to resources and care.

Future advancements in pediatric disaster preparedness should prioritize resilience-building initiatives, including community-based mental health programs and improved resource distribution. By leveraging emerging technologies and fostering cross-sectoral partnerships, healthcare systems can develop robust frameworks that safeguard the health and well-being of children in times of crisis.

List of abbreviations

PEDs	Pediatric Emergency Departments
PTSD	Post-Traumatic Stress Disorder
WHO	World Health Organization
FEMA	Federal Emergency Management Agency
PPE	Personal Protective Equipment
AI	Artificial Intelligence
ICU	Intensive Care Unit

Author contributions

Chibuike Daniel Onyejesi (CDO) is considered the first author. He participated in screening and selecting studies, contributed to conception, formulation, drafting of the article, and reviewed and revised the manuscript.Mohamed Alsabri (MA) is considered second and corresponding author. He proposed the project, contributed to the conception, formulation, drafting of the article, and reviewed and revised the manuscript.Jose Carlos Del Castillo Miranda, Mayam Mohamed Aziz, Muskaan Doulat Ram, Eslam Moumen Abady, and Sohaila Mohamed participated in writing and revising the final manuscript.All authors approved the final manuscript as submitted and agree to be accountable.

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Data availability

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

Declarations

Ethics approval and consent to participate

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Competing interests

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