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Specialized Rehabilitation Workforce Capacity and Acute Injury Management Readiness: A Tertiary Health System Competency Assessment

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Abstract

Rehabilitation services can play an important role in curtailing long-term disability and improving functional recovery in disasters and mass casualty incidents. The potential of the Physical Therapy workforce to assist complex trauma rehabilitation in a tertiary healthcare system is assessed. Using population statistics, regulatory workforce records, and facility-level survey data, a competency-based assessment framework was developed for Bahrain. We conducted an analysis of their workforce density, demographic characteristics, sector distribution, postgraduate qualifications, and specialization profiles. The results show significant deficiencies in advanced rehabilitation readiness. For example, the physical therapist density is only 1.7/10,000 population, along with 19% post-graduate specialization coverage. Orthopedics was the largest specialist group, and disaster-relevant areas, including neurological rehab, burn care, amputation rehab, and acute trauma, were underdeveloped. The assessment also recognized a reliance on expatriate clinicians and a lack of inclusion of rehabilitation professionals in disaster preparedness planning. Reinforcing postgraduate education and extending specialized training pathways, alongside enhancement of workforce planning and the formal inclusion of Physical Therapists in the emergency response systems, will yield a more resilient health system and ensure rehabilitation service delivery during future emergencies.

Keywords

• Rehabilitation • Disaster Preparedness • Workforce Capacity • Physical Therapy Specializations • Health System Resilience • Trauma Management

1. Introduction

The increasing frequency and severity of natural and man-made disasters around the world calls for a strong health care system to take care of sudden trauma disability. Physical Therapy and rehabilitation services are vital in limiting long-term disability and improving functional outcomes following disasters. While emergency medical intervention may save lives, medium to long-term recovery depends very much on access to rehabilitation care. This study looks into the readiness of a national Physical Therapy workforce to meet complex disaster injuries with a workplace capacity analysis of Physical Therapists' distribution by specialization and system integration in emergency planning.

The existing literature reveals the development of Physical Therapy as a discipline closely associated with war injury rehabilitation and at the same time as a discipline designed for trauma rehabilitation. Rehabilitation services are often not a priority in planning phases of modern day DRR response to disaster management which leads to disjointed responses and poor patient care. The integration of

Physical Therapists in teams responding to emergencies and disasters can improve functional recovery and prevent secondary complications. Although it was shown the above mentioned, there remain large gaps in workforce readiness, specialisation matching injury epidemiology, and institutional support for rehabilitation services in crisis situations.

In regions with upcoming health care facilities, the difficulties include varying economic conditions, reliance on expat health care professionals, and patchy regulatory oversight, as seen in the Middle East. This paper deals with this issue by proposing a competency-based framework for assessing the readiness of Physical Therapy in terms of number of workforce, specialisation coverage, level of post graduation and inclusion in disaster management plans. Using this framework, we apply it to Bahrain's rehabilitation system to highlight systemic weaknesses and offer suggestions for improving resilience to disasters.

In the following section, an outline of the methodology for data collection and analysis will be followed by the findings related to the workforce profile and specialization gaps. The implications for disaster readiness will be discussed and evidence-based recommendations to strengthen the rehabilitation systems will also be made. The study contributes to the increasing body of literature on health system resilience and provides a model to measure rehabilitation capacity that can be replicated in different contexts.

2. Related Work

Recent research demonstrates the growing role of artificial intelligence and advanced computational techniques in healthcare analytics, system optimization, and decision support. While much of the existing literature focuses on clinical prediction and diagnostic intelligence, these approaches provide important methodological foundations for strengthening health system readiness and rehabilitation capacity assessment.

Deep learning-based time-series forecasting has been widely adopted to model healthcare demand under dynamic environmental and population conditions. Arul [1] employed Long Short-Term Memory (LSTM) networks to forecast lung disease hospitalizations influenced by air quality degradation, highlighting the ability of recurrent neural networks to capture temporal dependencies in healthcare utilization. Such forecasting techniques are highly relevant to rehabilitation systems, where sudden surges in trauma-related disability following disasters can overwhelm existing workforce capacity. Similarly, Arul [2] demonstrated the effectiveness of Adaptive Neuro-Fuzzy Inference Systems (ANFIS) for diabetes risk prediction under uncertainty, illustrating how hybrid AI models can support early intervention and long-term care planning, both of which are critical in rehabilitation pathways.

Several studies emphasize efficiency, scalability, and interpretability of AI models for deployment in real-world environments. Jain [3] proposed deep learning-based wearable IMU systems for accurate human activity recognition, enabling objective assessment of functional movement and rehabilitation outcomes. Complementary work by Jain [4] applied deep learning to brain anomaly detection, reinforcing the importance of intelligent diagnostic pipelines for early identification of neurological impairments that often require prolonged rehabilitation services.

Beyond healthcare, advances in model optimization and evaluation provide transferable insights for health system analytics. Parashar [5] introduced neural network pruning strategies to enable lightweight yet accurate models suitable for edge deployment, which is relevant for deploying analytics in resource-constrained or disaster-affected healthcare settings. In addition, Parashar [6] explored visual statistical inference as an alternative to traditional hypothesis testing, offering robust analytical tools for complex, heterogeneous datasets such as workforce registries and facility surveys.

System-level optimization and resilience have also been studied in other domains. Reinforcement

learning-based spectrum optimization in cognitive radio networks [7] and cybersecurity analysis of programmable logic controllers [8] highlight the importance of adaptive, secure, and reliable infrastructures. These principles directly translate to healthcare information systems that must remain functional during emergencies. Furthermore, surrogate modeling for fast solid mechanics simulations [9] and efficient numerical solvers [10] demonstrate how computational efficiency can support rapid scenario analysis, which is essential for emergency preparedness planning.

Despite these advances, limited work explicitly integrates AI-driven methodologies into rehabilitation workforce readiness assessments. This gap motivates the present study, which focuses on competency-based evaluation of rehabilitation capacity within tertiary health systems.

3. AI-Enabled Decision Support and System Readiness Frameworks

AI-enabled decision support systems provide powerful tools for proactive health system planning, particularly in the context of disaster preparedness and rehabilitation workforce management. Predictive analytics, optimization models, and efficient computational frameworks collectively enable health systems to anticipate demand, allocate resources, and maintain operational resilience.

Forecasting approaches such as LSTM-based hospitalization prediction [1] demonstrate how historical and real-time data can be leveraged to anticipate peaks in healthcare utilization. When adapted to rehabilitation services, similar models can be used to predict post-disaster disability burden and Physical Therapy demand, enabling timely mobilization of specialized personnel. Fuzzy logic-based systems like ANFIS [2] further enhance decision-making by handling uncertainty inherent in clinical and population-level data, which is particularly valuable during emergency response planning.

Efficiency and deployability of AI models are critical for real-world healthcare systems. Lightweight neural networks achieved through pruning [5] and surrogate modeling approaches [9] enable rapid inference with minimal computational resources, supporting real-time decision support in constrained environments. Such techniques align with the need identified in this study for rapid assessment of rehabilitation capacity under surge conditions.

System reliability and security also play a crucial role in readiness frameworks. Studies on cybersecurity in industrial control systems [8] and reinforcement learning-based optimization [7] emphasize the importance of robust, adaptive infrastructures. These principles are directly applicable to healthcare systems coordinating multi-sector responses during disasters. Additionally, advances in diagnostic and functional assessment technologies [3, 4] highlight the potential for integrating intelligent monitoring tools into rehabilitation workflows, improving continuity of care when physical infrastructure is strained.

In this context, the present work complements existing AI-driven research by embedding technological insights within a population-based, competency-oriented rehabilitation readiness framework. By aligning workforce metrics with AI-enabled decision support, health systems can move toward adaptive, data-driven rehabilitation planning that strengthens resilience against both sudden-onset and slow-onset disaster scenarios.

4. Methodology

4.1 Data Sources and Collection

To ensure the Physical Therapy workforce in Bahrain and its service delivery infrastructure were adequately captured, this study employed a multi- modal data collection strategy.. The Information & eGovernment

Authority (IGA) supplied Bahrain's population statistics and pertinent socio-economic information; the Ministry of Health (MOH) provided health properties statistics and public sector service-use data; and the National Health Regulatory Authority (NHRA) supplied licensure data and professional classification.

These datasets provided estimates of population size and growth rates along with the registered Physical Therapy workforce in 2016. A cross-sectional survey was conducted on public and private healthcare facilities with Physical Therapy services to supplement administrative record. To ensure the representation of important public hospitals, primary health centers (PHCs), and private clinics, purposive sampling was used to select the facilities. A total of 45 healthcare facilities were approached, comprising 12 public hospitals, 20 primary health centers, and 13 private clinics, of which 38 facilities (84%) completed the survey. Data on clinician demographic details, areas of specialization, postgraduate qualifications, future perceived needs of specialised services was collected through the survey instruments.

4.2 Analytical Framework

The analytical approach was primarily quantitative, supplemented by qualitative contextualization to interpret workforce distribution patterns and specialization gaps. It refers to the number of licensed Physical Therapists per 10,000 populations as per World Confederation for Physical Therapy (WCPT) customized benchmarks for international comparison. Categories of clinical specialties for the purpose of coverage were devised according to their practice domains. These include orthopaedics, neurology, pediatrics, cardiopulmonary, sports, women's health, and integumentary systems. The highest level of education that one earned, the Postgraduate training levels were classified as Master of Science (MS), transitional Doctor of Physical Therapy (tDPT) or Doctor of Philosophy (PhD).

As a comparative assessment, the scheme's consequences were analysed in high income countries with established rehabilitation systems (Germany, Australia, United States) and regional neighbours with similar profile. In order to gauge surge capacity, the service demand was modeled during a complex trauma disaster scenario. This scenario assumed a mass casualty event involving 500 individuals with injuries requiring Physical Therapy, including 30% with spinal cord injury, 25% with traumatic brain injury, 20% with multiple fractures, and 25% with amputations or severe burns. Workforce demand was estimated based on recommended clinician-to-patient ratios for acute trauma rehabilitation. Potential problems include spinal cord injury, traumatic brain injury, amputation and other poly-trauma. The survey identified existing workforce constraints and gaps in specialisation alongside possible exit of expat clinicians.[11]

4.3 Limitations

The findings have many limitations that need to be acknowledged. Data from government organisations is often affected by a lag and does not capture private sector registrations. In some specialty fields, non-participation bias may occur, increasing the risk of under- or over-specialization. Outdated data on clinical outcomes shows that information on workforce characteristics cannot be linked to patient functional recovery. This static assessment also does not take account of any recent policy changes or any dynamic mobility of the workforce that could impact system readiness. Despite these limitations, the method provides a sound basis for identifying systemic strengths and weaknesses in rehabilitation service delivery.[12]

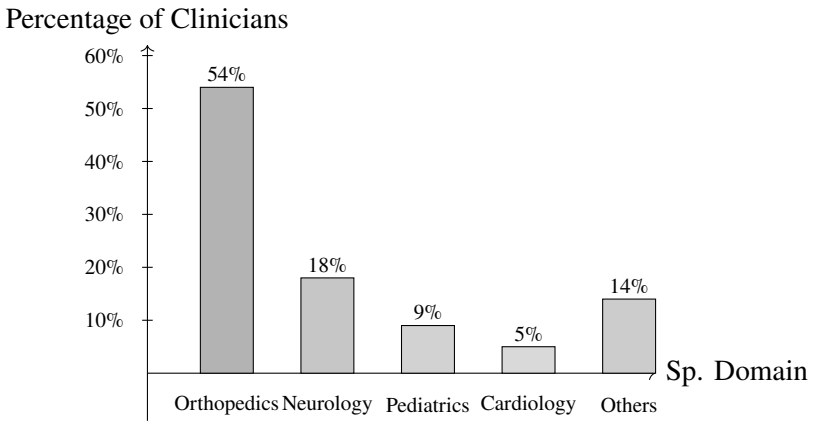


Figure 1: Distribution of specialization domains among postgraduate-trained Physical Therapists (N=20). Orthopedics dominates, while neurology, pediatrics, cardiology, and other domains remain comparatively underrepresented.

5. Workforce Demographics and Density Analysis

Bahrain's Physical Therapy workforce analysis shows the clinician-to-population ratio of Bahrain is 1.7 per 10,000, much below the global average of about 5 per 10,000 by international rehabilitation bodies. The high density esimates of Bahrain put it ahead of some regional peers like Saudi Arabia (0.88) and Egypt (0.37) but has a very long run behind high income countries like Germany (16), Australia (11) and the US (6). At the current rate at which people are born, we will need an annual growth in workforce size that is more than what local schools can graduate just to maintain this sub-optimal ratio.

Women account for 69% of registered Physical Therapists, indicating how gendered the profession has become. There is a larger gender imbalance in the public sector, as 57% of employees are female in contrast to 70% in the private sector. The "Societies" category refers to Physical Therapists employed within professional association or non-governmental organizational roles, while "Higher Education" includes those employed in academic institutions.Efforts are required to ensure greater gender diversity within the health professions. Moreover, there is considerable variation in the degree of gender diversity within practice settings and specialization tracks. According to the analysis of the workforce, 30% of the overall workforce are non-Bahraini expatriates, with a much higher concentration in private sector facilities (49%) than public (5%).

Employment in the public sector (49%) is almost equal to that in private sector (49%), with a negligible presence in academic or societal organization sectors. The type of distribution affects access to service. As an example, while public sector facilities cater to a larger proportion of the population, private clinics may cater to specific insurers or self-payers. Workforce stability considerations must take into account the potential loss of expatriate clinicians during any economic downturn or disaster event, which could lead to a sudden and almost one-third reduction in functional capacity.

Moreover, the analysis reveals significant shortcomings in postgraduate training, with just 8% of registered Physical Therapists having advanced qualifications. The highest proportion of specialists are in orthopedics (54%) with neurology (18%) and pediatrics (9%). There are now approximately no specialists available with specializations relevant to the disaster like burn care, amputee rehabilitation, prosthetics/orthotics, and acute trauma rehabilitation. The failure of doctors to meet the qualifications required to handle complex injuries caused by disasters.

Table 1: Licensed Physical Therapist Characteristics (2016)

Parameter	Category	n (%)
Sex	Males	75 (31%)
	Females	170 (69%)
Nationality	Bahraini	171 (70%)
	Non-Bahraini	74 (30%)
Sector	Public	120 (49%)
	Private	119 (49%)
	Societies	3 (1%)
	Higher Education	3 (1%)
Total		**245**

6. Specialization Gaps and Service Delivery Implications

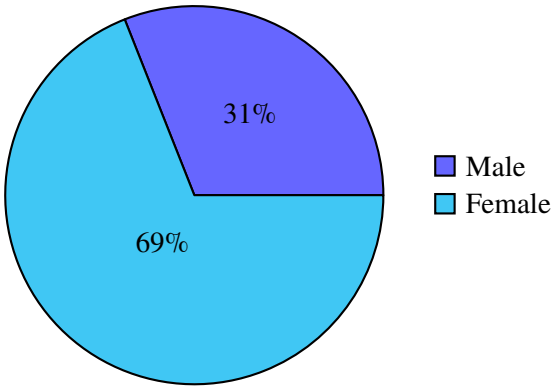
The existing competencies of the Physical Therapist workforce do not match the future disaster-related service requirements. Most advanced practice clinicians are in orthopedic specialty. Despite the fact that knowledge of musculoskeletal disorder is useful when dealing with fractures and later in rehab of the joints, yet the injuries because of disasters are basically multi-system and they are integrated in nature. Neurology and pediatric specialties are vital for managing spinal cord injury, traumatic brain injury, and pediatric trauma. However, all these specialties combined account for only 27% of postgraduate-trained Physical Therapists of advanced practice clinicians.

Results from surveys held in health facilities reveal that in future specialists in public and private healthcare in neurology (34-35%) orthopaedics (29-33%) and paediatrics (21-26%) will be in demand. The articulated needs are missing the specialisation of cardiorespiratory rehabilitation, integumentary (burn/wound care), and sports medicine, even though they can be useful in disaster recovery. Health administrators seem to be largely unaware of the Rehabilitation needs that may arise from mass casualty incidents.

Gaps in specialization are worsened by the absence of official training in disaster-related rehabilitation skills. At the moment, all of the Physical Therapists surveyed do not have certification in prosthetic/orthotic, burn rehabilitation, acute trauma management. The absence of such skills is particularly significant when managing amputations, deep burns, or other poly-traumas that need to be actively managed to avoid further complications and have better long-term outcomes. If the relevant clinicians trained appropriately are not available, then the rehabilitation response in disasters is likely to be generic.

Vulnerabilities in System Have Been Revealed by Patterns of Service Delivery. Outpatient Physical Therapy appointments at PHCs occur annually at a rate of 132,514, which is far higher than our country's largest public hospital (48,441). It could suggest that routine services are decentralized. This might indicate the curation of complex and serious cases at a single or few tertiary facilities. The integration of public and private sectors may cause impediments in coordinated responses during disasters if they do not have interoperable systems for information sharing and referral protocols.[13]

Measures international specialization gap with cross-national evidence. In Canadian provinces with comparable populations, it is estimated that around 12 percent of Physical Therapists are postgraduates. Furthermore, their distribution is fairly even across diverse specializations like cardiorespiratory, neurological and musculoskeletal. The ongoing education requirements for rehabilitation professionals often include disaster preparedness training so that they have at least basic competency in emergency systems.



Gender Distribution of Licensed Physical Therapists

Figure 2: Gender distribution among licensed Physical Therapists shows significant female predominance (69%), which may influence workforce retention patterns and specialization choices.

7. Disaster Preparedness and System Resilience Assessment

Health systems globally have little integration of rehabilitation services into national disaster management frameworks. The National Center for Disaster Management Crisis is in charge of executing and coordinating emergency health response in the Kingdom of Bahrain. So far, Physical Therapy professionals' representation on planning committees and response teams has not occurred in any formal capacity. This failure is also evident in other spheres with rehabilitation seen as a nice to have, rather than a necessity in the time of crisis.

Economic capacity plays a significant role in disaster preparedness. Bahrain's per capita GDP is almost 175% of the world's average, giving it the means to upgrade facilities. However, the level of investment being made in the workforce is not enough to reach targets for growth densities on a global level. Economic modelling shows disasters result in a 4-5% drop in employment and a 3-4% drop in wages. A mass exit of skilled foreign rehabilitation clinicians could occur, undercutting rehabilitation capacity at the time of greatest need.

Given the area is vulnerable to earthquakes, flash floods and rising temperatures, preparedness measures should be adapted to suit the region. Nearby nations have suffered blows of their own. Some examples are Earthquakes (Iran), floods (Saudi Arabia) Cyclones (Oman). Rehabilitation systems should look to have plans prepared for both sudden-onset (which would need an immediate surge capacity) as well as slow-onset (which would need the continuous delivery of services within limited resources) events.[14]

The assessment of readiness claims to identify critical gaps in resilience, including an insufficient number of skilled professionals with specialised training in complex trauma, inadequate postgraduate training pathways for future growth, training and competencies that are not disaster-specific, poorly coordinated services across sectors, and poor integration into the national emergency system. Addressing these challenges in the health system would involve action on different levels from education policy to workforce development to effective reorganization of service delivery. In case of disaster rehabilitation system will be overloaded. The disability of the affected population and long term recovery have already begun to be affected, highlighting the need for better early interventions.

Table 2: Specialization Needs Identified by Healthcare Facilities

Specialization	Public Sector (%)	Private Sector (%)
Orthopedics	29	33
Neurology	35	34
Pediatrics	21	26
Cardiopulmonary	12	0
Sports	0	0
Women's Health	1	7
Integumentary	2	0
Total Responses	**98**	**58**

8. Recommendations and Strategic Interventions

8.1 Workforce Development Initiatives

The post-graduate training on disaster issues should be expanded through collaboration with international universities and professional associations. Scholarships focus on areas that have a limited number of specialists like neurology, or pediatric rehabilitation or burn care. On the one hand, the inclusion of disaster rehabilitation competencies in undergraduate Physical Therapy curricula can guarantee that all new graduates are skilled in emergency preparedness.

The strategies for workforce expansion must cover the gap in both quantity and distribution of workforce. International benchmarks show that 5 Physical Therapists for 10,000 requires about 720 clinicians. According to the current levels, there is an increase of 475 persons clinician. Realistic trajectories assume that timelines at present graduation rates may take 15-years indicating necessity for faster development of education pipeline. Recruiting specialist expatriate clinicians can help address short-term capacity solutions while focusing on developing local capacity, provided retention incentives are implemented.

8.2 System Integration and Policy Reforms

It is important that representatives from the Physical Therapy profession are formally included on national disaster planning committees so that rehabilitation is part of the emergency planning. There should also be a regular participation in multi-disciplinary simulation exercises and the development of clinical guidelines for disaster injuries. The licensing authorities may require continuing education courses in disaster rehabilitation for renewal of the licensure by the professionals.

The models used for delivering public services should be reorganized to better coordinate the public and private sectors, perhaps through a centralized referral system and joint emergency response protocol. Tele-rehabilitation capabilities could extend the reach of specialists in times of crises when it is not possible to move. Infrastructural investments must include the earmarking of rehabilitation zones at temporary shelters and mobile units for community-based service delivery in disrupted settings.[15]

8.3 Research and Monitoring Framework

Robust monitoring systems that can track workforce metrics, specialisation development and service outcomes drive long-term resilience. Creating a national rehabilitation registry with real-time updates can help assess capacity and identify gaps. Research partnerships should examine models for the delivery of

disaster rehabilitation that are appropriate to context and evaluate their effectiveness in the face of varying patterns of injury and resource constraints.

International collaboration can provide another opportunity for learning through the sharing of knowledge with the region recently affected by the disaster. Rehabilitation response documentation in similar context could shape adaptive strategies and avoid earlier pitfalls. Analyses of the costs and benefits associated with rehabilitation services can be a useful way of establishing their return on investment in disaster recovery and can be helpful in advocating for their allocation of resources.

9. Conclusion

The Physical Therapy workforce capacity as well as disaster preparedness analysis show serious weaknesses in rehabilitation service delivery systems. The system lacks resilience because there are insufficient clinicians for the population, there are specialisation gaps in disaster relevant fields, post-graduate training is limited and inputs are less than adequate emergency planning. Addressing these challenges requires a coordinated, multi-sectoral intervention framework operating at policy, institutional, and educational levels.

The targeted enhancement of specialized skills in disaster epidemiology should be a priority in training the workforce particularly in the fields of neurology pediatrics trauma rehabilitation. Rehabilitation professionals must be formally included in national disaster planning committees to design emergency responses that consider long-term recovery functional needs. In the near future, the investment in disaster rehabilitation training for postgraduate education will create a sustainable capacity to deal with complex injury pattern.

The proposed system for assessing rehabilitation readiness can be utilized to implement other health systems to encourage resilience and disaster preparedness. By utilizing information on demographics, job history, facility analysis and international comparison, this approach identifies lack and fills it up. Subsequently, we will outline the implementation results relating to the effectiveness and success of each recommended strategy. There will also be a discussion on tweaking readiness metrics that will accommodate countering changes in disaster scenario as well as new rehabilitation support.

Rehabilitation systems should strengthen so that disability resulting from disaster can be minimized and future community should be planned. Climate change and urbanization have raised the frequency of natural disasters to an alarming rate. Consequently, there is an increasing need for the formal development of specialist rehabilitation capacity for disasters. In catastrophe circumstances it has become important to protect the health and functioning of the affected populace.

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