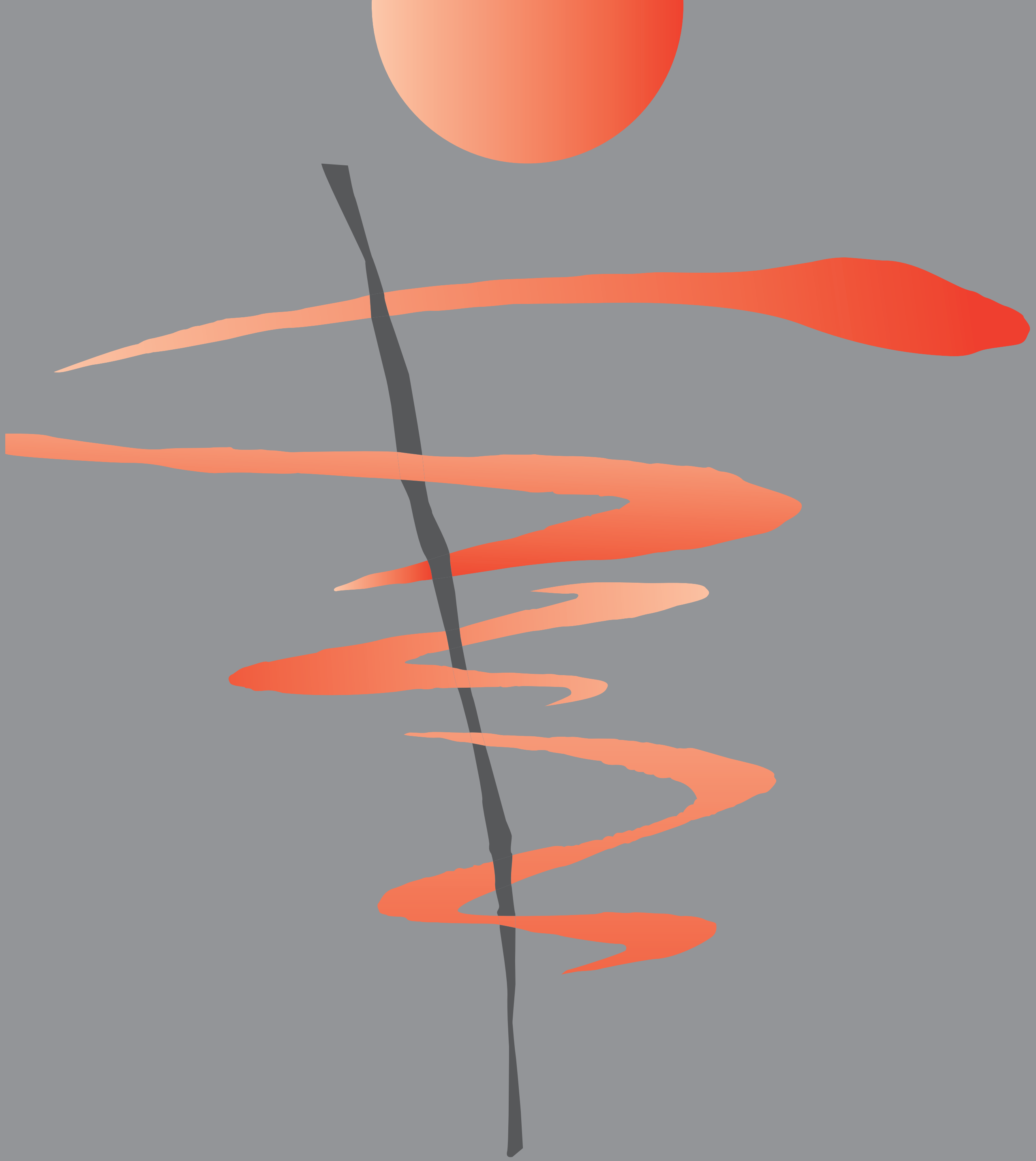

Theme: Strengthening rehabilitation in the health system

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GUEST EDITORIAL

Advancing rehabilitation science in Bangladesh: A call to action for a brighter future

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It is with immense pleasure and a profound sense of purpose that we present this special issue of the Bangabandhu Sheikh Mujib Medical University (BSMMU) Journal, dedicated to physical medicine and rehabilitation (PMR). This endeavor marks a significant milestone for BSMMU (currently, Bangladesh Medical University, BMU) and the burgeoning field of rehabilitation medicine in Bangladesh. As we navigate an increasingly complex global health landscape, the importance of PMR, with its holistic evidence-based approach to restoring function, enhancing participation, and improving the quality of life for individuals with disabilities, has never been more critical.

PMR, also called physiatry, a distinct medical specialty, has evolved significantly since its emergence in the aftermath of World War II. Although rooted in earlier practices, PMR emerged as a distinct specialty in the mid-20th century, shaped significantly by war, epidemics, sports, professional demands, environmental factors, and accidents, reflecting its crucial role in addressing complex rehabilitation challenges during both peace and conflict. [1]

In Bangladesh, PMR has steadily grown since the mid-1960s, tirelessly working towards addressing the diverse needs of our population. [2] The World Health Organization (WHO) now rightly recognizes 'function' as the third health indicator, alongside mortality and morbidity, underscoring a global paradigm shift towards a more comprehensive understanding of health. The recent WHO resolution on "Strengthening rehabilitation in health systems" further amplifies the urgent call to escalate rehabilitation services worldwide, aiming to address the vast "unmet rehabilitation" needs that persist globally [3]. With approximately 16% of the world's population living with some form of disability, as per United Nations estimates, the demand for integrated rehabilitation services, multidisciplinary rehabili-tation team work led by a PMR physician, is indisputable [4,5].

The bedrock of any medical specialty's advancement lies in its commitment to education, training, and rigorous research. While clinical knowledge is gained through dedicated education and training, it is scientific publication that serves as the indispensable conduit for disseminating this knowledge among peers and the wider scientific community. Publications foster intellectual discourse, validate new interventions, identify best practices, and ultimately translate research findings into tangible improvements in patient care. In the rapidly evolving field of PMR, bridging existing knowledge gaps is paramount to modernization and progress. This necessitates the initiation of new research projects and, crucially, the effective dissemination of their findings through appropriate, high-impact journals.

This special issue of the BSMMU Journal is more than just a collection of articles; it is a strategic platform designed to invigorate and accelerate research in disability, functioning, and rehabilitation within Bangladesh. We extend a heartfelt gratitude and a strong encouragement to all scientists, particularly the younger generation of researchers and clinicians, to engage actively in scholarly pursuits and to publish their valuable work within rehabilitation medicine-related scopes. For too long,

Key messages

Physical medicine and rehabilitation has become vital in restoring function and improving lives. This special Bangabandhu Sheikh Mujib Medical University Journal issue celebrates Bangladesh's growth related to physical medicine and rehabilitation since the 1960s, promoting research, education, and innovation. By fostering collaboration and young researcher engagement, it strengthens rehabilitation science and aligns with WHO's global call to advance function-focused, inclusive healthcare.

researchers in our region have faced challenges in finding suitable avenues for publishing their specialized work. This special issue provides a unique advantage: an accessible and dedicated forum within "their" own journal, fostering a sense of ownership and community. Notably, this issue is further enriched by the inclusion of a few scientific papers contributed by esteemed foreign faculty, fostering international collaboration and diverse perspectives.

By providing this dedicated platform, we aim not only to showcase the innovative research being conducted in Bangladesh but also to stimulate further inquiry, collaboration, and methodological rigor. Every published paper contributes to the collective knowledge base, strengthens the scientific foundation of PMR, and directly enriches the specialty [6]. Ultimately, this collective effort will translate into enhanced services and improved outcomes for people with disabilities, fulfilling our shared mission of promoting health, function, and participation.

We are confident that the contributions within this special issue will serve as a testament to the dedication and scientific prowess of PMR scientists in Bangladesh. We look forward to a future where this momentum continues, fostering a vibrant research culture that consistently pushes the boundaries of rehabilitation medicine for the betterment of society.

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REVIEW ARTICLE

Climate change, disability, and physical and rehabilitation medicine: A call for inclusive health action

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Abstract

Background: Climate change is an escalating global health emergency with widespread and disproportionate effects on populations. Despite representing over one billion individuals worldwide, people with disabilities (PwD) remain largely overlooked in climate adaptation and health planning. The health consequences of climate change for PwD are multifaceted and profound. This article aims to elaborate on the intersection of climate change and disability, explore the disproportionate impacts of climate change on PwD, emphasizing the pivotal role of Physical and Rehabilitation Medicine (PRM) professionals.

Methods: This narrative review synthesizes expert perspectives to examine the intersection of climate change, disability, and health. A focused review of literature identified key themes and policy gaps, complemented by conceptual analysis highlighting the implications for PRM.

Results: The complex interplay between climate change and disability is shaped by environmental stressors, health system disruptions, and pre-existing functional limitations. Evidence suggests that during climate-related events, PwD experience disproportionate impacts, including heightened morbidity, barriers to accessing essential services, and greater socio-economic and psychosocial vulnerability. PRM professionals are uniquely positioned to respond to the challenges of climate change through their expertise in functional restoration, long-term care, and disability-inclusive health services. However, rehabilitation remains underrepresented in many national and international climate response frameworks. The integration of rehabilitation into climate-resilient health systems requires all-inclusive governance, adaptive infrastructure, workforce capacity building, disability-focused research, and strengthened global partnerships.

Conclusion: There is an urgent need to embed rehabilitation within climate change policies to ensure equitable, sustainable, and inclusive health systems. PRM professionals have a pivotal role in shaping and implementing these strategies, advocating for the rights and needs of PwD in the evolving climate crisis. A structured roadmap for climate-resilient, rehabilitation-inclusive health systems is essential to achieve health equity and resilience for all.

Key messages

Climate change is a major health crisis, disproportionately affecting vulnerable populations, especially people with disabilities, due to physiological, mobility, and socioeconomic challenges. Physical and Rehabilitation Medicine professionals can play a vital role in mitigating these impacts through care, education, and advocacy. Global collaboration amongst all stakeholders is essential to build climate-resilient, rehabilitation-inclusive health systems.

Introduction

The intergovernmental Panel on Climate Change defines climate change as "any change in climate over time, whether due to natural variability or as a result of human activity" [1]. Climate change is widely recognized as one of the most significant public health emergencies of the 21st century, with over 3.3 billion people living in contexts highly vulnerable to climate hazards [1, 2]. Its effects are felt globally, with projections indicating a steady intensification of extreme weather events, rising sea levels, food and water insecurity, forced displacement, and environmental degradation, which pose critical risks to health and well-being [3].

The World Health Organization (WHO) estimates that between 2030 and 2050, climate change will contribute to an additional 250,000 deaths annually due to heat stress, malnutrition, vector-borne diseases, and diarrheal illnesses, etc., with associated direct health costs expected to reach between US$2 to 4 billion per year by 2030 [2]. These projections do not account for indirect impacts and socio-economic burden, such as the collapse of health infrastructure, mental health deterioration, and displacement-related trauma, which disproportionately affect vulnerable populations. The recently published 'The 2025 Lancet Countdown' report highlights that climate change is already exerting significant and measurable impacts on global health [4]. The report indicates that heat-related mortality has increased by an estimated 63% since the 1990s, with approximately 546,000 deaths annually from 2012–2021 [4]. Furthermore, it documents a widening spectrum of climate-related health risks, including increased exposure to wildfire-related air pollution, deteriorating food insecurity, heightened vulnerability to climate-sensitive infectious diseases, and substantial reductions in economic productivity [4].

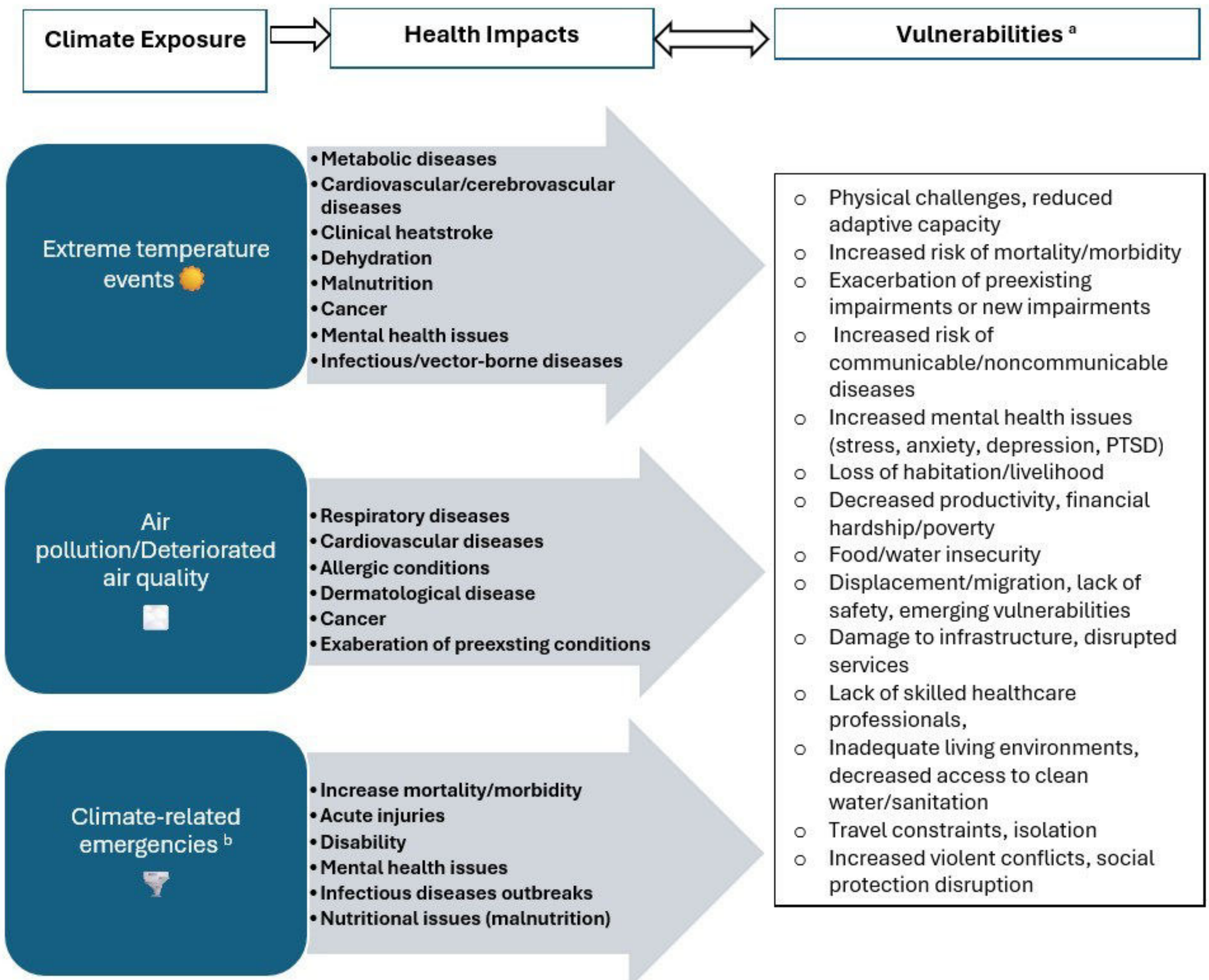
Climate change has profound impacts on human health, particularly for vulnerable populations such as individuals with pre-existing health conditions, older adults, children, low-income communities, and people with disabilities (PwD) [5, 6]. PwD represents a particularly at-risk group due to existing health disparities, limited mobility, and systemic marginalization from health, social, and emergency response systems [5]. An analytical study on this issue, conducted by the United Nations (UN), identifies the disproportionate impact of climate change on this vulnerable population and human rights obligations of member States, emphasizing the need for disability-inclusive climate action [5].

Health consequences of climate change

Climate change poses significant and multifaceted threats to human health, both directly and indirectly [5, 7]. Direct health impacts include those resulting from temperature extremes (e.g., heat waves, cold spells), natural disasters (e.g., floods, hurricanes, droughts, wildfires), and environmental degradation. These can cause injuries, fatalities, and acute exacerbations of chronic conditions like cardiovascular and respiratory diseases [8]. These events are increasing in frequency and intensity due to rising global temperatures and shifting climatic patterns [1]. For instance, extreme heat is associated with dehydration, heat exhaustion, heat stroke, and cardiovascular strain, which can be fatal, especially among individuals with pre-existing medical conditions [8, 9]. Moreover, extreme weather events can lead to physical trauma, interruptions in healthcare delivery, and long-term disability, particularly when health systems are overwhelmed or infrastructure is damaged. Indirect effects are subtler but equally damaging, and include changes in vector ecology leading to infectious disease outbreaks, disruption of food systems causing malnutrition, reduced access to clean water and sanitation, and declines in air quality due to pollution, etc [10,11]. For example, higher temperatures and increased rainfall variability have expanded the geographical range of vector-borne diseases such as malaria, dengue, and Zika virus [12]. Waterborne diseases such as cholera and typhoid are more likely to spread in flood-prone or drought-stricken areas due to contamination or scarcity of clean water sources [10]. Concurrently, air pollution, exacerbated by wildfires and fossil fuel combustion, is linked to increased morbidity and mortality from respiratory and cardiovascular diseases. According to WHO estimates, ambient air pollution was responsible for approximately 4.2 million premature deaths in 2016, primarily due to stroke, ischemic heart disease, chronic obstructive pulmonary disease (COPD), and lung cancer [13]. These can significantly affect one's mental health, such as anxiety, depression, post-traumatic stress disorder, etc., either by direct trauma from extreme events, or by climate-related stressors, including displacement and loss of livelihood, stress of economic and social disruption [7, 14].

Populations with chronic conditions such as cardiovascular disease, diabetes, COPD, and neurological disorders like stroke or multiple sclerosis (MS) are especially sensitive to climate-related stressors. For example, individuals with MS are known to experience worsening of fatigue and motor dysfunction in hot conditions due to impaired thermoregulation and neural conduction [15]. Further, individuals with cardiovascular disease, respiratory illness (e.g., COPD), or neurological conditions such as stroke often experience worsening symptoms under heat stress or pollution exposure [13, 14]. These physiological responses can significantly reduce functional independence and quality of life. Moreover, mental health issues related to climate change, such as anxiety, depression, and post-traumatic stress, are increasingly recognized, particularly among those already experiencing social disadvantage [16].

Climate change amplifies existing health disparities and challenges health systems to deliver accessible, continuous, and responsive care to those most at risk [5]. The complex interplay between environmental stressors, health system disruptions, and social determinants of health requires integrated,



Source: Amatya B and Khan F[7]
PTSD indicates post-traumatic stress disorder; [a] Manifest uniquely in people with disabilities, [b] Floods, droughts, hurricanes, storms, wildfires, etc

Figure 1 Potential climate change-related health impacts and vulnerabilities

equitable, climate-smart healthcare systems [5, 7]. Figure 1 summarizes the potential impact of climate change on health, which interacts and overlaps depending on climatic variability.

Impact of climate change on PwD

PwD, accounting for 16% of the world's population (estimated at over 1.3 billion people), faces heightened risks from climate change due to systemic vulnerabilities and inequalities, reduced adaptive capacity, and limited access to health and social services [5, 17]. These make them especially susceptible to health and psychosocial impacts. According to the UN Human Rights Council, PwD face disproportionate risks of injury, disease, and death during climate-related events, and are often excluded from emergency preparedness and response [5]. A 2022 scoping review by Lindsay et al found that extreme weather events worsened pre-existing conditions among PwD, increased mental health burden, and heightened exposure to physical injury and trauma [18]. Furthermore, displaced PwD often faces prolonged separation from caregivers, difficulty accessing medication and rehabilitation, and deteriorating health.

Gaskin et al highlighted four key dimensions of vulnerability in PwD using the ICF framework: impairments in body function, activity limitations, environmental barriers, and personal disadvantages such as age, gender, and income [19]. Despite these challenges, climate policy and health system adaptation strategies often fail to include PwD in a meaningful way, signaling a critical policy gap [5]. Further, the Lancet report calls for urgent, intersectional action to break down systemic barriers faced by PwD worldwide [4].

Some of the potential intersecting vulnerabilities in PwD from the impact of climate change include (but are not limited to) [2, 5, 7, 17-21]:

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Physiological vulnerabilities

Many PwD have underlying health conditions, including cardiopulmonary disease, reduced mobility, and impaired thermoregulation, that make them more susceptible to heat stress, respiratory complications, or infection.

Physical susceptibility

Many PwD have some form of limitation in mobility, sensory, or cognitive function that can restrict timely evacuation and emergency services access. Further, those who rely on assistive technologies (e.g., powered wheelchairs, ventilators) are particularly vulnerable during power outages or disruptions to essential services.

Barriers to healthcare access

During climate-related emergencies and other disasters, PwD often face difficulties in accessing medications, support and essential health services, including rehabilitation. A lack of disability-inclusive disaster planning frequently leaves them without appropriate evacuation, shelter, communication, or recovery services.

Socioeconomic disadvantage

Many PwD already encounter social and economic disadvantages, including poverty, unemployment, poor housing, and social exclusion, which increase climate vulnerability and reduce adaptive capacity. Further, these factors also limit their ability to recover from displacement, loss of assets, or disruption of social safety nets.

Disruption of support systems

Climate-related displacement, infrastructure collapse, or emergency responses may interrupt vital caregiving and assistive services, or community-based services, leaving individuals isolated and at risk.

Communication barriers

Individuals with sensory, cognitive, or intellectual disabilities may not receive accessible and timely information during emergencies, further hindering their ability to respond and seek help.

Understanding and addressing the unique needs of PwD is essential for building health systems that are resilient, equitable, and capable of protecting all members of society, especially in the face of climate change and other escalating disasters [5].

Role of PRM professionals

PRM professionals play a crucial role in addressing the functional, psychological, and social needs of people, including PwD [22]. They are uniquely positioned to address the intersection of disability and climate change, as their expertise spans from management of functional impairments, chronic conditions, and post-injury rehabilitation, to disability advocacy/education, areas that are highly sensitive to environmental stressors [7, 23]. As the climate crisis intensifies, their role becomes increasingly critical in managing the direct health impacts and advocating for inclusive, resilient health systems that support the most vulnerable population. The importance of integrating rehabilitation into all phases of emergency preparedness and response has been increasingly recognized by global health authorities [22]. PRM professionals play a critical role across this disaster care continuum and require a diverse skill set that spans diagnostic acumen, clinical management, education, systems coordination, and policy advocacy. Their involvement is particularly vital in the context of climate-related disasters, where the burden of injury, disability, and chronic health conditions is often compounded by disrupted services and infrastructure [24]. The complexity of these scenarios demands that PRM personnel be equipped to contribute effectively across all stages of the disaster management cycle, from preparedness and mitigation to response and recovery [22, 24]. Some of the key roles for PRM professionals in climate crisis management may include:

Clinical care and functional restoration

PRM specialists are trained to manage chronic disease complications, musculoskeletal injuries, neurodegenerative conditions, and functional impairments, which are either caused or worsened by climate-related factors. Their knowledge of how environmental factors impact function is essential in planning safe, individualized care plans that consider temperature, air quality, mobility, and fatigue. etc. Further, they can provide psychological support to help PwD manage stress, anxiety, and trauma related to climate events, displacement, or loss of social support.

Emergency and post-disaster rehabilitation

PRM teams have a crucial role in acute injury management (e.g., spinal cord injuries, traumatic brain injury, limb amputations, etc.), and in coordinating the care continuum, long-term post-disaster [22, 25]. They ensure that the victims receive timely interventions to prevent complications and facilitate successful community reintegration.

Enhance adaptive capacity and resilience

PRM teams can be key in the development of a structured system that improves the ability of PwD to adapt to and recover from climate catastrophes. This includes designing rehabilitation plans adapted to environmental constraints (e.g., safe exercise in heat-sensitive populations, dehydration, outdoor air quality), preparing individualized emergency preparedness plans, continuity of care for ongoing rehabilitation and medication needs, and collaborating across disciplines and systems to ensure accessibility and service continuity.

Education and advocacy

A growing number of PRM professionals recognize the importance of environmental health [23]. PRM professionals can lead in educating health workers, policymakers, and communities about the impact of climate change on disability and function, and the development of climate-resilient and sustainable healthcare systems. Further, their role is particularly essential in educating patients and caregivers on managing health in extreme conditions.

Leadership in global health and policy

Organizations like the International Society of Physical and Rehabilitation Medicine (ISPRM) have taken steps to elevate PRM's role in disaster and climate-health initiatives. The ISPRM Position Statement on Climate Change and Disability advocates for inclusive governance, data-driven strategies, and partnership with PwD and civil society [24]. It calls for a multisectoral collaboration to ensure that rehabilitation is integrated into broader climate adaptation and health system planning, maximizing resources and impact. It calls all stakeholders for: raising awareness, strengthening health systems' adaptive capacity, involving PwD in planning and decision-making, and conducting research on climate-related functional impairments and rehabilitation outcomes [7, 24].

The way forward

There is a growing call from global agencies, including the UN, WHO, and disability rights organizations, to adopt disability-inclusive climate action that acknowledges and addresses the specific vulnerabilities and needs of PwD. However, disability inclusion is often absent from mainstream climate adaptation and mitigation policies. To address the escalating risks posed by climate change, the following strategic actions are needed:

Inclusive governance

Disability must be mainstreamed in climate and disaster policy frameworks, including Nationally Determined Contributions. National adaptation and mitigation strategies must explicitly recognize and incorporate the needs of PwD, ensuring accessibility of early warning systems, evacuation protocols, and disaster shelters. Further, PwD and their representative organizations need to be involved in designing policies and action plans.

Resilient rehabilitation systems

Investment in climate-proof infrastructure, mobile service delivery, and backup systems is essential. Rehabilitation services must evolve to meet climate challenges, which include the use of tele-rehabilitation, artificial intelligence technologies, mobile units, climate-informed infrastructure planning, etc. Services should remain functional and accessible during disruptions.

Workforce education

Training programs in medical schools and continuing education should include climate-related health risks, disability-inclusive planning, and sustainable healthcare. The healthcare workforce education programs should be focused on climate adaptation, sustainability, and rehabilitation planning. Interdisciplinary collaboration across public health, climate science, and disability sectors should be promoted.

Research and evidence

There is a paucity of data on how climate change affects functional outcomes, rehabilitation access, and long-term recovery. More studies are needed on the functional outcomes of climate-related illness and injury, rehabilitation accessibility during emergencies, and long-term community reintegration. There is a need for the development of climate-disability vulnerability indices to inform health planning and support participatory research involving PwD, especially from low-resource and climate-exposed regions.

Global partnerships

Multisectoral collaboration among UN agencies, governments, non-government organisations, academia, and disability-related organizations is vital to implement comprehensive, equity-focused responses. Global agencies such as the WHO, United Nations Development Programme, and ISPRM have an essential role in setting standards and mobilizing actions and advocacy.

Conclusion

Climate change poses a significant and growing threat to global health, with widespread consequences to vulnerable populations, including PwD. A structured, people-centered approach is essential for building climate-resilient rehabilitation systems to ensure that the unique needs of PwD are met, to reduce health disparities, safeguard rights, and empower individuals and communities. The road ahead requires coordinated, evidence-informed, and equity-driven action. As the climate crisis escalates, integrating rehabilitation into national and global climate health responses becomes not just relevant but essential. The time to act is now, for proactive, inclusive, and interdisciplinary collaboration to help build a safer, more inclusive, and sustainable future for all in this era of climate uncertainty.

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Conflict of interest

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Data availability statement

We confirm that the data supporting the findings of the study will be shared upon reasonable request.

Supplementary file

None

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REVIEW ARTICLE

Novel robotic rehabilitation in Bangladesh: A narrative review

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Abstract

Background: Robotic rehabilitation has emerged as a transformative innovation in physical medicine, enabling high-intensity, task-specific, and measurable therapy that enhances neuroplasticity and functional recovery. This review summarises global evidence on robotic rehabilitation and examines its relevance and implementation challenges in low- and middle-income countries (LMICs), with a particular focus on the pioneering experience of the Bangladesh Medical University.

Methods: This narrative review synthesised literature from PubMed, Scopus, Web of Science, and Google Scholar published between January 2010 and September 2025. Included sources comprised reviews, meta-analyses, randomised controlled trials, observational studies, and policy documents addressing effectiveness, implementation, workforce, and health-system integration of robotic rehabilitation in LMICs. Evidence was thematically synthesised, prioritising higher-level studies, without formal PRISMA procedures or structured risk-of-bias assessment, consistent with accepted narrative review methodology.

Results: Global evidence supports robotic rehabilitation, with strongest benefits in stroke, moderate evidence in spinal cord injury, and emerging data in traumatic brain injury, neurodegenerative, paediatric, and musculoskeletal conditions. Effectiveness improves when robotics complement conventional therapy. In LMICs, adoption is hindered by financial, infrastructural, and workforce limitations. Bangladesh faces high disability burden and service gaps; the BMU Robotic Rehabilitation Centre represents a significant advancement in equitable, technology-driven rehabilitation.

Conclusion: Robotic rehabilitation offers measurable improvements in function and independence across diverse conditions. Strengthening infrastructure, workforce capacity, and policy support is essential for sustainable adoption in LMICs. The Bangladesh Medical University model demonstrates a feasible pathway for integrating advanced rehabilitation technologies in resource-constrained settings.

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Key messages

The Robotic Rehabilitation Centre at Bangladesh Medical University, the nation's first university-affiliated facility for advanced rehabilitation, integrates high-intensity robotic therapy to improve outcomes for neurological and musculoskeletal disorders. Despite challenges of cost and access, it fosters research, innovation, and training, demonstrates a sustainable and technology-driven rehabilitation within LMIC settings.

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Introduction

Rehabilitation medicine is transforming with robotic technologies that overcome limitations of conventional therapy, including therapist fatigue, limited intensity, and variability, enabling sustained, high-dose, task-specific training essential for neurological and musculoskeletal recovery. Robotic rehabilitation addresses many of these limitations by enabling standardised, intensive, repetitive, and data-driven therapy that can be individually tailored and objectively monitored. Devices such as exoskeletons, end-effector systems, robotic gait trainers, and sensor-based assistive platforms facilitate structured practice and real-time feedback, thereby supporting neuroplasticity and functional recovery [1-3].

Globally, disability remains a major public health concern. Stroke continues to be the leading cause of adult disability worldwide, while spinal cord injury (SCI), traumatic brain injury (TBI), neurodegenerative disorders, and musculoskeletal conditions contribute substantially to long-term functional impairment and reduced quality of life. The World Health Organization (WHO) estimates that more than one billion people live with some form of disability, with the greatest burden borne by low- and middle-income countries (LMICs) [4]. These regions face a dual challenge of rising non-communicable diseases and injury-related disability alongside constrained health-system resources.

Over the past two decades, robotic rehabilitation has been extensively studied in high-income countries (HICs). Evidence from systematic reviews and randomised controlled trials demonstrates improvements in upper-limb motor function, gait recovery, balance, and independence in activities of daily living when robotic interventions are combined with conventional therapy [5-8]. However, the translation of these advances into LMIC settings has been limited. Barriers include shortages of trained rehabilitation professionals, inadequate infrastructure, high acquisition and maintenance costs of robotic devices, lack of insurance coverage, and low public awareness of rehabilitation as a core component of health care.

Bangladesh exemplifies these challenges. Despite a high and growing burden of disability, rehabilitation services remain underdeveloped and unevenly distributed. In this context, Bangladesh Medical University (BMU) has established the country's first university-affiliated robotic rehabilitation centre. This initiative represents a significant institutional response to rehabilitation inequities and provides an opportunity to examine the feasibility, implementation, and early experience of robotic rehabilitation in a resource-constrained setting.

Methods

This study is a narrative review integrating peer-reviewed literature and relevant grey sources. Searches were conducted in PubMed, Scopus, Web of Science, and Google Scholar for publications between January 2010 and September 2025. Search terms included combinations of robotic rehabilitation, robot -assisted therapy, neurorehabilitation, stroke rehabilitation, spinal cord injury, LMIC rehabilitation, and Bangladesh rehabilitation.

Eligible sources included narrative and systematic reviews, meta-analyses, randomised controlled trials, large observational studies, and policy or guideline documents addressing clinical effectiveness, implementation, cost, workforce development, or health-system integration of robotic rehabilitation. Engineering-focused studies without clinical application, isolated case reports, and non-English publications without English abstracts were excluded.

Evidence was synthesised thematically, with emphasis on the strength and consistency of findings across conditions and relevance to LMIC contexts. Higher-level evidence (systematic reviews and meta-analyses) was prioritised where available. Formal PRISMA procedures, duplicate screening, or structured risk-of-bias scoring were not applied, in keeping with narrative review methodology.

Results

Global evidence on robotic rehabilitation

Robotic rehabilitation has evolved from experimental prototypes to clinically established tools across neurological, musculoskeletal, paediatric, and geriatric rehabilitation. The strength of evidence varies by condition, with the most robust data available for stroke, moderate evidence for SCI, and emerging evidence for other disorders.

Stroke rehabilitation

Stroke rehabilitation represents the most extensively studied application of robotic technologies. A large Cochrane review involving more than 7,000 participants demonstrated that electromechanical and robotic-assisted arm training significantly improves activities of daily living and upper-limb motor strength compared with usual care [2]. Robotic-assisted gait training has also been shown to improve walking independence, speed, and endurance, particularly in the subacute phase and when combined with body-weight support [6-8].

Randomised trials indicate that robotic therapy can deliver treatment intensities that are difficult to achieve with conventional therapy alone, while maintaining high patient motivation through interactive feedback. Importantly, robotic interventions appear most effective when integrated into comprehensive rehabilitation programmes rather than used as standalone treatments.

SCI

Exoskeleton-assisted walking has become a promising avenue in SCI rehabilitation. Evidence suggests improvements in cardiovascular endurance, bone density, and trunk control. Sale *et al.* [9] highlighted the role of robotic gait therapy in reducing secondary complications such as osteoporosis and pressure ulcers. A systematic review by Miller *et al.* [10] concluded that exoskeletons improved functional ambulation in selected SCI patients, although long-

Table 1 Gait and lower limb rehabilitation systems

Device names	Functions	Indications	Contraindications
ZEPU-AI1 (Gait Training & Evaluation System)	Robotic-assisted gait training with evaluation metrics	Stroke, spinal cord injury, TBI, Parkinson's, MS, CP, orthopedic recovery, balance disorders	Unstable fractures, severe spasticity, osteoporosis, DVT, uncontrolled epilepsy, open wounds
ZEPU-AI3 (Lower Limb Feedback Training System)	Active/passive stepping, lower limb strength evaluation	GBS, CIDP, SCI Myopathy, stroke, post-orthopedic surgery, early mobilization	Acute fractures, severe osteoporosis, severe dementia, pacemakers Bone malignancy, TB Severe cognitive impairment.
ZEPU-AI9 (Lower Limb Exoskeletal Gait Training System)	Exoskeleton-assisted walking	TBI, Stroke, SCI, CP, MS, PD, post-op mobilization, elderly with gait dysfunction, balance training	Severe spasms, unstable fractures, bone instability, skin ulcers, severe cognitive impairment
ZEPU-K2000E (Lower Limb Trainer)	Active/passive lower limb exercise	Stroke, SCI, TBI, post-surgical rehab, OA, fractures	Cardiopulmonary dysfunction, limb tumors, severe skin damage, TB

TBI indicates traumatic brain injury; MS, multiple sclerosis; CP, cerebral palsy; GBS, Guillain-Barré Syndrome; CIDP, chronic inflammatory demyelinating polyradiculoneuropathy; SCI, spinal cord injury; PD, Parkinson's disease; OA, osteoarthritis; DVT, deep vein thrombosis; TB, tuberculosis

term independence remained limited by injury severity. Nonetheless, patient satisfaction and quality of life outcomes were notably improved.

TBI

Compared with stroke and SCI, robotic rehabilitation in TBI has received less research attention. Emerging studies demonstrate improvements in gait symmetry, balance, postural control, and endurance following robotic gait training. Upper-limb robotic interventions show potential benefits in motor coordination and functional independence, although evidence remains limited to small trials and pilot studies [11]. Larger, well-designed studies are needed, particularly in LMICs where TBI burden is substantial due to road traffic accidents and occupational injuries.

Neurodegenerative disorders

Robotic rehabilitation is increasingly applied in neurodegenerative conditions such as Parkinson's disease and multiple sclerosis. In Parkinson's disease, robotic gait training reduces freezing episodes, improves stride length, and enhances balance [12]. In MS, robotic interventions improve walking speed, endurance, and fatigue resistance [13]. While evidence is less robust than for stroke, these findings support a complementary role for robotics in managing progressive neurological disorders.

Cerebral palsy

In paediatric cerebral palsy, robotic exoskeletons and robotic treadmills enable repetitive, engaging, task-specific training that is difficult to achieve manually. Studies demonstrate improvements in gait patterns, muscle strength, and gross motor function, particularly when robotic therapy is combined with conventional physiotherapy [14]. Robotic devices may also enhance motivation and adherence in children through interactive and gamified interfaces.

Musculoskeletal and orthopaedic rehabilitation

Robotic rehabilitation is increasingly used in musculoskeletal and post-operative care, including joint replacement, ligament reconstruction, and shoulder rehabilitation. These devices facilitate early mobilisation, graded loading, and precise range-of-motion control. Systematic reviews report reduced pain, improved joint mobility, and faster return to functional activities compared with standard therapy alone [15-17].

Table 2 Upper limb rehabilitation systems

Device names	Functions	Indications	Contraindications
ZEPU-AI2 (Upper extremity feedback training)	Repeated exercise training with proprioceptive feedback	Stroke, SCI, TBI, MS, Parkinson's, CP, orthopedic recovery, frozen shoulder	Acute fracture, tumors, severe osteoporosis, severe shoulder pain, pacemakers
ZEPU-AI6 Plus (3D Upper limb training system)	Active/passive 3D rehab (front-back, side-side, up-down)	Stroke, SCI, TBI, arthritis, CRPS, CP, prosthesis training, Adhesive capsulitis	Unstable fractures, tumors, severe spasticity, pacemakers, sever pain, TB, local infection
ZEPU-K2000D (Upper limb trainer)	Active/passive training for recovery	Stroke, TBI, orthopedic recovery, COPD, OA	Cardiopulmonary dysfunction, limb tumors, cognitive impairment
ZEPU-SG1 Plus (Hand function comprehensive training system)	Finger and hand function recovery	Stroke, SCI, CP, nerve injuries, RA, burns, MS, PD	Open wounds, unhealed fractures, severe cramps
ZEPU-K2000A (Upper/lower limb trainer)	Active/passive training, combined limbs	Stroke, CP, SCI, PD, post-fracture rehab, ICU deconditioning	Severe cardiopulmonary dysfunction, skin damage, severe joint deformities, open bleeding wounds

SCI indicates spinal cord injury; TBI, traumatic brain injury; MS, multiple sclerosis; CP, cerebral palsy; COPD, chronic obstructive Pulmonary disease; OA, osteoarthritis; PD, Parkinson's disease; ICU, intensive care unit; TB, tuberculosis

Table 3 Multi-joint and whole-body rehabilitation systems

Device names	Functions	Indications	Contraindications
ZEPU-AI4 (Multi-joint constant speed training system)	Isokinetic training and evaluation	Post-surgical rehab. Adhesive capsulitis stroke, SCI, ACL reconstruction, sports injury rehab	Acute fractures, tumors, severe osteoporosis, cognitive impairment Severe local inflammation, skin ulcers
ZEPU-AI7A (Upper & lower limb trainer)	Active/passive circular training	Stroke, SCI, Parkinson's, MS, CP, geriatric rehab, post-COVID weakness	Severe spasticity, unstable fractures, pacemakers
ZEPU-DK2 (Electric rehabilitation table)	Early mobilization, tilt and vibration	Stroke, SCI, TBI, arthritis, geriatrics, ICU patients	Hypotension, unstable fractures, severe heart failure, Severe joint deformities
ZP-PTC-3 (PT Training Bed)	Bed-based mobility, balance, transfer training	PD, CP stroke, paraplegia, quadriplegia, ICU early mobilization, post-operative rehabilitation	Unstable angina, DVT, severe osteoporosis, severe cognitive impairment

SCI indicates spinal cord injury; ACL, anterior cruciate ligament; MS, multiple sclerosis; CP, cerebral palsy; COVID, coronavirus disease; TBI, traumatic brain injury; ICU, intensive care unit; PD, Parkinson's disease; DVT, deep vein thrombosis

Cost-effectiveness and evidence gap

Although robotic rehabilitation requires substantial upfront investment, long-term benefits such as reduced disability, fewer complications, and decreased caregiver burden may render it cost-effective in high-burden conditions like stroke [3]. However, robust cost-effectiveness data from LMICs are lacking. Across conditions, effect sizes are often modest, device heterogeneity complicates comparisons, and long-term sustainability of gains remains uncertain.

Rehabilitation landscape in LMICs including Bangladesh

Despite a high burden of disability, rehabilitation services in LMICs remain underdeveloped. WHO estimates that more than 2.4 billion people could benefit from rehabilitation, the majority residing in LMICs [18]. Yet rehabilitation typically receives less than 2% of national health budgets, with services concentrated in urban tertiary centres [19]. Shortages of trained physiatrists, physiotherapists, occupational therapists, and speech therapists further limit access [20-22]. Out-of-pocket expenditure dominates health financing, and insurance coverage for rehabilitation is minimal [23]. In LMICs, stigma surrounding disability, low prioritisation of rehabilitation, and gender norms particularly restricting women's mobility and access to household resources significantly limit rehabilitation utilisation. In parallel, high device costs, limited technical expertise, unreliable electricity, poor internet access, and low digital literacy constrain adoption of robotic and tele-rehabilitation technologies [24-27].

In Bangladesh, stroke prevalence exceeds 11 per 1,000 population, contributing substantially to disability-adjusted life years lost [28]. Road traffic accidents and industrial injuries add to the burden of SCI and TBI. Musculoskeletal disorders, including osteoarthritis and low back pain, are leading causes of chronic disability. Despite this burden, Bangladesh has fewer than 400 registered physiatrists, and specialised rehabilitation centres are largely confined to Dhaka [29-31]. Community-based rehabilitation programmes exist but remain fragmented and underfunded [32]. Rehabilitation is not fully integrated into primary health care, and awareness remains low, particularly among women and rural populations [33-36].

Recent developments including endorsement of WHO Rehabilitation 2030, inclusion of rehabilitation in national policy documents, and expansion of telemedicine following the COVID-19 pandemic offer opportunities to strengthen rehabilitation delivery [37-38].

BMU robotic rehabilitation centre

Established in 2025, the BMU Robotic Rehabilitation Centre is the first university-affiliated facility of its kind in Bangladesh. The centre aims to integrate advanced rehabilitation technologies into clinical service delivery, education, and research. Its key functions include:

- Access: Introduction of advanced robotic rehabilitation previously unavailable in the country. This has improved access beyond affluent populations.
- Capacity building: Training of postgraduate medical students, physiatrists, and rehabilitation therapists.
- Research: Generation of local evidence on feasibility, outcomes, and implementation.

The centre houses 62 devices, among them 57 are robotic rehabilitation devices, and 22 are AI-enabled, covering upper-limb, lower-limb, multi-joint, and early-mobilisation applications.

Robotic therapy is delivered using a hybrid care model, complementing conventional physiotherapy and occupational therapy. Typical sessions involve 30–40 minutes of robotic training integrated into individualised rehabilitation plans based on functional status, affordability, and family support.

BMU has initiated observational data collection using validated outcome measures such as the Functional Independence Measure, Fugl–Meyer Assessment, Barthel Index, and six-minute walk test. Early experience suggests high patient motivation and acceptability, although formal effectiveness and cost-effectiveness analyses are ongoing.

Discussion

Despite its potential, robotic rehabilitation adoption in LMICs faces financial, infrastructural, workforce, cultural, and ethical barriers, requiring equitable, sustainable implementation strategies.

Financial and cost barriers

Robotic rehabilitation devices are capital-intensive, often costing between USD 100,000 and 300,000 for a single system. For resource-limited health systems, these costs compete with essential investments in acute care, medicines, and human resources [39]. Maintenance and servicing of devices add recurring expenses, while lack of local manufacturing inflates costs due to import taxes and logistics [40]. Minimal insurance coverage for rehabilitation in LMICs shifts costs to patients and families, disproportionately limiting access to advanced technologies to wealthier groups.

Infrastructure and technical challenges

Robotic rehabilitation requires stable electricity, technical expertise, and suitable infrastructure, which many LMIC facilities lack due to power, connectivity, and space constraints [41].

Workforce and training limitations

LMICs face severe shortages of rehabilitation professionals, with less than 10% of required workforce density compared to HICs [42]. Robotic rehabilitation demands additional training in device operation and safety, necessitating structured education, academic partnerships, and hands-on fellowship programs to prevent underutilization.

Cultural acceptance and patient perspectives

Cultural acceptance of robotics varies; enthusiasm for technology contrasts with distrust of machines, while gender norms may restrict women's participation, underscoring the need for awareness campaigns and family-centered counselling [43].

Policy and governance gaps

Rehabilitation is often neglected in LMIC health policies, with funding skewed toward acute care and infectious disease management [44]. Robotic rehabilitation requires long-term vision, national policy support, and integration into universal health coverage schemes. Without policy frameworks, centres may remain isolated pilot projects without scalability or sustainability.

Ethical considerations

Robotic rehabilitation raises important ethical issues: Equity: Risk of widening disparities if advanced technologies are limited to affluent patients. Consent and Autonomy: As a new device for human use the patients must understand the risks, limitations, and alternatives before consenting to robotic therapy. Data Privacy: Devices generate sensitive health data, which require secure storage and protection against misuse. · Prioritization of Resources: Ethical dilemmas arise when scarce funds are spent on robotics while basic rehabilitation services remain underfunded.

Sustainability concerns

Sustainability in LMICs requires management funds, local capacity building, and supply chain resilience. Public–private partnerships, philanthropic support, and domestic innovation may help reduce dependency on imported technology. Local universities and engineering institutions can collaborate with medical centres to design low-cost robotic prototypes adapted to regional needs [45].

Research gaps

Most clinical trials on robotics are conducted in HICs, raising concerns about external validity. LMIC-specific research is sparse, particularly regarding cost-effectiveness, patient satisfaction, and long-term functional outcomes [46]. Without locally generated data, policymakers and funders remain hesitant to scale up robotic rehabilitation.

Conclusion

Robotic rehabilitation improves motor recovery and independence, but its adoption in LMICs is limited by cost, infrastructure, and workforce constraints. The BMU Robotic Rehabilitation Centre demonstrates how advanced technologies can be integrated into resource -limited settings to strengthen access, equity, research, and capacity building.

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Author contributions

Concept and design, or design of the research; or the acquisition, analysis, or interpretation of data: MAS. MIH. *Drafting the manuscript or revising it critically for important intellectual content:* MIH, FN. *Final approval of the version to be published:* MAS, MIH, FN, MAKA. *Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved:* MAS, MAKA.

Conflict of interest

We do not have any conflict of interest.

Data availability statement

We confirm that the data supporting the findings of the study will be shared upon reasonable request.

Supplementary file

None

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RESEARCH ARTICLE

Comparison of concurrent training versus high intensity interval training on speed and performance in collegiate football players

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Abstract

Background: Football is a physically demanding sport with a unique combination of strength, speed, endurance, agility and technical expertise. To meet these demands, training programmes should be carefully designed to optimise players' performance. This study explored the comparison of concurrent training (CT) and high-intensity interval training (HIIT) on speed and overall performance in collegiate football players.

Methods: A comparative experimental study was carried out between 30 September and 23 November 2024, involving forty purposively selected male university-level players. Participants were randomly designated to either a CT or HIIT group using a simple lottery, with 20 players in each group. Both groups completed an eight-week programme comprising three sessions per week. Speed and agility were evaluated before and after the intervention using the Illinois agility test and the repeated sprint ability test.

Results: Both training approaches significantly improved agility and sprint performance (P <0.001). The CT group reduced Illinois agility test times from 16.0 to 14.2 seconds and sprint times from 42.4 to 40.8 seconds. The HIIT group demonstrated greater improvements with agility times dropping from 16.4 to 12.4 seconds and sprint times from 42.7 to 38.5 seconds.

Conclusion: The study displayed improvement in speed and agility performance after the training interventions. Both methods enhanced speed and agility, however HIIT proved to be more effective than CT in improving performance.

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Key messages

This study among 40 male collegiate football players emphasises that high-intensity interval training is effective in boosting agility and sprint ability compared to concurrent training.

Introduction

Football is an intermittent, high-intensity team sport requiring players to repeatedly execute rapid movements such as sprinting, accelerating, decelerating, jumping, and changing direction, combined with lower-intensity activity. These demands place considerable physiological and neuromuscular stress on players, necessitating well-developed strength, speed, endurance, agility and repeated sprint ability; especially for collegiate athletes facing growing competitive pressures [1].

Sprinting and rapid directional changes are critical to football performance and often influence match outcomes. However, performing these actions under fatigue significantly increases mechanical strain on the musculoskeletal system, particularly the hamstrings and ankle structures, contributing to a high incidence of non-contact injuries [2]. Subsequently, training programmes must be carefully designed to enhance performance-related qualities while reducing fatigue-related risks.

Resistance training is widely recognised for improving maximal strength, power output, and neuromuscular efficiency which translates into effective sprinting, jumping and change-of-direction ability [3]. Conversely, endurance training enhances aerobic capacity and fatigue resistance, enabling players to sustain high-intensity efforts throughout a match [4]. Considering the limited time available during collegiate seasons, integrating these components effectively remains a practical challenge.

Concurrent training (CT), which combines resistance and endurance work within the same programme, is commonly used in football conditioning to develop multiple physical qualities simultaneously. While CT can be effective, research recommends that poor organisation may lead to an interference effect, where endurance training diminishes strength and power gains [5]. High-intensity interval training (HIIT) has emerged as a time-efficient alternative, improving aerobic capacity, anaerobic performance and sprint ability. HIIT involves repeated bouts of near-maximal effort interspersed with short recovery periods, closely mirroring the intermittent demands of football match play [6].

Despite the widespread use of CT and HIIT, direct comparisons of their effects on speed, agility and repeated sprint performance in collegiate football players remain scarce. Furthermore, there is a need for studies employing valid, field-based assessments to provide evidence-based training prescriptions. This study therefore aimed to compare the effects of CT and HIIT on speed, agility and sprint performance in collegiate football players using practical, field-based tests.

Methods

Study design

This study employed a comparative experimental design to investigate the effects of CT and HIIT on speed and performance in collegiate football players. The study was conducted from 30 September 2024 to 23 November 2024. A pre-test–post-test design was used to evaluate changes in performance variables following an eight-week training intervention.

Study population

Forty male collegiate football players aged between 18 and 25 years were recruited from various universities in Chennai using purposive sampling technique. All participants were actively engaged in college-level or club football training. Players with a history of cardiovascular conditions, musculoskeletal disorders or any injury within the previous six months were excluded from the study.

Sample size and randomization

The sample size was determined based on feasibility and the need to achieve sufficient statistical power for between-group comparisons. Participants were randomly assigned to two equal groups (n=20 each) using a simple lottery method. The groups were designated as the CT group and the HIIT group.

Training intervention

Both groups completed supervised training over eight weeks, with three sessions per week scheduled on non-consecutive days. Training intensity and progression were standardised across the intervention. Each session comprised multiple sets with controlled rest intervals, which were progressively increased throughout the programme to ensure adaptation and maintain safety.

CT group

The CT programme combined resistance training, plyometrics, sprint drills, and aerobic conditioning to develop the key physical attributes required for football performance. Training was structured across three weekly sessions. Day one directed on lower-body strength and aerobic conditioning, including exercises such as back squats, Romanian deadlifts, walking lunges, core stability work, and aerobic interval running. Day two aimed upper-body strength and speed development, incorporating bench press, pull-ups, push-ups, shoulder press, short-distance sprint drills, and resistance-band–assisted sprint starts. Day three concentrated on neuromuscular power and game-specific fitness through plyometric exercises (depth jumps, bounding, lateral hops, and single-leg box jumps) alongside 4v4 small-sided games. This integrated approach aimed to enhance muscular strength, power, endurance, and football-specific conditioning.

HIIT group

The HIIT programme was designed to improve speed, agility, repeated sprint ability, and cardiorespiratory fitness through short bursts of maximal or near-maximal effort. Training was conducted three times per week. On day one, sprint interval training, including 20–40 m linear sprints, acceleration sprints, and combined broad jump–sprint drills were performed. On day two, agility and change-of-direction drills using zig-zag cone runs, ladder drills, reactive shuttle runs, and T—test agility protocols were followed. Day three engaged on repeated sprint capacity and explosive power through repeated sprints, shuttle runs, countermovement jumps, lateral skater jumps, and progressive box jumps. This coordinated HIIT approach aimed to enhance neuromuscular performance and high-intensity football-specific fitness.

Outcome measures

Speed and performance following the training interventions were assessed using validated field-based tests. Agility and change-of-direction speed were measured with the Illinois agility test, while repeated sprint performance was evaluated using the repeated sprint ability test. The outcome of the performance for both tests was recorded in seconds, with lower times indicating superior performance.

Statistical analysis

Descriptive statistics for all variables were calculated and expressed as mean (standard deviation). Normality of the data was assumed before analysis. Assessment of pre- and post-test changes in Illinois agility and repeated sprint ability in both the CT and HIIT groups (within-group) was analysed using a two-way repeated-measures analysis of variance. Comparisons of Illinois agility and repeated sprint ability scores between the CT and HIIT groups (between-group) were analysed using a two-way analysis of variance to determine speed and performance differences at post-intervention. Statistical analyses were performed using the SPSS, version 25. Results were presented as mean differences (95% confidence interval), calculated from pre minus post test. All statistical tests were two-tailed, and the level of significance was set at $P <0.05$.

Results

Participant characteristics

Forty collegiate football players completed the eight weeks training intervention in this study. Baseline characteristics were comparable between groups. The mean (standard deviation) age was 21.3 (1.9) years, height 172.4 (6.1) cm, body weight 68.7 (5.6) kg, and body mass index 23.1 (1.8) kg/m^2. No statistically significant differences were observed between groups at baseline.

Within-group changes

Both training interventions resulted in significant improvements in agility and repeated sprint performance. In the CT group, Illinois agility test times decreased from 16.0 (0.2) seconds to 14.2 (1.2) seconds ($P <0.001$). Repeated sprint ability performance also improved, with mean times reducing from 42.4 (0.5) seconds to 40.8 (0.5) seconds ($P <0.001$). The HIIT group demonstrated greater improvements. Illinois agility test times decreased from 16.4 (0.7) seconds to 12.4 (1.5) seconds ($P <0.001$). Repeated sprint ability test times improved from 42.7 (0.5) seconds to 38.5 (1.9) seconds ($P <0.001$) (Table 1).

Table 1 Pre- and post-test comparison in the concurrent training and high-intensity interval training groups (n=40)

Outcome measure	Pre-test	Post-test	Mean difference (95% CI)
Concurrent training group			
Illinois agility test (sec.)	16.0 (0.2)	14.2 (1.2)	−1.8 (−2.3 to −1.4)
Repeated sprint ability (sec.)	42.4 (0.5)	40.8 (0.5)	−1.6 (−2.0 to −1.1)
High-intensity interval training groups			
Illinois agility test (sec.)	16.4 (0.7)	12.4 (1.5)	−4.0 (−4.7 to −3.3)
Repeated sprint ability (sec.)	42.7 (0.5)	38.5 (1.9)	−4.3 (−5.1 to −3.4)

Results are mean (standard deviation); CI indicates confidence intervals
All changes are statistically significant at 1% level, two-way analysis of variances with repeated measures

Between-group comparison

Post-intervention comparisons demonstrated that the HIIT group performed better than the CT group in both tests. HIIT participants recorded significantly lower post-test times in the Illinois agility test [12.4 (1.5) seconds versus 14.2 (1.2) seconds] and the repeated sprint ability test [38.5 (1.9) seconds versus 40.8 (0.5) seconds] ($P <0.001$) (Table 2).

Table 2 Comparison of post-intervention outcomes between the training groups (n=40)

Outcome measure	Concurrent training	High-intensity interval training	P^a
Illinois agility test (sec.)	14.2 (1.2)	12.4 (1.5)	<0.001
Repeated sprint ability (sec.)	40.8 (0.5)	38.5 (1.9)	<0.001

[a]Two-way analysis of variance

Discussion

This study compared the effects of CT and HIIT on agility and repeated sprint ability in collegiate football players over an eight-week intervention. The key findings indicate that both training methods produced significant improvements in agility and repeated sprint performance; however, HIIT resulted in markedly greater gains across both measures. These outcomes suggested that, integrated strength–endurance approaches are beneficial, while HIIT may offer superior adaptations for speed and sprint-related performance in this population.

The greater improvements observed in the HIIT group can largely be supported by the principle of training specificity. Football match play is characterised by repeated high-intensity efforts interspersed with short recovery periods, closely reflecting the work-to-rest structure of HIIT. Training of this kind has been shown to enhance anaerobic capacity, phosphocreatine resynthesis, sprint economy and neuromuscular efficiency, which are essential for rapid accelerations, decelerations and repeated sprint actions [7,8]. The substantial reductions in Illinois agility test and repeated sprint ability times recorded in the HIIT group in this study support these physiological adaptations [9].

Although the CT group demonstrated significant improvements, the level of change was smaller compared with HIIT. This understanding aligns with an earlier study suggesting a potential interference effect when resistance and endurance training are performed within the same cycle in combination [10]. Residual neuromuscular fatigue and competing molecular signaling pathways may limit maximal speed and power adaptations, particularly when training duration and recovery are constrained [11]. Nevertheless, the improvements observed in the CT group highlight their value in developing multiple

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physical qualities simultaneously, which may be advantageous during extended preparatory phases. Evidence also suggests that the organisation and sequencing of CT that includes intensity distribution and recovery critically influence the extent of these adaptations in team sport athletes [12]. In this study, CT was shown to improved agility and repeated sprint ability, probably due to the inclusion of sport-specific strength and power exercises within the programme.

The significant improvements in repeated sprint ability following HIIT are consistent with previous studies reporting enhanced fatigue resistance and sprint maintenance in football players after HIIT [13]. Considering that, repeated sprint ability is strongly associated with match running performance and decisive game actions, these findings have important practical implications for football conditioning [14]. Moreover, the time-efficient nature of HIIT makes it particularly suitable during congested competitive schedules where training volume must be carefully managed [15]. Both groups exhibited meaningful improvements in agility, highlighting the role of high-intensity, football-specific training in enhancing neuromuscular coordination and change-of-direction performance. However, the superior agility gains in the HIIT group further support the use of movement-specific, high-velocity drills to optimise performance adaptations [16].

The strengths of this study include randomised group allocation, supervised training, and the use of validated field-based performance measures. The eight-week intervention reflects realistic training durations applicable to collegiate football settings. Despite having strengths in this research, it has some limitations. These include the relatively small sample size, short intervention period, and the inclusion of only male collegiate players, which may limit generalisability. Additionally, real game-play performance and long-term adaptations assessment were beyond the scope of this study.

Conclusion

In this study, both CT and HIIT significantly improved speed, agility and repeated sprint performance in collegiate football players. However, HIIT was more effective in enhancing these performance outcomes. These findings encourage the use of HIIT as an efficient and sport-specific conditioning strategy for football players. Future research should be done on larger samples, longer intervention periods, and match -based performance analysis to further validate these findings.

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Author contributions

Concept or design of the work; or the acquisition, analysis, or interpretation of data for the work: SPS. *Drafting the work or reviewing it critically for important intellectual content:* VNK. *Final approval of the version to be published:* SPS, RK, BA, VNK, PK. *Accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved:* BA.

Conflict of interest

We do not have any conflict of interest.

Data availability statement

We confirm that the data supporting the findings of the study will be shared upon reasonable request.

Supplementary file

None

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RESEARCH ARTICLE

Comparison of disability levels between haemorrhagic and ischaemic stroke in the sub-acute phase: A cross-sectional study

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Abstract

Background: Stroke remains a leading cause of disability worldwide, with hemiplegia being a common consequence. The Barthel Index (BI) is a widely used tool for assessing disability in activities of daily living (ADL). This study aimed to evaluate the level of disability among patients with sub-acute hemiplegic stroke and compare disability levels between ischaemic and haemorrhagic stroke within 3 weeks of onset in an acute rehabilitation setting.

Methods: A cross-sectional study was conducted at Sher-E-Bangla Medical College and Hospital in the Barishal division of Bangladesh, from October 2022 to March 2023. Seventy-five patients aged 20–85 years, experiencing a first-ever stroke with hemiplegia, were assessed using the BI. Patients with subarachnoid haemorrhage, recurrent stroke, or severe comorbidities were excluded. BI scores and dependency levels were expressed in mean and standard deviation and compared between groups using Student's *t* tests, with statistical significance set at $P < 0.05$.

Results: The mean (standard deviation) BI scores were significantly higher ($P < 0.001$) in ischaemic stroke patients, 62.0 (20.8), compared to haemorrhagic stroke patients, 24.6 (21.3). The ischaemic stroke patients predominantly exhibited severe dependency (64.1%), while haemorrhagic stroke patients showed total dependency (52.8%). Bathing, bladder control, and stair climbing were the most affected ADL domains in both groups. Hypertension was the most common risk factor (62.7%), followed by diabetes mellitus (37.3%).

Conclusion: Haemorrhagic stroke patients exhibit greater disability than ischaemic stroke patients in the acute rehabilitation phase. These findings underscore the need for tailored rehabilitation strategies to address severe dependency, particularly in haemorrhagic stroke survivors.

Key messages

Patients with haemorrhagic stroke generally experience more severe disability in the early weeks after onset compared to those with ischaemic stroke. They often face greater challenges in daily activities such as bathing, bladder control, and stair climbing. Hypertension is the most common underlying risk factor. These findings highlight the importance of starting early, intensive rehabilitation that is tailored to the type of stroke in order to achieve better recovery outcomes.

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Introduction

Stroke remains a leading cause of adult disability worldwide. In 2019, there were approximately 143 million disability-adjusted life years lost due to stroke, with sub-Saharan and South Asian regions bearing a disproportionate burden [1]. In Bangladesh, the incidence and prevalence of stroke continue to rise, estimated at approximately 11 per 1000 population, with ischaemic strokes accounting for two-thirds of cases [2, 3]. Hemiplegia, partial or complete paralysis of one side of the body, is one of the most prevalent and disabling sequelae of stroke, affecting up to 80% of survivors early on [3].

The immediate period following a stroke, particularly within the first few weeks, is critical for functional recovery. Comprehensive rehabilitation interventions initiated during this sub-acute phase have been shown to significantly improve functional independence and reduce long-term disability. Accurate and reliable assessment of disability levels during this period is essential for tailoring rehabilitation programs to individual patient needs and monitoring their progress [4].

The Barthel Index (BI) is a widely recognized and validated tool used to assess functional independence in performing activities of daily living (ADL) [5]. It provides a quantitative measure of disability by evaluating a patient's ability to perform ten basic ADLs, including feeding, bathing, grooming, dressing, bowel and bladder control, toilet use, transfers from bed to chair and back, mobility on level surfaces, and stairs [6]. The BI is known for its ease of administration, reliability, and sensitivity to changes in functional status, making it a valuable instrument in both clinical practice and research settings for stroke rehabilitation [7].

Despite the recognized burden of stroke and the importance of early disability assessment, comparative data on the levels of disability between ischaemic and haemorrhagic strokes within three weeks of onset remain limited, particularly in the context of Bangladesh. This study aimed to evaluate the level of disability among patients with sub-acute hemiplegic stroke in a tertiary care hospital in Bangladesh and compare the disability levels between those with ischaemic and haemorrhagic stroke in an acute rehabilitation setting.

Methods

Study design and participants

This cross-sectional study was conducted in the Department of Physical Medicine and Rehabilitation at Sher-E-Bangla Medical College Hospital, Barishal, Bangladesh, from October 2022 to March 2023. This study consecutively enrolled patients with a first-ever stroke with hemiplegia. Inclusion criteria were age between 20–85 years, assessed within three weeks of stroke onset and within 48 hours of admission, and diagnosis of hemiplegia confirmed by clinical examination and computed tomography (CT) scan of the brain. Patient were excluded if they had subarachnoid haemorrhage, a history of recurrent stroke, severe comorbidities (e.g., persistent unconsciousness, recent myocardial infarction). A total of 75 patients meeting the eligibility criteria were included in the analysis. Ischaemic and haemorrhagic stroke types were classified based on CT scan findings.

Instruments and data collection

Data were collected using a structured case record form that included sociodemographic variables (age, sex, education, occupation, residence), stroke characteristics (side of hemiplegia, handedness etc.), and risk factors (e.g., hypertension and diabetes).

Disability was assessed by trained postgraduate doctors familiar with standardized Barthel Index (BI) administration within 48 hours of admission, which evaluates 10 activities of daily living (ADL) domains (feeding, bathing, grooming, dressing, bowel, bladder, toilet use, transfers, mobility and stairs) with a total score ranging from 0 (total dependency) to 100 (full independence). BI scores were categorised as: 0–20 (total dependency), 21–60 (severe dependency), 61–90 (moderate dependency), 91–99 (slight dependency), and 100 (complete independence) [5]. Assessments were performed at admission (or specify timing) by trained postgraduate doctors using standardized instructions, through direct observation and patient self-report.

Ethical considerations

This study was conducted following strict adherence to ethical principles outlined in the Declaration of Helsinki. Informed written consent was obtained from all participants or their legally authorised representatives after providing clear explanations about the study objectives, procedures, potential risks, and benefits. Participants were assured that their involvement was voluntary and that they could withdraw at any point without affecting their standard care. Confidentiality and anonymity of all personal and clinical data were strictly maintained. No invasive procedures or interventions were carried out as part of the study. Only routine clinical assessments and non-invasive disability evaluations were included. No financial or material inducements were provided for participation.

Statistical analysis

Data were analysed using SPSS version 20. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarise demographic and clinical variables. There were no missing data for primary outcome variables, and data distribution was assessed prior to analysis and deemed suitable for parametric testing. An independent-sample Student's *t* test was used to compare mean BI scores and domain-specific ADL scores between ischaemic and haemorrhagic stroke groups. Categorical variables, including levels of dependency, were compared using the chi-square test or Fisher's exact test, as appropriate. A P of <0.05 was considered statistically significant.

Results

Demographic characteristics

Of the 75 patients, 50 (66.7%) were men and 25 (33.3%) were women (between-group P = 0.99). The overall mean (standard deviation) age was 58.0 (13.5) years, with no significant difference between ischaemic 60.0 (12.8) years and haemorrhagic stroke patients 56.0 (14.9) years. Haemorrhagic stroke were more frequent in older adults (60-85 years) the compared with the ischaemic group (41.7% vs. 20.5%, P = 0.020) compared to younger adults (20-59 years). The distribution of risk factors did not differ significantly between stroke subtypes (Table 1).

Table 1 Background and clinical characteristics of the study participants with stroke (n=75)

Variables	Overall n=75	Ischaemic n=39	Haemorrhagic n=36	P
Age group				
20-59	52 (69.3)	31 (79.5)	21 (58.3)	0.02
60-85	23 (30.7)	8 (20.5)	15 (41.7)	
Sex				
Men	50 (66.7)	26 (66.7)	24 (66.7)	0.99
Women	25 (33.3)	13 (33.3)	12 (33.3)	
Side of hemiplegia				
Right	44 (58.7)	24 (61.5)	20 (55.6)	0.59
Left	31 (41.3)	15 (38.5)	16 (44.4)	
Clinical impairments				
Speech abnormalities	47 (62.7)	23 (59.0)	24 (66.7)	0.49
Spasticity	39 (52.0)	15 (38.5)	24 (66.7)	0.02
Dysphagia	22 (29.3)	9 (23.1)	16 (44.4)	0.05
Bowel/bladder incontinence	5 (6.7)	4 (10.3)	1 (2.8)	0.20[a]
Risk factors				
Hypertension	47 (62.7)	25 (64.1)	22 (61.1)	0.80
Diabetes mellitus	28 (37.3)	17 (43.6)	11 (30.6)	0.24
Smoking	23 (30.7)	13 (33.3)	10 (27.8)	0.60
Family history	15 (20.0)	9 (23.1)	6 (16.7)	0.49
Barthel Index score group				
Total dependency (0–20)	19 (25.3)	0 (0)	19 (52.8)	<0.01[a]
Severe dependency (21–60)	41 (57.0)	25 (64.1)	17 (47.2)	
Moderate dependency (61–90)	10 (13.3)	10 (25.6)	0 (0)	
Slight dependency (91–99)	0 (0)	0 (0)	0 (0)	

All are number (%); [a] Fisher's exact test

Clinical impairments and risk factors

All participants were right-handed. Right-sided hemiplegia was observed in 44 patients (58.7%), with no difference between stroke subtypes. Within three weeks of stroke onset, common clinical impairments included speech abnormalities, spasticity, and dysphagia. Speech abnormalities were present in 62.7% of patients overall (59.0% ischaemic vs. 66.7% haemorrhagic). Spasticity was significantly more frequent in haemorrhagic stroke patients than in ischaemic stroke patients (66.7% vs. 38.5%, P = 0.02). Dysphagia was also more prevalent in haemorrhagic stroke (44.4%) compared with ischaemic stroke (23.1%). Bowel and bladder incontinence was uncommon overall and occurred in a small proportion of patients. Hypertension was the most prevalent vascular risk factor (62.7%), followed by diabetes mellitus (37.3%), smoking (30.7%), and positive family history (20.0%).

Table 2 Comparison of mean (standard deviation) Barthel activities of daily living (ADL) scoring of ischaemic and haemorrhagic stroke (n=75)

ADL scores	Ischaemic stroke	Haemorrhagic stroke	P
Feeding score	5.8 (2.9)	4.2 (3.5)	0.04
Bathing score	1.2 (2.1)	0 (0)	-
Grooming score	2.3 (2.5)	1.8 (0.9)	0.05
Dressing score	6.3 (3.2)	2.1 (2.5)	<0.001
Bowel score	8.1 (2.5)	1.5 (2.3)	<0.001
Bladder score	9.0 (2.9)	1.3 (3.0)	<0.001
Toilet use score	6.2 (2.1)	2.8 (3.3)	<0.001
Transfers score	8.3 (4.0)	3.6 (3.1)	<0.001
Mobility score	10.0 (3.4)	5.3 (4.0)	<0.001
Stair score	5.1 (2.4)	1.3 (2.2)	<0.001
Overall	62.0 (20.8)	24.6 (21.3)	<0.001

Levels of dependency and ADL domains

Dependency levels differed significantly between groups (P < 0.001). In the ischaemic stroke group, 64.1% of patients had severe dependency (BI: 21–60) and 25.6% had moderate dependency (BI: 61–90), with no cases of total dependency. In contrast, 52.8% of haemorrhagic stroke patients had total dependency (BI: 0–20) and the remainder had severe dependency, with no moderate or slight dependency.

Disability outcomes

Mean Barthel Index (BI) scores were significantly higher in ischaemic stroke patients 62.0 (20.8) compared with haemorrhagic stroke patients 24.6 (21.3). Their mean different 37.4 (95% confidence interval, 27.8–47.2) was statistically significant (P <0.001). Age-stratified analysis demonstrated that older adults (60–85 years) had lower mean BI scores than younger adults (20–59 years) in both stroke subtypes. Across the age groups (20–59 and 60–85 years) patients with haemorrhagic stroke consistently exhibited markedly lower functional independence compared patients with ischaemic stroke, based on Barthel Index scores (Figure 1).

Across individual ADL domains, bathing, bladder control, and stair climbing were the most severely affected activities in both groups (Table 2). Haemorrhagic stroke patients demonstrated significantly lower scores across most ADL domains, particularly dressing, bowel and bladder control, toilet use, transfers, mobility, and stair climbing (P < 0.001), as well as feeding, bathing, and grooming (P < 0.05).

Discussion

This study reveals that, within 3 weeks of onset in an acute rehabilitation setting, haemorrhagic strokes are associated with significantly greater disability than ischaemic strokes. The mean BI score for ischaemic stroke patients (62.0) corresponds to moderate to severe dependency on the BI scale, while the haemorrhagic group's score (24.6) reflects total to severe dependency. These findings challenge the common assumption that ischaemic strokes result in greater disability during the acute phase, likely due to the more severe neurological impact of intracerebral haemorrhage.

The higher disability observed in haemorrhagic strokes aligns with previous studies. For example, Nakao *et al.* [8] reported lower BI scores in

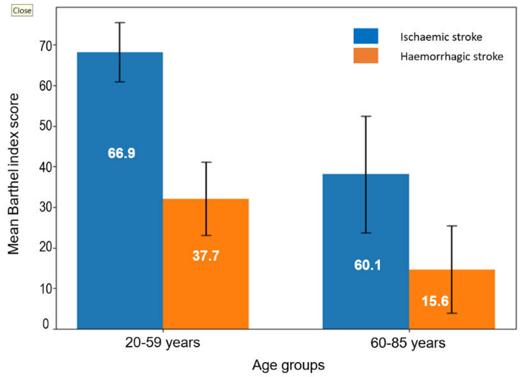

Figure 1 **Mean Barthel Index (95% confidence interval) score by age group and stroke type (n=75)**

haemorrhagic stroke compared to ischaemic stroke. The greater disability in haemorrhagic stroke patients may be attributed to larger hematoma volumes and cerebral oedema, which cause more extensive neurological damage [9].

The predominance of total dependency among haemorrhagic stroke patients (52.8%) versus severe dependency in ischaemic stroke patients (64.1%) underscores the need for intensive early rehabilitation interventions tailored to haemorrhagic stroke survivors. Bathing, bladder control, and stair climbing emerged as the most consistently impaired domains, highlighting critical targets for rehabilitation aimed at improving mobility and personal care.

Demographically, the male predominance (2:1) and mean age (58.0 years) are consistent with regional studies [9]. The higher prevalence of right-sided hemiplegia (59%) contrasts with some studies reporting left-sided predominance, which may reflect sample characteristics or local epidemiological variations [10]. Hypertension as the leading risk factor (62.7%) aligns with global and local data, emphasizing its role in stroke prevention [11].

The study's findings also highlight the predictive value of early BI scores. Granger *et al.* [12] identified a BI score of 60 as a threshold indicating transition from dependence to assisted independence, suggesting that ischaemic stroke patients, with a mean BI of 62, may have better potential for recovery compared to haemorrhagic stroke patients. The greater impairment in bladder control observed among haemorrhagic stroke patients highlights the need for targeted interventions, such as timed voiding schedules or pharmacological management. The consistently lower Barthel Index scores observed among older adults, particularly those with haemorrhagic stroke, likely reflect age-related frailty, higher comorbidity burden, and reduced physiological reserve, underscoring the need for age- and stroke-specific rehabilitation strategies.

The sample size was determined by consecutive enrolment during the study period, and no formal power calculation was conducted, which may limit the generalizability of findings. This study did not adjust for potential confounders such as age or comorbidities, which may influence disability outcomes.

Conclusion

Haemorrhagic stroke patients experience more severe disability than ischaemic stroke patients within 3 weeks of onset, as evidenced by lower BI scores and higher rates of total dependency. Bathing, bladder control, and stair climbing are critical areas for intervention. These findings advocate for early, intensive rehabilitation tailored to stroke type to optimize functional outcomes. Larger, multi-centre studies are needed to validate and expand these insights.

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Conflict of interest

We do not have any conflict of interest.

Data availability statement

We confirm that the data supporting the findings of the study will be shared upon reasonable request.

Supplementary file

None

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RESEARCH ARTICLE

Quality of life in patients with adhesive capsulitis and diabetes mellitus

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Abstract

Background: Adhesive capsulitis is a common and disabling musculoskeletal complication in diabetes mellitus, often affecting the dominant shoulder. This results in significant pain, limited movement, and decreased quality of life (QoL). This study aimed to evaluate the stage-specific effects on QoL in diabetic patients with adhesive capsulitis of the dominant shoulder.

Methods: This cross-sectional study was carried out over six months at a tertiary care hospital in Bangladesh. Diabetic patients with adhesive capsulitis of the right shoulder were included. Pain, disability, and quality of life were assessed using the Visual Analogue Scale, shoulder pain and disability index, disabilities of the arm, shoulder and hand score, and the Short-Form Health Survey (SF-36). Data were analysed using nonparametric tests, correlation analysis, and multiple linear regression.

Results: Among 80 participants, most were in the freezing stage (77.5%). This stage was marked by the most severe pain [mean (standard deviation) Visual Analogue Scale: 7.5 (0.9)] and the highest overall upper-limb disability [mean (standard deviation) disabilities of the arm, shoulder and hand: 80.3 (6.3)]. The frozen stage also showed the most significant shoulder-specific disability [mean (standard deviation) shoulder pain and disability index-Disability: 76.0 (4.3)] and the lowest scores on the SF-36 physical 30.9 (3.7) and mental 28.1 (0.5) components. Regression analysis identified the SF-36 physical component summary as the strongest predictor of mental health-related QoL (β=0.900, P <0.001).

Conclusion: Adhesive capsulitis of the dominant shoulder imposes a significant, stage-specific burden on QoL in patients with diabetes. The burden shifts from a pain-focused phase to a stiffness-focused phase, with substantial functional and psychosocial effects. Early detection and stage-specific rehabilitation are crucial for reducing disability and improving patient outcomes.

Key messages

Adhesive capsulitis of the dominant shoulder in diabetic patients significantly impairs quality of life. The freezing stage involves intense pain, while the frozen stage is marked by severe stiffness and the greatest decline in physical and mental well-being. Recognizing these distinct stages early is crucial for guiding targeted treatment, reducing disability, and enhancing long-term functional and quality-of-life outcomes.

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Introduction

Adhesive capsulitis, also known as frozen shoulder, is a disabling musculoskeletal condition characterized by progressive shoulder pain and stiffness, accompanied by restriction of active and passive glenohumeral movements. Although often considered self-limiting, with resolution occurring over 12–18 months, up to 40% of patients experience persistent pain, stiffness, and functional limitations due to capsular inflammation and fibrosis [1, 2].

Adhesive capsulitis is associated with diabetes mellitus [3]. People with diabetes have a 5 fold higher risk of developing adhesive capsulitis , with a reported prevalence of 10–30%. In patients with diabetic, adhesive capsulitis is often more severe, lasts longer, and responds poorly to treatment, which increases the risk of long-term disability [4, 5, 6].

Clinically, adhesive capsulitis progresses through well-recognised stages-painful, freezing, frozen, and thawing-over months or even years, with variable degrees of pain and functional impairment [7]. While many patients eventually regain shoulder motion, recovery may be delayed or incomplete, particularly in the presence of diabetes or poor glycaemic control [8]. Conservative management remains the cornerstone of treatment, though diabetic patients frequently experience residual symptoms despite intervention. Clinically, adhesive capsulitis progresses through stages of pain, freezing, and thawing over several months to years, with varying degrees of pain and functional limitation [6]. Recovery may be delayed or incomplete, especially in patients with diabetes or poor glycaemic control, and residual symptoms often persist despite conservative treatment [8].

The shoulder plays a critical role in performing activities of daily living, occupational tasks, and self-care. Adhesive capsulitis affecting the dominant shoulder, typically the right, can substantially impair function, leading to increased dependency and psychosocial stress. In individuals with diabetes, who often present with additional systemic complications, involvement of the dominant shoulder may further exacerbate functional limitations and compromise quality of life (QoL). QoL, encompassing physical, psychological, and social well-being, is substantially reduced in adhesive capsulitis, particularly in physical functioning and pain, and these effects are more pronounced among patients with diabetes [9]. Despite this, data on QoL in diabetic patients with adhesive capsulitis of the dominant shoulder remain limited, especially in low- and middle-income countries [10]. The present study aims to assess QoL in patients with adhesive capsulitis of dominant shoulder and diabetes mellitus.

Methods

Design and population

This cross-sectional study was conducted at the Department of Physical Medicine and Rehabilitation at Dhaka Medical College Hospital from July to December 2018. The study population included diabetic patients presenting with adhesive capsulitis of the dominant (right) shoulder at the outpatient department.

Sample and sampling

A purposive sampling technique was used to enroll eligible participant patients were recruited consecutively form the start date. A total of 80 patients were enrolled. Inclusion criteria included: (i) diagnosed cases of adhesive capsulitis of the right shoulder, (ii) confirmed diagnosis of diabetes (type 1 or type 2), and (iii) age 30 years or older. Patients with a history of shoulder trauma, rotator cuff tears, cervical radiculopathy, inflammatory arthritis, or recent shoulder surgery were excluded.

Data collection process

Eligible participants were selected through a detailed clinical history, physical examination, and relevant investigations. The diagnosis of adhesive capsulitis was made clinically, based on established diagnostic criteria, including an insidious onset of shoulder pain, progressive restriction of both active and passive glenohumeral range of motion-particularly external rotation-and exclusion of alternative causes of shoulder stiffness through regular radiographic evaluation.

Data collection tools

The visual analogue scale (VAS) [11] was used to measure pain intensity. The shoulder pain and disability index (SPADI) [12] assessed pain and functional limitations related to shoulder movement. The disabilities of the arm, shoulder, and hand (DASH) [13] score measured overall upper-extremity disability. Finally, the Short-Form Health Survey (SF-36) [14] assessed QoL across eight domains, encompassing physical and mental health.

Statistical analysis

Data were analysed using SPSS version 26. Descriptive statistics summarised demographic and clinical variables, presenting frequencies and percentages for categorical data and means with standard deviations for continuous data. The normality of continuous outcome variables VAS, DASH, SPADI, and SF-36 scores was assessed with the Shapiro-Wilk test. Since the assumption of normality was violated, non-parametric tests were used for subsequent inferential analysis. The Kruskal-Wallis H test compared scores across the three stages of adhesive capsulitis (Freezing, Frozen, Thawing). When a significant difference was found (P <0.05), post-hoc pairwise comparisons were carried out using the Dunn-Bonferroni method.

To identify predictors of mental health-related QoL, a multiple linear regression analysis was conducted with the SF-36 mental component summary score as the dependent variable. The model included key clinical scores (VAS, DASH, SPADI, and SF-36 physical component summary scores) and demographic variables. Multicollinearity was evaluated through variance inflation factors. For all analyses, a *P* <0.05 was considered statistically significant.

Ethical considerations

All participants provided prior written informed consent after being thoroughly informed about the study's purpose and procedures. Participation was voluntary, with confidentiality maintained through data anonymisation and secured storage. Patients had the right to withdraw at any time without affecting their medical care. The study was conducted in accordance with the Declaration of Helsinki to ensure that participants' rights and welfare were protected throughout the study.

Results

The study participants (n=80) primarily consisted of older adults, women, and socioeconomically disadvantaged individuals. The mean (standard deviation) age was 56.6 (7.3) years, with women making up 66.3%. Nearly 40% were illiterate, and most were homemakers (66.3%). The average duration of adhesive capsulitis was 7.0 (3.7) months (Table 1).

Table 1 Background characteristics of the study participants (n=80)

Variables	Number (%)
Age in years [a]	56.6 (7.3)
Sex	
Male	27 (33.7)
Female	53 (66.3)
Educational status	
Illiterate	31 (38.8)
Primary	23 (28.8)
Secondary and above	26 (32.5)
Occupational status	
Homemaker	53 (66.3)
Service holders	18 (22.5)
Others	9 (11.3)
Duration of adhesive capsulitis in month [a]	7.0 (3.7)

[a] Mean (standard deviation)

The distribution of participants across adhesive capsulitis stages was as follows: 77.5% in the freezing stage, 18.8% in the frozen stage, and 3.8% in the thawing stage. Patient-reported outcomes varied significantly across these stages (Table 2). The freezing stage was characterised by the most severe pain, with a mean (standard deviation) VAS score of 7.5 (0.9), and the highest overall upper limb disability, reflected in a mean (standard deviation) DASH score of 80.3 (6.3). In contrast, the frozen stage showed the most significant shoulder-specific functional disability, with an average SPADI score of 78.0 (2.9), despite lower pain levels. The thawing stage demonstrated significant improvement across all measures, approaching normal function and minimal pain.

Table 2 Distribution of patients by stages of adhesive capsulitis and pain score according to visual analogue scale, disabilities of the arm, shoulder and hand score, and shoulder pain and disability index (n=80)

Stages of adhesive capsulitis	Freezing	Frozen	Thawing	*P*[a]
Visual analogue scale	7.5 (0.9)	5.6 (0.5)	1.0 (0.0)	0.001
Disabilities of the arm, shoulder and hand	80.3 (6.3)	73.1 (5.6)	10.0 (0.0)	0.001
Shoulder pain and disability index	78.0 (2.9)	78.6 (3.4)	35.4 (1.5)	0.427

[a]Kruskal-Wallis H test; Values are mean (standard deviation); Post-hoc adjustment method (Dunn-Bonferroni)

Health-related QoL, as assessed by the SF-36, was significantly reduced during active disease phases. Both the physical component summary and mental component summary scores were at their lowest during the frozen stage [physical component summary: 30.9 (3.7); mental component summary: 28.1 (0.5)], reflecting significant declines in physical and mental health. Scores improved substantially during the thawing stage [physical component summary: 79.5 (1.0); mental component summary: 85.6 (1.0); *P* <0.001] for both comparisons), highlighting the reversible nature of QoL impairment with disease recovery (Table 3).

Table 3 Distribution of patients by stages of adhesive capsulitis (AC) with shoulder pain and disability index (SPADI) and short form health survey (SF-36) scores (n=80)

Scores by stages	Mean (standard deviation) [a]
SPADI scores	
Pain scale	
Freezing	39.4 (4.4)
Frozen	26.2 (1.4)
Thawing	11.0 (1.0)
Disability scale	
Freezing	54.6 (5.1)
Frozen	76.0 (4.3)
Thawing	35.0 (1.0)
SF-36 scores	
Physical component summary	
Freezing	38.5 (1.1)
Frozen	30.9 (3.7)
Thawing	79.5 (1.0)
Mental component summary	
Freezing	31.2 (1.0)
Frozen	28.1 (0.5)
Thawing	85.6 (1.0)

[a] Kruskal-Wallis H test; Post-hoc adjustment method (Dunn-Bonferroni), All differences were significant at 1% level

Multiple regression analysis further clarified predictors of mental health-related QoL (Table 4). The physical component summary (β=0.900, *P* <0.001) and duration of adhesive capsulitis (β=0.185, *P* <0.001) were significant positive predictors of the mental component summary. Meanwhile, the DASH score was a significant negative predictor (β=−0.170, *P*=0.001). The model accounted for 96% of the variance in mental health outcomes (Adjusted R^2=0.96).

Discussion

Adhesive capsulitis is a chronic, debilitating musculoskeletal disorder that substantially affects health-related QoL depending on the stage. This study specifically explored this impact in a high-risk group diabetic patients with adhesive capsulitis of the dominant shoulder. Our results not only confirm a significant decline in QoL but also demonstrate a clear temporal progression in disability type, shifting from an initial pain-focused phase to a later stiffness-focused phase, with the latter having the most significant overall effect on physical and psychological health.

Table 4 **Multiple regression model of mental component summary with physical component summary, visual analogue scale, shoulder pain and disability index, disabilities of the arm, shoulder and hand among the respondents (n=80)**

Independent variables	Unstandardized Coefficients β	Standardized Coefficients β	Partial Correlations	P
Visual analogue scale	-0.24	-0.036	-0.082	0.493
Shoulder pain and disability index	0.197	0.161	0.219	0.064
Disabilities of the arm, shoulder and hand	-0.123	-0.170	-0.373	0.001
Physical component summary	1.08	0.900	0.823	<0.001
Age	0	0	-0.001	0.994
Duration of adhesive capsulitis	0.529	0.185	0.446	<0.001
Sex	-0.694	-0.031	-0.051	0.669
Education	0.228	0.026	0.066	0.582
Occupation	-0.661	-0.043	-0.091	0.447

Dependent variable: Mental component summary; Adjusted R2 = 0.96

The established association between adhesive capsulitis and diabetes mellitus is evident in our cohort, in which all participants had a confirmed diabetes mellitus diagnosis [3, 4]. Although detailed data on the duration of diabetes were not formally analysed due to inconsistencies in data collection methods, the literature strongly supports the conclusion that prolonged hyperglycemia, along with associated microvascular and collagen abnormalities, contributes to the development and severity of capsular fibrosis [4, 10]. The demographic composition of our sample—primarily older women of lower socioeconomic status provides essential context. However, it is essential to note that socioeconomic variables were only described and not included in the inferential analyses, as the validity and standardization of their measures were not ensured within the scope of this study.

The distribution of participants across disease stages freezing, frozen and thawing likely reflects real-world healthcare-seeking patterns, in which patients most often seek treatment during the highly symptomatic freezing phase [6]. This distribution also highlights the chronic nature of adhesive capsulitis, with only a few individuals achieving full resolution during the study's cross-sectional observation period [15].

Our results reveal distinct, stage-specific profiles of pain, disability, and QoL impairment. The freezing stage was characterised by the most intense pain, as indicated by peak VAS and SPADI pain scores. This phase also corresponded to the highest level of overall upper-limb disability, as reflected by the maximum DASH score. This aligns exactly with the clinical understanding of the initial, inflammatory pain-focused phase of adhesive capsulitis [6]. In contrast, progression to the frozen stage was characterised by a notable decrease in pain, yet it exhibited the greatest shoulder-specific functional disability, as indicated by the peak SPADI-disability score. Importantly, this stage was linked to the most severe decline in overall QoL, with both the physical and mental component summaries of the SF-36 reaching their lowest points. This pattern indicates that while pain primarily drives early suffering and overall dysfunction, the intense stiffness and mechanical restriction during the frozen stage.

The multiple regression model, which explained 96% of the variance in mental health-related QoL, identified the physical component summary as the most significant positive predictor, underscoring the close association between physical and mental well-being in chronic musculoskeletal disease [16]. Additionally, although adhesive capsulitis duration was a significant positive predictor in the model, the DASH score a measure of overall upper-limb disability was a significant negative predictor, indicating that general functional impairment affects mental health outcomes beyond the shoulder joint.

These findings sharpen the clinical understanding of disability in adhesive capsulitis. The high DASH score during the freezing stage shows that severe pain significantly hinders integrated arm function. Conversely, the peak SPADI-disability score in the frozen stage indicates the specific mechanical failure of the stiffened glenohumeral joint. This distinction has direct therapeutic implications: during the freezing stage, management should focus on aggressive multimodal pain control to enable patient participation in rehabilitation, whereas the frozen stage requires targeted, persistent manual therapy and mobilization techniques aimed at restoring joint mechanics and functional capacity [8].

The SF-36 results effectively quantify the multidimensional burden of adhesive capsulitis. The significantly decreased scores across both physical and mental health domains during the active disease stages, especially the frozen phase, confirm that adhesive capsulitis is not merely a localised orthopedic condition but a substantial determinant of overall health status. The notable normalisation of scores during the thawing stage strongly suggests that resolution of capsular pathology is directly linked to the restoration of QoL. This underscores the importance of incorporating patient-reported outcome measures, such as the SF-36, into routine clinical assessment to fully understand the disease burden and guide patient-centered management strategies [16].

This study's strengths include the use of multiple validated tools to provide a thorough, patient-centered clinical assessment, a focus on the dominant shoulder in a diabetic population in a low-resource setting an understudied context and the use of advanced statistical methods to clarify predictive relationships. However, limitations must be acknowledged. The cross-sectional design prevents causal conclusions about disease progression. The small sample size, especially during the thawing stage, restricts the generalizability of the results for that phase. The purposive sampling approach may introduce selection bias. Importantly, although some demographic and clinical variables were collected, they were not included in formal multivariate models because of concerns about their measurement validity and consistency, which limits the ability to examine their potential moderating or mediating effects.

Despite these limitations, this study provides valuable clinical insights. It highlights the usefulness of clinical staging not only for prognosis but also for predicting the patient's primary challenge-whether pain or stiffness-and for assessing the resulting impact on QoL. This knowledge is essential for setting realistic treatment expectations, prioritising stage-specific rehabilitation goals, and ultimately improving functional and quality-of-life outcomes for diabetic patients with this disabling condition. The sample is predominantly female, older, and of lower socioeconomic status, which may limit the generalisability of the findings to other populations. Socioeconomic and duration-of-diabetes data were excluded from the analysis due to insufficient data collection validity.

Conclusion

Adhesive capsulitis of the dominant shoulder significantly affects QoL in patients with diabetes, which vary with stages. The freezing stage is marked by severe pain and overall upper-limb impairment, whereas the frozen stage is characterised by extreme stiffness, maximal shoulder dysfunction, and the most significant decline in both physical and mental health. The regression analyses showing physical health and overall disability as key predictors of mental well-being, emphasize the complex effects of this condition. Management strategies should be adjusted to target the main challenge at each stage such as aggressive pain management during the freezing phase and intensive mobilisation in the frozen phase. Patient-reported QoL measures in routine assessments can enhance clinical understanding, guide personalised treatment, and ultimately improve functional and mental outcomes for this vulnerable group.

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Author contributions

Concept or design of the work; or the acquisition, analysis, or interpretation of data for the work: JJU, NN. *Drafting the work or reviewing it critically for important intellectual content:* FN, SC. *Final approval of the version to be published:* JJU, FN, NN, SC, MAA. *Accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved:* JJU, NN.

Conflict of interest

We do not have any conflict of interest.

Data availability statement

We confirm that the data supporting the findings of the study will be shared upon reasonable request.

Supplementary file

None

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RESEARCH ARTICLE

Combined manual lymphatic drainage and exercise for lymphedema in breast cancer survivors: A randomised controlled trial

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Abstract

Background: Breast cancer–related lymphedema (BCRL) is a common and disabling complication of breast cancer treatment. Although exercise is recommended for BCRL management, the additional benefit of manual lymphatic drainage (MLD) remains unclear. This study compared the effectiveness of combined MLD and exercise versus exercise alone in reducing limb circumference and improving quality of life (QoL) among breast cancer survivors.

Methods: A randomised controlled trial was conducted between January 2022 and December 2023 at the Department of Physical Medicine and Rehabilitation, Khwaja Yunus Ali Medical College and Hospital, Enayetpur, Sirajganj, Bangladesh. Forty-two women with Stage I and II unilateral BCRL were randomly assigned to an exercise-only group (Group A, n=21) or a combined MLD and exercise group (Group B, n=21). Limb circumference at four anatomical sites and QoL, using the Bangla Lymphedema Life Impact Scale Version 2, were measured at baseline and after six weeks. Effects were evaluated using two-way repeated measures of analysis of variance. Adjusted mean differences between groups were further estimated using analysis of covariance, controlling for age, overweight, duration of oedema, chemotherapy, and radiotherapy.

Results: Both groups demonstrated significant improvements in limb circumference and QoL after six weeks; however, reductions were significantly greater in the combined MLD and exercise group (Group B), $P<0.001$. The largest mean difference in limb circumference was observed above the elbow (6.6 cm) in Group B. For QoL, the greatest improvement was noted in the physical domain, with a mean reduction of 5.2 points in Group B.

Conclusion: Combining MLD with exercise provides greater reduction in limb swelling and greater improvement in QoL compared with exercise alone in patients with BCRL.

Key messages

Breast cancer–related lymphedema remains a common complication despite the availability of several management options. This study demonstrated that incorporating manual lymphatic drainage (MLD) with exercise results in greater reductions in limb swelling and enhance quality of life compared to exercise alone. These findings advocate for the routine use of combined MLD and exercise in the rehabilitation of women with breast cancer-related lymphedema.

Introduction

Breast cancer-related lymphedema (BCRL) is a chronic and potentially debilitating complication arising from breast cancer surgery and adjuvant therapies, characterised by lymphatic fluid accumulation, limb swelling, pain, and functional impairment, which substantially reduces health-related quality of life (QoL) among survivors [1, 2, 3]. The prevalence of BCRL remains noteworthy, with variable estimates depending on treatment modalities and follow-up duration, and survivors often experience long-term physical and psychosocial sequelae [4]. Conservative interventions remain the cornerstone of management due to the absence of universally effective pharmacological therapies [5, 6].

The accepted standard of care available for BCRL includes manual lymphatic drainage (MLD), multilayer compression bandaging, skin care, and prescribed exercise. However, both MLD and exercise aim to enhance lymphatic transport, reduce extracellular fluid accumulation, and improve limb function. Despite widespread clinical use, the individual contributions of these components particularly MLD, remain the subject of ongoing investigation and debate [6].

Evidence indicates mixed outcomes regarding the effectiveness of MLD as an adjunct to exercise or other conservative treatments. Meta-analyses of RCTs have demonstrated that MLD may confer statistically significant improvements in pain intensity and may influence the incidence of lymphedema onset but have not consistently shown significant benefits in limb volume reduction or QoL outcomes when compared to control regimens without MLD [7].

Exercise interventions, including combined aerobic and resistance training, have increasingly been recognised for their potential to safely influence lymphatic function and mitigate lymphedema symptoms. Recent systematic reviews suggest that structured exercise, specifically high-intensity and combined modality programmes, can improve fluid balance and functional outcomes without exacerbating lymphedema and may enhance physical fitness and QoL in breast cancer survivors [8]. However, there remains limited high-quality evidence directly comparing the additive effect of MLD when combined with exercise versus exercise alone on objective measures such as limb circumference and patient-reported QoL. Given these gaps in the literature, the present randomised controlled trial was undertaken to compare the effectiveness of combining MLD with exercise versus exercise alone in reducing limb circumference and improving quality of life among breast cancer survivors with established lymphedema.

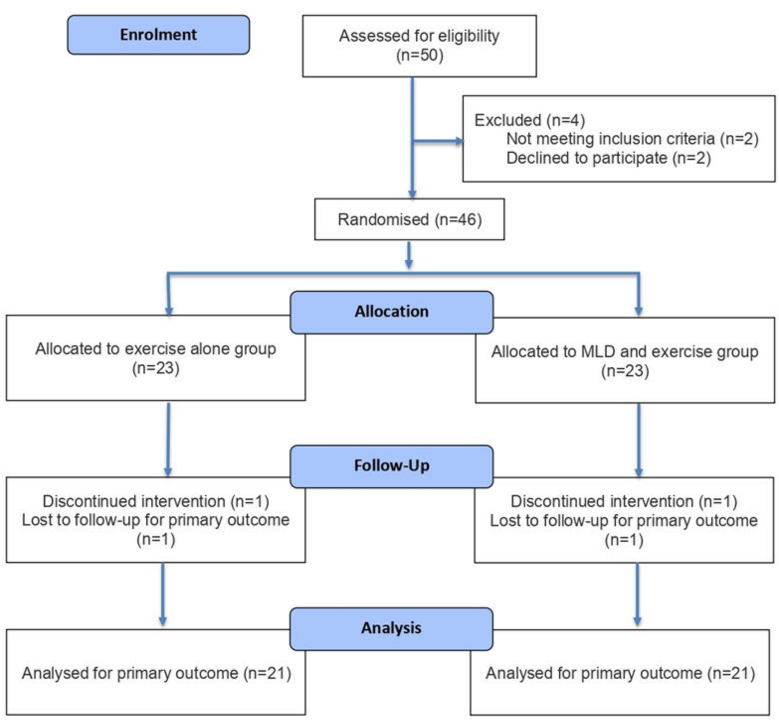

Figure 1 CONSORT flowchart of subject recruitment

Methods

Study design and setting

This was randomised controlled trial conducted at the Department of Physical Medicine and Rehabilitation (PMR), Khwaja Yunus Ali Medical College and Hospital, Enayetpur, Sirajganj, Bangladesh, a tertiary referral hospital. The trial was conducted out over a two-year period from January 2022.

Participants and eligibility criteria

Women aged 18 years or older with unilateral BCRL were eligible for inclusion. Participants had previously undergone modified radical mastectomy and received radiotherapy, chemotherapy, with or without hormonal therapy. Additional inclusion criteria were the presence of Stage I or II lymphedema without stiffness, a stable level of physical activity, and the absence of shoulder joint dysfunction, upper limb lymphatic disease, or cognitive impairment.

Patients were excluded if they had primary lymphedema, metastatic breast cancer, stage III lymphedema, bilateral upper limb involvement, a history of upper limb surgery other than breast cancer treatment, active infection, recent lymphedema-related interventions, or unwillingness to participate.

Eligible participants were identified from the PMR outpatient department following referral from department of General Surgery and Oncology. Screening was conducted by a physiatric team prior to enrolment.

Sample size and participant flow

Fifty patients were assessed for eligibility. Four were excluded (two did not meet the inclusion criteria and two declined participation). Forty-six participants were randomised equally into two groups (n=23 per group). During follow-up, four participants were lost (two from each group) due to discontinuation of intervention or inability to attend follow-up sessions. Consequently, 42 participants (21 per group) completed the study and were included in the final analysis. Participant flow is presented in the CONSORT diagram (Figure 1).

Randomisation and blinding

Participants were randomised using a computer-generated random numbers into either the exercise-only group (Group A) or the combined MLD plus exercise group (Group B). Allocation concealment was ensured using sealed, opaque envelopes prepared by an independent staff member not involved in recruitment or intervention delivery. Outcome assessors were blinded to group allocation throughout the study period.

Diagnosis of lymphedema

Lymphedema was diagnosed by circumferential measurement of both upper limbs at four standardised anatomical sites: 7.5 cm above the elbow crease, 7.5 cm below the elbow crease, the metacarpophalangeal joints, and the ulnar styloid process. A circumferential difference of ≥2 cm at any site between the affected and unaffected limbs was considered diagnostic for lymphedema [9].

Interventions

The patients' functional outcomes were assessed using Glasgow Outcome Scale (GOS) at 2-month follow-up, and the following categories were used: GOS 1 (Death), GOS 2 (Persistent vegetative state), GOS 3 (Severe disability), GOS 4 (Moderate disability), and GOS 5 (No disability).

Exercise-*only group*

Participants in Group A received supervised functional exercise sessions twice weekly for six weeks. Each 40-minute session consisted of approximately 30% stretching exercises targeting the neck, shoulder, and upper thoracic musculature; 60% active and assisted range-of-motion exercises for the shoulder; and 10% relaxation techniques. All sessions were supervised by trained physiotherapists. Participants also received standardised education on limb care, including prevention of trauma, infection, excessive load, and repetitive strain.

MLD *plus exercise group*

Participants in Group B received the same exercise protocol and limb care education as Group A, in addition to manual lymphatic drainage. MLD was administered by trained physiotherapists, following a modified standard protocol involving proximal lymphatic clearance, trunk drainage, and distal-to-proximal limb drainage using gentle, rhythmic strokes [10]. Each MLD session lasted approximately 30–40 minutes and was delivered twice weekly for six weeks. MLD was performed in a supine or half-lying position without the use of oils or emollients.

Outcome measures

Limb circumference

Limb circumference was assessed as an objective outcome measure of lymphedema severity using standardised circumferential measurements at four predefined anatomical sites of the affected upper limb. Measurements were obtained using a non-elastic measuring tape with the limb positioned in a standardised posture to ensure consistency. All measurements were recorded at baseline and repeated after completion of the six-week intervention period.

Quality of life

Quality of life was assessed using the Bangla version of the Lymphedema Life Impact Scale Version 2 (B-LLIS v2). This validated instrument evaluates physical, psychological, and functional domains of lymphedema-related quality of life, with scores ranging from 0 to 100; lower scores indicate better quality of life and reduced disease burden [11]. The B-LLIS v2 was administered at baseline and after completion of the six-week intervention.

Table 1 Socio-demographic and clinical profile of study participants stratified into exercise alone (Group A) and manual lymphatic drainage plus exercise (Group B) groups

Variables	Group A (n=21)	Group B (n=21)	P^a
Age in years			
18–40	4 (19.0)	7 (33.3)	0.29
41–51	17 (81.0)	14 (66.7)	
Area of residence			
Rural	9 (42.9)	13 (61.9)	0.22
Urban	12 (57.1)	8 (38.1)	
Occupation			
Employed	4 (19.0)	1 (4.8)	0.34
Homemaker	17 (81.0)	20 (95.2)	
Body mass index in kg/m^2			
Normal (18–24.9)	12 (57.1)	14 (66.7)	0.53
Overweight (≥25.0)	9 (42.9)	7 (33.3)	
Treatment received			
Chemotherapy (n=42)	14 (66.7)	20 (95.2)	0.05
Radiotherapy (n=42)	10 (47.6)	15 (71.4)	0.12

Values are presented as number (%); [a]*P* values were obtained using chi square test and Fisher's exact test, as appropriate

Covariates

Potential confounding variables were selected a priori based on clinical relevance and existing evidence. These included age (in years), overweight status defined as a body mass index ≥25 kg/m^2, duration of oedema (in months), and receipt of chemotherapy and radiotherapy (yes/no).

Statistical analysis

Continuous variables were summarised as means with standard deviations, while categorical variables were presented as frequencies and percent. The normality of continuous data was assessed using the Shapiro–Wilk test and visual inspection of distributions. Baseline comparisons between groups were performed using independent *t* tests (Mann-Whitney U test for non-normal distribution) for

Table 2 Limb circumference at different level at baseline and 6 weeks after intervention and comparison between and within the groups

Limb circumference in cm	Group A[a] (n=21)	Group B[a] (n=21)
7.5 cm above the elbow crease		
Baseline in cm	35.4 (2.5)	34.9 (4.2)
6th weeks in cm	34.1 (2.3)	28.3 (3.5)
Mean difference (95% CI)	1.2 (1.0–1.5)	6.6 (6.4–6.8)
7.5 cm below the elbow crease		
Baseline in cm	31.9 (3.4)	31.2 (3.6)
6th weeks in cm	30.3 (3.2)	26.0 (4.5)
Mean difference (95% CI)	1.6 (1.7–1.4)	5.2 (5.4–5.1)
Metacarpophalangeal joint		
Baseline in cm	25.1 (1.4)	24.8 (3.0)
6th weeks in cm	23.5 (1.1)	20.0 (1.6)
Mean difference (95% CI)	1.6 (1.2–2.0)	4.81 (4.4–5.2)
Ulnar styloid		
Baseline in cm	20.7 (2.0)	20.6 (1.7)
6th weeks in cm	19.7 (2.0)	17.6 (2.1)
Mean difference (95% CI)	1.1 (1.1–1.0)	3 (3.1–2.9)

[a]Group A: Exercise alone; Group B: Manual lymphatic drainage and exercise
CI indicates confidence interval; All differences were significant at 1% level

continuous variables and Chi-square or Fisher's exact tests for categorical variables, as appropriate.

To examine intervention effects over time and between groups, a two-way repeated-measures of analysis of variance (ANOVA) was conducted, with time (baseline and six weeks) as the within-subject factor and group (exercise alone versus combined MLD and exercise) as the between-subject factor. Additionally, analysis of covariance (ANCOVA) was performed to estimate adjusted between-group mean differences at six weeks while controlling for prespecified covariates, including age in years (quantitative), overweight as body mass index≥25 kg/m² (yes=1, no=0), duration of edema in months (quantitative), chemotherapy (yes=1, no=0), and radiotherapy (yes=1, no=0) at baseline. Results are reported as mean differences with 95% confidence intervals. A two-sided $P<0.05$ was considered statistically significant. All analyses were conducted using JAMOVI version 2.6.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki. Participation was voluntary, and refusal or withdrawal did not affect routine clinical care. Written informed consent was obtained from all participants prior to enrolment. We didn't blind the participants and therapists, which may create treatment bias.

Results

A total of 42 participants were analysed, with 21 in each group. Most participants were aged 41–51 years, and there were no significant between-group differences in age, area of residence, occupation, overweight, radiotherapy, or mean duration of lymphedema (Table 1). A marginally higher proportion of participants in the combined MLD and exercise group received chemotherapy compared with the exercise-only group (95.2% versus 66.7%; $P=0.05$).

Both groups demonstrated significant improvements in limb circumferences at all anatomical levels after six weeks of intervention. However, the magnitude of reduction was significantly greater in Group B than in Group A ($P<0.001$). The greatest differences were observed above and below the elbow crease, with mean reductions of 6.6 cm and 5.2 cm, respectively, in Group B compared with reductions of 1.2 cm and 1.6 cm in Group A (Table 2).

Both groups demonstrated significant improvements in QoL across all domains of the B-LLIS v2 after six weeks of intervention. However, improvements were significantly greater in group B compared with group A ($P<0.001$). The greatest differences were observed in physical and functional, with mean reductions of 5.2 cm and 4.1 cm, respectively, in Group B compared with reductions of 0.6 cm and 0.9 cm in Group A (Table 3).

After adjusting for age, overweight, duration of oedema, chemotherapy, and radiotherapy, the combined MLD and exercise group demonstrated significantly greater improvements in both limb circumference and quality of life compared with the exercise-only group at 6 weeks (Table 4).

Table 3 Quality of life using Bangla Lymphedema Life Impact Scale version 2 (B-LLIS V2) score at baseline and after 6 weeks of intervention and comparison between the two groups

Domains of the B-LLIS V2 scale	Group A[a] (n=21)	Group B[a] (n=21)
Physical		
Baseline in cm	5.9 (1.3)	8.5 (1.7)
6th weeks in cm	5.3 (1.4)	3.3 (2.0)
Mean difference (95% CI)	0.6 (0.6–0.5)	5.2 (5.3–5.1)
Psychosocial		
Baseline in cm	3.8 (1.7)	3.9 (3.2)
6th weeks in cm	2.8 (1.5)	0.9 (1.2)
Mean difference (95% CI)	1.0 (0.4–1.5)	3.0 (2.4–3.5)
Functional		
Baseline in cm	3.3 (1.7)	5.5 (0.9)
6th weeks in cm	2.4 (1.5)	1.5 (0.5)
Mean difference (95% CI)	0.9 (0.8–0.9)	4.1 (4.0–4.1)
Total score		
Baseline in cm	12.9 (4.2)	17.9 (5.2)
6th weeks in cm	10.5 (3.8)	5.7 (3.0)
Mean difference (95% CI)	2.4 (1.8–3.0)	12.2 (11.6–12.8)

[a]Group A: Exercise alone; Group B: Manual lymphatic drainage and exercise
CI indicates confidence interval; All differences were significant at 1% level;

Discussion

This randomised controlled trial demonstrated that the addition of MLD to a structured exercise programme resulted in significantly greater reductions in limb circumference and improvements in quality of life among breast cancer survivors with Stage I–II lymphedema compared with exercise alone. These findings highlight the potential clinical benefits of combining MLD with exercise in the management of BCRL.

The observed reductions in limb circumference with combined MLD and exercise align with previous studies suggesting that MLD can enhance lymphatic transport, facilitate fluid mobilisation, and reduce extracellular fluid accumulation when delivered alongside exercise or compression therapy [12, 13]. While exercise alone was effective in reducing limb swelling, the magnitude of change was consistently smaller, supporting the additive effect of MLD in enhancing lymphatic drainage. Our findings are consistent with systematic reviews indicating that combined conservative interventions may achieve superior limb volume reductions compared to single modalities [14].

Table 4 Adjusted mean differences of limb circumference and quality of life scores between groups from analysis of covariance (n=42)

Outcome variables	Adjusted mean difference (95% CI)[a]
Limb circumference in cm	
7.5 cm above the elbow crease	5.2 (5.8–4.7)
7.5 cm below the elbow crease	4.5 (5.0–4.0)
Metacarpophalangeal joint	3.2 (3.6–2.9)
Ulnar styloid	
Quality of life (B-LLIS V2 scale)[b]	
Physical	3.8 (4.2–3.4)
Psychological	1.7 (2.1–1.3)
Functional	2.9 (3.1–2.6)
Total score	7.9 (8.8–7.0)

[a]Mean difference were adjusted for age in years, overweight (yes=1, no=0), duration of oedema in months, chemotherapy (yes=1, no=0) and radiotherapy (yes=1, no=0). All differences were significant at 1% level.; [b]B-LLIS V2 indicates Bangla Lymphedema Life Impact Scale version 2
CI indicates confidence interval

In addition to objective improvements, combined MLD and exercise also led to greater improvements in health-related quality of life, particularly in physical, functional, and psychosocial domains. These results suggest that reductions in limb swelling translate into meaningful patient-reported benefits, reinforcing the importance of integrating MLD into routine rehabilitation programmes for BCRL. Previous research has reported mixed effects of MLD on quality -of-life outcomes, with some trials failing to demonstrate significant improvements beyond exercise alone [15, 16]. In contrast, our study employed a structured, supervised exercise programme in combination with standardised MLD sessions, which may have enhanced adherence and therapeutic efficacy.

The study also demonstrated the feasibility and safety of delivering MLD alongside exercise. No adverse events were reported, supporting the established safety profile of these interventions in BCRL management [17]. Importantly, all interventions were standardized and monitored, ensuring consistency and allowing for reproducible clinical application.

Several strengths of this study should be noted. The trial employed a randomised, controlled design enhancing internal validity. The use of objective limb measurements alongside a validated, culturally adapted quality-of-life instrument (B-LLIS v2) provided a comprehensive assessment of treatment effects. Furthermore, multivariable adjustment for potential confounders such as age, overweight, duration of oedema, and adjuvant therapies strengthened the robustness of the findings.

However, certain limitations should be acknowledged. The study was conducted in private medical college hospital with a relatively small sample size, the follow-up period was limited to six weeks, and the longer-term effects of combined therapy on limb volume and quality of life remain unknown. Additionally, although outcome assessors were blinded, participants and intervention providers were not, which might have introduce performance bias overall restrict the generalisability.

Conclusion

The findings of this trial indicate that MLD combined with structured exercise produces greater reductions in limb circumference and improvements in QoL compared with exercise alone among breast cancer survivors with early-stage lymphedema. These results support the integration of MLD into multidisciplinary rehabilitation programmes and provide evidence for optimising conservative management strategies for BCRL.

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Author contributions

Concept or design of the work; or the acquisition, analysis, or interpretation of data for the work: ME, SF. *Drafting the work or reviewing it critically for important intellectual content:* ME, MIH, SF. *Final approval of the version to be published:* ME, MIH, SF, NA. *Accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved:* ME, SF, NA.

Conflict of interest

We do not have any conflict of interest.

Data availability statement

We confirm that the data supporting the findings of the study will be shared upon reasonable request.

Supplementary file

None

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RESEARCH LETTER

Sociodemographic and neurological profile of patients with spinal cord injury in a trauma hospital in Bangladesh

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Traumatic spinal cord injury (TSCI) is a severe public health problem associated with long-term motor, sensory, and autonomic impairments, resulting in substantial physical, psychological, and socio-economic consequences for affected individuals and health systems [1, 2]. The global incidence of TSCI ranges from 15 to 40 cases per million population annually, with clear disparities between high-income countries and low- and middle-income countries (LMICs) [3]. Although improved safety measures have contributed to stable or declining trends in many developed settings, the burden of TSCI continues to increase in LMICs due to rapid urbanisation, expanding road traffic, inadequate enforcement of safety regulations, and persistent occupational hazards [4, 5].

In South Asia, including Bangladesh, reliable epidemiological data on TSCI remain limited because of under-reporting and weak health information systems. Available evidence suggests that falls and road traffic accidents are the leading causes of injury. Individuals with TSCI frequently experience long-term complications that necessitate prolonged and multidisciplinary rehabilitation. However, access to specialized rehabilitation services in resource-constrained settings is often insufficient, exacerbating disability, loss of productivity, and socioeconomic vulnerability for patients and their families.

Neurological classification is fundamental for assessing injury severity and guiding clinical management. Comprehensive data on the socio-demographic and neurological characteristics of TSCI patients in Bangladesh are scarce, particularly for injuries related to rural and occupational exposures. This lack of context-specific evidence limits the development of targeted prevention strategies and the effective allocation of healthcare resources. To address this gap, the present study aims to investigate the socio-demographic and neurological profiles of patients with TSCI admitted through the emergency department of a specialised hospital.

This cross-sectional study was conducted at the National Institute of Traumatology, Orthopaedics and Rehabilitation, Dhaka, the largest tertiary-level referral centre for trauma and rehabilitation in Bangladesh. Adult patients (aged ≥18 years) with a confirmed diagnosis of TSCI admitted between June 2022 and November 2023 were included. Diagnosis was established through clinical evaluation and radiological investigations. Patients with non-traumatic spinal cord conditions, pre-existing neurological deficits that could confound assessment, or those who died before complete evaluation were excluded. A convenience sampling strategy was applied, enrolling all eligible patients admitted during the study period.

Key messages

Traumatic spinal cord injury in Bangladesh predominantly affects young rural males, often due to preventable falls from trees. Lumbar injuries and paraplegia are most common, with over one-third presenting complete neurological deficits. These findings underscore the need for early neurological assessment, targeted prevention strategies, and improved rehabilitation services, particularly in underserved rural communities.

Table 1 Clinical presentation and cause of spinal cord injuries (n=182)

Variable	Number (%)
Clinical presentation	
Unable to move lower limb	67 (36.8)
Unable to move all four limbs	16 (8.2)
Muscle weakness in lower limb	79 (43.4)
Muscle weakness in all four limbs	13 (7.1)
Bladder - catheter in situ	118 (64.8)
Bladder - incontinence	24 (13.2)
Bowel - not passed yet	66 (36.3)
Breathing difficulty	26 (14.3)
Swelling in affected part	91 (50.0)
Difficulty in standing/sitting	87 (47.8)
Vital signs and clinical signs	
Tachycardia	25 (13.7)
Hypertension	17 (9.3)
Tachypnea	30 (16.5)
Absent bowel sound	23 (12.6)
Sensory involvement present	118 (64.8)
Motor involvement present	120 (65.9)
Decreased muscle tone	83 (45.6)
Radiological injury type	
Compression	115 (63.2)
Translation	49 (26.9)
Mixed pattern	18 (9.9)
Region of injury	
Lumbar	91 (50.0)
Thoracic	48 (26.4)
Cervical	30 (16.5)
Combined (thoracolumbar, cervicothoracic)	13 (7.1)
Clinical Status	
Paraplegia	158 (86.8)
Tetraplegia	24 (13.2)
Pain Severity	
Severe (Visual Analogue Scale ≥ 7)	105 (57.7)
Moderate (Visual Analogue Scale 4–6)	60 (33.0)
Mild (VAS 1–3)	17 (9.3)
Autonomic Dysreflexia	4 (2.2)
Cause of injury	
Fall from height	121 (66.5)
Fall from tree	78 (64.5)
Fall from rooftop	43 (35.5)
Fall of heavy object	30 (16.4)
Road traffic accident	26 (14.2)
Other (workplace, bull attack, etc.)	5 (2.7)
Spinal region of injury	
Lumbar	91 (50.0)
Thoracic	48 (26.4)
Cervical	30 (16.5)
Others (thoracolumbar, etc.)	13 (7.1)
Clinical status	
Paraplegia	158 (86.8)
Tetraplegia	24 (13.2)
Type of bony injury	
Compression	115 (63.2)
Translation	49 (26.9)
Others (destruction/facet)	18 (9.9)

Patients were initially identified from hospital records and subsequently screened in the inpatient departments based on predefined eligibility criteria. After obtaining written informed consent, data were collected using a structured case record form by trained postgraduate residents in physical medicine and rehabilitation. Information was gathered through patient interviews, caregiver reports when required, clinical examinations, and review of medical records. Collected data included socio-demographic characteristics (age, sex, residence, and occupation), mechanism and level of injury, associated injuries, and time since injury.

Neurological assessment was performed within 24 hours of admission using the International Standards for Neurological Classification of Spinal Cord Injury, and injury severity was graded according to the Asia Impairment Scale. Participant confidentiality and anonymity were strictly maintained throughout the research process.

Data were analysed using SPSS statistics software. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize sociodemographic and clinical characteristics, while neurological profiles were presented by injury level and Impairment Scale grades.

Sociodemographic factors

A total of 182 patients with TSCI were analysed. Majority (63.7%) of them were examined within three days of the injury. The mean (standard deviation) of age was 38.0 (14.6) years; most patients were male (93%) and from rural areas (90%). One-third (32%) of them were farmers and one-fourth (24.7%) had no formal education. Fifteen per cent of them had injuries other than spinal injuries.

Clinical profile

Paraplegia was the most common clinical presentation (87%), with 37% unable to move their lower limbs at admission (Table 1). Bladder catheterisation was required in 64.8% of patients. The lumbar spine was most frequently affected (50%), followed by the thoracic spine (26%). Moderate to severe pain was reported by 91% of patients. Falls from height were the leading cause of injury (67%), particularly falls from trees (43%), while road traffic accidents accounted for 14.2%. According to the Impairment Scale, 36.2% had complete spinal cord injury (Grade A).

This study highlights the substantial burden of TSCI in Bangladesh, disproportionately affecting young males from rural areas who are engaged in physically demanding, low-income occupations. Falls from trees emerged as the leading cause of injury, reflecting a context-specific occupational hazard within rural agrarian communities and aligning with findings from regional studies that emphasize the need for locally tailored prevention strategies [6]. The predominance of male patients and rural residents is consistent with evidence from other LMICs, where TSCI commonly affects individuals involved in high-risk manual labour such as farming and day labour [7]. Low household income and limited educational attainment further underscore the socioeconomic vulnerabilities that may hinder timely care, access to rehabilitation, and social reintegration.

Falls from height, particularly tree-related falls, accounted for over two-thirds of injuries, while road traffic accidents contributed a smaller proportion. This pattern contrasts with high-income countries, where road traffic accidents are often the primary cause, but are consistent with LMIC settings where occupational and environmental risks play a dominant role [8]. These findings support the need for targeted public health interventions, including safety education, use of protective equipment, and community-based injury prevention initiatives.

The lumbar spine was the most frequently affected region, differing from injury patterns reported in many high-income countries and reflecting variability in trauma mechanisms across regions. Similar regional variation has been reported in neighboring South Asian countries [9]. Although most patients presented within three days of injury, delays among a substantial proportion indicate gaps in pre-hospital care, emergency transport, and public awareness.

Neurologically, more than one-third of patients sustained complete spinal cord injuries, while the majority had incomplete injuries, suggesting potential for functional recovery with timely rehabilitation. This pattern is consistent with reports from Bangladesh and comparable LMICs [10, 11]. High levels of pain, bladder dysfunction, and paraplegia highlight the need for comprehensive, multidisciplinary management. Study limitations include recall bias, lack of longitudinal follow-up, and absence of standardised rehabilitation outcome measures.

In conclusion, TSCI in Bangladesh primarily affects socioeconomically deprived rural males and is largely driven by preventable causes such as falls from trees, underscoring the urgent need for culturally appropriate prevention strategies, improved emergency care, and accessible rehabilitation services.

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Author contributions

Conception and design: MM, TU. *Acquisition, analysis, and interpretation of data:* MM, MMI, MIR, TU. *Manuscript drafting and revising it critically:* MM, MMI, MIR, TU. *Approval of the final version of the manuscript:* MM, MMI, MIR, TU. *Guarantor of accuracy and integrity of the work:* TU.

Conflict of interest

We do not have any conflict of interest.

Data availability statement

We confirm that the data supporting the findings of the study will be shared upon reasonable request.

Supplementary file

None

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RESEARCH LETTER

Preliminary effects of robotic-assisted gait training in post-stroke patients: A pilot study

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Stroke remains a leading cause of long-term disability worldwide, with gait impairment and balance dysfunction being among the most disabling sequelae affecting independence and quality of life [1, 2]. Restoration of walking ability is therefore a primary goal of post-stroke rehabilitation. Conventional physiotherapy remains the cornerstone of gait rehabilitation; however, variability in training intensity, therapist fatigue, and limited opportunities for high-repetition, task-specific practice may limit optimal recovery [3]. Robotic-assisted gait training (RAGT) has emerged as a promising adjunct, enabling repetitive, controlled and task-oriented walking practice in a safe and standardised environment [4, 5]. Despite growing interest, evidence regarding its feasibility and preliminary clinical effects in routine rehabilitation settings remains heterogeneous, particularly in low- and middle-income contexts. This research letter reports the preliminary findings of a randomised pilot study comparing robotic-assisted gait training with conventional physiotherapy in individuals recovering from stroke.

This hospital-based pilot randomised study was conducted at a neurorehabilitation centre, with institutional ethical approval obtained in line with the declaration of Helsinki. Written informed consent was obtained from all participants before enrollment. Ten individuals with first-ever ischemic or hemorrhagic stroke, aged 30–60 years, were recruited and randomly allocated to either robotic-assisted gait training (RAGT group, n=5) or conventional physiotherapy (control group, n=5) using a sealed-envelope method. All participants had mild to moderate lower-limb spasticity (Modified Ashworth Scale ≤ 2), Brannstrom stages II–IV, Mini-Mental State Examination scores ≥ 24 and functional ambulation category scores between 2 and 4. No participants were lost to follow-up.

The RAGT group received treadmill-based robotic gait training using the Lokomat system with partial body-weight support, three sessions per week for 12 weeks. Training parameters such as walking speed and body-weight support were progressively adjusted according to participant tolerance and clinical judgment. Each session lasted approximately 40 minutes and focused on repetitive, task-specific gait practice under guided robotic assistance. The control group received conventional physiotherapy three times per week, consisting of breathing exercises, facilitatory techniques, bed mobility training, lower-limb stretching, balance activities and overground gait training, with progressive advancement over the intervention period. All interventions were delivered by licensed physiotherapists experienced in neurorehabilitation. No adverse events were reported in either group.

Balance, motor recovery and gait performance were assessed at baseline and after 12 weeks using validated clinical outcome measures: The Berg Balance Scale, Fugl–Meyer Assessment for Lower

Key messages

Restoration of gait is central to post-stroke independence and functional recovery. This small pilot study demonstrates that robotic-assisted gait training adds value to maintaining balance, motor function and mobility compared with conventional therapy in the rehabilitation of people with stroke. However, adequately powered studies for longer-term follow-up are warranted.

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Extremity, Functional Gait Assessment and Timed Up and Go test. Data were analysed using Wilcoxon signed-rank test for within-group changes ($P < 0.01$) and Mann–Whitney U test for between-group differences ($P < 0.05$).

Both groups demonstrated statistically significant improvements across all outcome measures over the 12-week intervention period. However, participants in the RAGT group consistently showed greater preliminary mean improvements in balance, motor recovery and functional mobility compared with those receiving conventional physiotherapy. The most notable between-group differences favored RAGT for Berg Balance Scale, lower-limb motor recovery Fugl–Meyer Assessment for Lower Extremity, dynamic gait performance and functional mobility Timed Up and Go test. A consolidated summary of outcome changes is presented in Table 1.

These preliminary findings suggest that robotic-assisted gait training may offer additional benefits over conventional physiotherapy in improving balance, gait and mobility following stroke. The observed improvements may be attributed to the high-repetition, task-specific nature of robotic training, which facilitates motor relearning and may enhance neuroplastic adaptation through consistent sensory feedback and guided movement patterns [6, 7]. Previous studies have highlighted the importance of intensive, repetitive gait practice in promoting functional walking recovery after stroke, and robotic systems provide a practical means of delivering such training with reduced therapist burden [8].

Table 1 Comparison of mean changes (post minus pre) between robot-assisted gait training and conventional therapy according to outcome measures

Outcome measure	Group for each (n=5)	Mean change (95% confidence interval) [a]
Berg balance scale	Robot-assisted gait training	21.2 (18.7–23.7)
	Conventional	5.4 (4.0–6.8)
Fugl–Meyer assessment	Robot-assisted gait training	6.6 (6.1–7.3)
	Conventional	2.4 (1.9–2.9)
Functional gait assessment	Robot-assisted gait training	4.4 (4.1–4.7)
	Conventional	1.6 (1.4–1.8)
Timed up and go	Robot-assisted gait training	8.1 (7.5–8.7)
	Conventional	3.7 (3.4–4.0)

[a] All P values for within group comparisons are significant at 1% level (according to the Wilcoxon signed-rank test). Between-group mean changes are significantly different at the 5% level (Mann–Whitney U test).

Improvements in balance, as reflected by higher Berg Balance Scale scores in the RAGT group, are clinically meaningful, given the strong association between balance deficits and fall risk in stroke survivors [9]. Similarly, greater gains in Fugl–Meyer Assessment for Lower Extremity scores indicate enhanced lower-limb motor recovery, likely driven by repetitive practice of near-normal gait kinematics. Enhanced Functional Gait Assessment and reduced Timed Up and Go test times further suggest superior improvements in dynamic gait control and functional mobility, which are essential for safe community ambulation.

Robotic-assisted gait training improved balance, motor recovery, and gait in individuals with stroke more effectively than conventional physiotherapy. Nevertheless, these findings must be interpreted cautiously. Given the pilot study's small sample size, the results are exploratory and not powered to establish definitive efficacy. The absence of a blinding and reliance on clinical outcome measures limit generalisability. Additionally, long-term retention of gains and cost-effectiveness of robotic-assisted training were not evaluated. Despite these limitations, the study demonstrates feasibility and safety, thereby justifying adequately powered randomised controlled trials.

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We do not have any conflict of interest.

Data availability statement

We confirm that the data supporting the findings of the study will be shared upon reasonable request.

Supplementary file

None

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CASE REPORT

Synergistic neurotoxicity of ciprofloxacin and nimesulide in unmasking a hidden catalyst for seizures: A case report

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Abstract

Background: Fluoroquinolones are widely prescribed broad-spectrum antibiotics with favourable pharmacokinetics but are associated with neurotoxicity in 1–2% of users. Reported manifestations include seizures, encephalopathy, psychosis, myoclonus, and dyskinesia. Ciprofloxacin, a commonly used agent, disrupts central nervous system homeostasis by inhibiting γ-aminobutyric acid-A (GABA-A) receptors and enhancing N-methyl-D-aspartate (NMDA) receptor activity, creating an excitatory milieu that heightens seizure risk, especially in predisposed individuals.

Case description and management: A 54-year-old man with type 2 diabetes mellitus presented with diarrhoea, fever, and abdominal discomfort. He was empirically started on ciprofloxacin, nimesulide, and paracetamol; stool analysis later confirmed polymicrobial gastroenteritis. Two hours after his second ciprofloxacin dose, he developed a generalized tonic–clonic seizure (GTCS) despite no prior seizure history. Comprehensive metabolic, infectious, and neuroimaging evaluations were unremarkable. The Naranjo score was 7, indicating a probable adverse drug reaction. Ciprofloxacin was discontinued and seizures were controlled with levetiracetam and lacosamide. His antimicrobial therapy was switched to amoxicillin–clavulanic acid, resulting in full neurological recovery and no further seizures.

Conclusion: Ciprofloxacin-induced seizures likely stem from GABA inhibition and NMDA overactivation, potentiated by concomitant NSAID use. Prompt drug withdrawal and appropriate seizure management are essential. Prudent fluoroquinolone prescribing is critical to minimize CNS adverse effects and ensure patient safety.

Key messages

Ciprofloxacin, though widely prescribed for its efficacy, can precipitate seizures via GABA-A antagonism, especially when combined with NSAIDs such as nimesulide. This case report highlights the critical need for clinicians to be aware of ciprofloxacin-induced neurotoxicity in vulnerable patients. Early recognition, drug discontinuation, and targeted anticonvulsant therapy are essential to prevent life-threatening complications and ensure optimal neurologic recovery in affected individuals.

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Introduction

Ciprofloxacin, a second-generation fluoroquinolone introduced in 1986, is widely used to treat various bacterial infections because of its potent bactericidal activity [1]. It targets DNA gyrase and topoisomerase IV, disrupting DNA replication and transcription in both Gram-positive and Gram-negative bacteria. Its favourable pharmacokinetics, including high oral bioavailability and excellent tissue penetration, make it a preferred choice for urinary, respiratory, gastrointestinal, and soft tissue infections [2]. However, central nervous system (CNS) adverse drug reactions (ADRs), although rare, have gained increasing recognition.

Neurotoxicity from fluoroquinolones includes a range of effects, from mild anxiety and insomnia to hallucinations, psychosis, and seizures. The U.S. FDA has issued warnings about fluoroquinolone-induced neuropsychiatric effects. The proposed mechanism involves antagonism of γ-aminobutyric acid type A (GABA-A) receptors, leading to reduced inhibitory neurotransmission and increased neuronal excitability. When co-administered with nonsteroidal anti-inflammatory drugs (NSAIDs), these effects may be exacerbated due to synergistic inhibition of GABA-A [3]. Recognising these rare but serious events is essential for clinical safety.

Case description and management

A 54-year-old male with type 2 diabetes mellitus (on metformin 500 mg once daily) presented with a 7-day history of watery diarrhoea, fever, and abdominal pain. Two days before admission, he was empirically started on ciprofloxacin (500 mg twice daily) along with nimesulide (100 mg) and paracetamol (325 mg) for fever. Stool multiplex PCR identified Campylobacter jejuni, Salmonella enterica, and Escherichia coli as the causative organisms.

On hospital admission, he was hydrated and continued on ciprofloxacin. After the second dose, the patient experienced a generalised tonic-clonic seizure lasting two minutes, followed by postictal confusion. He had no prior history of seizures, head trauma, or neurological illness. Neurological examination was unremarkable before the episode. Laboratory investigations revealed serum calcium of 9.0 mg/dL (reference range: 8.5–10.5 mg/dL) and serum magnesium of 2.0 mg/dL (reference range: 1.7–2.3 mg/dL), both within normal limits, excluding electrolyte imbalance as a precipitating factor. Blood cultures taken before antibiotics were started remained sterile after 72 hours of incubation, and serum procalcitonin was 0.23 ng/mL (reference <0.5 ng/mL), thereby ruling out sepsis as the cause. Quantitative estimation of serum ciprofloxacin levels was not performed, as therapeutic drug monitoring for fluoroquinolones is not routinely available at the institution. Other laboratory parameters, including electrolytes, blood glucose, renal and hepatic profiles, and arterial blood gases, were within normal limits. A non-contrast computed tomography (CT) scan of the brain showed no intracranial abnormalities.

A clinical pharmacist's review implicated ciprofloxacin as the probable cause. The seizure was attributed to ciprofloxacin's GABA-A antagonism, potentially worsened by concurrent NSAID use. The Naranjo algorithm yielded a score of 7, suggesting a "probable" adverse drug reaction [4]. Ciprofloxacin and nimesulide were discontinued. The patient was treated with intravenous levetiracetam (1 g) and a loading dose of lacosamide (100 mg). Antibacterial therapy was switched to intravenous amoxicillin-clavulanate. He remained seizure-free, neurologically stable, and was discharged after 72 hours with outpatient neurology follow-up.

Discussion

Fluoroquinolone-induced seizures are rare but serious. Ciprofloxacin is known to lower the seizure threshold through GABA-A receptor inhibition and possible NMDA receptor modulation [5]. In this patient, several contributing factors likely increased susceptibility: diabetes-associated subclinical renal impairment, systemic inflammation from polymicrobial gastroenteritis, and co-administration of nimesulide—an NSAID known to potentiate fluorquinolone neurotoxicity [3].

Although there is no obvious renal dysfunction, impaired clearance of ciprofloxacin cannot be discounted. NSAIDs may decrease renal perfusion, leading to increased systemic drug levels. Additionally, inflammatory cytokines from infection might disrupt neurotransmitter balance, sensitising neurons to excitotoxic injury. These combined effects likely triggered the seizure.

The patient's rapid recovery after stopping the medication, lack of structural CNS pathology, and typical presentation strongly suggest ciprofloxacin as the cause. Treatment with levetiracetam, known for its minimal interactions and wide-ranging anti-epileptic effectiveness, was successful [6]. The Naranjo score further confirmed the drug-event association [4]. This case underscores the importance of clinical vigilance when prescribing fluoro-

Table 1 Fluoroquinolone-associated neurotoxicity cases with co-therapy, symptoms, and management

Ref.	Age Sex	Medication	Dosage (mg)	Route/ Frequency	Co-therapy	Symptom onset	Motor dysfunction	Symptom duration	Intervention
4	49 Woman	Ciprofloxacin	200 mg	Intravenous 12 hourly	Paracetamol	Day 2	Involuntary facial myokymia	Not reported	Clonazepam[a]
7	84 Man	Ciprofloxacin	500 mg	Per oral 6 hourly	Acetylsalicylic acid	Day 3	Dysarthria with involuntary oromandibular dyskinesia	48 hours	Sodium valproate 200 mg per oral 8 hourly[b]
8	67 Man	Levofloxacin	300 mg	Per oral daily	Mefenamic acid derivative	Day 4	Choreiform tremors, gait ataxia, visual perceptual disturbances	7 days	No pharmacologic intervention
10	68 Man	Ciprofloxacin	500 mg	Per oral 12 hourly	Paracetamol	Day 5	Orofacial dyskinesia with buccolingual stereotypies	8 hours	Biperiden 2 mg[c]

[a]Specific details on dose, frequency, and duration not provided; [b]Medication was discontinued upon hospital discharge; [c]Number of doses administered was not documented

quinolones, especially in patients with chronic illness, concurrent NSAID use, or systemic infections. Ciprofloxacin's favourable pharmacokinetics must be weighed against its neurotoxic potential, particularly in vulnerable populations.

Relevant studies on fluoroquinolone-associated neurotoxicity with concurrent pharmacotherapy in Table1. These cases demonstrate a range of neurological symptoms, including dyskinesias, choreiform tremors, and orofacial stereotypies, occurring at different dosages and routes of adminis-tration. The variety of symptoms and the influence of concomitant medications, such as NSAIDs and paracetamol, further emphasise the multifactorial nature of fluoroquinolone-induced CNS toxicity. This comparison reinforces the idea that fluoroquinolone-related neurotoxicity is not solely determined by drug dose or route but involves an interaction between pharmacodynamic effects and patient-specific susceptibilities.

Conclusion

Ciprofloxacin can precipitate seizures even in individuals without a prior seizure history, particularly when metabolic stress, systemic infection, or interacting medications are present. In this case, the temporal association with ciprofloxacin and the patient's rapid recovery after discontinuation suggest a probable drug-related event, with nimesulide serving as a possible contributory factor rather than an independent cause. Although paracetamol exposure and infection-related meta-bolic disturbances cannot be entirely excluded, the overall clinical pattern favours ciprofloxacin-induced neurotoxicity. Clinicians should remain vigilant when prescribing fluoroquinolones—especially in patients with underlying comorbidities or concurrent agents such as nimesulide—and promptly withdraw the suspected drug when neurological symptoms emerge.

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CASE REPORT

Integrating Brain Gym exercises and progressive muscle relaxation in a college student with neurasthenia: A case report

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Abstract

Background: Neurasthenia, a condition marked by chronic mental and physical fatigue with poor sleep, is increasingly prevalent among young adults facing academic stress which has been poorly addressed. The case report aims to assess the combined effect of Brain Gym activities and progressive muscle relaxation on fatigue and sleep disturbances in a young adult with neurasthenia in terms of improving mental health outcomes.

Case description and management: A 22-year-old male college student presented with persistent fatigue, tension headaches, irritability, and non-restorative sleep for four months. Clinical findings met ICD-10 diagnostic criteria for neurasthenia. Baseline Multidimensional Fatigue Inventory (MFI-20) and Pittsburgh Sleep Quality Index (PSQI) scores were 62 and 10, respectively, indicating severe fatigue and poor sleep. A four-week combined programme of Brain Gym exercises and progressive muscle relaxation was administered five days per week. Post-intervention assessment showed substantial improvement for four weeks, with MFI-20 reduced to 44 and PSQI to 5 signifying better energy levels and improved sleep efficiency. The participant reported high satisfaction, with no adverse events.

Conclusion: This case demonstrates that integrating Brain Gym with progressive muscle relaxation may effectively reduce fatigue and enhance sleep quality in college students with neurasthenia, supporting a safe and accessible therapeutic strategy to improve mental health and quality of life.

Key messages

Neurasthenia in young adults causes persistent mental and physical fatigue with poor sleep quality. Brain Gym exercises enhance cognitive function, focus and coordination, thereby reducing mental fatigue. Progressive muscle relaxation lowers stress, promotes deep relaxation and improves sleep quality. Combining Brain Gym with progressive muscle relaxation offers an effective, non-pharmacological approach to manage fatigue and restore healthy sleep patterns in college students with neurasthenia.

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Introduction

Neurasthenia is a chronic condition characterised by persistent mental and/or physical fatigue accompanied by at least two symptoms such as dizziness, dyspepsia, muscular aches, tension headaches, inability to relax, irritability, or sleep disturbance. Neurasthenia was often caused by mental overstimulation and strain at home and work. Excessive "brain-work," long hours, sleepless nights, and high-pressure lifestyles led to mental exhaustion, especially when an individual's nerve strength was insufficient for ambitious careers. Neurasthenia (ICD-10 code: F48.0) as a distinct disorder, while DSM-IV lists it under undifferentiated somatoform disorders [1]. Brain Gym is a set of structured movement-based activities designed to stimulate both hemispheres of the brain, enhance neuroplasticity, and improve mood, attention, and sleep quality. Although some of the early theoretical explanations proposed for Brain Gym—such as hemispheric balancing and specific neuro-physiological mechanisms—remain debated and lack strong validation, its use in this case is grounded in the functional outcomes reported in empirical studies [2]. Progressive muscle relaxation, developed by Edmund Jacobson, involves systematic contraction and release of muscles to lower sympathetic arousal, relieve fatigue, and promote restorative sleep [3]. Multidimensional Fatigue Inventory (MFI-20) [4] was used to measure the fatigue. To measure sleep quality, Pittsburgh sleep quality index (PSQI) is widely used [5]. Although Brain Gym and progressive muscle relaxation have been studied individually, there is limited research on their combined effect in reducing fatigue and improving sleep specifically among college students with neurasthenia. This case report aims to determine the effectiveness of Brain Gym and progressive muscle relaxation intervention in a young adult with neurasthenia, focusing on its effect on fatigue and sleep quality in terms of improving overall quality of life.

Case description and management

A 22-year-old male college student presented with persistent fatigue for four months, generalised body pain on exertion, tension headaches during cognitively demanding tasks, difficulty initiating and maintaining sleep, irritability, inability to relax, and reduced concentration. These symptoms met the ICD-10 criteria for neurasthenia, characterized by distressing fatigue after mental effort and bodily weakness after minimal exertion, accompanied by at least two associated features. He had no history of chronic illness, psychiatric treatment, or use of sleep medications, and his family history was unremarkable with no known genetic or neurological disorders. The patient underwent routine clinical assessment, and no red-flag medical, neurological, or psychiatric symptoms were identified during evaluation. Psychosocially, he reported typical college stressors without significant environmental risk factors. He had not previously received interventions for fatigue or sleep disturbances. At baseline, a demographic questionnaire were used to assess fatigue and sleep. No other diagnostic tool was used. The total MFI score was 62, indicating severe fatigue, and the total PSQI score was 10, reflecting poor sleep quality. The study duration is from 26 May 2025 to 25 August 2025. Written informed consent was obtained for participation and publication of de-identified data.

A four-week combined programme of Brain Gym exercises and progressive muscle relaxation was initiated, delivered in supervised sessions of 45–60 minutes, five days per week in a quiet setting.

Week 1 included spot marching, cross crawl, brain buttons, hook-ups, and lazy eight movements, followed by 30 minutes of full-body progressive muscle relaxation. These exercises aimed to warm up, improve cross-lateral coordination, enhance blood flow, balance hemispheres, and support visual attention.

Week 2 introduced step touch, positive points (gentle pressure on the eyes with breathing), thinking cap (unrolling ears), and neck circles, again concluding with progressive muscle relaxation. These activities addressed lateral balance, stress reduction, mental alertness, and neck tension.

Week 3 added cook's hook-up, earth buttons (hand on navel and below lips), trace X with eye tracking, and active arms (overhead stretch). Progressive muscle relaxation was continued for 20 minutes at the end of each session. This phase focused on grounding, spatial orientation, visual focus, posture, and hand–eye coordination.

Week 4 incorporated gravity glider (arm gliding in cross-legged sitting), foot flex (ankle movements), repetition of lazy eight, and integration of all prior Brain Gym exercises in a 25–30-minute routine. progressive muscle relaxation was performed after each session to consolidate relaxation and recovery. The final week aimed to integrate all learned movements for maximum benefit on fatigue and sleep quality.

At the end of four weeks, re-assessment with the same tools showed marked improvement. The total MFI score dropped from 62 to 44, and the total PSQI score decreased from 10 to 5. Since the patient reported that he has no serious side effects during the therapy tolerability was evaluated based on the lack of adverse reactions. No adverse events were reported and the participant expressed satisfaction with the programme.

The patient expressed satisfaction with the intervention, noting improved energy, focus, and sleep quality. He gradually experienced reduced fatigue and enhanced mental clarity. He found the sessions engaging and easy to follow, reporting better daily functioning and overall well-being.

Discussion

The present study investigated the effectiveness of Brain Gym exercises combined with progressive muscle relaxation in college students diagnosed with neurasthenia, a condition characterised by persistent fatigue, impaired concentration, and non-restorative sleep. Diagnosis of neurasthenia was based on the ICD-10 criteria, which identify seven core symptoms: dizziness, dyspepsia, muscular aches or pains, tension headaches, inability to relax, irritability, and sleep disturbances. This study specifically focused on assessing changes in fatigue levels and sleep quality, both essential components of mental health and overall quality of life.

Participants followed a supervised four-week intervention program, performing Brain Gym exercises integrated with progressive muscle relaxation five days per week. The structured regimen aimed to target both mental and physical dimensions of fatigue while promoting relaxation and restorative sleep. Post-intervention assessment using standardised scales demonstrated significant improvements across outcome measures, indicating that the combined intervention effectively alleviated fatigue and enhanced sleep quality, both essential components of mental health, quality of life, and well-being in the student population.

The findings from this case align with existing literature reinforcing that Brain Gym exercises enhance sleep quality statistically and clinically by increasing the hours of sleep, cognitive functions, attention, coordination, and mental stamina through bilateral hemispheric activation, particularly in student populations under academic stress [2, 6]. In this case report, Brain Gym is presented as an evidence-supported behavioral movement routine rather than a mechanistic neurophysiological intervention, with its inclusion justified by functional outcomes, clinical safety, and prior literature demonstrating benefits in student populations.

Several studies reports that progressive muscle relaxation helps in reducing fatigue in multiple population [7]. For instance, a quasi-experimental study found that progressive muscle relaxation effectively alleviates academic stress among students, which is often associated with fatigue. By reducing stress, progressive muscle relaxation may indirectly contribute to lower fatigue levels in student populations [8]. An historical analysis in neurasthenia shows that breathing exercise elevates fatigue and restores balance [9].

Conclusion

Brain Gym combined with progressive muscle relaxation may be considered evidence-based, non-pharmacological strategy for reducing fatigue and sleep disturbances in young adult, aligning with the broader literature on fatigue management, cognitive enhancement, and autonomic regulation. Further studies with longer follow-up periods are necessary to confirm the generalisability and long-term effectiveness of this combined intervention".

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We confirm that the data supporting the findings of the study will be shared upon reasonable request.

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CASE REPORT

Patient-made axillary crutches enabled home-based rehabilitation: A case report

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Abstract

Background: Pelvic fractures substantially impair mobility and functional recovery, particularly in low- and middle-income countries where access to rehabilitation services and assistive devices is limited. This report highlights the role of patient-led innovation at the patient's home in addressing such constraints.

Case description and management: A 68-year-old physically active man from rural Bangladesh sustained a stable pelvic fracture following a fall. He was managed non-surgically. Due to the unavailability of standard mobility aids and financial constraints, the patient himself designed and constructed an axillary crutch using locally sourced bamboo and wood. A physiatrist trained him on safe crutch use and proper gait through in-person visits and telemedicine. Iterative functional trials informed device modifications to ensure appropriate fit, reduce axillary pressure, and support an effective three-point gait. Follow-up at 6, 9, and 12 weeks post-discharge demonstrated progressive improvement in mobility and pain control. The Functional Independence Measure score improved from 115 at baseline to 123 at final follow-up.

Conclusions: This case demonstrates that with proper guidance and motivation, patient-driven, low-cost assistive technologies can be a viable means of functional recovery in resource-limited settings. This example of patient-led assistive device development and its use may assist people who work in community-based rehabilitation.

Key messages

This case demonstrates how a motivated patient in a rural, resource-limited setting achieved early mobility and functional recovery using locally made axillary crutches under the guidance of a physiatrist. This example of patient-led assistive device development and its use may assist people who work in community-based rehabilitation.

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Introduction

Traumatic pelvic fractures, resulting from high-energy trauma such as falls, are a important cause of morbidity and disability [1]. These injuries often lead to severe pain, impaired mobility and are frequently associated with other injuries, complicating recovery [2]. Effective management requires a multidisciplinary approach, beginning with initial trauma care and followed by comprehensive medical rehabilitation. However, a substantial gap in rehabilitation services persists globally and in many low- and middle-income countries (LMIC). Over half the population lacks access to essential rehabilitation services, and as few as 5-15% of those who need assistive devices receive them [3, 4, 5].

Innovative, context-specific solutions are needed to address disparities in access to rehabilitation. Highly motivated individuals, supported by professional guidance and local knowledge, can develop effective ways to meet their rehabilitation needs. This case report describes a financially constrained patient who, lacking standard equipment, designed and built his own axillary crutches, enabling functional recovery.

Case description and management

A 68-year-old physically active man from a rural community presented to a local clinic with a pelvic fracture sustained after falling from a second-floor rooftop. He had no formal education and no chronic comorbidities such as diabetes or hypertension. He lives with his wife, and three of his four sons work abroad. Despite his age, he was cognitively alert and socially engaged.

Figure 1 **Patient-made axillary crutch, front and lateral views**

Initial clinical and radiographic evaluations revealed a stable fracture of the superior pubic ramus and a left hip sprain. Given the stable fracture and the absence of neurovascular deficiency, the patient was managed conservatively under orthopaedic care, with in-person and remote physiatric consultations in accordance with the Advanced Trauma Life Support protocol [6].

Initial management focused on bed rest, pain control, and proper positioning. The patient's initial pain score was 8/10 on the Visual Analogue Scale (VAS), which decreased to 4/10 within two weeks with analgesics. A physiatrist-designed exercise programme was initiated during his hospital stay, including breathing exercises, upper-limb strengthening, crutch muscle exercises, and pre-ambulatory training. Hands-on axillary crutch demonstrations and safety education were provided during ward rounds.

Upon discharge from hospital, the patient was instructed to progress to a non-weight-bearing protocol. Faced with financial constraints and the unavailability of standard mobility aids, he constructed an assistive device and trained using a bamboo parallel bar and wooden auxiliary crutches. He had received a demonstration of the proper use of axillary crutches during his hospital stay and used this knowledge to guide the design. The crutches were crafted from pieces of wood, with padded axillary supports and an iron-hooked, handgrip-secured design (Figure 1). He adjusted the device based on functional trials to ensure a comfortable fit that allowed slight elbow flexion and minimised axillary pressure. The crutch height was set three finger-widths below the armpit, with the handgrip positioned to allow approximately 30 degrees of elbow flexion, and the crutch tip placed six inches lateral to his foot.

The patient's progress was monitored at follow-up visits at 6, 9, and 12 weeks. At eight weeks, he began partial weight-bearing with a three-point gait pattern under supervision. By the 12-week follow-up, he had progressed to full weight-bearing with protection. No complications, such as skin abrasions or neurovascular symptoms, were reported. His gait improved, and he reported increased confidence and stride length. His Functional Independence Measure score rose from 115 at the initial assessment to 123 at the final follow-up, indicating a transition from modified independence to complete independence in most activities of daily living, though he remained partially dependent on assistance for more complex tasks. He continued to use crutches for approximately 12 weeks, gradually reducing his reliance as his strength and stability improved.

Discussion

Pelvic fractures are serious injuries that can lead to long-term complications, including chronic pain and limited mobility [7]. Assistive devices are crucial for recovery, yet their accessibility remains a major challenge in low-resource settings [8]. This case highlights how patient-led innovation can bridge this gap. The patient's improvised axillary crutches exemplify appropriate technology, tailored to his specific needs and local resources.

This approach aligns with the "walking aid kit" proposed by Nickpour and O'Sullivan, which emphasises adaptability and user-centred design [9]. The patient's success was not solely due to the device itself but also to the collaborative relationship between the patient and the healthcare providers. The guidance he received on device design and safety was instrumental in preventing potential complications, such as axillary nerve compression or instability.

Physiatrist-led rehabilitation faces multiple challenges, including limited availability of specialists, resource constraints, fragmented care coordination, and variable access to multidisciplinary services [10]. Although this patient did not have access to a comprehensive team, his ingenuity, together with remote guidance from a physiatrist, proved highly effective. The homemade device was virtually free, constructed from scrap materials, whereas a standard pair of crutches would have cost the equivalent of four to five days' wages for a labourer in his community. Physiatrist-led counselling, exercise instruction, and assistive device training facilitated rapid, cost-effective functional recovery. This experience highlights the importance of integrating rehabilitation into primary healthcare in the community. Training and using local resources can improve access and sustainability, aligning with the WHO Rehabilitation 2030 agenda.

This case report illustrates the potential of patient motivation and ingenuity, combined with basic rehabilitation guidance, to achieve functional recovery in a resource-limited setting. The successful use of a self-made axillary crutch demonstrates the clinical value of context-appropriate, low-cost innovations. Although the lack of advanced imaging, such as computed tomography or magnetic resonance imaging, limited a detailed assessment of the pelvic injury, the positive functional outcome highlights the feasibility of healthcare solutions at the primary care level. This case serves as an example of empowering patients to take an active role in their own health and rehabilitation.

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Conflict of interest

We do not have any conflict of interest.

Data availability statement

We confirm that the data supporting the findings of the study will be shared upon reasonable request.

Supplementary file

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CASE REPORT

Rehabilitation of a repatriated worker with spinal cord and brain injuries in a low-resource setting: A case report

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Abstract

Background: Combined spinal cord injury and traumatic brain injury pose complex rehabilitation challenges, particularly in low- and middle-income countries where structured neurorehabilitation services and transitional care pathways are limited. Repatriated migrant workers often return without ongoing rehabilitation, increasing reliance on family caregivers and risk of suboptimal functional recovery.

Case description and management: We report a 27-year-old construction worker who sustained an incomplete L1 spinal cord injury (American Spinal Injury Association C) with mild traumatic brain injury following a fall abroad. After surgical stabilisation, he was repatriated to Bangladesh without rehabilitation and remained wheelchair dependent. On admission, he presented with paraplegia, spasticity, bowel and bladder incontinence, cognitive impairment, anxiety, and a sacral pressure ulcer. A physiatrist-led multidisciplinary team-based rehabilitation program was offered with intensive family caregiver training. His spouse was actively involved in daily care, learning pressure relief techniques, bladder management, transfer assistance, and emotional support strategies. Over ten weeks, the patient demonstrated significant improvements in motor strength, spasticity, cognitive orientation, bladder control, pain, and functional mobility, progressing to supervised ambulation. The spouse's consistent involvement and skill acquisition were central to adherence and recovery.

Conclusion: This case highlights that structured family caregiver training is a pivotal component of successful rehabilitation, enabling meaningful functional gains even in resource-constrained settings. Integrating caregivers into multidisciplinary care offers a practical, sustainable model aligned with WHO Rehabilitation 2030 priorities.

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Key messages

A coordinated multidisciplinary team, combined with active family participation, enabled meaningful recovery for a repatriated worker with spinal cord injury and traumatic brain injury in a low-resource setting. This case highlights how caregiver involvement, especially spousal support alongside structured, physiatrist-led rehabilitation team work, can bridge service gaps and significantly improve functional and psychosocial outcomes.

Introduction

Spinal cord injury combined with traumatic brain injury [1] presents substantial challenges for rehabilitation, particularly in low- and middle-income countries where coordinated neurorehabilitation services remain limited. Migrant construction workers from low- and middle-income countries often sustain injuries abroad, receive acute surgical treatment, and are subsequently repatriated without a structured rehabilitation plan [2]. Upon return, they commonly face health care problems, no care guidance, fragmented healthcare systems, minimal insurance coverage, and dependence on family caregivers who receive little formal guidance [3]. Bangladesh is experiencing a growing number of such injured returnees, yet it lacks transitional care pathways tailored to their complex needs.

The case highlights how a physiatrist-led multidisciplinary team working in close collaboration with a motivated family caregiver can facilitate meaningful functional recovery even within a low-resource environment. The report further underscores the essential role of family participation, especially spousal involvement, and advocates for coordinated team-based care and structured discharge planning in similar contexts.

Case description and management

A 27-year-old migrant construction worker sustained a fall from a second-story building at his overseas worksite. He lost consciousness immediately and was transported to a nearby hospital, where imaging and neurological assessment confirmed a mild traumatic brain injury and an unstable L1 burst fracture with spinal cord compression. He underwent intensive care management followed by posterior spinal fixation with plates and screws (Figure 1). Although inpatient rehabilitation was recommended, limited insurance support and lack of employer facilitation led to his repatriation four weeks post-surgery, still wheelchair-dependent and without ongoing care.

Figure 1 Posterior spinal fixation with plates and screws

Upon returning to Bangladesh, the patient was brought to the Physical Medicine and Rehabilitation outpatient department of a tertiary university hospital and admitted for comprehensive inpatient rehabilitation. Initial evaluation showed an L1 incomplete spinal cord injury (American Spinal Injury Association C). Lower limbs demonstrated weakness according to Medical Research Council (MRC) grade 3/5 [4] with spasticity (grade 2) [5], intact upper-limb strength (MRC 4/5), and bowel and bladder incontinence with a pain score of 5/10 in visual analog scale. A grade 2 sacral pressure ulcer was noted. Cognitive assessment indicated Rancho Los Amigos Level III [6] with confusion, inconsistent responses, and moderate anxiety. His spouse, who had accompanied him to the hospital, expressed a strong commitment to participating actively in his rehabilitation.

Given the combination of neurological, cognitive, and psychosocial impairments, a structured multidisciplinary rehabilitation plan was initiated under the supervision of a physiatrist. The core rehabilitation team included physiotherapists, occupational therapists, a rehabilitation nurse, a clinical psychologist, a medical social worker, and a nutritionist, with the patient's wife integrated as an essential caregiver within the team. Care giver focused management priorities included: a) Pressure ulcer care: daily wound dressing, repositioning strategies, and caregiver training on pressure-relief techniques, b) Psychological support: counseling for both patient and spouse focusing on adjustment, caregiver stress, and motivation and c) Caregiver empowerment: Hands-on training was emphasized throughout, with the spouse learning transfer techniques, bladder care, skin inspection, and emotional regulation strategies.

Over ten weeks, the patient demonstrated consistent improvement: lower-limb strength increased (MRC grade 4/5), spasticity reduced, and independent bladder emptying was achieved. Cognitive orientation improved significantly (Rancho Los Amigos Level VII), with a reduction in pain (Visual Analog Scale 2/10), anxiety, and behavioral disorganisation. Functionally, he progressed from dependent wheelchair mobility to supervised ambulation with assistive devices. His spouse's continuous involvement in reinforcing therapy goals, assisting in exercises, and providing emotional support proved central to his adherence and overall recovery trajectory.

Discussion

The case illustrates the value of integrated, team-based neurorehabilitation for a repatriated worker with combined Spinal cord injury combined with traumatic brain injury in a resource-constrained setting. Mild traumatic brain injury complicated the patient's presentation, affecting cognition, emotional stability, and functional learning [1]. International guidelines recommend coordinated post-acute rehabilitation for such cases [7], yet access is limited in many low- and middle-income countries. In Bangladesh, physiatrist-led rehabilitation units exist, but structured inpatient programs and community follow-up remain insufficient (12.5%) [8].

A key strength of this case was the continuity of multidisciplinary care—addressing pressure injury, spasticity, bladder and bowel dysfunction, mobility limitations, and cognitive issues simultaneously. Equally critical was the active participation of the patient's spouse, whose presence provided psychological security, consistent reinforcement of therapy goals, and reliable caregiving support [9]. Evidence from low- and middle-income countries rehabilitation literature consistently affirms the impact of family engagement on functional outcomes, therapy adherence, and long-term reintegration [10].

This case demonstrates that even in low-resource contexts, functional gains are achievable when rehabilitation is coordinated, patient-centered, and family-supported.

Conclusion

This case shows that functional recovery after complex neurological injury is achievable in low-resource settings through coordinated multidisciplinary rehabilitation and active family participation. The physiatrist-led team addressed physical, cognitive, and psychosocial needs, while the patient's spouse provided consistent caregiving and emotional support. Together, the team's work strengthened the patient's functional gains and reintegration potential, demonstrating a practical, sustainable model aligned with the WHO Rehabilitation 2030 goals.

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PERSPECTIVE

Integrating bioethics-driven rehabilitation to address non-communicable diseases and disabilities in Bangladesh and other low- and middle-income countries

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Low- and middle-income countries (LMICs) are undergoing an epidemiological transition with noncommunicable diseases (NCDs) such as stroke, diabetes, and cardiovascular diseases rising sharply [1]. These conditions often lead to long-term disability, yet rehabilitation services remain peripheral in most health strategies [2]. Globally, 16% of people live with disabilities, but their needs are consistently marginalised. Rehabilitation, particularly under the leadership of physiatrists, offers a means to uphold justice and dignity in health systems [3]. This article argues for a bioethics-driven framework to guide disability-inclusive NCD management, with Bangladesh providing a case example [4].

Traditional biomedical ethics emphasises autonomy and beneficence, but LMICs require broader principles: distributive justice, solidarity, and the capability approach. Exclusionary practices—such as inaccessible facilities, discriminatory consent processes, and catastrophic out-of-pocket expenses—compound inequities. Stroke survivors, individuals with spinal cord injury, and those with diabetic complications often face functional impairment without adequate rehabilitation or assistive technologies [5]. Neglecting rehabilitation violates justice and undermines human dignity.

Rehabilitation operationalises ethical principles by restoring function, independence, and participation. Physiatrists lead multidisciplinary teams comprising physiotherapists, occupational therapists, speech therapists, psychologists, and social workers, ensuring comprehensive care. In LMICs, where systems are fragmented and resources are scarce, this leadership is essential.

In Bangladesh, the expansion of community clinics and community-based rehabilitation provides a platform for incorporating disability-sensitive NCD care, with union-level health and family welfare centres delivering services close to home [1]. Yet major constraints persist weak infrastructure, limited training, and underfunded services. Recognising rehabilitation as a core element of universal health coverage is therefore an ethical imperative [2].

Despite international commitments such as the United Nations Convention on the Rights of Persons with Disabilities, implementation remains weak. Rehabilitation and non-pharmacological strategies are often excluded from NCD plans, and disability-disaggregated data are scarce [6]. Emerging tools such as digital health and artificial intelligence risk widening inequities unless inclusivity standards are mandated. Social determinants like poverty, stigma, and climate displacement—further entrench exclusion.

A bioethics-driven rehabilitation strategy in LMICs should include:

a) Mainstreaming rehabilitation in NCD policies.
b) Strengthening physical medicine and rehabilitation leadership and expanding multidisciplinary training.
c) Ensuring universal accessibility—physical, digital, and communicative.
d) Establishing social protection schemes to reduce out-of-pocket costs.
e) Enforcing ethical governance of AI and digital health.
f) Creating accountability mechanisms led by organizations of persons with disabilities.

Key messages

Noncommunicable diseases are rapidly increasing in low and middle income countries, deepening disability and inequality. Integrating rehabilitation into NCD care is both an ethical and practical imperative. Guided by justice, solidarity, dignity, and capability, bioethics provides a framework for inclusive health systems. Physiatrists and rehabilitation teams play a vital role in promoting equitable care in Bangladesh and similar contexts.

These measures promote justice, solidarity, and sustainability in health systems.

In conclusion, rehabilitation in LMICs must be reframed as an ethical necessity rather than an optional adjunct. Embedding rehabilitation within NCD pathways secures not only survival but also dignity, participation, and independence for persons with disabilities. For Bangladesh, integrating bioethics into rehabilitation policy and practice offers both a moral obligation and a pragmatic route toward inclusive, resilient health systems.

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PERSPECTIVE

Advanced robotic rehabilitation in Bangladesh Medical University

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Robotic rehabilitation is an emerging field within physical medicine and rehabilitation that provides high-intensity, repetitive, and precise rehabilitation to enhance neuroplasticity and promote functional recovery. The global evidence base for robotic rehabilitation in post-stroke and spinal cord injury populations shows improvements in gait parameters, mobility, and training although there is heterogeneity in functional outcomes has been comprehensively reviewed elsewhere [1, 2, 3]. This perspective therefore focuses on implementation experience, early outputs, and unresolved challenges in Bangladesh.

Bangladesh Medical University, a national centre of excellence for postgraduate medical education and tertiary care, has recently established a Robotic Rehabilitation Centre to support patients with complex disabilities. The robotic systems deployed at the centre were provided as a governmental gift from the People's Republic of China for humanitarian rehabilitation purposes, rather than procured through direct institutional or public financial investment. Regulatory requirements of national authorities are being followed and approved temporarily by Directorate General of Drug Administration of Bangladesh. This initiative, therefore, lies in the responsible, ethical, and effective utilisation of this advanced medical technology within a public-sector health system. Since inception, approximately 220 patients with neurological and musculoskeletal conditions have received robot-assisted therapy. It is assumed that 60% more improvement was found in the robotic rehabilitation than that of conventional therapy. No serious device-related adverse events have been observed so far. The programme has demonstrated operational feasibility in a public university hospital, including staff training, routine maintenance, and integration with conventional therapy pathways. However, systematic outcome analysis and health-economic evaluation are ongoing. These advantages relate primarily to therapy delivery and monitoring rather than proven superiority in functional outcomes, which remains to be established through comparative studies. At present, the centre lacks systematically analysed outcome data comparing robotic-assisted and conventional rehabilitation. Cost-effectiveness, long-term functional outcomes, and patient-reported measures will be evaluated.

Bangladesh is a country with a growing burden of disability together with unmet rehabilitation needs and a shortage of physical medicine and rehabilitation specialists [4, 5]. National surveys consistently report fragmented service delivery, urban-rural disparities, and limited access to modern rehabilitation technologies. At this context, the Robotic Rehabilitation Centre at Bangladesh Medical University took an attempt to introduce structured, task-specific, and data-driven rehabilitation within a public sector setting. In this stage robotic systems are used as adjuncts to drug therapy and allow objective monitoring through parameters such as range of motion and muscle strength, in line with global

Key messages

Bangladesh Medical University's Robotic Rehabilitation Centre introduces advanced robotic systems for neurological and musculoskeletal care. Robotic therapy delivers high-intensity, precise treatment that can improve patient outcomes. The centre builds research and training capacity and advances Bangladesh toward excellence in rehabilitation despite cost and access challenges.

evidence suggesting potential benefits of integrated robotic rehabilitation. Clinically, robotics help to extend therapist capacity by reducing physical workload during repetitive training and facilitating delivery of higher-intensity, standardised rehabilitation. Academically, integration of robotic systems provides trainees with exposure to contemporary rehabilitation technologies. Research initiatives, including prospective registries and pragmatic studies, are planned to generate local evidence on feasibility, safety, and cost-benefit in a Bangladesh context.

Bangladesh Medical University's initiative demonstrates that advanced rehabilitation technologies can be introduced in a resource-constrained setting. Future work should focus on publishing patient-reported and programme outcome data, comparing robotic-assisted versus conventional therapy. With strategic investment, policy support, and attention to equity, this centre could be a regional hub for innovation in rehabilitation in Bangladesh.

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METHODS ARTICLE

Pedagogy of community-engaged research

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Abstract

Community-engaged research (CEnR) has emerged as a transformative approach to knowledge co-creation, challenging academic hierarchies through equitable partnerships between communities and researchers. While much attention has been devoted to CEnR methodologies and ethics, less focus has been placed on how to effectively teach and learn its principles and practices. This paper presents a conceptual framework for CEnR pedagogy, outlining its foundational components rather than a full implementation strategy. The framework includes three interconnected elements that move beyond transmissive teaching toward transformative, learner-centered education. The first, Foundational Principles, addresses the "why" of CEnR education, emphasising epistemic humility, critical consciousness, relational competence, and ethical accountability. The second, Design Strategies, translates these principles into curriculum through capacity bridging, experiential learning, cultural responsiveness, and sustainability planning. The third, Teaching–Learning Practices, operationalises the framework through participatory teaching, community-based engagement, applied projects, reflexive practices, and contextual placement. Preparing researchers for authentic community engagement requires more than technical skills. It calls for critical reflexivity and relational accountability. We also acknowledge practical challenges, including institutional constraints and the risk of "lite pedagogy" that superficially incorporates CEnR principles without promoting genuine transformation. Safeguards include structured mentorship, reflective assessments, and co-teaching arrangements that center community voices. This conceptual pedagogical model supports learners in embodying CEnR's core values while developing technical competencies, thereby strengthening both the integrity and societal relevance of community-engaged research. While the framework outlines strategies and methods conceptually, empirical testing, co-designed curricula, and evaluative metrics are future work that will require thoughtful investigation.

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Key messages

Pedagogy in community-engaged research requires more than technical skill; it integrates epistemic humility, relational accountability, and collaborative praxis within flexible frameworks. Through strategies like capability bridging, culturally responsive curricula, and participatory teaching in community contexts, educators transcend transmissive models, fostering critical consciousness, adaptability, and shared knowledge that enable ethical, equitable, and reflexive engagement with real-world research challenges.

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Pedagogy

Pedagogy refers to the approach to teaching and learning that encompasses the theory and practice of how educators instruct, guide, and facilitate learning to achieve specific educational goals. It encompasses not only the "what" (content) of curriculum but also the "why" (values and purposes), the "how" (methods of delivery and learning), the "with whom" (multifaceted relationships that shape teaching), the "where" (contexts and institutional settings), and the "to what effect" (assessment and impact) [1]. Essentially, pedagogy describes the entire approach to teaching and learning, covering the aspects from initial planning and curriculum design to the actual delivery of lessons and assessment of learner progress (Table 1). A central concept in contemporary scholarship is learner-centered pedagogy, which places the learner at the heart of the educational process, emphasising active participation, coconstruction of knowledge, and responsiveness to individual needs [2, 3]. It is not simply about transferring knowledge but about shaping the ways educators and learners think, act, and relate to others in the teaching-learning processes [4]. Rather than considering students as a "blank slate", this approach takes into account the previous knowledge, skills, and experience that everyone involved brings to the learning process.

Conducting research in the community setting

Community-Engaged Research (CEnR) or Community Based Research (CBR) has emerged as a cornerstone of equitable and impactful scholarship, fundamentally challenging traditional academic hierarchies and knowledge production practices when conducted in community settings [5]. Much of the discourse emphasises "how to conduct CEnR"; methodological approaches for co-designing studies, ensuring ethical, equitable, and empowering engagement, co-creation of knowledge products, and sustaining community partnerships [6, 7]. Yet far less attention has been given to "how we teach and learn CEnR". If CEnR is to fulfill its promise of transforming research into a collaborative and justice-oriented endeavor, then dedicated scholarly attention needs to be devoted to its pedagogy.

Pedagogy of CEnR

Conventional research training focuses heavily on technical skills, such as research design, ethics approval processes, data collection, analysis, and interpretation [8]. While essential, these skills are insufficient for authentic CEnR [8]. CEnR represents a transformative model of knowledge co-creation that emphasises collaboration between academic researchers and community members [9, 10]. While much attention has been given to the methodologies and ethical considerations of CEnR, there is growing recognition of the need for a pedagogy that prepares university students and other learners to engage meaningfully with communities to conduct research in the local settings. This requires moving beyond transmissive models, where educators deliver information to passive learners, toward transformative pedagogy that cultivates critical consciousness, agency, and reflective practice [11]. Alongside this, inclusive pedagogy emphasises equity, inclusion, and responsiveness to diversity, ensuring that all learners are recognised as capable contributors in the learning process [12]. Building on this, open pedagogy further invites learners to co-create knowledge, engage collaboratively in the learning process, and participate in shaping both content and methods, thereby deepening engagement and ownership of learning outcomes [13].

To achieve this, a CEnR pedagogy needs a structured yet flexible framework that equips learners not only with technical competencies but also with the reflexivity, relational accountability, and critical consciousness necessary for meaningful engagement with communities [14, 15]. Explicit recognition of learner-centered and context-responsive approaches is essential, as both the needs of learners and the cultures of partner communities must inevitably shape teaching and research practices. This manuscript focuses on concepttualising such a pedagogy; specific examples of tested models or measurable learning outcomes are planned for future empirical work. Operationalising CEnR pedagogy calls for attention to three interconnected components: Foundational Principles, Design Strategies, and Teaching–Learning Practices (Figure 1). These components not only structure the teaching-learning experience but also correspond to core pedagogical questions: Foundational Principles address the 'why' of teaching, articulating the values and purposes that guide CEnR; Design Strategies outline the 'what', translating principles into actionable curricula and learning experiences; and Teaching–Learning Practices encompass the 'how', 'with whom', 'where', and 'assessment', detailing interactive methods, collaborative engagement, evaluation approaches, and contextual considerations. Framing the pedagogy in this way helps educators and learners plan and arrange learning that is both theoretically grounded and pragmatic.

Foundational principles (the Why)

Foundational principles provide the philosophical and ethical grounding for CEnR pedagogy, answering the question of why educators and learners engage in CEnR

Epistemic humility and critical consciousness

Emphasising the value of situated knowledge, challenging academic dominance, and fostering reflexivity about power, positionality, privilege, and structural dynamics that shape research relationships [11]. Learners reflect critically on their own social location and biases to engage ethically with communities.

Relational competencies and ethical accountability

Prioritising skills for building and sustaining respectful, reciprocal partnerships. Trust, transparency, and long-term commitment underpin the ethical conduct of CEnR [8].

Table 1 Aspects of pedagogy

Components of pedagogy (The foundational building blocks of pedagogy; essential elements that constitute the teaching-learning process)
Learning design and content
Learning objectives and goals
Curriculum content and subject matter
Instructional strategies and teaching methods
Assessment and feedback
Assessment and evaluation
Feedback mechanisms
Learning environment and resources
Learning resources and materials
Learning environment
Learning support systems
Interest-holders and context
Teacher and facilitator expertise, skills, and pedagogical knowledge
Learner characteristics
Time management and pacing of instruction
Policy and institutional context
Dimensions of pedagogy (The perspectives or approaches through which pedagogy is framed; reflecting variations in context, approach, and learner engagement)
Delivery and interaction
Mode of delivery
Teacher-centered and learner-centered approaches
Individual and collaborative learning
Active engagement and participation
Cognitive and scholastic focus
Cognitive and affective focus
Reflective and metacognitive focus
Scaffolding and differentiated instruction
Inquiry-driven and problem-solving approaches
Context and inclusivity
Formal and informal learning contexts
Discipline-specific and interdisciplinary approaches
Culturally responsive and inclusive pedagogy
Experiential and hands-on learning
Gamified and playful learning approaches
Social-emotional learning integration
Ethical and values-based education
Attributes of pedagogy (The qualities or characteristics that influence the effectiveness, style, and perception that shape pedagogy)
Adaptability and creativity
Flexibility and adaptability
Creativity and innovation
Responsiveness to feedback
Adaptation to technology and innovation in teaching
Relational and ethical
Empathy and relational sensitivity
Ethical and culturally sensitive practice
Collaboration and teamwork facilitation
Emotional intelligence and social awareness
Effectiveness and impact
Clarity and transparency
Motivation and engagement fostering
Critical thinking promotion
Communication effectiveness
Consistency and reliability
Sustainability and long-term impact focus
Curiosity and inquiry stimulation
Empowerment of learners
Resilience and perseverance in teaching practice
Accountability and responsibility in learning outcomes

Praxis-oriented collaboration
Supporting learners to engage in genuine co-learning and co-creation, ensuring community partners participate as equitable agents throughout question formulation, methodology, data collection, interpretation, and mobilisation.

Design strategies (the What)

Design strategies translate foundational principles into actionable curriculum content, focusing on what learners are taught in order to operationalise CEnR values:

Capacity bridging and mutual exchange
Equipping both educators and community partners as co-learners and co-educators in skills exchange, recognising and leveraging community expertise.

Experiential and applied learning
Embedding scaffolded, real-world partnerships that foster reflective engagement with relational processes and community impact.

Cultural responsiveness
Adapting curricula to local languages, knowledge systems, and cultural practices to ensure research relevance and respect.

Sustainability and relationship maintenance
Structuring support for long-term engagement that extends beyond the classroom or project timeline.

Teaching–Learning Practices (the How/ With Who/ Where/ assessment)

Teaching–Learning Practices encompass the practical methods through which learners experience CEnR, covering how, with whom, where, and to what effect learning occurs:

Participatory and interactive teaching
Interactive workshops, case-based discussions, and hands-on sessions foster bidirectional knowledge exchange, modeling reflexivity, relational accountability, and equitable collaboration. This includes content or modules co-designed and co-taught with community partners.

Scaffolded community-based engagement
Structured experiential placements allow learners to progressively engage with communities, building skills and responsibility in real-world contexts.

Applied project activities
Hands-on assignments and exercises, such as joint dissemination efforts or participatory action research projects, operationalise principles and design strategies. Facilitating opportunities for community members to identify research priorities and to name research questions can be excellent learning opportunities for university students, especially those who are not used to listening and learning from community partners.

Reflexive and evaluative practices
Critical incident analyses, positionality reflections, and structured feedback loops encourage ongoing assessment of both process and outcomes.

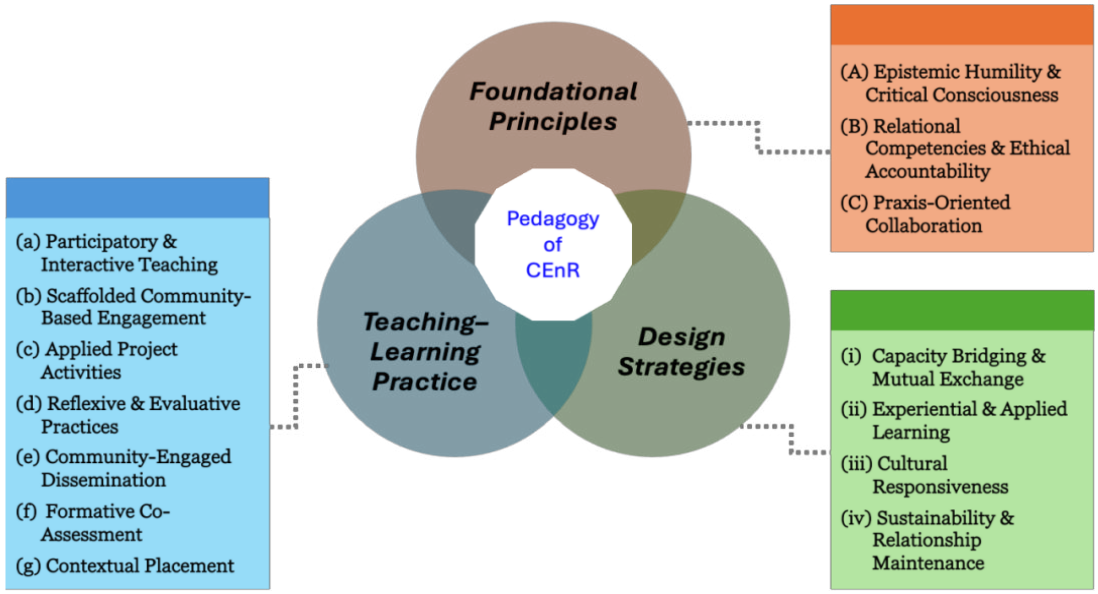

Figure 1 **The pedagogy of community engaged research**

Community-engaged dissemination

Joint authorship, community forums, and co-facilitated presentations ensure findings are shared ethically and inclusively.

Formative co-assessment

Continuous, participatory evaluation—reflexive journals, peer and community feed-back, and codesigned rubrics—captures both technical competencies and relational skills. Engaging community partners in co-designing contents and co-evaluating student learning also makes it clear to students that community members bring valuable knowledge and expertise to these endeavors.

Contextual placement

Learning occurs in authentic community settings, bridging classroom knowledge with real-world research practice and enabling meaningful engagement.

Circumstantial realities and challenges

Implementing a multilevel CEnR pedagogy is not without challenges. Foundational research skills remain essential; learners must master study design, data collection, and analysis. Institutional constraints, including accreditation requirements and curricular restrictions, also shape research curriculum and program design [16]. A progressive developmental approach, starting with methodological fundamentals and gradually integrating transformative community-engaged practices, may be the most feasible solution. However, care must be taken to avoid "lite pedagogy," where engagement with CEnR principles is superficial, failing to disrupt entrenched hierar-chies or support true transformation. Indeed, teaching students that CEnR is simply a collection of items on a checklist, is not only a lost opportunity, but a way of co-opting research practices that are meant to be grounded in transformative justice. Deliberately designed and critically evaluated pedagogy that centers critical consciousness, reflexivity, relational accountability, and ethical engagement is essential to avoid such reductionism [11].

Conclusion

A structured, multilevel approach to CEnR pedagogy is critical for developing learners who embody core values, not just technical methods. By integrating foundational principles, design strategies, and teaching–learning practices, this pedagogy equips learners to engage ethically, equitably, and effectively with communities.

This paper serves as a conceptual and methodological foundation. Future work needs to focus on piloting the framework, empirically evaluating learning outcomes, and refining implementation across disciplines, institutions, and cultural contexts. Documenting these applications will contribute to evidence-based refinement of the framework and enhance its adaptability.

Institutions and educators have a responsibility to design, implement, and iteratively refine pedagogical models that balance technical competencies with transformative, community-engaged learning. Such models improve research outcomes and support broader social justice by preparing learners to navigate complex social, cultural, and structural dynamics.

As CEnR continues to evolve, ongoing reflection and adaptation of pedagogy is vital to ensure research remains equitable, impactful, and responsive to diverse community needs. By embracing a structured, multilevel pedagogy, educators and learners together can strengthen both the integrity and societal relevance of CEnR.

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