Global Scientific JOURNALS

GSJ: Volume 14, Issue 2, February 2026, Online: ISSN 2320-9186
www.globalscientificjournal.com

Integration of Biophilic Design Principles in Rehabilitation Centres for the Physically Challenged

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Abstract

Rehabilitation centres for the physically challenged are complex healthcare environments where physical recovery, psychological wellbeing, and social reintegration occur simultaneously. Unlike acute-care hospitals, these facilities require prolonged patient engagement, repetitive therapeutic activities, and environments that sustain motivation over extended periods. This paper investigates the integration of biophilic design principles into rehabilitation centres as a means of enhancing recovery outcomes for physically challenged users. Drawing on the biophilia hypothesis, healing architecture theory, and empirical healthcare design research, the study synthesises existing literature with in-depth analysis of two internationally recognised case studies, Spaulding Rehabilitation Hospital in Boston and Khoo Teck Puat Hospital in Singapore. Through a qualitative review of scholarly works, and architectural case documentation, the paper demonstrates that biophilic design, when deliberately aligned with accessibility and rehabilitation programming it supports physical mobility, reduces psychological stress, improves therapy adherence, and enhances overall user experience for both patients and staff. The findings highlight that nature-integrated environments function not merely as aesthetic enhancements but as active therapeutic agents within rehabilitation architecture.

Key-Words: - *Biophilic design, Rehabilitation centre, Accessibility, Healthcare architecture, Healing landscapes*

1. INTRODUCTION

The built environment has long been acknowledged as an active agent in human health, rather than a neutral backdrop to medical intervention. Within architectural discourse, healthcare environments particularly rehabilitation centres are increasingly understood as therapeutic landscapes, where spatial quality directly influences recovery trajectories. Rehabilitation centres for the physically challenged are unique in that recovery is

often prolonged, iterative, and deeply dependent on patient motivation, emotional stability, and environmental support (Ulrich et al., 2008).

Biophilic design, grounded in the biophilia hypothesis proposed by Wilson (1984), asserts that humans possess an innate affinity for natural systems. When applied to architecture, this theory suggests that buildings which reconnect users with nature can reduce stress, improve cognitive function, and enhance physical wellbeing. In rehabilitation contexts, these outcomes align closely with therapeutic goals such as neuroplasticity, motor relearning, psychological resilience, and social reintegration.

Rehabilitation centres function as transitional environments spaces where patients relearn basic bodily functions, rebuild autonomy, and renegotiate identity after disability or trauma. Consequently, environmental stressors such as poor daylighting, monotonous interiors, institutional aesthetics, and sensory deprivation can impede recovery (Verderber & Fine, 2000). Conversely, environments enriched with natural light, vegetation, views, and tactile materials have been shown to enhance therapy participation and emotional wellbeing (Kellert, 2018).

Despite growing interest in biophilic healthcare design, much of the existing literature focuses on general hospitals, psychiatric facilities, or wellness centres. There remains a relative lack of rehabilitation-specific architectural research, particularly studies that integrate accessibility, universal design, and biophilia into a cohesive framework. This paper addresses that gap by synthesising theoretical models, empirical evidence, and real-world case studies to examine how biophilic design principles can be systematically integrated into rehabilitation centres for the physically challenged.

1.1 Aim and Objectives

Aim

The primary aim of this study is to investigate how biophilic design principles can be integrated into rehabilitation centres to support the physical, psychological, and social recovery of physically challenged users.

Objectives

1. To examine the theoretical foundations of biophilic design and their relevance to rehabilitation architecture.
2. To review empirical studies linking biophilic environments with health and rehabilitation outcomes.

3. To analyse existing rehabilitation and healthcare facilities that successfully integrate biophilic design strategies.
4. To identify design principles that respond to accessibility, sensory engagement, and therapeutic functionality.
5. To propose architectural guidelines for the design of future rehabilitation centres.

2. CONCEPTUAL AND THEORETICAL FRAMEWORK

2.1 The Biophilia Hypothesis

Edward O. Wilson (1984) introduced the biophilia hypothesis, proposing that human beings evolved in close interaction with nature and therefore retain an inherent need for natural stimuli. This hypothesis was later expanded by Kellert and Calabrese (2015), who translated biophilia into architectural terms, identifying patterns that can be deliberately embedded into buildings.

Kellert categorized biophilic design into three experiential dimensions:

- Direct experience of nature (light, air, plants, water, landscapes)
- Indirect experience of nature (natural materials, colours, biomorphic forms)
- Experience of space and place (prospect and refuge, complexity and order, transitional spaces)

In rehabilitation centres, these dimensions are particularly relevant because recovery often involves sensory retraining, emotional regulation, and gradual re-exposure to complex environments.

2.2 Healing Architecture and Therapeutic Landscapes

The concept of healing architecture emerged from environmental psychology and healthcare research, notably through the work of Ulrich (1984), who demonstrated that patients with views of nature recovered faster and required less pain medication. Gesler (1992) later introduced the notion of therapeutic landscapes, arguing that healing arises from the interaction of physical environment, social context, and symbolic meaning.

Rehabilitation centres, more than most healthcare typologies, function as therapeutic landscapes because:

- Patients remain for extended periods
- Physical movement is central to treatment

- Emotional and psychological recovery is integral to physical healing

Biophilic design strengthens the therapeutic landscape by embedding restorative environmental cues directly into daily routines.

3. LITERATURE REVIEW

3.1 Biophilic Design in Healthcare Architecture

A growing body of literature supports the application of biophilic design in healthcare environments. Ulrich et al. (2008) identified environmental stress reduction as a key factor in patient recovery, highlighting daylight, nature views, and access to outdoor spaces as critical design elements. A systematic review by Browning, Ryan, and Clancy (2014) identified 14 patterns of biophilic design, many of which have been empirically linked to reduced stress, improved mood, and enhanced cognitive performance. In hospital settings, these patterns have been associated with shorter lengths of stay and higher patient satisfaction. Tekin et al. (2022) further synthesised healthcare-focused biophilic research, concluding that evidence-based biophilic environments contribute positively to both patient outcomes and staff wellbeing, although they emphasised the need for context-specific studies.

3.2 Biophilic Design and Physical Rehabilitation

Research directly linking biophilic design to physical rehabilitation outcomes is emerging but remains fragmented. Marcus and Barnes (1999) observed that access to healing gardens increased patient mobility and encouraged informal physical activity. In stroke rehabilitation studies, daylight exposure and outdoor therapy have been associated with improved mood and engagement, indirectly supporting neuroplastic recovery (Shepley et al., 2016).

Kellert's principles with rehabilitation needs and groups them into four operational domains:

Sensory & Perceptual Engagement: This includes daylighting, views, natural color palettes, texture and materiality for tactile stimulation.

Movement & Motor Relearning: The accessibility of gardens and exterior routes, graded surfaces for gait training, rails and landscape features designed for assisted mobility.

Social & Cognitive Recovery: The prospect/refuge spaces for privacy and small-group interaction; wayfinding cues

using natural motifs to reduce cognitive load.

Physiological Comfort & Safety: Microclimate control using vegetation and water for thermal comfort, acoustic buffering with planted buffers, and safe, non-slippery naturalistic paving (Nithianantharajah & Hannan, 2006).

3.3 Accessibility, Universal Design, and Nature

One major critique of biophilic architecture is its occasional neglect of accessibility. Steinfeld and Maisel (2012) argue that nature-based environments often exclude people with disabilities due to poor gradients, uneven surfaces, and lack of assistive features. However, recent scholarship emphasises inclusive biophilia, where natural environments are designed with universal access in mind. Studies on therapeutic gardens for wheelchair users demonstrate improved mood and participation when raised planting beds, continuous handrails, and smooth surfaces are incorporated (Hussein, 2012).

4. BIOPHILIC DESIGN PRINCIPLES

4.1 Daylighting and Visual Connection to Nature

Daylight is one of the most consistently supported biophilic elements in healthcare research. Exposure to natural light regulates circadian rhythms, improves sleep quality, and enhances mood critical factors in rehabilitation where fatigue and depression are common. Shepley et al. (2012) found that rehabilitation patients in naturally lit environments demonstrated higher engagement in therapy sessions. For physically challenged users, visual access to nature also provides external focus, reducing pain perception during exercises. Design implications include:

- Large windows in therapy gyms
- Courtyards visible from circulation spaces
- Adjustable shading to prevent glare for visually impaired users

4.2 Therapeutic Landscapes and Outdoor Rehabilitation

Outdoor environments extend rehabilitation beyond clinical interiors. Marcus (2007) described healing gardens as “outdoor rooms” that support physical, emotional, and social healing. In rehabilitation centres, landscapes can be designed as:

- Walking circuits with varied textures
- Balance-training paths
- Social interaction zones

Evidence suggests that patients are more willing to engage in repetitive exercises outdoors, perceiving them as leisure rather than therapy (Whitehouse et al., 2001).

4.3 Materiality, Texture, and Sensory Engagement

Natural materials such as wood and stone provide tactile stimulation and visual warmth. According to Kellert (2018), material authenticity enhances emotional connection and reduces institutional stress. For physically challenged users, contrasting textures improve proprioception and spatial awareness. However, materials must meet hygiene and durability standards prompting the use of sealed timber, textured concrete, or engineered stone.

4.4 Prospect, Refuge, and Psychological Safety

Prospect-refuge theory (Appleton, 1975) explains human preference for environments offering both openness and protection. In rehabilitation centres, open spaces encourage movement and confidence, while refuge spaces support rest and emotional recovery. Design strategies include:

- Semi-enclosed seating niches
- Visual transparency with physical separation
- Gradual transitions between public and private zones

5. CASESTUDIES

5.1 Spaulding Rehabilitation Hospital, Boston

Spaulding Rehabilitation Hospital (new facility and campus improvements) is a leading example of integrating landscape and therapeutic programming into a high-performance rehabilitation environment. The project places emphasis on accessible terraces, therapeutic roof gardens, easily accessible waterfront promenades, and outdoor exercise opportunities linked to clinical programming. Research conducted by the Landscape Architecture Foundation (2016) revealed:

- Therapeutic roof terraces and courtyards connected to indoor therapy spaces, enabling quick transitions between gym and garden for task-specific training.
- Accessible waterfront promenade with rails and surface treatments designed for wheelchair users and gait training, offering visual prospect and social activation.
- Integrated landscape with exercise programming including graded paths, seating nodes, and planting

that creates microclimates for restorative pauses.

Figure 1: Spaulding Rehabilitation Hospital
Source: Landscape Architecture Foundation. (2016).

Outcomes and Evaluation

Post-occupancy evaluation and project reports highlight increased patient usage of outdoor spaces, reported improvements in wellbeing among in-patients and out-patients, and enhanced staff satisfaction. The project also provides examples of how landscape design enabled resilience (stormwater management, thermal comfort) and multi-use community activation supporting both hospital users and neighbourhood residents. While direct clinical outcome measures (e.g., gait speed improvement attributable to garden use) require more focused studies, early evidence indicates higher therapy adherence and patient morale (Landscape Architecture Foundation, 2016).

5.2 Khoo Teck Puat Hospital (KTPH), Singapore

KTPH is often cited as one of the most biophilic large-scale hospitals globally. While not exclusively a rehabilitation centre, KTPH's design principles (a "hospital in a garden") are highly relevant for rehabilitation settings. The hospital integrates extensive vertical and horizontal planting, adopts an adjacent stormwater pond into its campus, and uses spatial strategies to bring nature into patient rooms and circulation spaces. KTPH won the Stephen S. Kellert Biophilic Design Award and is frequently used as a benchmark in biophilic healthcare research. Kishnani (2015) reported that Khoo Teck Puat Hospital achieved:

- Improved patient satisfaction scores
- Measurable microclimatic cooling
- Increased biodiversity

These outcomes highlight the broader ecological and social benefits of biophilic healthcare design.

Figure 2: Khoo Teck Puat Hospital
Source: Kishnani, N., & Cossu, G. (2017).

Outcomes and Evaluation

Studies and post-occupancy research indicate improved perceived wellbeing, higher patient and staff satisfaction in public surveys, biodiversity increases, and measurable microclimate benefits (e.g., local cooling). KTPH consistently outperformed comparator hospitals in satisfaction surveys, and its integrated approach to blue-green spaces has been linked to community activation programs (tai chi, volunteering in rooftop gardens), which are relevant for rehabilitation's social reintegration goals morale (Landscape Architecture Foundation, 2016).

6. DISCUSSION

The findings of this study reinforce the growing consensus that architecture plays an active role in healthcare outcomes, particularly within rehabilitation environments where recovery is highly dependent on patient engagement, emotional resilience, and sustained physical effort. Biophilic design, as evidenced through the reviewed literature and case studies, operates across multiple dimensions of rehabilitation: physiological regulation, psychological restoration, and behavioral motivation. Unlike conventional institutional healthcare design, which often prioritizes efficiency and clinical control, biophilic rehabilitation environments promote a sense of autonomy, dignity, and connection to life beyond illness or disability. This aligns with Ulrich et al.'s (2008) stress-reduction theory, which posits that exposure to natural elements reduces negative emotional states that otherwise hinder healing processes.

A critical insight emerging from this research is that the effectiveness of biophilic design in rehabilitation centres is strongly linked to intentional integration with therapeutic objectives, rather than superficial application. In Spaulding Rehabilitation Hospital, for example, outdoor terraces and waterfront paths were not merely landscaped amenities but were deliberately designed to support gait training, balance exercises, and endurance walking under therapist supervision. This integration transforms the environment into an extension of the clinical programme, thereby reinforcing motor relearning through real-world spatial conditions (Landscape Architecture Foundation, 2016). This supports earlier findings by Marcus and Barnes (1999), who argued that healing landscapes are most effective when they are embedded into everyday routines rather than treated as optional retreats.

From a psychological and emotional perspective, the discussion reveals that

biophilic environments mitigate feelings of institutionalization, which are common among physically challenged individuals undergoing long-term rehabilitation. Research indicates that prolonged exposure to monotonous interiors, artificial lighting, and restricted outdoor access can contribute to depression, learned helplessness, and withdrawal from therapy (Verderber & Fine, 2000). In contrast, environments enriched with daylight, vegetation, water, and natural materials foster emotional stability and hope qualities essential for sustained rehabilitation engagement. Khoo Teck Puat Hospital exemplifies this approach by creating a hospital setting that visually and experientially resembles a public garden rather than a medical institution, thereby reducing anxiety and reinforcing a sense of normalcy (Kishnani, 2015).

Another significant discussion point relates to accessibility and inclusivity, which remain underrepresented in mainstream biophilic discourse. While nature-based design is often celebrated, it can unintentionally exclude physically challenged users if accessibility is not prioritized. This study demonstrates that inclusive biophilic design are characterised by smooth gradients, continuous handrails, raised planting beds, and sensory cues which enables physically challenged users to engage with nature independently and safely. Hussein (2012) notes that therapeutic gardens designed for wheelchair users significantly improve mood and social interaction when accessibility is treated as a core design driver rather than an afterthought. The case studies analysed illustrate that when biophilic environments are universally accessible, they promote independence and self-efficacy, which are fundamental goals of rehabilitation.

Finally, the discussion highlights the broader systemic implications of biophilic rehabilitation architecture. Beyond patient outcomes, such environments positively influence staff wellbeing, operational efficiency, and community integration. Staff working in biophilic healthcare settings report lower burnout levels and higher job satisfaction, which indirectly improves patient care quality (Tekin et al., 2022).

7. CONCLUSION

The integration of biophilic design principles into rehabilitation centres for the physically challenged represents a critical shift toward more holistic, humane, and performance-driven healthcare architecture. The evidence reviewed confirms that biophilic design contributes

meaningfully to physical rehabilitation by encouraging movement, enhancing sensory engagement, and supporting motor relearning in real-world spatial contexts. Simultaneously, it supports psychological recovery by reducing stress, alleviating anxiety, and fostering emotional resilience factors that are often overlooked yet essential for long-term rehabilitation success.

The case studies of Spaulding Rehabilitation Hospital and Khoo Teck Puat Hospital demonstrate that biophilic environments achieve their greatest impact when nature is treated as a therapeutic medium rather than a decorative element. These facilities illustrate that accessible landscapes, daylight-filled interiors, and multisensory natural elements can be seamlessly integrated into highly technical medical settings without compromising safety or clinical efficiency. Importantly, the study reveals that rehabilitation architecture must be understood as a transitional and adaptive environment, where users gradually rebuild independence and reconnect with society. Biophilic design supports this transition by reintroducing users to complexity, variability, and sensory richness in a controlled and supportive manner.

This research affirms that biophilic design has the capacity to transform rehabilitation centres from purely clinical institutions into environments of recovery, dignity, and empowerment. As healthcare systems increasingly recognise the importance of patient-centred and inclusive design, biophilic principles offer architects a scientifically grounded and ethically compelling framework for shaping the future of rehabilitation architecture.

8. RECOMMENDATION

The following recommendations are proposed for architectural practice, research, and policy in the design of rehabilitation centres for the physically challenged:

I. Integrate Biophilic Design from the Earliest Design Stages

Biophilic strategies should be embedded during the conceptual and schematic design phases rather than retrofitted at later stages. Early integration allows architects to align building orientation, spatial organisation, and landscape systems with daylight access, ventilation, and therapeutic programming. Kellert (2018) emphasises that biophilic design is most effective when it informs the overall architectural concept rather than being applied as isolated features.

II. Foster Interdisciplinary Collaboration

Designing effective rehabilitation environments requires close collaboration between architects, landscape architects, physiotherapists, occupational therapists, psychologists, and facility managers. Such collaboration ensures that biophilic spaces support specific rehabilitation goals, such as gait training, balance improvement, or sensory integration therapy. Evidence from Spaulding Rehabilitation Hospital shows that clinician involvement in design leads to higher utilisation and therapeutic relevance of outdoor spaces (Landscape Architecture Foundation, 2016).

III. Prioritise Universal Accessibility in Biophilic Environments

All biophilic features gardens, courtyards, terraces, and interior nature elements must be fully accessible to users with diverse physical abilities. Designers should adhere to universal design principles, ensuring smooth surfaces, appropriate gradients, tactile cues, and assistive elements. Inclusive access not only ensures equity but also enhances therapeutic independence, which is central to rehabilitation outcomes (Steinfeld & Maisel, 2012).

IV. Adopt Evidence-Based Evaluation and Post-Occupancy Studies

Future rehabilitation projects should incorporate structured post-occupancy evaluations that assess both environmental performance and patient outcomes. Metrics may include therapy adherence rates, patient-reported wellbeing, functional mobility scores, and staff satisfaction. Tekin et al. (2022) argue that expanding evidence-based research in biophilic healthcare design is essential for translating architectural innovation into measurable health benefits.

V. Contextualise Biophilic Design to Local Climate and Culture

Biophilic strategies must respond to regional climatic conditions, cultural perceptions of nature, and local healthcare realities. In tropical contexts, for example, shaded outdoor spaces, water features for evaporative cooling, and native planting are essential for usability. Context-sensitive design ensures sustainability, reduces maintenance burdens, and strengthens users' cultural connection to place (Kishnani, 2015).

VI. Encourage Policy Support and Design Guidelines

Finally, policymakers and healthcare authorities should recognise biophilic design as a contributor to public health and

rehabilitation efficiency. Developing design guidelines and standards for biophilic rehabilitation centres can support consistent implementation across public healthcare infrastructure, particularly in resource-constrained settings.

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