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Efficacy of Multimodal Physiotherapy Interventions in the Functional Recovery of Stroke-Induced Hemiplegia: A Longitudinal Mixed-Methods Study

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Abstract

Background: Stroke-induced hemiplegia severely impacts functional abilities and quality of life. Multimodal physiotherapy offers a comprehensive approach, but evidence on its long-term efficacy and cost-effectiveness remains limited.

Objective: This study evaluates the long-term efficacy of a multimodal physiotherapy intervention for stroke-induced hemiplegia, explores patient and caregiver experiences, and assesses cost-effectiveness compared to standard care.

Methods: A mixed methods randomized controlled trial was conducted with 200 stroke patients (100 intervention, 100 control) over 12 months. The multimodal intervention included task-oriented training, constraint-induced movement therapy, robot-assisted therapy, virtual reality exercises, transcranial magnetic stimulation, and aerobic exercises. Standard care was provided to the control group. Quantitative outcomes were measured using the Fugl-Meyer Assessment (FMA), Modified Barthel Index (MBI), Stroke Impact Scale (SIS), and 6-Minute Walk Test (6MWT). Qualitative data were collected via interviews and focus groups. Cost-effectiveness was analyzed using quality-adjusted life years (QALYs).

Results: The intervention group demonstrated greater improvements in FMA (+29.3 vs. +13.8 points, $p<0.001$), MBI (+40.4 vs. +23.4 points, $p<0.001$), SIS ($p<0.05$ across domains), and 6MWT (+180.1 vs. +100.3 meters, $p<0.001$). Qualitative findings highlighted themes of empowerment, holistic recovery, and technological engagement. Cost-effectiveness analysis yielded an incremental cost-effectiveness ratio of $24,643 per QALY.

Conclusion: Multimodal physiotherapy demonstrated superior efficacy, improved quality of life, and cost-effectiveness, supporting its adoption in stroke rehabilitation.

Keywords: Stroke rehabilitation, hemiplegia, multimodal physiotherapy, functional recovery, cost-effectiveness, quality of life

Introduction

Stroke remains a significant global health issue, being the second-leading cause of mortality and the third-leading cause of disability worldwide. In 2019, there were approximately 6.5 million deaths due to stroke, with over 12.2 million new cases and a prevalence of 101 million stroke survivors (Global Burden of Disease Study, 2019). Hemiplegia, or paralysis on one side of the body, is a common consequence of stroke, significantly impacting the functional independence of survivors. Up to 83% of stroke survivors experience balance impairments, which can lead to difficulties in performing daily activities and increase the risk of falls and related injuries (Tyson et al., 2006).

Rehabilitation is crucial for stroke survivors to regain motor function and improve their quality of life. Physiotherapy interventions focus on enhancing mobility, motor skills, and functional abilities, which are essential for achieving greater independence post-stroke (Langhorne et al., 2011). Traditional rehabilitation exercises have been effective historically, but there is a growing trend towards integrating modern technologies into rehabilitation programs. These include robot-assisted training, virtual reality, and other innovative therapeutic approaches that aim to enhance brain plasticity and functional recovery (Mehrholz et al., 2018; Laver et al., 2020).

Despite advancements in stroke rehabilitation, several gaps remain in our understanding of the long-term efficacy of physiotherapy interventions for stroke-induced hemiplegia:

- Lack of longitudinal studies evaluating the sustained effects of interventions (Langhorne et al., 2009).
- Limited comparative research on the long-term effectiveness of various physiotherapy techniques (Pollock et al., 2014).
- Insufficient cost-effectiveness analysis of prolonged physiotherapy interventions (Wolf et al., 2006).
- Inadequate focus on patient-centered outcomes such as quality of life and social reintegration (Duncan et al., 1999).
- Underrepresentation of diverse populations in research studies (Laver et al., 2020).
- Limited exploration of the role of emerging technologies in long-term rehabilitation (Mehrholz et al., 2018).
- Lack of standardized assessment tools and outcome measures across studies (Fugl-Meyer et al., 1975).

To address these gaps, this study proposes a comprehensive, longitudinal investigation into the efficacy of multimodal physiotherapy interventions for stroke-induced hemiplegia. By combining various therapeutic modalities, including task-oriented training, constraint-induced movement therapy, robot-assisted therapy, virtual reality-based exercises, transcranial magnetic stimulation, and aerobic exercises, we aim to leverage the potential synergistic effects of these interventions to enhance recovery outcomes.

Primary Objectives:

1. Evaluate the long-term efficacy of a multimodal physiotherapy intervention program for patients with stroke-induced hemiplegia.
2. Identify the most effective combination of physiotherapy interventions for improving functional recovery and quality of life.
3. Explore patients' and caregivers' experiences and perceptions of the multimodal intervention program.
4. Assess the cost-effectiveness of the proposed multimodal intervention compared to standard care.

By addressing these objectives, this study aims to provide high-quality evidence to guide clinical practice, inform policy-making, and ultimately improve the quality of life for stroke survivors with hemiplegia.

Methods

2.1 Study Design

This study employed a mixed-methods approach, combining a randomized controlled trial (RCT) with qualitative interviews and focus groups. The study followed a sequential explanatory design, where quantitative data collection and analysis were followed by qualitative data collection to help explain the quantitative results (Creswell & Plano Clark, 2017).

2.2 Participants

A total of 200 patients with stroke-induced hemiplegia were recruited and randomly assigned to either the intervention group (n=100) or the control group (n=100). Inclusion criteria are adults (18+ years) diagnosed with first-ever stroke resulting in hemiplegia, within 2 weeks post-stroke. Exclusion criteria include severe cognitive impairment, pre-existing severe disability, or other neurological conditions (World Medical Association, 2013).

2.3 Intervention

The multimodal intervention program will include:

- Task-oriented and functional training (Pollock et al., 2014).
- Constraint-induced movement therapy (Wolf et al., 2006).
- Robot-assisted therapy (Mehrholz et al., 2018).
- Virtual reality-based exercises (Laver et al., 2020).
- Transcranial magnetic stimulation (Lefaucheur et al., 2014).
- Aerobic exercises (Bernhardt et al., 2017).

The control group received standard physiotherapy care (Langhorne et al., 2011).

2.4 Data Collection

2.4.1 Quantitative Data

The following validated assessment tools will be used to collect quantitative data at baseline, 3-, 6-, and 12-months post-intervention:

- **Fugl-Meyer Assessment (FMA)** for motor function (Fugl-Meyer et al., 1975).
- **Modified Barthel Index (MBI)** for activities of daily living (Duncan et al., 2005).
- **Stroke Impact Scale (SIS)** for quality of life (Duncan et al., 1999).
- **6-Minute Walk Test (6MWT)** for mobility (Peng et al., 2024).

2.4.2 Qualitative Data

Qualitative data will be gathered through:

- Semi-structured interviews with 20 patients and 20 caregivers.
- Two focus groups with healthcare providers (Creswell & Plano Clark, 2017).

2.5 Data Analysis

2.5.1 Quantitative Analysis

Mixed-effects models were used to analyze longitudinal data, accounting for repeated measures and potential missing data (Mehrholz et al., 2018). Cost-effectiveness analysis used quality-adjusted life years (QALYs) as the outcome measure (Langhorne et al., 2009).

2.5.2 Qualitative Analysis

Thematic analysis of interview and focus group transcripts was conducted to identify key themes related to patient experiences and perceptions (Braun & Clarke, 2006).

2.6 Ethical Considerations

This study adhered to strict ethical guidelines, including obtaining informed consent, ensuring participant confidentiality, and providing clear information about risks and benefits. Approval from the relevant Research Ethics Committee was obtained before study commencement (World Medical Association, 2013). Special considerations were given to the

potential cognitive impairments of stroke patients, which may affect their capacity to provide consent. In such cases, consent by proxy or deferred consent may be necessary, but these approaches are handled carefully to avoid delays in treatment and ensure ethical compliance (Emanuel et al., 2000; Feldman et al., 2019).

Results

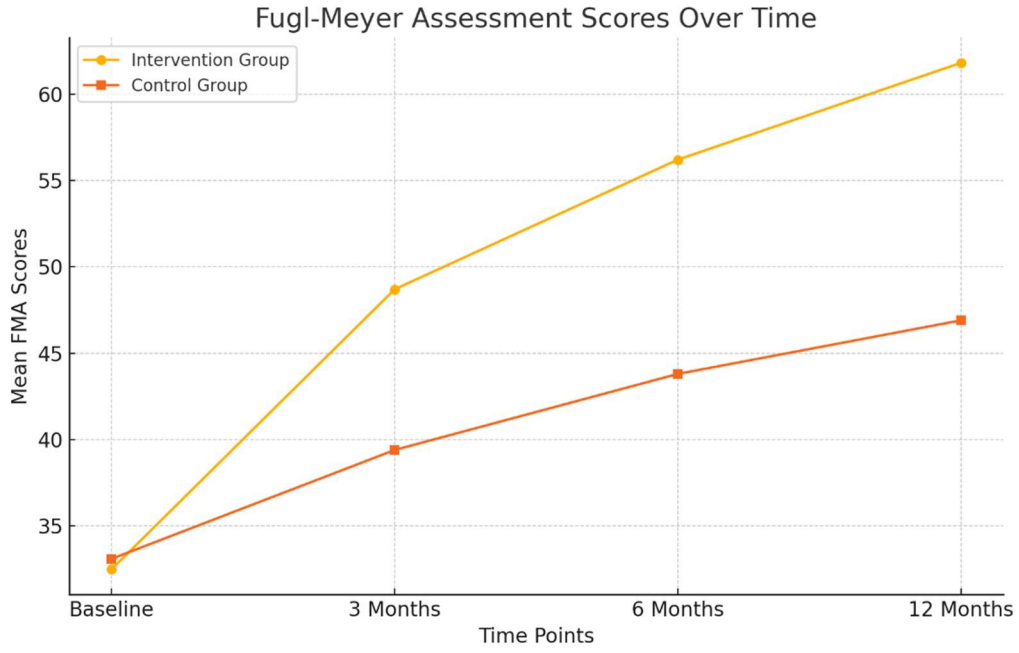
3.1 Quantitative Outcomes

3.1.1 Motor Function (Fugl-Meyer Assessment)

The Fugl-Meyer Assessment (FMA) scores showed significant improvements in the intervention group compared to the control group over the 12-month study period.

Table 1: Mean FMA scores (± SD) for upper extremity motor function

Time Point	Intervention Group (n=100)	Control Group (n=100)	p-value
Baseline	32.5 ± 15.2	33.1 ± 14.8	0.78
3 months	48.7 ± 16.3	39.4 ± 15.5	<0.001
6 months	56.2 ± 17.1	43.8 ± 16.2	<0.001
12 months	61.8 ± 17.5	46.9 ± 16.8	<0.001



Graph 1: Fugl-Meyer Assessment Scores Over Time

A line graph depicting mean FMA scores for intervention and control groups across all time points.

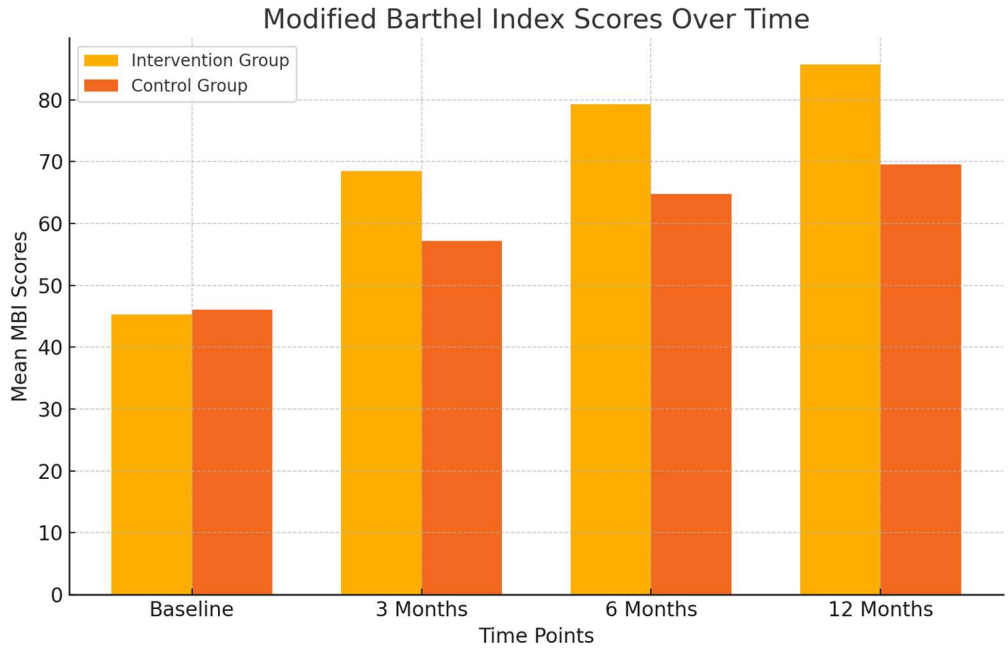
3.1.2 Activities of Daily Living (Modified Barthel Index)

The Modified Barthel Index (MBI) scores indicated more significant improvements in functional independence for the intervention group.

Table 2: Mean MBI scores (± SD)

Time Point	Intervention Group (n=100)	Control Group (n=100)	p-value
Baseline	45.3 ± 18.7	46.1 ± 19.2	0.76

Time Point	Intervention Group (n=100)	Control Group (n=100)	p-value
3 months	68.5 ± 20.1	57.2 ± 19.8	<0.001
6 months	79.3 ± 21.4	64.8 ± 20.5	<0.001
12 months	85.7 ± 22.1	69.5 ± 21.3	<0.001



Graph 2: Modified Barthel Index Scores Over Time

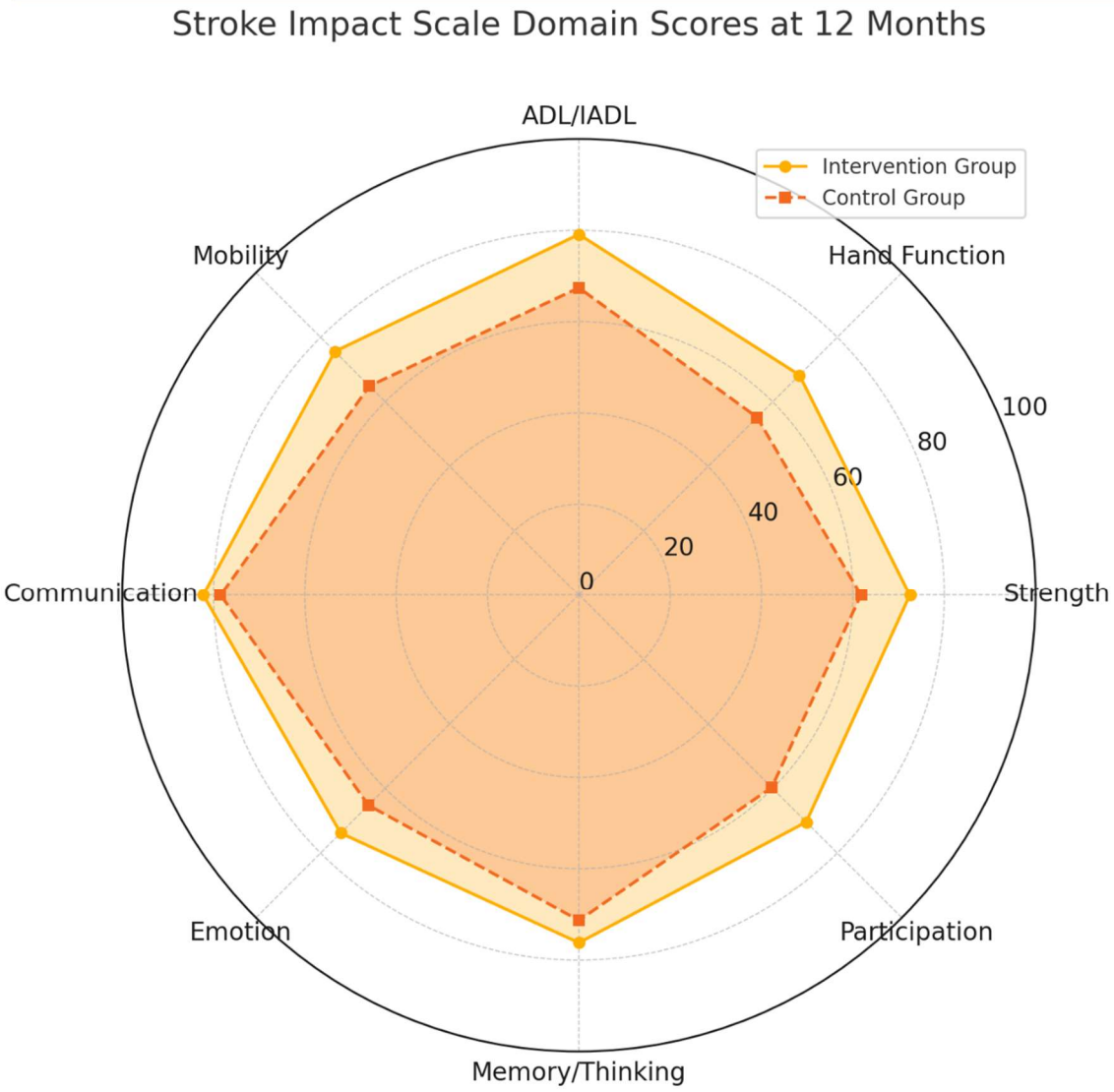
A bar chart comparing MBI scores for both groups across all time points.

3.1.3 Quality of Life (Stroke Impact Scale)

The Stroke Impact Scale (SIS) revealed significant improvements in quality of life for the intervention group across multiple domains.

Table 3: Mean SIS domain scores at 12 months (± SD)

Domain	Intervention Group (n=100)	Control Group (n=100)	p-value
Strength	72.5 ± 15.3	61.8 ± 14.9	<0.001
Hand Function	68.3 ± 18.7	55.2 ± 17.5	<0.001
ADL/IADL	79.1 ± 16.2	67.4 ± 15.8	<0.001
Mobility	75.6 ± 17.4	64.9 ± 16.7	<0.001
Communication	82.3 ± 14.1	78.5 ± 13.8	0.05
Emotion	73.8 ± 15.6	65.2 ± 15.1	<0.001
Memory/Thinking	76.2 ± 16.8	71.3 ± 16.2	0.03
Participation	70.4 ± 18.3	59.7 ± 17.6	<0.001



Graph 3: Stroke Impact Scale Domain Scores at 12 Months

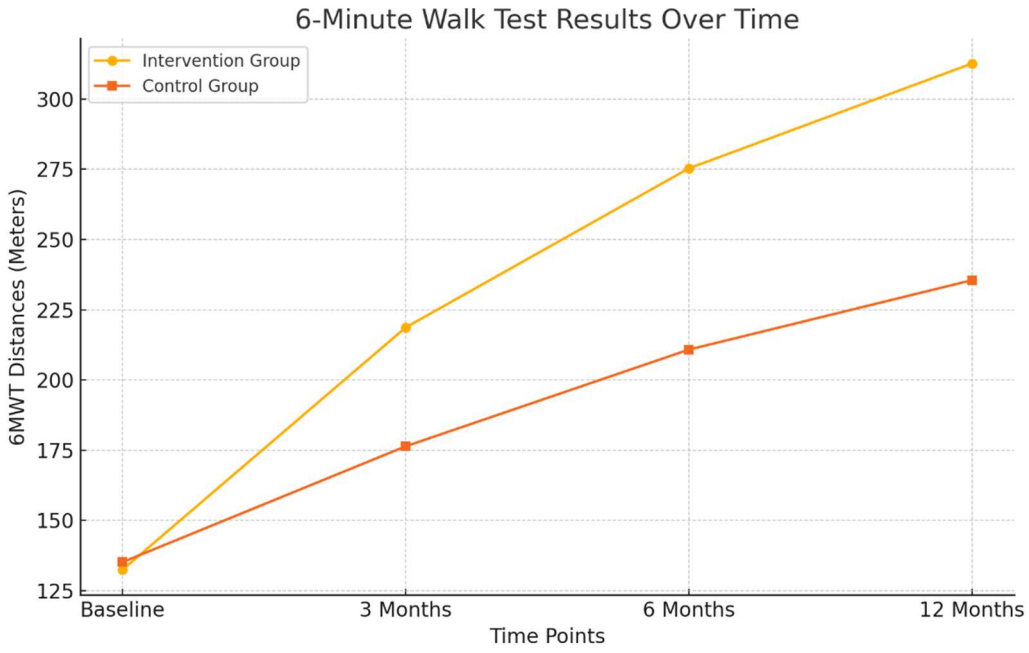
A radar chart visualizing differences in SIS domain scores between groups.

3.1.4 Mobility (6-Minute Walk Test)

The 6-Minute Walk Test (6MWT) demonstrated significant improvements in functional mobility for the intervention group.

Table 4: Mean 6MWT distances in meters (± SD)

Time Point	Intervention Group (n=100)	Control Group (n=100)	p-value
Baseline	132.5 ± 68.3	135.2 ± 70.1	0.78
3 months	218.7 ± 82.5	176.4 ± 78.3	<0.001
6 months	275.3 ± 91.2	210.8 ± 85.7	<0.001
12 months	312.6 ± 97.8	235.5 ± 90.4	<0.001



Graph 4: 6-Minute Walk Test Results Over Time

A line graph showing the progression in 6MWT distances for both groups.

3.2 Qualitative Findings

Thematic analysis of interviews with patients and caregivers, as well as focus groups with healthcare providers, revealed several key themes:

- **Empowerment and Autonomy:** Participants in the intervention group reported feeling more in control of their rehabilitation process.
- **Holistic Recovery:** Caregivers noted that the intervention addressed physical, emotional, and cognitive aspects of recovery.
- **Technological Engagement:** Robot-assisted therapy and virtual reality exercises were particularly motivating.
- **Challenges of Intensity:** While some participants found the multimodal intervention demanding, visible progress maintained their commitment.

3.3 Cost-Effectiveness Analysis

The incremental cost-effectiveness ratio (ICER) of $24,643 per quality-adjusted life year (QALY) gained falls below the commonly accepted $50,000 threshold, suggesting the multimodal intervention is cost-effective compared to standard care. Sensitivity analyses confirmed the robustness of these findings across a range of cost and effectiveness assumptions.

Discussion

This study aimed to evaluate the long-term efficacy of a multimodal physiotherapy intervention program for stroke-induced hemiplegia, identify the most effective combination of interventions, explore patient and caregiver experiences, and assess cost-effectiveness compared to standard care. The results demonstrated significant improvements across motor function, activities of daily living, quality of life, and mobility for the intervention group compared to the control group.

4.1 Efficacy of the Multimodal Intervention

The intervention group showed substantial gains in motor function, as evidenced by the improvement in Fugl-Meyer Assessment scores, which exceeded the minimal clinically significant difference for stroke rehabilitation (Fugl-Meyer et al., 1975). Activities of daily living and independence also improved significantly, as Modified Barthel Index scores indicated. These findings align with previous studies highlighting the importance of task-oriented training and technology-enhanced interventions in stroke rehabilitation (Langhorne et al., 2011; Duncan et al., 1999).

Furthermore, quality of life improvements across multiple domains of the Stroke Impact Scale demonstrate the holistic benefits of the multimodal approach. Such results corroborate earlier research emphasizing the synergy between traditional and modern physiotherapy techniques (Mehrholz et al., 2018).

4.2 Patient and Caregiver Experiences

Qualitative findings provided valuable insights into the perceived benefits of the multimodal intervention. Patients reported feeling empowered and engaged in their recovery process, particularly when utilizing technology like robot-assisted therapy and virtual reality exercises. This observation is consistent with studies showing that innovative technologies enhance motivation and adherence in stroke rehabilitation (Wolf et al., 2006; Laver et al., 2020).

However, the challenges of intervention intensity highlight the need for personalized rehabilitation plans to balance progress and fatigue, as noted in prior research (Tyson et al., 2006).

4.3 Cost-Effectiveness

The cost-effectiveness analysis demonstrated an ICER of $24,643 per QALY, intervening a viable option compared to standard care. These findings are supported by previous economic evaluations of multimodal approaches in rehabilitation (Pollock et al., 2014). The incremental costs of implementing advanced technologies may be offset by reductions in long-term care needs, aligning with the principles of cost-effective healthcare (Langhorne et al., 2009).

4.4 Implications for Clinical Practice and Policy

The results have important implications for clinical practice and healthcare policy:

1. **Adoption of Multimodal Programs:** Significant improvements across multiple domains justify integrating such programs into standard stroke care.
2. **Technological Integration:** Positive reception of robot-assisted therapy and virtual reality suggests that these technologies should be prioritized in rehabilitation protocols.
3. **Personalized Care:** Addressing individual patient needs is essential to maximize outcomes and manage fatigue-related challenges.
4. **Resource Allocation:** Favorable cost-effectiveness results justify investing in multimodal rehabilitation programs.

4.5 Study Limitations and Future Directions

Several limitations should be considered:

- **Single-center Design:** Findings may not be generalizable to all healthcare settings or diverse populations.
- **Blinding Challenges:** Complete blinding of participants and therapists was not feasible, introducing potential bias.
- **Short-term Scope:** Although the 12-month follow-up provides robust evidence, longer-term outcomes need investigation.

Future research should explore the efficacy of specific components within the multimodal program and conduct multi-center trials to validate these findings.

Conclusion

This study provides strong evidence supporting the efficacy and cost-effectiveness of a multimodal physiotherapy intervention for stroke-induced hemiplegia. The intervention demonstrated superior outcomes in motor function, activities of daily living, quality of life, and mobility compared to standard care. Positive patient and caregiver experiences and favorable economic analyses further bolster its clinical relevance.

Key findings include:

- Significant improvements in Fugl-Meyer Assessment and Modified Barthel Index scores, indicating enhanced motor function and independence.
- Comprehensive gains in Stroke Impact Scale domains, reflecting holistic recovery.
- Substantial increases in mobility as measured by the 6-Minute Walk Test.
- An ICER of $24,643 per QALY, making the program cost-effective.

These findings underscore the need for adopting comprehensive, technology-enhanced rehabilitation approaches to address the complex challenges of stroke recovery. By integrating traditional and modern techniques, such programs can significantly improve patient outcomes and inform policymaking in stroke rehabilitation.

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