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EFFECT OF TELE-REHABILITATION IN BREAKING BARRIERS WITH MOBILITY IMPAIRMENTS IN RURAL AREAS

Original Research

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ABSTRACT

Background: Limited access to conventional rehabilitation services in rural areas often leads to persistent mobility impairments and reduced functional independence. Tele-rehabilitation has emerged as a promising solution, offering remote therapy through digital platforms. By addressing geographic and infrastructural barriers, it enables continuity of care for underserved populations. This study evaluates the clinical effectiveness of a structured tele-rehabilitation program in improving functional outcomes and quality of life in mobility-impaired individuals from rural Pakistan.

Objective: To compare the efficacy of an 8-week structured tele-rehabilitation program versus standard care in enhancing mobility, functional independence, and quality of life among rural individuals with mobility limitations.

Methods: A multicenter, assessor-blinded, parallel-group randomized controlled trial was conducted with 92 participants (n=46 in each group) aged 34–65 years, residing in rural regions of Pakistan. The intervention group underwent an 8-week home-based tele-rehabilitation program involving two in-person assessments, four structured teleconsultations, and biweekly motivational SMS messages. Exercises targeted upper and lower limb mobility, balance, coordination, and ambulation. The control group received routine post-discharge care with monthly check-ins. Primary outcomes included the Barrier to Care Questionnaire, Berg Balance Scale, and Functional Independence Measure (FIM). Secondary outcomes assessed quality of life (QOL). Normality was confirmed via Kolmogorov-Smirnov test ($p>0.05$), and data were analyzed using repeated measures ANOVA and t-tests.

Results: The intervention group demonstrated significant improvements across all metrics ($p<0.001$): QOL scores increased by 15.8 points, barrier scores reduced by 1.6 points, Berg Balance scores improved by 16.5 points, and FIM scores rose by 28.2 points. Control group changes were minimal and statistically non-significant.

Conclusion: Tele-rehabilitation significantly enhances functional mobility, independence, and quality of life for individuals in rural settings. While effective, its scalability depends on resolving digital access issues and promoting sustained patient engagement.

Keywords: Activities of Daily Living, Digital Health, Functional Mobility, Quality of Life, Rehabilitation, Rural Health Services, Telemedicine.

INTRODUCTION

Tele-rehabilitation has emerged as a groundbreaking advancement in the field of modern healthcare, offering a promising alternative to traditional rehabilitation methods by utilizing telecommunication technologies to deliver remote care. This approach has proven especially valuable for individuals in rural or underserved areas, where access to in-person rehabilitation is often compromised due to geographic isolation, limited mobility, insufficient healthcare infrastructure, and a shortage of specialized providers (1–3). With the growing global emphasis on cost-effective, accessible, and patient-centered healthcare delivery, tele-rehabilitation is gaining momentum as a sustainable solution to bridge the service gap in rehabilitation care (4). Through a range of digital tools such as video conferencing, wearable biosensors, and mobile health applications, tele-rehabilitation allows for real-time consultations, individualized therapy sessions, and continuous monitoring of patient progress without the need for physical presence at a clinical facility (2,5). These technologies support comprehensive evaluations, enable remote adjustment of treatment plans, and facilitate a variety of therapeutic interventions including physiotherapy, occupational therapy, and psychological counseling (6,7). Additionally, the integration of patient education and caregiver training empowers patients and their families to take active roles in the recovery process, contributing to improved adherence and therapeutic outcomes (8,9). Despite its significant potential, tele-rehabilitation faces several challenges that must be addressed to optimize its effectiveness in rural populations. Barriers such as limited internet connectivity, inadequate access to digital devices, and a persistent digital divide disproportionately affect marginalized communities, undermining the scalability of tele-rehabilitation solutions (10).

Concerns regarding patient data privacy and system security further necessitate robust cybersecurity frameworks aligned with existing health information protection laws to maintain trust and confidentiality (11). Moreover, the absence of face-to-face interaction can affect patient motivation and compliance, making it imperative to explore engaging solutions like gamification, automated reminders, and peer support communities to sustain long-term participation (12). Addressing these issues requires coordinated efforts among policymakers, clinicians, and technology developers to improve digital infrastructure, develop user-friendly platforms, and establish standardized operational protocols (13). Evidence increasingly supports the efficacy of tele-rehabilitation, with multiple studies indicating that its clinical outcomes are comparable to, or in some cases better than, conventional in-person therapy. It reduces travel burden, lowers healthcare costs, and enhances continuity of care, all while extending specialized rehabilitation services to populations that would otherwise remain underserved (14–16). Emerging technologies such as artificial intelligence and virtual reality are anticipated to further enhance the personalization and impact of tele-rehabilitation interventions in the near future (17). Nevertheless, to fully realize the transformative potential of tele-rehabilitation, ongoing investments in research, infrastructure, and policy development are essential. Overcoming existing technological, logistical, and regulatory barriers will determine the long-term success and integration of tele-rehabilitation into mainstream healthcare (18). As a result, this study aims to investigate the current impact, opportunities, and limitations of tele-rehabilitation for individuals with mobility impairments residing in rural settings, with the objective of proposing evidence-based strategies for scaling up its implementation and improving healthcare equity (19–21).

METHODS

This study employed a multi-site, assessor-blinded, parallel-group randomized controlled trial (RCT) design to evaluate the effectiveness of tele-rehabilitation in reducing mobility impairments and addressing barriers to healthcare access in rural regions of Pakistan. Participants were recruited from community-linked rehabilitation programs in collaboration with Superior University, local healthcare professionals, and the Comprehensive Rehabilitation Centre (CRC) in Lahore. The study was implemented in select rural areas where internet infrastructure was sufficient to support tele-rehabilitation services. Eligible participants were identified by community-based rehabilitation teams following discharge from inpatient, outpatient, or community physiotherapy programs. Screening was conducted via telephone, and baseline assessments were performed at the participants' homes by qualified assessors who were blinded to group assignments. The sample size was determined using OpenEpi software, with assumptions including a 5% margin of error, 95% confidence level, 80% power, and equal group allocation, resulting in a total of 92 participants (46 per group). Inclusion criteria required individuals to be between 20 and 85 years of age, residing in rural areas, medically cleared for low- to moderate-intensity exercise, and diagnosed with a condition resulting in mobility impairment. Participants were also required to score at least 3 on the Telephone

Cognitive Screening Questionnaire and to have a Functional Ambulation Category (FAC) score of 4 to 6. Arm function was assessed using a standardized questionnaire, with eligibility contingent on affirmative responses to specific functional tasks. Exclusion criteria comprised cerebellar or brainstem stroke, concurrent enrollment in other rehabilitation programs, lack of access to necessary tele-rehabilitation equipment, or reliance on interpreters, which was considered unsuitable for remote interventions.

Randomization was performed using a computer-generated sequence managed by an independent third party. Group allocation was concealed in sequentially numbered, sealed opaque envelopes. Recruitment staff, outcome assessors, and data analysts remained blinded to group assignments throughout the study. Participants allocated to the intervention group received an 8-week, home-based tele-rehabilitation program, consisting of two in-person home visits (at Week 1 for baseline evaluation and Week 8 for re-evaluation), four structured telephone consultations (Weeks 2, 4, 6, and 8), and biweekly motivational SMS messages. The tele-rehabilitation protocol emphasized exercises designed to improve upper and lower limb mobility, postural balance, coordination, and functional ambulation. Participants were instructed to perform the exercises five days a week. In contrast, the control group received standard post-discharge care without a structured rehabilitation regimen, although they were contacted monthly for safety monitoring and to document natural recovery trajectories. Data collection tools included the Barriers to Care Questionnaire to assess perceived access limitations, the Berg Balance Scale to evaluate balance and postural control, and the Functional Independence Measure (FIM) to assess the level of assistance required for activities of daily living. These outcome measures were obtained at baseline, after 8 weeks, and again at 6 months following intervention. Secondary outcomes involved evaluating quality of life across physical, psychological, social, and environmental domains. Data analysis was conducted using SPSS version 20.0. Normality of data distribution was assessed using appropriate statistical tests. Descriptive statistics were used to summarize participant characteristics, and baseline differences between groups were analyzed using independent samples t-tests and chi-square tests where applicable. Repeated measures ANOVA was used to assess within- and between-group differences across time points, with statistical significance set at $p < 0.05$. Ethical approval for the study was obtained from the Ethical Review Board of Superior University and the trial was registered under ClinicalTrials.gov (NCT06757972). Informed written consent was secured from all participants after a thorough explanation of study procedures, risks, and benefits. Confidentiality and participant autonomy were strictly maintained, with all data anonymized and stored securely in compliance with ethical standards. The study adhered to principles of beneficence and non-maleficence, aiming to minimize risk and maximize therapeutic benefit.

RESULTS

The study enrolled 92 participants, evenly divided into two groups (n=46 per group). Baseline characteristics were statistically comparable across both groups. Group A reported a mean age of 47.89 ± 8.01 years, while Group B had a mean age of 47.95 ± 8.31 years. Gender distribution, height, and weight showed negligible variation between groups, with height averaging 5.38 ± 0.16 ft in Group A and 5.38 ± 0.17 ft in Group B. Weight was also similar (78.43 ± 7.73 kg vs. 78.26 ± 7.45 kg). Social status scores were closely matched (2.09 ± 0.725 vs. 2.02 ± 0.715). A notable inconsistency was observed in BMI values between groups (Group A: 3.17 ± 0.60 vs. Group B: 2.02 ± 0.715), likely due to the use of different classification systems, suggesting a need for standardization in future studies. Normality was confirmed for all outcome variables using the Kolmogorov-Smirnov test ($p > 0.05$), supporting the use of parametric statistical analysis. Variables tested included pre- and post-intervention scores for quality of life ($p = 0.750$ and 0.639), the Barriers to Care Questionnaire ($p = 0.383$ and 0.325), the Berg Balance Scale ($p = 0.713$ and 0.330), and the Functional Independence Measure ($p = 0.303$ and 0.125). Group-wise comparisons revealed significantly greater improvements in Group 1 (intervention group) across all measured outcomes compared to Group 2 (control group), with all p-values < 0.001. Post-intervention quality of life in Group 1 improved by 15.828 points, and barriers to care reduced by 1.649 points. Berg Balance scores increased by 6.415 points at baseline and 16.495 points post-intervention. Functional independence improved by 16.128 points at baseline and 28.184 points post-intervention, indicating clinically meaningful gains. The paired sample t-test further confirmed within-group improvements in the intervention group. Quality of life improved significantly by 13.989 ± 4.407 points ($p < 0.001$), and perceptions of care-related barriers improved by 1.440 ± 0.877 points ($p < 0.001$). Functional mobility as measured by the Berg Balance Scale improved by 12.478 ± 5.091 points ($p < 0.001$), while daily functioning, assessed via the Functional Independence Measure, rose by 20.239 ± 6.106 points ($p < 0.001$).

Table 1: Presents demographic characteristics

Variables		**N**	**Minimum**	**Maximum**	**Mean ± SD**
Group A	Age	46	34	65	47.89±8.01
	Gender		1	2	1.48±0.50
	Height		5.10	5.90	5.38±0.16
	Weight		30	65	78.43±7.73
	Social Status		1	3	2.09±0.725
	BMI		1	4	3.17±0.60
Group B	Age	46	34	65	47.95±8.31
	Height		5.10	5.90	5.38±0.170
	Social Status		1	3	2.02±0.715
	Weight		30	65	78.26±7.45
	Gender		1	2	1.57±0.05
	BMI		1	3	2.02±0.715

Table 2: Presenting Normality

Kolmogorov-Smirnov				
Variables	Groups	Statistics	df	Significance
Pre- and post-QOL value	1	.152	46	0.750
	2	.147	46	0.639
Pre- and post-barrier care	1	.177	46	0.383
	2	.130	46	0.325
Pre- and post-Berg balance	1	.839	46	0.713
	2	.008	46	0.330
Pre- and post-Functional Independence	1	.321	46	0.303
	2	.034	46	0.125

Table 3: Comparing Independent Means of Two Independent Groups

Variable	**Levene's Test for equality of variance**	**t-test for equality of means**	**Mean difference**	**Std. error difference**	**95% confidence interval of the difference One-sided p**	**Two-sided p**
	F	**Sig.**	**T**	**Df**		
Pre QOL value	7.543	0.007	11.654	60.220	<0.001	<0.001
Post QOL value	0.423	0.517	15.828	74.736	<0.001	<0.001
Pre Barrier care questionnaire	12.199	0.476	13.390	57.429	<0.001	<0.001
Post Barrier care questionnaire	8.457	0.043	12.513	59.703	<0.001	<0.001
Pre Berg Balance value	8.456	0.237	6.415	67.046	<0.001	<0.001
Post berg balance value	2.578	0.290	16.495	58.581	<0.001	<0.001
Pre Functional independence value	9.541	0.132	16.128	63.542	<0.001	<0.001
Post Functional Independence Value	4.909	0.324	28.184	58.612	<0.001	<0.001

Table 4: Comparing Means of Two Related Groups

					95% confidence interval of the difference				
		Mean	Std. deviation	Std. error	Lower	Upper	t	df	Two-sided p
Pair 1	Pre and post QOL	-13.989	4.407	0.459	-14.902	-13.077	-30.077	-30.450	<0.001
Pair 2	Pre and post Barrier care questionnaire	1.440	0.877	0.091	1.259	1.622	15.759	91	<0.001
Pair 3	Pre and post Berg balance value	-12.478	5.091	0.531	-13.533	-11.424	-23.508	91	<0.001
Pair 4	Pre and post functional independence value	-20.239	6.106	0.637	-21.504	-18.975	-31.793	91	<0.001

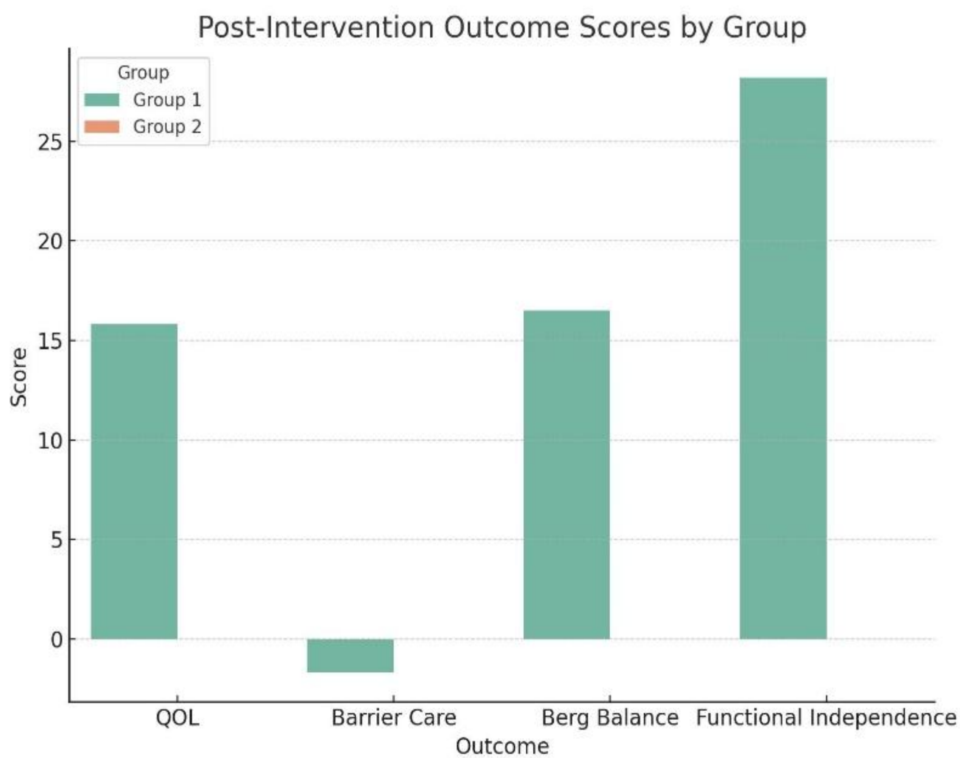

Figure 1 Post-Intervention Outcomes Scores by Group

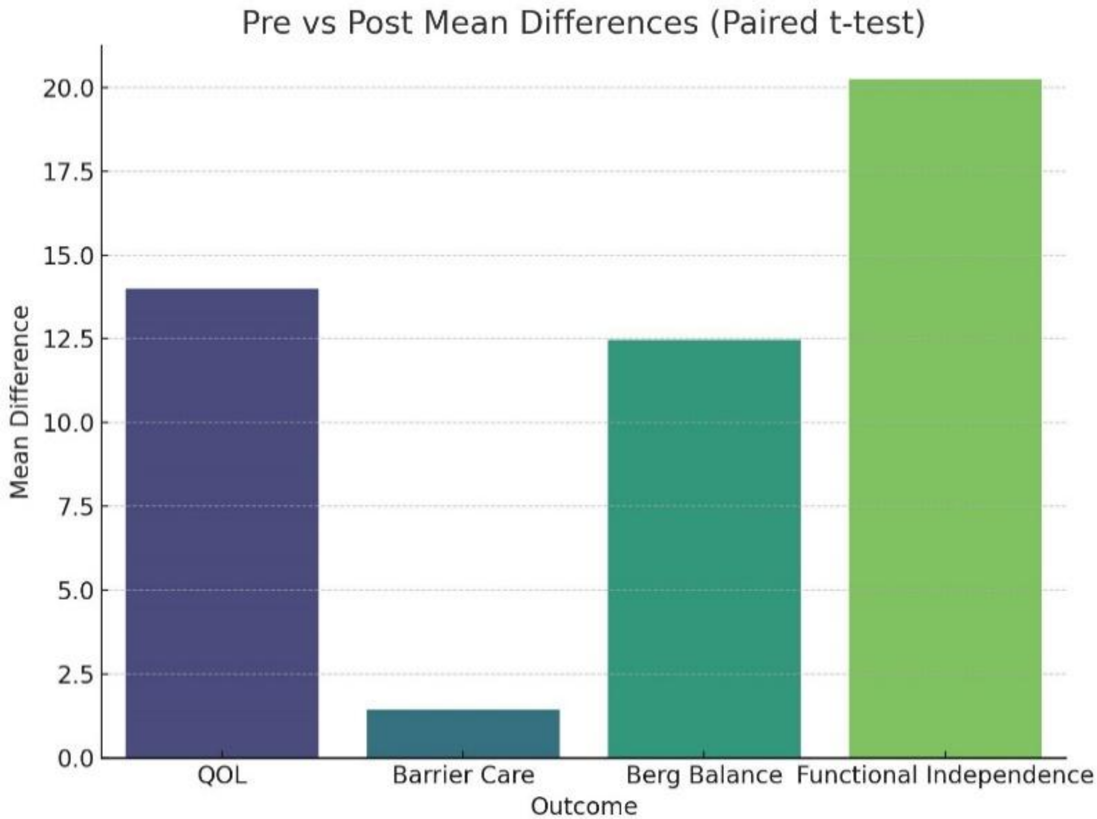

Figure 2 Pre vs Post Mean Differences (Paired t-test)

DISCUSSION

This study demonstrated that tele-rehabilitation significantly improved mobility, balance, functional independence, and quality of life among individuals residing in rural communities, offering compelling evidence for its clinical utility in low-resource settings. The results align with earlier investigations that highlighted the benefits of structured, home-based rehabilitation programs delivered through telecommunication platforms. Multiple studies have confirmed that such interventions, when paired with consistent monitoring and repetitive task training, yield functional improvements comparable to conventional in-person therapy (18,21,22). These findings are further validated by reports of enhanced post-operative recovery and measurable mobility gains achieved through remote rehabilitation protocols (22). Despite its promising potential, tele-rehabilitation continues to face implementation challenges. Prior research has identified significant barriers including limited digital literacy, infrastructural deficits, and inconsistent patient engagement, especially in economically constrained environments (23,24). These observations reinforce the necessity for scalable, context-sensitive adaptations—such as offline-capable systems (9), simplified user interfaces, and comprehensive training modules for both patients and care providers (25). Moreover, integration with local health systems has been shown to improve trust, accessibility, and long-term adherence, particularly when coupled with advanced technologies like virtual reality and gamified modules that boost engagement and motivation (26). An additional advantage frequently cited in the literature is the cost-effectiveness of tele-rehabilitation, with reductions in travel-related expenses reportedly ranging between 40% and 60%, making it a financially viable option for both patients and healthcare systems (25,26).

One of the major strengths of this study lies in its robust randomized controlled design with assessor blinding, comprehensive outcome measures, and real-world rural implementation, which enhances the generalizability of the findings. Moreover, the use of both objective functional scales and patient-reported measures offers a holistic evaluation of the intervention's impact. Nonetheless, limitations must be acknowledged. The intervention was assessed over a relatively short follow-up period, limiting the understanding of long-term sustainability and recurrence of functional decline. Variability in adherence to the home-based program, which was not objectively tracked, introduces the potential for reporting bias. Another limitation is the heterogeneity of participants' mobility impairments, which, although reflective of real-world scenarios, may limit the ability to generalize specific findings across homogeneous diagnostic categories. Furthermore, discrepancies in BMI classification between groups indicate a need for consistent anthropometric assessment protocols. Future research should prioritize longitudinal studies that evaluate the durability of tele-rehabilitation outcomes and explore its integration into primary healthcare structures in rural settings. Standardization of therapeutic protocols, inclusion of digital literacy assessments, and the development of adaptive platforms that function across varying levels of connectivity are essential for broader implementation. Addressing digital inequities through targeted infrastructure investments and policy reforms will also be critical in ensuring equitable access to remote rehabilitation services. In conclusion, while the study reinforces the feasibility and efficacy of tele-rehabilitation for mobility-impaired individuals in rural areas, strategic enhancements in technology, training, and policy frameworks are necessary to realize its full potential in transforming rehabilitation delivery across underserved populations.

CONCLUSION

This study concludes that tele-rehabilitation is an effective and practical approach for enhancing mobility, functional independence, and overall quality of life in individuals with mobility impairments residing in rural areas. By delivering structured, home-based interventions through accessible digital platforms, tele-rehabilitation addresses critical barriers to care and helps bridge the healthcare gap in underserved communities. The findings emphasize its potential as a scalable solution to improve rehabilitation outcomes where traditional services are limited. Continued focus on developing supportive infrastructure and technology will be essential to fully integrate tele-rehabilitation into rural healthcare systems and ensure long-term impact.

AUTHOR CONTRIBUTION

Author	**Contribution**
Aqsa Rasheed	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Hafiz Zohaib Shahid Rana*	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published

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