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TELEREHABILITATION: OPTIMIZING PATIENT OUTCOMES AND ACCESSIBILITY IN POST-STROKE RECOVERY

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Abstract
Background: Stroke remains a leading cause of long-term disability worldwide, necessitating intensive and prolonged rehabilitation interventions.
Aim: Telerehabilitation has emerged as a promising alternative to traditional in-person therapy, offering potential solutions to barriers in accessibility, cost, and continuity of care.
Methods: to examine the effectiveness, accessibility, implementation challenges, and patient outcomes associated with telerehabilitation for post-stroke recovery, reveals that telerehabilitation demonstrates comparable or superior outcomes to conventional therapy across multiple domains including motor function, activities of daily living, quality of life, and patient satisfaction. Evidence indicates that synchronous video-based interventions, combined with asynchronous monitoring and virtual reality applications, yield significant improvements in functional recovery.
Results: shows standardized mean differences ranging from 0.42-0.68 for upper extremity function, no significant difference in ADL outcomes (SMD -0.00, 95% CI -0.15 to 0.15), and improvements in balance outcomes. Cost analyses demonstrate savings of $654-$867 per participant compared to conventional care. Accessibility benefits include 78% reduction in travel burden and enhanced service delivery to rural populations where rehabilitation access is 45% lower than urban areas. However, implementation challenges persist, including technology barriers affecting 23-35% of older adults, digital literacy gaps, and regulatory uncertainties.
Conclusion: This review synthesizes current evidence with detailed results tables, identifies best practices for telerehabilitation delivery, and proposes frameworks for optimizing patient outcomes while addressing existing barriers to widespread adoption.

keywords: telerehabilitation, stroke recovery, remote therapy, motor function, accessibility, digital health, neurorehabilitation

1. INTRODUCTION

1.1 Stroke Burden and Rehabilitation Needs

Stroke represents a critical global health challenge, ranking as the second leading cause of death and third leading cause of death and disability combined worldwide [1]. According to the World Stroke Organization Global Stroke Fact Sheet 2025, from 1990 to 2021, the global burden increased substantially with a 70% increase in incident strokes, 44% increase in deaths from stroke, 86% increase in prevalent strokes, and 32% increase in disability-adjusted life years (DALYs) [2]. Table 1 presents the comprehensive global stroke burden statistics.

Table 1. Global Stroke Burden Statistics (1990-2021)

Metric	1990	2021	Change (%)
Incident strokes	7.2 million	12.2 million	+70%
Deaths from stroke	5.7 million	8.2 million	+44%
Prevalent strokes	58.9 million	109.4 million	+86%
DALYs (millions)	111.4	147.2	+32%
Global cost (USD)	Not available	$890 billion	-
% of global GDP	Not available	0.66%	-

Source: Feigin et al., 2025 [2]

Post-stroke disability is manifested in different areas, with about 50-80% of stroke survivors experiencing an upper limb impairment, about 50% continuing to have these deficits at the chronic phase six months post-stroke [3]. Cognitive impairment following stroke also affects some 75% of acute stage stroke patients, with many individuals having persistent deficits in the medium to long term [4]. Executive dysfunction is seen in as many as 75% of stroke survivors, which limits their ability to adapt to post-stroke [5].

The severe, critical need for rehabilitation after stroke is confirmed, with evidence demonstrating that intensive, repetitive, task-specific training in the acute and subacute periods maximizes functional outcome [6]. However, a range of obstacles to access to optimal rehabilitation care are present, such as geographical barriers, transportation problems, caregiver burden, cost, and capacity constraints of the healthcare system [7].

1.2 Telerehabilitation Emergence

Telerehabilitation, or the delivery of rehabilitation interventions through information and communication technologies, has become a viable solution to these accessibility concerns [8]. The COVID-19 pandemic fueled adoption exponentially, remaining feasible and acceptable when necessity required innovation [9].

Present telerehabilitation encompasses a range of modalities including synchronous video conference with live supervision by a therapist, asynchronous monitoring using wearable devices and smartphone applications, virtual reality (VR) and augmented reality (AR) platforms for interactive therapy experience, and hybrid models that incorporate both face-to-face and tele-supervised sessions [3,10]. Table 2 presents a summary of the key telerehabilitation modalities and features.

1.3 Objectives and Scope

This systematic review aims to evaluate the current status of telerehabilitation for recovery after stroke across four broad areas: clinical efficacy compared with conventional therapy, facilitation of access and population reach, issues of implementation and adoption barriers, and best practices for optimization of patient outcomes. Through the integration of evidence from recent literature (2020-2025), the review provides clinicians, healthcare managers, and policy-makers with actionable recommendations for implementing telerehabilitation into standard stroke care pathways.

Table 2. Telerehabilitation Modalities and Characteristics

Modality	Description	Technology Requirements	Key Advantages	Primary Limitations
Synchronous Video	Real-time video conferencing with therapist	High-speed internet, webcam, video platform	Real-time feedback, therapeutic relationship	Requires scheduled appointments, internet dependency
Asynchronous Monitoring	Wearable sensors, mobile apps for data collection	Smartphone or tablet, sensors/wearables	Flexible timing, objective data collection	Limited immediate feedback, delayed intervention
Virtual Reality	Immersive VR environments for therapy	VR headset, motion controllers, gaming PC or console	High engagement, gamification, intensive practice	Equipment cost, motion sickness risk, technical complexity
Robot-Assisted	Robotic devices with remote supervision	Robotic equipment, internet connection	Precise movement assistance, objective measurement	High initial cost, space requirements

Hybrid Models	Combination of in-person and remote sessions	Variable based on components	Balances benefits of both approaches	Coordination complexity, mixed reimbursement

2. METHODOLOGY

2.1 Literature Search Strategy

A comprehensive search in several electronic databases including PubMed, Cochrane Library, Web of Science, and rehabilitation-specific databases was conducted for articles from January 2020 to October 2025. Controlled vocabulary as well as keywords related to telerehabilitation, stroke, and outcome measure were included in the search terms. A strategy was devised that sought to identify randomized controlled trials, systematic reviews, meta-analyses, and observational studies that evaluated telerehabilitation interventions in stroke recovery.

2.2 Inclusion and Exclusion Criteria

Inclusion criteria set studies with adult stroke patients (≥18 years) receiving telerehabilitation treatments with outcomes measuring motor function, functional independence, quality of life, cognitive function, or accessibility. The subacute (<26 weeks post-stroke) and chronic (>26 weeks post-stroke) phases were included [11]. Exclusion criteria excluded conference proceedings with no full-text access, duplicate publications, and missing control groups or comparison data.

2.3 Data Extraction and Synthesis

Data extraction documented study characteristics, population demographics, intervention details, outcome measures, and results. Due to extreme heterogeneity in intervention designs, technology platforms, and outcome measures across studies, data were narratively synthesized with synthesis on an outcome domain-by-domain basis [3,12]. Table 3 provides an overview of the characteristics of main systematic reviews included in this systematic review

Table 3. Characteristics of Key Systematic Reviews (2020-2025)

Study	**Year**	**Review Type**	**Studies Included**	**Total Participants**	**Primary Focus**	**Key Outcome Measures**
Alwadai et al. [3]	2025	Umbrella review	28 systematic reviews (245 primary studies)	>15,000	Comprehensive telerehabilitation outcomes	Motor function, ADL, balance, gait, QOL
Stangenberg-Gliss et al. [11]	2025	Pyramid review	42 studies	1,847	Upper extremity synchronous telerehab	FMA-UE, ARAT, WMFT, MAL
Pitliya et al. [23]	2025	Meta-analysis	18 RCTs	1,456	Balance and functional outcomes	BBS, BI, TIS
Laver et al. [20]	2020	Cochrane Review	22 studies	1,937	Post-discharge telerehabilitation	ADL, HRQOL, mortality
Chen et al. [21]	2018	Meta-analysis	15 studies	1,339	Comprehensive telerehabilitation	BI, mRS, HRQOL
Hao et al. [16]	2023	Meta-analysis	24 RCTs	1,203	VR-based telerehabilitation	FMA-UE, BBS, gait parameters

Abbreviations: ADL, activities of daily living; ARAT, Action Research Arm Test; BBS, Berg Balance Scale; BI, Barthel Index; FMA-UE, Fugl-Meyer Assessment Upper Extremity; HRQOL, health-related quality of life; MAL, Motor Activity Log; mRS, modified Rankin Scale; QOL, quality of life; TIS, Trunk Impairment Scale; WMFT, Wolf Motor Function Test

3. Outcomes: Clinical Efficacy

3.1 Return of Motor Function

3.1.1 Upper Extremity Function

Systematic reviews and meta-analyses published in the last few years indicate telerehabilitation has considerable impacts on motor function of the upper limb. An umbrella review of 28 systematic reviews (included 245 primary studies) identified motor function as the most commonly researched outcome category and high to moderate-

quality evidence indicating significant or no difference effects in favour of, or against, compared interventions and telerehabilitation [3].
Table 4 contain meta-analyses of upper limb outcomes after different telerehabilitation interventions with some of the highlighted findings.

3.1.2 Lower Limb and Gait Function

Lower limb function and gait intervention has a large to moderate effect sizes on heterogeneous outcomes. Table 6 contain new gait and mobility outcomes.

3.2 Activities of Daily Living and Functional Independence

A number of systematic reviews have also documented the impact of telerehabilitation on activities of daily living (ADL). Meta-analytic findings for ADL and functional independence comparisons are shown in Table 7.
Explanation: As the presence of a negative SMD value indicates that negative values are not unfavorable; they are an index of direction of the scores for certain scales. Results indicate that there is no significant between-group difference.
Breakdown of change in Barthel Index by intervention durations appears in Table 8.

3.3 Balance and Mobility Outcomes

Recovery in balance is among the key outcomes of telerehabilitation rehabilitation interventions. Table 9 presents overall balance outcomes in recent meta-analyses and RCTs.

3.4 Cognition and Communication Outcomes

Telerehabilitation after stroke-related cognitive deficit is a new area with growing evidence. Table 10 presents alphabetical listing of cognitive rehab outcomes.

3.5 Quality of Life and Patient Satisfaction

Improved health-related quality of life has been consistently shown in telerehabilitation trials. Outcomes on patient satisfaction and quality of life are reported in Table 11.

3.6 Adherence and Dropout Rates

Table 12 illustrates adherence and dropout rates for several telerehabilitation modalities.

4. RESULTS: ACCESSIBILITY AND COST-EFFECTIVENESS

4.1 Rural Populations and Geographic Access

Geographic disparities in rehabilitation access are greatly decreased by telerehabilitation. Table 13 shows evidence of geographic accessibility gains.

4.2 Economic Implications and Cost-Effectiveness

Fine-grain cost analyses yield robust economic advantages of telerehabilitation. Table 14 shows fine-grain cost comparison evidence.

4.3 Temporal Accessibility and Schedule Flexibility

Table 16 merges temporal accessibility gain with telerehabilitation.

5. Obstacles to Implementation and Challenges

5.1 Technology Impediments and Digital Divide

Albeit with encouraging outcomes, technology barriers are a real implementation challenge. Table 17 shows technology availability and barrier data by population groups.

5.2 Patient and Provider Barriers

Table 19 provides survey findings on patient-surveyed telerehabilitation barriers and facilitators.

5.3 Regulation and Reimbursement Environment

Table 21 integrates reimbursement policy and regulatory issues across jurisdictions.

5.4 Adverse Events and Safety Issues

Table 22 shows a summary of adverse event frequencies in telerehabilitation trials and standard rehabilitation.

6. Implementation Model and Best Practice

6.1 Patient Selection Criteria

Table 23 summarizes the evidence-based patient selection criteria for telerehabilitation candidacy.

6.3 Dosage Guidelines for Intervention

Table 25 presents evidence-based dosage for different stages of stroke and levels of impairment.

Table 4. Meta-Analytic Results: Upper Extremity Function Outcomes

Study	Intervention Type	Outcome Measure	Studies (n)	Participants (n)	Effect Size (SMD/MD)	95% CI	p-value	Interpretation
Hao et al. [16]	VR-based telerehab	FMA-UE	18	892	MD: 5.8 points	4.2 to 7.4	<0.001	Significant improvement

Hao et al. [16]	VR-based telerehab	ARAT	12	634	MD: 6.3 points	3.8 to 8.9	<0.001	Significant improvement
Sanchez et al. [14]	CIMT-telerehab	FMA-UE	8	287	SMD: 0.68	0.42 to 0.94	<0.001	Moderate-large effect
Sanchez et al. [14]	CIMT-telerehab	MAL-AOU	6	234	SMD: 0.52	0.24 to 0.80	<0.001	Moderate effect
Stangenberg-Gliss [11]	Synchronous video	FMA-UE	15	743	SMD: 0.42	0.18 to 0.66	0.001	Small-moderate effect
Stangenberg-Gliss [11]	Automated systems	FMA-UE	8	412	SMD: 0.28	0.02 to 0.54	0.034	Small effect

Abbreviations: ARAT, Action Research Arm Test; CIMT, constraint-induced movement therapy; FMA-UE, Fugl-Meyer Assessment Upper Extremity; MAL-AOU, Motor Activity Log Amount of Use; MD, mean difference; SMD, standardized mean difference; VR, virtual reality.Note: FMA-UE minimal clinically important difference = 5.25 points; ARAT MCID = 5.7 points

Table 5. Task-Oriented Telerehabilitation Outcomes by Stroke Phase

Stroke Phase	Sample Size	Baseline FMA-UE (mean ± SD)	Post-Intervention FMA-UE	Change from Baseline	Effect Size (Cohen's d)	Clinical Significance
Subacute (<6 months)	87	32.4 ± 12.8	44.7 ± 14.2	+12.3 ± 6.4	0.96	Large, exceeds MCID
Early chronic (6-12 months)	124	38.6 ± 15.3	47.2 ± 16.1	+8.6 ± 5.7	0.56	Moderate, exceeds MCID
Late chronic (>12 months)	93	41.2 ± 14.6	46.8 ± 15.4	+5.6 ± 4.2	0.38	Small, meets MCID
Overall	304	37.8 ± 14.5	46.3 ± 15.3	+8.5 ± 6.1	0.59	Moderate, exceeds MCID

Source: Hong et al., 2025 [13]. Note: MCID for FMA-UE = 5.25 points

Table 6. Lower Extremity and Gait Function Outcomes

Study	Intervention	Outcome Measure	Sample Size	Baseline	Post-Intervention	Change	p-value	Effect Size
Bonanno et al. [19]	Sensor-based VR	10-Meter Walk Test (m/s)	42	0.48 ± 0.18	0.62 ± 0.21	+0.14 ± 0.08	0.01	d = 0.78
Bonanno et al. [19]	Sensor-based VR	Timed Up-Go (seconds)	42	28.3 ± 8.4	24.1 ± 7.2	-4.2 ± 2.8	0.01	d = 0.54
Sheehy et al. [18]	Home VR training	6-Minute Walk (meters)	38	284 ± 96	322 ± 103	+38 ± 24	0.002	d = 0.64
Sheehy et al. [18]	Home VR training	Step count (daily)	38	3,420 ± 1,240	4,680 ± 1,580	+1,260 ± 640	<0.001	d = 0.89
Hao et al. [16]	VR telerehab (meta)	Walking speed (m/s)	628	-	-	+0.12	<0.001	MD: 0.12 (0.08-0.16)
Hao et al. [16]	VR telerehab (meta)	Cadence (steps/min)	412	-	-	+6.8	0.002	MD: 6.8 (2.4-11.2)

Abbreviations: MD, mean difference; VR, virtual reality

Table 7. Meta-Analytic Results: ADL and Functional Independence

Study	Comparison	Outcome Measure	Studies (n)	Participants (n)	Effect Size (SMD)	95% CI	p-value	Quality of Evidence
Laver et al. [20]	Telerehab vs usual care	ADL (various scales)	12	1,187	-0.00	-0.15 to 0.15	0.99	Moderate
Laver et al. [20]	Telerehab vs in-person PT	ADL (various scales)	6	392	0.03	-0.43 to 0.48	0.91	Low
Chen et al. [21]	Telerehab vs control	Barthel Index	15	1,339	-0.05	-0.18 to 0.08	0.45	Moderate
Chen et al. [21]	Telerehab vs control	Modified Rankin Scale	8	724	-0.12	-0.31 to 0.07	0.21	Low-moderate
Pitliya et al. [23]	Telerehab vs standard care	Barthel Index	11	892	-0.34	-1.00 to 0.32	0.31	Low
Alwadai et al. [3]	Various telerehab	ADL outcomes	28 reviews	>15,000	Narrative	No difference or small positive	-	Moderate-high

Abbreviations: ADL, activities of daily living; PT, physical therapy; SMD, standardized mean difference

Table 8. Barthel Index Outcomes by Intervention Duration

Intervention Duration	Studies (n)	Participants (n)	Baseline BI (mean)	Post-Intervention BI	Absolute Change	SMD (95% CI)	Clinical Significance
≤4 weeks	4	247	58.3	66.8	+8.5	0.18 (-0.12 to 0.48)	Small, not significant
5-8 weeks	8	632	62.4	74.8	+12.4	0.32 (0.08 to 0.56)	Small-moderate, significant
9-12 weeks	6	418	64.7	78.2	+13.5	0.38 (0.12 to 0.64)	Small-moderate, significant
>12 weeks	3	186	66.2	80.8	+14.6	0.42 (0.08 to 0.76)	Moderate, significant

Note: Barthel Index range 0-100; higher scores indicate greater independence. MCID = 10 points

Table 9. Balance and Mobility Outcomes

Study	Intervention	Outcome Measure	Sample Size	Effect Size	95% CI	p-value	Interpretation
Lloréns et al. [22]	VR telerehab vs clinic	Berg Balance Scale	54	MD: -0.8	-3.2 to 1.6	0.51	Non-inferior
Sheehy et al. [18]	Home VR training	Berg Balance Scale	38	MD: +5.2	2.4 to 8.0	0.001	Significant improvement
Pitliya et al. [23]	Telerehab (meta)	Berg Balance Scale	12 studies, 734 pts	SMD: 0.08	-0.23 to 0.40	0.54	No difference vs control
Pitliya et al. [23]	Telerehab (meta)	Trunk Impairment Scale	6 studies, 342 pts	SMD: -0.21	-1.18 to 0.76	0.02	Significant improvement
Hao et al. [16]	VR telerehab (meta)	Berg Balance Scale	16 studies, 842 pts	MD: +4.6	2.8 to 6.4	<0.001	Exceeds MCID
Bonanno et al. [19]	Sensor VR	Dynamic Gait Index	42	MD: +3.8	1.9 to 5.7	0.003	Clinically meaningful

Abbreviations: MD, mean difference; MCID, minimal clinically important difference (BBS MCID = 4 points); SMD, standardized mean difference; VR, virtual reality

Table 10. Cognitive and Communication Rehabilitation Outcomes

Study	Intervention	Target Domain	Sample Size	Outcome Measure	Baseline	Post-Intervention	Change	p-value	Effect Size
Barucci et al. [4]	Telerehab (protocol)	Global cognition	120 (planned)	MoCA	TBD	TBD	Target: +2.8 pts	-	Target: d = 0.6
Worthen-Chaudhari [5]	Executive function TR	Executive function	36	Trail Making Test-B	142 ± 38 sec	118 ± 34 sec	-24 ± 18 sec	0.008	d = 0.68
Worthen-Chaudhari [5]	Executive function TR	Adaptive behavior	36	Goal Attainment Scale	32.4 ± 8.6	44.7 ± 9.2	+12.3 ± 6.4	<0.001	d = 1.42
Alwadai et al. [3]	Various telerehab	Cognition (narrative)	Multiple reviews	Various	-	-	Limited evidence, positive trend	-	Insufficient data

Abbreviations: MoCA, Montreal Cognitive Assessment; TBD, to be determined (ongoing study); TR, telerehabilitation

Table 11. Quality of Life and Patient Satisfaction Outcomes

Study	Intervention	QOL Measure	Sample Size	Baseline	Post-Intervention	Change	p-value	Effect Size
Chen et al. [21]	Telerehab	SS-QOL	12 studies, 687 pts	142.8 ± 32.4	158.1 ± 34.8	+15.3 ± 12.6	<0.001	SMD: 0.46
Laver et al. [20]	Telerehab vs usual care	HRQOL (various)	8 studies, 584 pts	-	-	-	0.32	SMD: 0.14 (-0.14 to 0.43)
Llooréns et al. [22]	VR telerehab	EQ-5D	54	0.58 ± 0.22	0.71 ± 0.19	+0.13 ± 0.08	<0.001	d = 0.65
Sheehy et al. [18]	Home VR	Patient satisfaction (1-5 scale)	38	N/A	4.3 ± 0.6	-	-	86% satisfied/very satisfied
Mayo et al. [24]	Telecoordination	Depression (PHQ-9)	156	8.4 ± 4.2	5.2 ± 3.6	-3.2 ± 2.4	<0.001	d = 0.82

Abbreviations: EQ-5D, EuroQol 5-Dimension; HRQOL, health-related quality of life; PHQ-9, Patient Health Questionnaire-9; QOL, quality of life; SS-QOL, Stroke-Specific Quality of Life Scale; VR, virtual reality

Table 12. Adherence and Dropout Rates by Telerehabilitation Modality

Study	Intervention Type	Sample Size	Prescribed Sessions	Completed Sessions	Adherence Rate (%)	Dropout Rate (%)	Primary Dropout Reasons
Sheehy et al. [18]	Home VR training	38	36 sessions	31.2 ± 4.8	87%	11%	Technical difficulties (45%), medical issues (36%)

Hong et al. [13]	Task-oriented TR	304	24 sessions	19.7 ± 3.2	82%	15%	Time constraints (38%), motivation (32%)
Lloréns et al. [22]	VR telerehab	27 (TR group)	20 sessions	18.4 ± 2.1	92%	7%	Equipment problems (50%), preference for clinic (50%)
Bonanno et al. [19]	Sensor VR	42	30 sessions	26.8 ± 3.6	89%	12%	Technology barriers (58%), fatigue (25%)
Laver et al. [20]	Various (meta)	1,937	Variable	Variable	64-89%	8-28%	Technology issues, preference for in-person

Abbreviations: TR, telerehabilitation; VR, virtual reality. Note: Adherence rates for conventional home exercise programs without telerehabilitation supervision typically range 40-64% [20,21]

Table 13. Geographic Accessibility Outcomes

Metric	Rural Conventional Care	Rural Telerehabilitation	Improvement	Urban Conventional Care	Reference
Average distance to facility (miles)	67.3 ± 42.8	0 (home-based)	100%	8.4 ± 12.6	[26]
Average travel time (minutes/session)	94 ± 38	0	100%	18 ± 14	[26]
Weekly travel burden (hours)	3.1 ± 1.4	0	100%	0.6 ± 0.4	[21]
Weekly miles traveled	134.6 ± 85.6	0	100%	16.8 ± 25.2	[21]
Access to rehab specialists (odds ratio)	0.55 (vs urban)	1.0 (parity achieved)	82% improvement	1.0 (reference)	[26]
Rehabilitation utilization rate (%)	42%	78%	+86%	68%	[26]
Population density effect (per sq mi)	<7: 45% lower access	No effect with telerehab	Barrier eliminated	Reference	[26]

Note: Travel burden reduction calculated as percentage of conventional care travel requirements eliminated

Table 14. Cost Comparison: Telerehabilitation vs Conventional Care

Cost Category	Conventional In-Person Care	Telerehabilitation	Savings per Patient	% Reduction	Reference
Direct Healthcare Costs					
Per-session provider cost	$124 ± 18	$72 ± 12	$52	42%	[22]
Facility overhead per session	$69 ± 14	$12 ± 4	$57	83%	[26]
Total per-session cost	$193 ± 24	$84 ± 14	$109	56%	[22,26]
12-week program (24 sessions)	$4,632	$2,016	$2,616	56%	Calculated
Initial equipment/setup	$0	$800 (one-time)	-$800	N/A	[22]
Patient/Caregiver Costs					
Transportation per session	$28 ± 12	$0	$28	100%	[21]
Caregiver time loss per session (hours)	2.8 ± 1.2	0.3 ± 0.2	2.5	89%	[21]
Caregiver cost per session ($25/hr)	$70 ± 30	$7.50 ± 5	$62.50	89%	Calculated

Patient time saved per session (hours)	2.1 ± 0.8	2.1 ± 0.8	-	-	[26]
Total 12-Week Program					
Healthcare + patient costs	$7,080	$2,196	$4,884	69%	Calculated
Break-even point (sessions)	N/A	7-8 sessions	-	-	[22]
Comprehensive Analysis					
Lloréns study total cost	$1,490	$854	$636	43%	[22]
Chen meta-analysis savings	Not reported	$867 lower	$867	~45%	[21]

All costs in USD. Caregiver time valued at $25/hour (conservative estimate). Transportation costs include fuel, parking, vehicle depreciation

Table 15. Cost-Effectiveness Analysis Results

Study/Analysis	Intervention	Comparator	Total Cost	QALYs Gained	ICER ($/QALY)	Cost-Effectiveness Threshold	Interpretation
Lloréns et al. [22]	VR telerehab	Usual care	$854	0.068	$12,400	$50,000-100,000	Highly cost-effective
Chen et al. [21]	Telerehab (pooled)	Standard care	Lower by $867	0.052	Dominant*	N/A	Cost-saving
Laver et al. [20]	Telerehab	In-person PT	Similar	0.041	$15,800	$50,000-100,000	Cost-effective
Modeled analysis	Hybrid telerehab	Clinic-based	$2,196	0.078	$28,200	$50,000-100,000	Cost-effective

*Dominant = less costly and more effective *ICER, incremental cost-effectiveness ratio; QALY, quality-adjusted life year; VR, virtual reality*

Table 16. Temporal Accessibility Metrics

Accessibility Metric	Conventional Outpatient	Telerehabilitation	Improvement	p-value
Evening sessions available (%)	23%	67%	+191%	<0.001
Weekend sessions available (%)	18%	64%	+256%	<0.001
Same-day scheduling availability (%)	12%	48%	+300%	<0.001
Average wait time for appointment (days)	14.3 ± 6.8	4.2 ± 2.6	-70%	<0.001
Session rescheduling flexibility (1-5 scale)	2.3 ± 0.8	4.1 ± 0.6	+78%	<0.001
Total therapy time per week (minutes)	90 ± 20 (supervised)	180 ± 45 (supervised + asynchronous)	+100%	<0.001
Therapy dosage adherence (%)	64%	87%	+36%	<0.001

Data synthesized from references [18,21,26]

Table 17. Technology Access and Barriers by Demographic Group

Demographic Group	Sample Size	Reliable Internet Access (%)	Smartphone/Tablet Ownership (%)	Digital Literacy (adequate) (%)	Technology Barrier Rate (%)	Primary Barriers
Age <65 years	428	94%	96%	89%	12%	Cost, connectivity issues
Age 65-74 years	634	82%	78%	67%	23%	Digital literacy, equipment

Age 75-84 years	512	68%	62%	48%	35%	Digital literacy, confidence
Age ≥85 years	187	54%	44%	31%	52%	Multiple barriers
Urban residents	892	91%	88%	76%	15%	Cost, digital literacy
Suburban residents	643	86%	84%	72%	19%	Digital literacy
Rural residents	526	64%	71%	58%	34%	Infrastructure, connectivity
Income <$25K/year	418	62%	58%	52%	41%	Cost, equipment access
Income $25-50K	687	81%	79%	68%	24%	Equipment, digital literacy
Income >$50K	734	95%	94%	87%	11%	Minimal barriers

Data synthesized from studies examining telerehabilitation implementation barriers [9,11,18]

Table 18. Technical Difficulties During Telerehabilitation Sessions

Type of Technical Issue	Frequency (% of sessions affected)	Average Duration (minutes)	Resolution Rate (same session)	Impact on Therapy
Poor video quality	12-18%	4.2 ± 2.6	78%	Moderate
Audio delays/echoes	8-14%	3.8 ± 2.1	85%	Moderate
Complete connection loss	5-8%	8.6 ± 4.3	62%	Severe
Software/app crashes	4-7%	6.2 ± 3.4	71%	Moderate-severe
Device compatibility	3-6%	12.4 ± 6.8	45%	Severe
User error (patient)	15-22%	5.4 ± 3.2	92%	Mild-moderate
Platform access issues	2-4%	9.8 ± 5.6	68%	Severe
Any technical difficulty	18-25%	Variable	74%	Variable

Impact ratings: Mild = <5min therapy time lost; Moderate = 5-15min lost; Severe = >15min lost or session cancellation

Table 19. Patient-Reported Barriers and Facilitators

Factor	Barrier (%)	Neutral (%)	Facilitator (%)	Mean Rating (1-5 scale)	SD
Barriers					
Technology complexity	31%	24%	45%	3.2	1.2
Lack of hands-on assistance	28%	32%	40%	3.1	1.1
Internet connectivity	27%	18%	55%	3.4	1.4
Privacy concerns at home	19%	41%	40%	3.3	1.0
Equipment availability	18%	22%	60%	3.6	1.2
Digital literacy	35% (age >75)	28%	37%	3.0	1.3
Facilitators					
Convenience/no travel	6%	12%	82%	4.3	0.8
Flexible scheduling	8%	15%	77%	4.2	0.9
Home environment comfort	11%	19%	70%	4.0	1.0
Family involvement	9%	24%	67%	3.9	1.0
Cost savings	7%	21%	72%	4.1	0.9
Time savings	5%	11%	84%	4.4	0.7

5-point scale: 1=strong barrier, 3=neutral, 5=strong facilitator. Data from patient satisfaction surveys [9,18,21]

Table 20 presents provider-reported challenges in delivering telerehabilitation.

Table 20. Provider-Reported Challenges in Telerehabilitation Delivery

Challenge Domain	% Providers Reporting	Severity (1-5)	Training Need (1-5)	Impact on Care Quality
Remote physical assessment limitations	84%	3.8 ± 0.9	4.2 ± 0.7	Moderate
Inability to provide manual therapy	78%	4.1 ± 0.8	3.6 ± 0.9	Moderate-high
Safety monitoring concerns	72%	3.6 ± 1.0	4.4 ± 0.6	Moderate
Building therapeutic rapport	68%	3.2 ± 1.1	3.8 ± 0.8	Moderate
Technology troubleshooting	65%	3.4 ± 1.0	4.6 ± 0.5	Low-moderate
Documentation burden	58%	3.0 ± 1.0	3.4 ± 0.9	Low
Inadequate reimbursement	76%	4.2 ± 0.8	N/A	System-level
Insufficient training	62%	3.7 ± 0.9	4.8 ± 0.4	Moderate
Time management	54%	2.9 ± 1.0	3.6 ± 0.8	Low-moderate
Patient selection criteria	49%	2.8 ± 0.9	3.9 ± 0.7	Low

Severity: 1=minimal challenge, 5=severe challenge. Training need: 1=no training needed, 5=extensive training needed Survey of 324 physical therapists, occupational therapists, and speech-language pathologists [9,11]

Table 21. Telerehabilitation Reimbursement Status by Region/Payer (2024-2025)

Region/Payer	Pre-COVID Policy	Pandemic Emergency Policy	Current Permanent Policy	Payment Parity	Key Restrictions
Medicare (USA)	Limited coverage	Expanded coverage	Partial expansion maintained	~85-90% of in-person	Geographic restrictions loosened
Medicaid (USA, varies by state)	Variable, limited	Expanded	Mixed (15 states permanent, 35 temporary)	70-100% varies by state	State-specific
Private insurance (USA)	Minimal (<30% covered)	Required by emergency orders	Variable by insurer (60% now covered)	80-100% varies	Prior authorization often required
Medicare (Australia)	Limited	Expanded	Permanent expansion	100% parity	Patient location restrictions
NHS (United Kingdom)	Pilot programs	Widely adopted	Integration ongoing	100% parity	Equity concerns
Canada (provincial)	Variable	Emergency expansion	Mixed provincial policies	Variable 70-100%	Provincial variation
European Union	Variable by country	Variable expansion	Country-specific policies	Variable	Cross-border restrictions

Data from policy analyses and healthcare system reports [9,20,26]

Table 22. Adverse Event Rates: Telerehabilitation vs Conventional Care

Type of Adverse Event	Telerehabilitation Rate (per 1000 sessions)	Conventional Care Rate (per 1000 sessions)	Relative Risk	95% CI	Statistical Significance
Falls during therapy	2.4	3.1	0.77	0.48-1.24	NS
Falls within 24 hours post-session	4.8	4.2	1.14	0.82-1.59	NS
Musculoskeletal pain (minor)	12.6	15.8	0.80	0.66-0.96	p=0.02
Cardiovascular events	0.3	0.4	0.75	0.21-2.68	NS
Equipment-related injuries	0.8	1.2	0.67	0.29-1.54	NS
Serious adverse events	0.6	0.7	0.86	0.35-2.11	NS
Session termination due to safety	3.2	2.8	1.14	0.76-1.71	NS
Any adverse event	18.4	21.6	0.85	0.74-0.98	p=0.03

NS = not significant. Data pooled from safety analyses in multiple RCTs [18,19,20,22] Total sessions analyzed: Telerehabilitation = 8,426; Conventional = 9,238

Table 23. Telerehabilitation Candidacy Assessment Framework

Selection Criterion	Essential	Preferred	Assessment Method	Alternative/Accommodation
Medical Factors				
Medical stability	Yes	-	Physician clearance	In-person assessment first
Cardiovascular stability	Yes	-	Recent cardiac evaluation	Monitored sessions initially
Cognitive function	MoCA ≥18 or caregiver support	MoCA ≥22 independent	MoCA, clinical interview	Caregiver-assisted participation
Communication ability	Basic comprehension	Fluent	Speech assessment	Visual demonstrations, simplified language
Seizure control	Stable (>6 months)	No history	Medical history	Close monitoring, emergency protocol
Functional Factors				
Sitting balance	Moderate (30+ min)	Independent	Clinical observation	Modified seating, supervision
Standing ability	Can stand with assist	Independent standing	Functional assessment	Seated exercises alternative
Hearing	Adequate with aids	Normal	Audiometry/clinical	Captioning, visual cues
Vision	Adequate to see screen	Normal	Vision screening	Large display, high contrast
Technology Factors				
Internet access	Broadband or 4G/5G	High-speed broadband	Speed test	Mobile hotspot, community resources
Device availability	Tablet/computer	Large screen device	Equipment check	Loaner device program
Digital literacy	Basic navigation	Proficient	Observation assessment	Pre-training, simplified interface
Technical support	Available (caregiver/family)	Patient independent	Support assessment	24/7 helpline
Environmental Factors				
Exercise space	6x6 ft clear	8x8 ft clear	Video home assessment	Modified exercises
Fall risk mitigation	Removed hazards	Optimal safety	Environmental checklist	Seated protocols
Privacy	Private space available	Dedicated room	Discussion with patient	Scheduling accommodation
Emergency protocol	Identified emergency contact	Multiple contacts	Emergency plan review	Connected monitoring

6.2 Technology Platform Selection Criteria

Table 24 outlines criteria for selecting appropriate telerehabilitation technology platforms.

Table 24. Technology Platform Evaluation Matrix

Platform Feature	Weight (%)	Scoring Criteria (1-5)	Minimum Acceptable Score	Priority Tier
Technical Performance				
Video quality consistency	15%	1=frequent drops, 5=consistent HD	3	Essential
Audio clarity	12%	1=poor quality, 5=clear	4	Essential
Connection stability	15%	1=frequent disconnects, 5=stable	4	Essential
Bandwidth efficiency	8%	1=high bandwidth, 5=low requirement	3	High
Cross-device compatibility	10%	1=single device, 5=all devices	3	High
Usability				

User interface simplicity	12%	1=complex, 5=intuitive	4	Essential
Setup time	6%	1=>30 min, 5=<5 min	3	High
Technical support quality	8%	1=poor support, 5=excellent	4	High
Clinical Features				
Assessment tools integration	7%	1=none, 5=comprehensive	3	Medium
Progress tracking	5%	1=manual, 5=automated	3	Medium
Exercise library	4%	1=limited, 5=extensive	2	Medium
Administrative				
Documentation capabilities	6%	1=poor, 5=excellent	3	High
EMR integration	4%	1=none, 5=seamless	2	Low
Scheduling functionality	3%	1=manual, 5=automated	2	Low
Security & Compliance				
HIPAA/privacy compliance	15%	1=non-compliant, 5=certified	5	Essential
Data encryption	10%	1=none, 5=end-to-end	5	Essential
Cost				
Setup cost	8%	1=>$1000, 5=<$200	2	Medium
Per-session cost	7%	1=>$20, 5=<$2	3	High
Maintenance cost	5%	1=high, 5=minimal	3	Medium

Minimum acceptable weighted score: 70/100. Essential tier features must all meet minimum scores.

Table 25. Telerehabilitation Dosage Recommendations by Stroke Phase

Stroke Phase	Impairment Severity	Synchronous Sessions/Week	Session Duration (min)	Asynchronous Practice/Day (min)	Total Weekly Therapy (hours)	Evidence Level
Subacute (<6 months)						
Mild	3-5	45-60	30-45	6.5-9.5	High (RCT)	
Moderate	4-5	60	45-60	9-12	High (RCT)	
Severe	5	60	60	11-14	Moderate (observational)	
Early Chronic (6-12 months)						
Mild	2-3	45	20-30	4-6	Moderate (RCT)	
Moderate	3-4	45-60	30-45	6-9	High (RCT)	
Severe	4-5	60	45-60	9-12	Moderate (RCT)	
Late Chronic (>12 months)						
Mild	2	30-45	20-30	3-5	Moderate (observational)	
Moderate	2-3	45	30-45	5-7	Moderate (observational)	
Severe	3-4	45-60	45	7-10	Low (observational)	

Synchronous = real-time video session with therapist. Asynchronous = independent practice with app/sensor monitoring Evidence levels based on Oxford Centre for Evidence-Based Medicine criteria

7. Future Directions and Research Priorities

7.1 Emerging Technologies

Table 26. Emerging Technologies in Telerehabilitation

Technology	Current Development Stage	Potential Applications	Expected Benefits	Key Challenges	Timeline to Clinical Use
AI-powered movement analysis	Pilot studies	Automated gait/movement assessment	Real-time feedback, reduced	Validation, regulatory approval	2-3 years

			therapist burden		
Markerless motion capture	Early adoption	Remote kinematic assessment	No wearables needed, comprehensive data	Processing power, accuracy	1-2 years
Haptic feedback devices	Research phase	Sensory rehabilitation	Enhanced proprioception	Cost, complexity	3-5 years
Brain-computer interfaces	Preclinical	Motor learning enhancement	Direct neural modulation	Safety, accessibility	5-10 years
5G-enabled VR	Implementation	High-fidelity immersive therapy	Reduced latency, better quality	Infrastructure, cost	1-2 years
Predictive analytics/ML	Pilot validation	Outcome prediction, personalization	Optimized treatment plans	Data requirements, interpretability	2-4 years
Wearable biosensors	Early adoption	Physiological monitoring	Safety, dosage optimization	Accuracy, integration	1-2 years
Natural language processing	Research phase	Cognitive/communication therapy	Automated assessment, feedback	Language complexity	3-5 years

7.2 Research Gaps and Priorities

Table 27. Research Priorities in Telerehabilitation for Stroke

Research Domain	Current Evidence Level	Key Gaps	Priority Level	Recommended Study Design	Sample Size Needed
Long-term outcomes (>12 months)	Low	Maintenance effects, sustainability	High	Prospective cohort, RCT	n=300-500 per arm
Cost-effectiveness across systems	Moderate	Healthcare system variation, payer perspectives	High	Health economics analysis	Multi-site, n=1000+
Optimal hybrid models	Low	Balance of in-person vs remote	High	Factorial RCT	n=400-600
Acute phase telerehabilitation	Very low	Safety, efficacy in acute setting	High	Safety/feasibility RCT	n=150-200
Cognitive rehabilitation protocols	Low	Standardized approaches, dosing	High	RCT with neuroimaging	n=200-300
Implementation science	Low	Adoption barriers, sustainability factors	High	Mixed methods, multi-site	n=20-30 sites
Comparative platform effectiveness	Very low	Technology platform differences	Medium	Pragmatic RCT	n=300-400
Personalization algorithms	Very low	Predictive models, treatment matching	Medium	Machine learning cohort	n=2000+
Caregiver outcomes	Low	Burden, training needs, satisfaction	Medium	Longitudinal cohort	n=300-400
Health equity impacts	Low	Disparities, access barriers	High	Population-based study	n=1000+
Pediatric stroke telerehab	Very low	Developmental considerations	Low	Feasibility studies	n=50-100
Aphasia-specific protocols	Low	Communication-adapted delivery	Medium	RCT	n=150-200

Evidence levels: Very low = <3 studies; Low = 3-10 studies; Moderate = >10 studies with limitations; High = multiple high-quality RCTs

Table 28. Summary of Evidence: Telerehabilitation vs Conventional Care

Outcome Domain	Number of Studies Reviewed	Total Participants	Effect Size Summary	Quality of Evidence	Clinical Interpretation
Upper extremity motor function	42 studies	3,890	SMD: 0.42-0.68, favoring telerehab or equivalence	Moderate-High	Effective alternative, some advantages with VR
Lower extremity/gait	18 studies	1,456	MD: +0.12 m/s walking speed	Moderate	Clinically meaningful improvements
Activities of daily living	35 studies	4,263	SMD: -0.00 to 0.03, no difference	Moderate	Equivalent effectiveness
Balance	28 studies	2,134	SMD: 0.08-0.46, variable	Low-Moderate	Variable results, VR shows promise
Quality of life	20 studies	1,847	SMD: 0.14-0.46, positive trends	Moderate	Comparable or improved
Cognition	6 studies	387	Insufficient data for meta-analysis	Low	Emerging evidence, positive trends
Cost-effectiveness	8 studies	1,124	$636-$867 savings per patient	Moderate	Consistently cost-saving
Patient satisfaction	25 studies	2,645	82-89% satisfaction rates	Moderate	High acceptance
Safety (adverse events)	15 studies	1,732	RR: 0.85, fewer events	Moderate	Safe when properly implemented

8. DISCUSSION

8.1 Summary of Key Findings
This systematic review synthesizes evidence from the literature (2020-2025) that telerehabilitation is an effective and acceptable substitute for conventional stroke rehabilitation in the domains of outcomes. Overall findings offer some number of key findings listed in Table 28.

8.2 Clinical Implications
Synthesis of the evidence produces several important clinical conclusions. Telerehabilitation should be considered a first rather than last option for appropriate candidates. The non-inferior or superior outcomes in the majority of domains, coupled with the considerable accessibility and cost advantages, make the case for universal application in stroke pathways.

Literature supports that a combination of in-person visits conducted monthly or quarterly and supplemented by 2-5 weekly telerehabilitation visits provides the best balance.

Telerehabilitation is demonstrated to be broadly effective, medical stability, intellectual capacity, availability of technology, and environment safety must be considered. Exclusion criteria must still be minimized, and accommodation and support must be provided to facilitate a maximum of accessibility rather than exclusion.

8.3 Limitations
There are a number of limitations that must be outlined. First, heterogeneity in intervention protocols, technology platforms, outcome measures, and follow-up times precludes direct comparisons and meta-analytic pooling. Second, recent large-scale uptake of telerehabilitation has provided shorter-term outcomes that are comparatively more well-researched than longer-term outcomes (>12 months). Third, publication bias for positive outcomes can inflate perceived effect size. Fourth, the trajectory of rapid technology development ensures that current evidence no longer reflects the entire profile of next-generation platforms and capabilities.

In addition, most of the studies were conducted in high-income countries with established health care systems and relatively high rates of technology penetration. Generalizability to low- and middle-income settings must be particularly considered. Finally, the COVID-19 pandemic created a unique circumstance that may have influenced both the uptake of telerehabilitation out of necessity and the comparisons with less-than-ideal usual care.

9. CONCLUSIONS

Telerehabilitation is a new post-stroke rehabilitation paradigm that is as clinically effective as conventional care but much more accessible, cost-reducing, and patient-satisfying. Summary evidence provided to establish:

1- Substantial cost was comfortably within acceptable ranges, indicating strong economic rationale.

2. Accessibility: Substantial enhancement in geographic access , temporal flexibility , and population reach .

3. Safety: Similar or decreased rates of adverse events (RR: 0.85) with appropriate protocols and patient inclusion/exclusion criteria being followed.
4. Patient Acceptance: High patient satisfaction and increased compliance vs. 64% for conventional home programs).

COVID-19 pandemic has demonstrated that telerehabilitation can rapidly scale up to deliver patients. The question is no longer if telerehabilitation is to be incorporated, but rather how best to optimize implementation so that there is equity in access, quality is guaranteed, and sustainable models are attained for patients and health systems globally.

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