

Effectiveness of Exercise-Based Telerehabilitation in Adults with Chronic Stroke: A Systematic Review

Zainab Marafie

`zainab.marafie@student.manchester.ac.uk`

University of Manchester

Dr Steve Jones

University of Manchester

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By: Zainab Marafie¹ (Corresponding Author), Dr Steve Jones²

Affiliation 1: University of Manchester, Manchester, UK

Affiliation 2: University of Manchester, Manchester, UK

Email Address: zainab.marafie@student.manchester.ac.uk

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Abbreviations List

6MWT = 6-Minute Walk Test

10MWT = 10-Meter Walk Test

ADL = Activities of Daily Living

BBA = Brunel Balance Assessment

BBS = Berg Balance Scale

BI = Barthel Index

EQ-5D-5L = EuroQol Five-Dimension Five-Level

FIM = Functional Independence Measure

MCID = Minimal Clinically Important Difference

mHealth = Mobile Health

POMA = Performance-Oriented Mobility Assessment

POMA-B = Performance-Oriented Mobility Assessment-Balance

POMA-G = Performance-Oriented Mobility Assessment-Gait

PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses

PROSPERO = International Prospective Register of Systematic Reviews

QoL = Quality of Life

RCT = Randomised Controlled Trial

RoB 2 = Risk of Bias 2

SMART = Sequential Multiple Assignment Randomised Trial

SUS = System Usability Scale

VAS = Visual Analogue Scale

VR = Virtual Reality

1.0 Abstract

Background: Stroke is a leading cause of long-term disability worldwide. Rehabilitation improves motor function, but geographical barriers, transportation difficulties, and resource constraints limit access to in-person services. Exercise-based telerehabilitation may offer an accessible alternative for chronic stroke survivors, but its effectiveness compared with conventional rehabilitation remains unclear.

Methods: A systematic review of randomised controlled trials and feasibility studies was conducted. Electronic searches of MEDLINE and Embase were performed in English-language publications. Two independent reviewers screened 279 records. Study quality was assessed using the Cochrane Risk of Bias 2 tool. Five studies (n=156; age 50–80 years) investigating exercise-based telerehabilitation in chronic stroke (>3 months post-stroke) were included. Interventions included virtual reality systems, mobile health applications, and hybrid models compared with conventional rehabilitation or usual care. Narrative synthesis was performed due to heterogeneity in study designs and outcomes.

Results: All five studies were small pilot or feasibility trials (10–50 participants). No serious adverse events were reported. Balance and gait improved in both telerehabilitation and conventional groups, with no between-group differences. Mobile health interventions showed greater improvements in physical activity and walking speed than virtual reality. Walking speed improvements exceeded the minimal clinically important difference (0.21–0.27 m/s). Wearable devices achieved higher adherence (90.7%) than complex applications (56.3%). One study reported a 43.9% reduction in per-participant costs with home-based delivery, primarily due to reduced transportation costs. Only two studies included follow-up beyond three months.

Discussion/Implication: Exercise-based telerehabilitation yields functional improvements comparable to those of conventional rehabilitation. Simpler technologies demonstrate better engagement than complex applications. Small sample sizes, short follow-up periods, and heterogeneity in interventions limit the evidence base. Larger trials with longer follow-up are essential to establish effectiveness and identify which patients benefit most from telerehabilitation.

2.0 Introduction

2.1 Introduction to Stroke

Stroke remains a leading cause of long-term disability worldwide, affecting nearly nine million people annually (Feigin et al., 2017; Sun et al., 2025). Long-term complications include reduced mobility, impaired balance, muscle weakness, fatigue, and reduced ability to perform activities of daily living, leading to decreased independence and quality of life (Cramer, 2008). Although acute stroke care has improved, more patients now live with long-term stroke-related disability (Winstein et al., 2016).

2.2 Overview of Rehabilitation

Rehabilitation is essential for stroke recovery, improving motor function and supporting neuroplasticity (Teasell et al., 2009; Langhorne et al., 2011). However, access is often limited by geographical location, transport difficulties, staff shortages, and limited healthcare resources (Laver et al., 2020). The chronic phase of stroke (>3 months post-onset) differs from acute phases; recovery depends more on rehabilitation-driven neuroplasticity and continued exercise rather than spontaneous neurological recovery (Krakauer, 2006). Figure 1 illustrates this timeline.

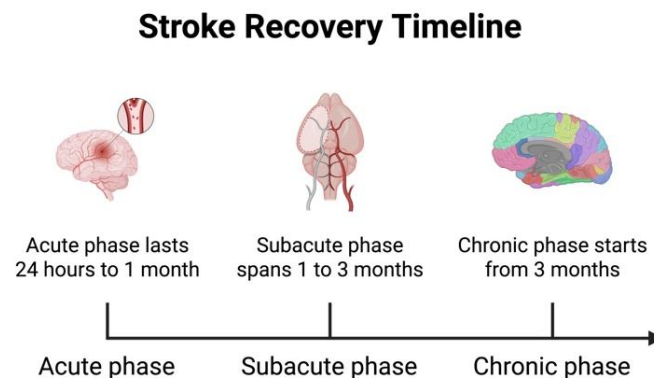


Figure 1: Progression of stroke recovery across the acute, subacute, and chronic phases following stroke onset. Created using BioRender.

2.3 Telerehabilitation After Stroke

Telerehabilitation refers to remote delivery of rehabilitation using modern technologies including video conferencing, mobile health applications, wearable devices, and virtual reality systems (Howard and Kaufman, 2018; Aminov et al., 2018). Exercise-based telerehabilitation allows stroke survivors to complete rehabilitation exercises at home with online supervision (Piron et al., 2004). Evidence suggests telerehabilitation improves functional outcomes, reduces transport burden, and is cost-effective compared with conventional rehabilitation (Lloréns et al., 2015; Laver et al., 2020). These benefits are shown in Figure 2.

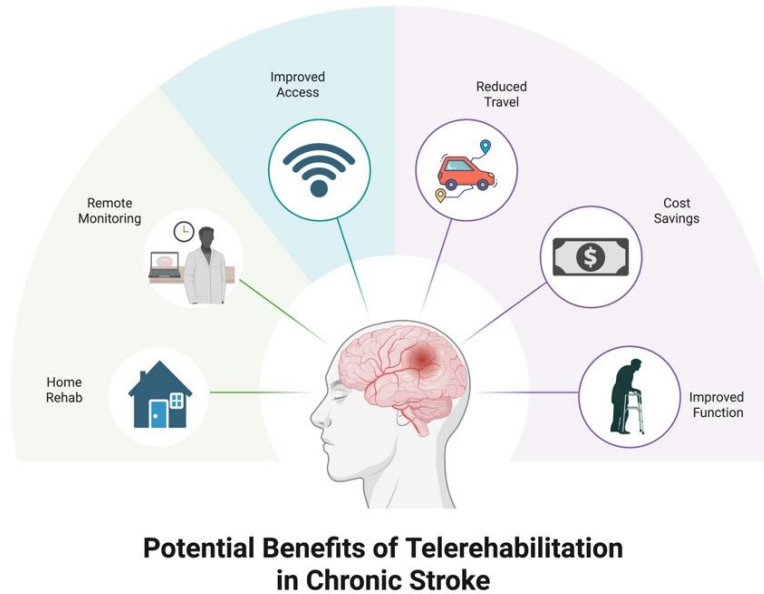


Figure 2: Potential benefits of exercise-based telerehabilitation for chronic stroke patients. Created using BioRender.

2.4 Limitations of Current Evidence

Previous systematic reviews have included mixed stroke populations, acute stroke patients, and non-exercise telehealth interventions (Laver et al., 2020). Critically, no review has systematically compared technological approaches in chronic stroke, despite evidence that technological complexity significantly affects patient engagement. Conventional rehabilitation varies considerably between studies and settings, contributing to heterogeneity. Therefore, the effectiveness of exercise-based telerehabilitation specifically for adults with chronic stroke, and which technology approaches optimise outcomes, remains unclear.

2.5 Aim and Objectives

This systematic review evaluated the effectiveness of exercise-based telerehabilitation in chronic stroke. The primary objectives were to compare telerehabilitation with conventional rehabilitation and to specifically compare different technological approaches (virtual reality versus mobile health). Secondary objectives examined functional outcomes, quality of life, adherence, and cost-effectiveness.

3.0 Methods

3.1 Eligibility Criteria

3.1.1 Study Design

This review included randomised controlled trials, feasibility studies, and SMART trials investigating exercise-based telerehabilitation in individuals with chronic stroke. Studies were eligible if they compared telerehabilitation with conventional rehabilitation, usual care, or another telerehabilitation approach. Protocol papers,

conference abstracts, observational studies, narrative reviews, and case reports were not included. This systematic review protocol was registered with PROSPERO (Registration No. CRD420261395878).

3.1.2 Participants

Eligible studies involved adult participants with a confirmed diagnosis of stroke. For this review, chronic stroke referred to individuals more than three months post-stroke. Studies focusing only on acute or subacute stroke populations were excluded. Research involving mixed neurological conditions, including Parkinson's disease, multiple sclerosis, spinal cord injury, traumatic brain injury, or Alzheimer's disease, was excluded.

3.1.3 Interventions

Interventions included exercise or rehabilitation programmes delivered remotely using technology. These included telehealth systems, video conferencing, virtual reality programmes, mobile applications, online rehabilitation platforms, and wearable devices. These interventions focused on improving functional recovery after stroke.

Studies that only focused on education, lifestyle advice, passive monitoring, or non-rehabilitation telehealth services were excluded from the review.

3.1.4 Comparator Groups

Comparator interventions included standard physiotherapy, outpatient rehabilitation, home exercise programmes, routine follow-up care, usual care, or alternative telerehabilitation methods. Definitions of usual care differed across studies depending on the healthcare setting and the rehabilitation services available.

3.1.5 Outcome Measures

The primary outcome of interest was functional independence after intervention. Commonly reported measures included the Functional Independence Measure (FIM), Barthel Index (BI), and assessments of activities of daily living (ADLs).

Secondary outcomes included:

- quality of life;
- adherence and programme completion;
- mobility and balance outcomes;
- psychological outcomes, including depression;
- participant satisfaction;
- adverse events; and
- outcomes such as cost-effectiveness.

3.2 Search Strategy

Electronic database searches were conducted in MEDLINE and Embase via the Ovid platform. Searches were restricted to English-language publications, and animal studies were excluded.

The search strategy combined terms related to chronic stroke, telerehabilitation, rehabilitation outcomes, and health economics. Boolean operators were used to combine keywords and subject headings.

The following search terms were used:

- (chronic or “long-term” or “long term” or “post-acute” or “post stroke” or “post-stroke”).ti,ab.
- (telerehab* or tele-rehab* or telehealth or tele-health or telemedicine or “remote rehabilitation” or “virtual rehabilitation” or eHealth or mHealth).ti,ab.
- (“functional outcome” or “functional recovery” or “functional independence” or FIM or “Barthel Index” or “activities of daily living” or ADL or “quality of life” or QoL or EQ-5D or cost-effectiveness or cost effectiveness or cost utility or cost-benefit or economic evaluation or health economics or cost analysis or healthcare costs or cost savings or cost minimization or ICER or incremental cost effectiveness ratio or quality-adjusted life year* or QALY or budget impact).ti,ab.

Reference lists from the included studies were also manually reviewed to identify additional relevant publications. Furthermore, included studies represented a range of international rehabilitation settings in different countries. This helped compare various telerehabilitation approaches across different healthcare systems.

3.3 Additional Search Procedures

PROSPERO and other clinical trial registries were searched to identify ongoing or recently registered reviews on telerehabilitation after stroke. Existing registrations focused on both the clinical outcomes and economic impact of telerehabilitation interventions. However, many registered reviews included participants across all phases of stroke recovery. Furthermore, they incorporated mixed neurological populations such as Parkinson’s disease, multiple sclerosis, spinal cord injury, and Alzheimer’s disease. On the other hand, several reviews concentrated mainly on economic evaluation rather than rehabilitation effectiveness in chronic stroke populations.

Where necessary, study authors were contacted to clarify intervention characteristics, eligibility criteria, or missing methodological information.

3.4 Study Selection

Two independent researchers evaluated titles and abstracts according to the predefined eligibility criteria. Full-text articles were then assessed to determine final inclusion.

Studies were excluded when they:

- were not randomised controlled trials;
- included only acute or subacute stroke populations;
- investigated non-exercise telehealth interventions;
- involved mixed neurological populations without separate stroke data;
- represented protocol-only publications; or
- failed to report relevant rehabilitation outcomes.

Reasons for exclusion were documented throughout the screening process and presented within the PRISMA flow diagram.

3.5 Data Extraction

Data from eligible studies were collected and organised into a standardised table. Extracted information included:

- author details and year of publication;
- participant characteristics;
- stroke chronicity;
- intervention details;
- comparator interventions;
- outcome measures;
- adherence findings;
- economic outcomes; and
- follow-up duration.

3.6 Quality Assessment

Risk of bias was evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool for randomised controlled trials. Assessment domains included:

- sequence generation;
- allocation concealment;
- blinding procedures;
- incomplete outcome reporting;
- selective reporting; and
- other possible sources of bias.

3.7 Data Synthesis

A quantitative meta-analysis was not undertaken due to differences among studies in intervention design, comparator groups, and outcome measures. Consequently, findings were synthesised narratively.

The included studies were compared based on intervention characteristics, participant populations, functional outcomes, quality-of-life findings, adherence rates, and economic outcomes. Similarities and differences across studies were explored descriptively.

4.0 Results

4.1 Study Selection

A total of 425 records were identified through database searching, including MEDLINE via Ovid (n = 173) and EMBASE via Ovid (n = 252). One additional study was identified through citation searching. After removing 146 duplicate records, 279 records remained for title and abstract screening. Following screening, 274 records were excluded as they did not meet the predefined eligibility criteria. Common reasons for exclusion included non-stroke populations, non-exercise-based telerehabilitation interventions, acute or subacute stroke populations, protocol papers, review articles, and studies with ineligible designs or outcomes.

Five full-text articles were assessed for eligibility: four from the primary database search and one identified through citation searching. One article was excluded at the full-text stage because it was a protocol study without outcome data. Ultimately, five studies met the inclusion criteria and were included. Figure 3 presents the PRISMA flow diagram showing the study selection process.

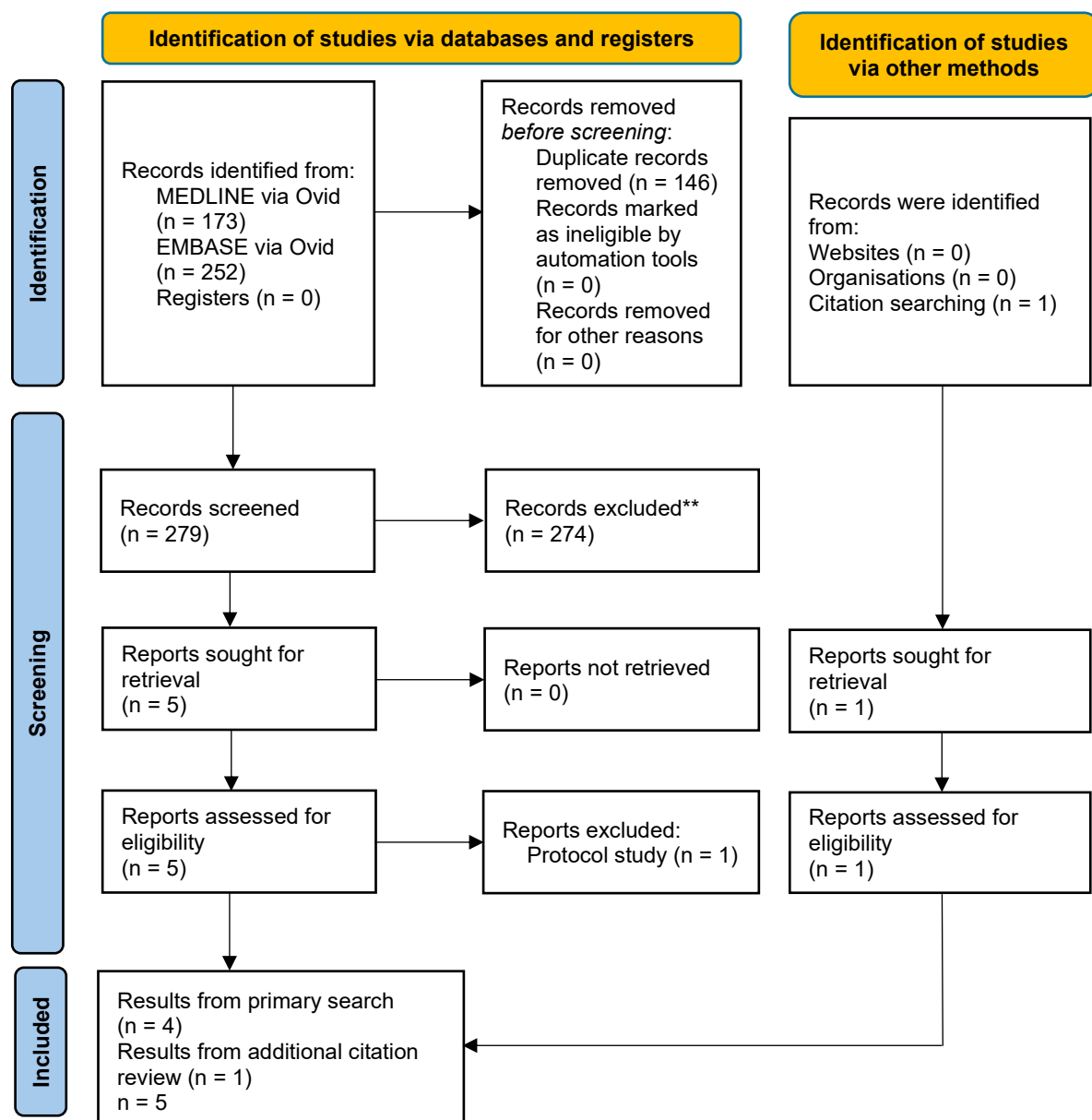


Figure 3: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

4.2 Risk of Bias Assessment

The included studies demonstrated variation in methodological quality and overall risk of bias. Most studies used randomised or controlled study designs; however, several methodological limitations were identified across the included papers (Lin et al., 2014, Lloréns et al., 2015, Grau-Pellicer et al., 2020, Garcia et al., 2022, Whiston et al., 2026).

The main source of bias related to blinding of participants and therapists. Due to the nature of exercise-based rehabilitation interventions, both participants and therapists were aware of the treatment being delivered. This increased the risk of performance bias across most studies (Lin et al., 2014, Grau-Pellicer et al., 2020, Garcia et al., 2022). In comparison, several studies reported blinded outcome assessors, which reduced the likelihood of detection bias (Lloréns et al., 2015, Whiston et al., 2026).

Attrition bias was generally low, as most studies reported outcome data for most participants and clearly described dropouts. However, some studies included relatively small sample sizes and pilot or feasibility designs. Therefore, this may limit the generalisability of the findings and increase the risk of bias due to incomplete data (Garcia et al., 2022, Whiston et al., 2026).

Selective reporting was low in most studies, as outcomes and intervention procedures were adequately described. Overall, the included studies demonstrated low to moderate risk of bias, although limitations related to blinding, small sample sizes, and feasibility-based study designs should be considered when interpreting the findings.

Table 1: Characteristics, study design, and risk of bias assessment of the included studies.

Study (Author, Year)	Study Design	Tool Used	Risk of Bias
Lin et al., 2014	Pilot RCT	Cochrane RoB 2	Some concerns
Garcia et al., 2022	Pilot randomized cross-over feasibility study	Cochrane RoB 2	Some concerns
Lloréns et al., 2015	Single-blind RCT	Cochrane RoB 2	Some concerns
Grau-Pellicer et al., 2020	Pilot RCT	Cochrane RoB 2	Some concerns
Whiston et al., 2025	Feasibility Sequential Multiple Assignment	Cochrane RoB 2	Some concerns

4.3 Study Characteristics

Five studies involving a total of 156 participants were included in this review. Sample sizes ranged from 10 to 50 participants, with most studies recruiting chronic stroke patients living in community or long-term care settings (Lin et al., 2014; Lloréns et al., 2015; Grau-Pellicer et al., 2020; Whiston et al., 2025). Participant ages across the included studies ranged from approximately 50 to 80 years.

Three categories of interventions were identified. First, virtual reality and technology-assisted programmes used videoconferencing, motion sensors, and remote supervision to improve balance and mobility through home-based exercises (Lin et al., 2014; Lloréns et al., 2015; Garcia et al., 2022). Second, mHealth-supported exercise and physical activity programmes were included. mHealth (mobile health) refers to the delivery of healthcare using mobile technologies such as smartphones, wearable devices, and digital apps. These programmes were designed to improve adherence to home exercise and increase daily activity levels after stroke (Grau-Pellicer et al., 2020; Whiston et al., 2025). Third, hybrid models combined conventional therapy with remote exercise sessions or telemonitoring (Lin et al., 2014; Grau-Pellicer et al., 2020).

Interventions lasted 4–12 weeks with sessions several times per week. Outcome measures focused on balance, gait, physical activity, functional independence, and satisfaction, using the Berg Balance Scale, Barthel Index, Timed Up and Go test, and walking performance measures (Lin et al., 2014; Lloréns et al., 2015; Grau-Pellicer et al., 2020).

4.4 Outcome Measures Used

Table 2: Outcome measurement domains and specific instruments reported in the included studies.

Outcome Domain	Measure	Studies (n)
Balance	Berg Balance Scale	5
	POMA-Balance	2
	Brunel Balance Assessment	2
Gait	POMA-Gait	2
	Walking speed (10MWT, 6MWT)	3
Functional Independence	Barthel Index	3
	Functional Independence Measure	1
Physical Activity	Accelerometer/Fitbit	2
Quality of Life	EQ-5D-5L	2
	Stroke-Specific QoL Scale	1

4.5 Summary of Included Studies

Table 3: Summary of the characteristics, outcomes, key findings and limitations of the included studies shown on pages 15-17.

Study Title (Year)	Patient Group	Study Type (Level of Evidence)	Outcomes (Primary/ Secondary)	Key Results	Study Weaknesses
Lin et al. (2014) – Bidirectional and Multi-User Telerehabilitation System: Clinical Effect on Balance, Functional Activity and Satisfaction in Patients with Chronic Stroke Living in Long-Term Care Facilities	Chronic stroke patients in long-term care facilities (n = 24)	Pilot Randomised Controlled Trial (Level 2)	Primary: Balance (Berg Balance Scale). Secondary: Functional independence (Barthel Index), self-care, mobility, satisfaction.	Both groups showed significant improvements in balance (BBS, $p < 0.001$), functional independence (BI, $p = 0.008$) and self-care ($p = 0.014$). There were no significant differences between telerehabilitation and conventional therapy, suggesting comparable effectiveness.	Small sample size. Short intervention duration (4 weeks). Pilot design.
Lloréns et al. (2015) – Effectiveness, Usability and Cost-Benefit of a Virtual Reality-Based Telerehabilitation Programme for Balance Recovery After Stroke	Chronic stroke survivors with balance impairments (n = 30)	Single-Blind Randomised Controlled Trial (Level 2)	Primary: Balance (Berg Balance Scale). Secondary: Balance and gait performance (POMA-B, POMA-G, BBA), usability, motivation and cost-effectiveness.	Significant improvements were observed in BBS ($p = .001$), POMA-B ($p = .006$), POMA-G ($p = .001$) and BBA ($p = .002$) in both groups. Home-based telerehabilitation achieved similar outcomes to clinic-based rehabilitation while reducing treatment costs by approximately 44%.	Small sample size. Limited follow-up. Participants required VR equipment and internet access.
Grau-Pellicer et al. (2020) – Impact of mHealth Technology on Adherence to Healthy Physical Activity in Stroke Patients	Community-dwelling chronic stroke survivors (n = 41)	Pilot Randomised Controlled Trial (Level 2)	Primary: Physical activity adherence and sedentary behaviour. Secondary: Walking speed, walking endurance, functional	Community ambulation increased by 105%, sitting time decreased by 30%, comfortable walking speed improved by 0.21 m/s and walking endurance increased	Small sample size. Single-centre study. Lack of participant blinding. Technical issues limited app

			mobility, activities of daily living, quality of life and satisfaction.	by 47.6 m in the intervention group. The improvement in walking speed exceeded the reported MCID for chronic stroke and participants achieved independence in ADLs.	use in some participants.
Garcia et al. (2022) – A Feasibility Study to Assess the Effectiveness of Muvity in Chronic Post-Stroke Rehabilitation	Chronic post-stroke participants (n = 10)	Randomised Cross-Over Feasibility Study (Level 2)	Primary: Functional independence (FIM). Secondary: Pain (VAS), balance (BBS), range of movement, usability and satisfaction.	Four of six participants (66.7%) achieved equal or higher FIM scores following telerehabilitation. Five of six participants (83.3%) reported reduced pain levels, with pain demonstrating the largest treatment effect (Hedges' g = 0.65). Balance generally improved following treatment, although differences between interventions were not statistically significant. User satisfaction was high (4.1/5).	Very small sample size. Feasibility study. Limited statistical power. Most outcomes were not statistically significant.
Whiston et al. (2025) – The Adaptive Physical Activity Study in Stroke (TAPAS)	Community-dwelling stroke survivors (n = 50)	Feasibility Sequential Multiple Assignment Randomized Trial (SMART) (Level 2)	Primary: Feasibility, recruitment, retention and adherence. Secondary: Physical activity, fatigue, quality of life, psychological wellbeing, sedentary behaviour and reintegration into normal living.	Overall adherence was 82.16%. Retention rates were 88% for objective physical activity measures and 86% for questionnaires. Fitbit adherence was 90.69%, while app adherence was 56.29%. Positive trends were observed for daily step count, fatigue, stroke-specific quality of life, general quality of life	Feasibility study not powered to evaluate clinical effectiveness. Small sample size. Short follow-up period. No statistically significant efficacy outcomes reported.

and reintegration into normal living. No significant differences were found between intervention pathways.

4.6 Feasibility and Adherence

Feasibility and adherence outcomes were reported across all five included studies. Whiston et al. (2025) reported strong feasibility indicators, with recruitment reaching 84.8% of eligible participants and retention rates of 86–88% throughout the study period. Overall intervention adherence was 82.2%, with notably higher adherence to the Fitbit wearable (90.7%) than to the mobile application (56.3%). Garcia et al. (2022) reported user satisfaction scores of 4.1 out of 5, indicating positive acceptability of the telerehabilitation system.

Engagement with technology varied across studies. Grau-Pellicer et al. (2020) found that only 50% of participants could successfully use the mobile application, citing technical complexity and internet connectivity issues as primary barriers. Lloréns et al. (2015) and Lin et al. (2014) did not report significant technical barriers but noted that participants required access to reliable internet and appropriate home equipment to engage successfully. Satisfaction ratings were generally high across studies reporting this outcome, ranging from 3.9 to 4.1 out of 5.

Overall, the included studies suggest that exercise-based telerehabilitation is a feasible and acceptable intervention for people with chronic stroke. However, implementation barriers related to technology complexity and internet access may limit participation in some populations. Simpler devices, such as wearables, demonstrated higher engagement rates than complex mobile applications.

Table 4: Feasibility and adherence outcomes across the included studies, including recruitment rates, retention rates, overall adherence, key barriers, and satisfaction scores.

Study	Recruitment Rate (%)	Retention Rate (%)	Overall Adherence (%)	Main Barriers	Satisfaction Score
Lin et al. (2014)	Not reported	92%	Not reported	None reported	High (positive feedback)
Lloréns et al. (2015)	81%	100%	82%	Internet access, VR equipment required	85–87.5/100 (SUS score)
Grau-Pellicer et al. (2020)	44%	83%	50% app use	Technical issues, app complexity, internet reliability	Not formally rated
Garcia et al. (2022)	63%	60%	Varied	Small sample, crossover design	4.1/5

Whiston et al. (2025)	84.8%	86–88%	82.2%	Lower app use (Fitbit 90.7% vs app 56.3%)	Not formally rated
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4.7 Economic Findings

Economic outcomes from only one study are presented in Table 5. Lloréns et al. (2015) conducted a detailed cost-effectiveness analysis comparing home-based and clinic-based virtual reality rehabilitation. The home-based programme cost \$835.61 per participant compared with \$1,490.23 for clinic-based rehabilitation, representing a cost difference of \$654.72. Transportation expenses accounted for 87.77% of the total cost difference, indicating that savings were primarily driven by reduced travel requirements rather than differences in intervention delivery costs (Lloréns et al., 2015).

Given that economic data were available from only one small RCT (n=30), the evidence base for cost-effectiveness conclusions is limited. However, Lloréns et al. (2015) demonstrate that home-based telerehabilitation may offer cost savings compared with clinic-based delivery, particularly when transportation costs are substantial.

Table 5: Economic outcomes across the included studies.

Study	Intervention (home virtual reality) Cost per Participant	Comparator (clinic virtual reality) Cost per Participant	Cost Difference (\$)	Percentage Savings (%)
Lloréns et al. (2015)	\$835.61	\$1,490.23	\$654.72	43.9%
Lin et al. (2014)	Not reported	Not reported	—	—
Grau-Pellicer et al. (2020)	Not reported	Not reported	—	—
Garcia et al. (2022)	Not reported	Not reported	—	—
Whiston et al. (2025)	Not reported	Not reported	—	—

4.8 Analysis of Clinical Outcomes

4.8.1 Balance and gait

Balance and gait outcomes were assessed using measures including the Berg Balance Scale, Brunel Balance Assessment, Performance-Oriented Mobility Assessment, walking speed, and walking endurance (Lin et al., 2014, Lloréns et al., 2015, Grau-Pellicer et al., 2020). Lin et al. (2014) reported significant improvements in balance following both telerehabilitation and conventional rehabilitation, with no significant differences observed between groups. Similarly, Lloréns et al. (2015) found improvements in balance performance in both intervention groups following treatment.

Grau-Pellicer et al. (2020) reported greater improvements in gait performance in the intervention group compared with the control group. Comfortable walking speed increased by 0.21 m/s in the intervention group compared with 0.04 m/s in the control group, while fast walking speed increased by 0.27 m/s and 0.03 m/s, respectively. Walking endurance also improved more in the intervention group, with participants increasing their six-minute walk distance by 47.62 metres, compared with 19.79 metres in the control group.

4.8.2 Activities of daily living and functional independence

Activities of daily living and functional independence were evaluated using the Barthel Index and Functional Independence Measure (Lin et al., 2014, Garcia et al., 2022, Grau-Pellicer et al., 2020). Lin et al. (2014) reported significant improvements in Barthel Index scores in both intervention groups, indicating enhanced independence in daily activities. Grau-Pellicer et al. (2020) found that participants receiving the intervention achieved independence in activities of daily living, whereas participants in the control group remained mildly dependent.

Garcia et al. (2022) assessed functional independence using the Functional Independence Measure. They found that 4 of 6 participants (66.7%) achieved equal or higher post-treatment scores following the telerehabilitation intervention than with conventional therapy. In addition, five of six participants (83.3%) reported reductions in pain intensity following use of the telerehabilitation system.

4.8.3 Quality of life

Quality-of-life outcomes were reported in two studies (Grau-Pellicer et al., 2020, Whiston et al., 2026). Grau-Pellicer et al. (2020) assessed health-related quality of life using the EQ-5D-5L and reported improvements in the intervention group, while no meaningful changes were observed in the control group. Whiston et al. (2025) evaluated quality of life using the Stroke-Specific Quality of Life Scale and EQ-5D-5L and reported positive trends following participation in the intervention programme. Improvements in reintegration into normal living were also observed; however, as this was a feasibility study, the findings should be interpreted as preliminary.

4.8.4 Physical activity

Physical activity outcomes were assessed in the studies by Grau-Pellicer et al. (2020) and Whiston et al. (2025). Grau-Pellicer et al. (2020) reported increased physical activity levels following participation in the mHealth-supported intervention programme. Similarly, Whiston et al. (2025) observed favourable trends in daily step count and physical activity participation, particularly among participants who transitioned from structured exercise to lifestyle physical activity interventions. Overall, the included studies suggest that exercise-based telerehabilitation may improve balance, mobility, physical activity, functional independence, and quality of life in individuals with chronic stroke. However, the small number of included studies and variation in intervention approaches should be considered when interpreting these findings.

4.9 Safety and Adverse Events

All five included studies assessed safety outcomes. No serious adverse events were reported across any study. Overall, exercise-based telerehabilitation appears safe for use in individuals with chronic stroke.

4.10 Comparative Effectiveness of Intervention Types

The included studies employed three distinct intervention approaches: virtual reality-based telerehabilitation (Lin et al., 2014, Lloréns et al., 2015, Garcia et al., 2022), mobile health technology with structured exercise (Grau-Pellicer et al., 2020, Whiston et al., 2026), and hybrid models incorporating both approaches.

Virtual reality-based interventions (n=64 participants) demonstrated significant improvements in balance outcomes (BBS, POMA) in both intervention and control groups, with no between-group differences. This suggests that VR systems were equivalent to conventional therapy rather than superior to it. Mobile health interventions (n=91 participants) demonstrated greater between-group differences, with the intervention group showing significantly greater improvements in physical activity, walking speed, walking endurance, and functional independence compared with controls. The mHealth approach may be more effective than VR for improving community-based physical activity and mobility outcomes.

Differences in effectiveness may relate to intervention intensity, delivery setting (home vs clinic), and the focus on functional, real-world activities in mHealth approaches versus task-specific balance training in VR systems.

4.11 Feasibility and Implementation Considerations

Exercise-based telerehabilitation demonstrated acceptable feasibility across five studies with varying levels of evidence. The strongest feasibility evidence came from Whiston et al. (2025), a larger trial (n=50) reporting recruitment of 84.8% and adherence of 82.2%. Engagement varied by technology type: wearable devices (Fitbit) achieved 90.7% adherence, while mobile applications achieved only 56.3% adherence in the same study, suggesting that simpler, less complex technologies may be more acceptable to older adults with stroke.

A critical barrier emerged in Grau-Pellicer et al. (2020), where only 50% of participants successfully engaged with the mobile application due to technical complexity. This contrasts with high satisfaction ratings (4.1–4.5/5) in studies using simpler interfaces or wearables. These findings suggest that technology selection and user support are essential factors in implementation. Internet connectivity and access to home equipment were prerequisites in all studies, potentially limiting applicability in resource-limited settings.

4.12 Economic Implications

Only Lloréns et al. (2015) reported comprehensive economic data. Home-based telerehabilitation cost \$836 per participant, compared with \$1,490 for clinic-based delivery, with transportation costs accounting for 87.77% of the savings. This suggests that cost-effectiveness depends heavily on context. In settings with high participant transportation burden (rural areas, elderly populations), telerehabilitation offers meaningful savings. However, in urban settings with accessible rehabilitation facilities or for younger stroke survivors, the economic advantage may be less pronounced. No other studies reported economic outcomes, limiting evidence on cost-effectiveness across different healthcare systems.

4.13 Limitations to the Evidence Base

Several factors limit the strength of conclusions. All five studies were underpowered pilot or feasibility trials with small sample sizes (range $n=10-50$; total $N=156$). Three studies used pilot RCT designs not powered to detect clinical efficacy. Only two studies included follow-up assessments beyond 3 months, limiting knowledge of long-term effectiveness. Intervention heterogeneity (VR vs mHealth vs hybrid, 4–12 week duration) precluded meta-analysis and made direct comparison difficult. Blinding of participants and therapists was not possible due to the nature of the intervention, increasing risk of performance and detection bias across all studies. These limitations mean that while preliminary evidence suggests telerehabilitation may be effective, higher-quality evidence from larger, longer-duration RCTs is needed before firm conclusions can be drawn.

5.0 Discussion

5.1 Main Findings

This systematic review examined five randomised controlled trials and feasibility studies investigating exercise-based telerehabilitation in adults with chronic stroke. The principal finding was that telerehabilitation yielded outcomes comparable to those of conventional in-person rehabilitation across multiple domains. Participants receiving telerehabilitation demonstrated significant improvements in balance, gait, and functional independence, with no consistent superiority over standard care (Lin et al., 2014, Lloréns et al., 2015). However, certain outcome measures showed promising results. Walking speed improvements in the intervention group exceeded the minimal clinically important difference for chronic stroke populations (Grau-Pellicer et al., 2020). Mobile health approaches appeared more effective than virtual reality systems at improving real-world physical activity and community ambulation.

The evidence suggests that telerehabilitation is a viable alternative to conventional therapy rather than necessarily being superior.

5.2 Comparison with Previous Literature

Recent systematic reviews have reached similar conclusions about exercise-based telerehabilitation in stroke populations (Alwadai et al., 2024). However, previous reviews included mixed stroke populations and non-randomised designs, limiting their applicability to chronic stroke (Carbajal Galarza et al., 2025). A previous Cochrane review reported that telerehabilitation outcomes were generally comparable to face-to-face rehabilitation, although the evidence was limited by heterogeneity, small sample sizes, and risk of bias (Laver et al., 2020). Recent high-quality systematic reviews found that exercise-based telerehabilitation significantly improved balance and activities of daily living in post-stroke survivors, supporting its use as an effective strategy for functional recovery (Carbajal Galarza et al., 2025). The current review adds to this evidence by focusing exclusively on chronic stroke populations and newer telerehabilitation technologies.

5.3 Clinical Implications

These findings have important implications for stroke rehabilitation practice. Telerehabilitation offers a practical alternative for patients who cannot access facility-based rehabilitation due to geographical distance, mobility limitations, or limited availability of specialist services (Contrada et al., 2021). Home-based virtual reality rehabilitation allows patients to complete exercises in their own environment, potentially improving accessibility and engagement (Prajwal et al., 2024). The evidence suggests that simpler, user-friendly technologies such as wearable devices achieve higher engagement than complex mobile applications. This finding should guide implementation decisions in clinical practice. For example, programmes using pedometers or activity trackers may be more acceptable to older adults than smartphone-based interventions. Remote therapist supervision and structured support appear essential for successful engagement (Somville et al., 2026). Telerehabilitation may be particularly valuable in underserved or resource-limited regions where access to specialist rehabilitation is inconsistent or unavailable. However, telerehabilitation cannot replace in-person assessment and treatment for all patients. Initial comprehensive evaluation by a therapist remains important before transitioning to remote delivery.

5.4 Strengths

This systematic review followed rigorous PRISMA guidelines and pre-registered the protocol on PROSPERO. The search strategy was comprehensive, covering two major databases and including citation searching. Two independent reviewers screened records, reducing the risk of selection bias. Data extraction was performed systematically from all included studies. The review focused specifically on chronic stroke populations and exercise-based interventions, providing a more targeted evidence base than reviews that include mixed populations. By including only randomised controlled trials and feasibility studies, the review prioritised higher-quality evidence. The inclusion of more recent studies (up to 2025) provides up-to-date information on emerging telerehabilitation technologies and approaches.

5.5 Limitations

Several limitations affect the strength of conclusions. All five included studies were pilot or feasibility trials with small sample sizes (total N=156; range 10–50). Only two studies included follow-up assessments beyond three months, limiting knowledge of long-term effectiveness. Heterogeneity across studies was substantial. Interventions differed in type (virtual reality, mobile health, hybrid), duration (4–12 weeks), frequency, and comparator conditions. Outcome measures varied considerably, preventing meta-analysis. Blinding of participants and therapists was not possible due to the nature of the intervention, increasing performance and detection bias. The mobile health intervention study used a convenience sample rather than consecutive recruitment, potentially introducing selection bias. Most studies did not report long-term adherence or sustained behaviour change. Economic data were limited, with only one small study reporting costs.

5.6 Future Research

Several important research gaps remain. Large, adequately powered randomised controlled trials are needed to establish whether telerehabilitation is equivalent or superior to conventional rehabilitation in chronic stroke populations. Studies should include longer follow-up periods, with a minimum of 6–12 months, to determine long-term effectiveness and sustainability. Researchers should standardise intervention protocols and outcome measures to enable future meta-analysis. Long-term adherence and retention rates require investigation in larger samples. Research should examine which patient characteristics predict better outcomes with telerehabilitation versus in-person treatment. Future studies should provide comprehensive economic analyses, including implementation costs, therapist time, and indirect costs such as caregiver involvement. The optimal combination of technology, for example, wearables vs apps vs videoconferencing, and intensity of remote therapist support requires evaluation. Research is needed to integrate telerehabilitation into existing healthcare systems and to identify barriers to implementation across different settings. Finally, the investigation of telerehabilitation in resource-limited and rural settings is essential, given its potential to improve access for underserved populations.

6.0 Conclusion

This systematic review found that exercise-based telerehabilitation yields functional improvements comparable to those of conventional in-person rehabilitation in adults with chronic stroke, with the strongest evidence for improvements in walking speed and functional independence. Telerehabilitation is feasible and acceptable, though technology complexity and internet access may limit uptake in some populations. Simpler technologies achieve significantly better engagement than complex applications. Small sample sizes, short follow-up periods, and heterogeneous interventions limit the evidence base. Telerehabilitation represents a practical alternative delivery model, particularly in settings with limited access to specialist services. Larger, longer-duration trials are needed before definitive clinical recommendations can be made. Future research should focus on identifying which patients benefit most from telerehabilitation and optimising technology selection to maximise engagement and outcomes.

7.0 Declarations

7.1 Ethics approval and consent to participate

Not applicable. This is a systematic review of published studies. No primary human research data were collected, and no ethical approval was required.

7.2 Consent for publication

Not applicable. This manuscript does not contain data from individual participants.

7.3 Availability of data and materials

All data used in this systematic review are from publicly available, peer-reviewed published studies listed in the references section. The original data from the five included studies (Lin et al. 2014; Lloréns et al. 2015; Garcia et al. 2022; Grau-Pellicer et al. 2020; Whiston et al. 2025) are publicly available in their respective journals and are cited with their DOIs in the reference list.

The data extraction tables, study characteristics, quality assessments using the Cochrane Risk of Bias 2 tool, and results synthesis are provided in the manuscript. All data are publicly accessible through the DOI links provided in the references.

7.4 Competing interests

The authors declare that they have no competing interests as defined by BMC, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

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7.6 Authors' contributions

ZM conceived the study, conducted the literature search of MEDLINE and Embase, extracted data from included studies, assessed study quality using the Cochrane Risk of Bias 2 tool, conducted the narrative synthesis of results, interpreted findings, and wrote the main manuscript. ZM and SJ independently evaluated titles and abstracts according to the predefined eligibility criteria and assessed full-text articles to determine final inclusion. SJ provided supervisory guidance, provided critical feedback on the narrative synthesis, and revised the manuscript for intellectual content. Both authors reviewed and approved the final manuscript and agree to be accountable for all aspects of the work.

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