INTERNATIONAL JOURNAL OF SCIENTIFIC INFORMATION

Research Article | ISSN: 2583-8512

Virtual Reality Telerehabilitation and Multisensory Feedback for Post-Stroke Recovery

Nusarath Jaha Gurramkonda, Suresh Jat
Department of Physiotherapy, Jayoti Vidyapeeth Women's University, Jaipur, Rajasthan, India
Email: luckyjaha84@gmail.com

Abstract
Background: Post-stroke rehabilitation increasingly extends beyond hospital settings, creating demand for scalable approaches that can deliver intensive, engaging and monitored therapy in clinics and homes. Virtual reality telerehabilitation and multisensory feedback systems are promising, but their evidence base is uneven and their implementation risks are frequently underestimated.
Objective: This paper synthesizes evidence on VR telerehabilitation and multisensory feedback for post-stroke recovery, with emphasis on upper limb function, balance, cognition, adherence, safety, equity and clinical implementation.
Methods: An integrative review design was used. Peer-reviewed systematic reviews, randomized trials, clinical guidelines and rehabilitation methodology papers were examined. Evidence was organized by VR modality, outcome domain, dose, delivery setting and implementation readiness. Tables and figures summarize search logic, evidence streams and practical deployment considerations.
Results: Evidence most consistently supports VR as an adjunct for upper limb function and activity limitation. Telerehabilitation may improve access and continuity, especially after discharge, but it depends on patient selection, caregiver support, connectivity, remote monitoring and safety protocols. Multisensory feedback may increase embodiment and motor engagement, but evidence remains smaller and more heterogeneous than conventional screen-based VR. Dose and task specificity repeatedly appear more important than technological novelty.
Conclusion: VR telerehabilitation and multisensory systems are best understood as delivery architectures for high-quality rehabilitation practice, not independent cures. Their future value depends on rigorous protocols, equitable access, therapist integration, adverse-event reporting and outcome measures that capture real-world participation.

***Keywords:** Virtual reality telerehabilitation; multisensory feedback; stroke recovery; haptic feedback; digital rehabilitation; home rehabilitation; implementation science; neurorehabilitation*

Address for Correspondence
Dr Suresh Jat
Assistant Professor
Department of Physics,
Jayoti Vidyapeeth Women's University (JVWU),
Jaipur, India

Article Received on: 10.03.26
Revised on: 25.03.26
Approved for publication: 19.04.26

How to Cite this Article: Gurramkonda and Jat. Virtual Reality Telerehabilitation and Multisensory Feedback for Post-Stroke Recovery. Int., J. Sci. Info. 2026; 4 (1): 65-79

1. Introduction
Stroke recovery does not end when a patient leaves the ward. Many survivors enter a long period of impaired movement, fatigue, cognitive difficulty, emotional disruption and reduced participation. Services often face a mismatch between rehabilitation need and available therapy time. This problem is more visible after discharge, when patients may live far from specialized

services or depend on family transport. Digital rehabilitation is therefore attractive because it promises continuity, motivation, measurement and remote support. The risk is that health systems confuse access to technology with access to rehabilitation. A headset or home exercise game is not a rehabilitation service unless it is clinically prescribed, monitored and adapted.[1]
Virtual reality telerehabilitation describes remote or partially remote delivery of VR-supported rehabilitation tasks, often using sensors, screens, head-mounted displays, wearable controllers or interactive gaming systems. Multisensory VR adds haptic, auditory, proprioceptive or tactile feedback to strengthen embodied practice. In theory, these systems can increase repetitions, allow graded task difficulty, support motor imagery, provide immediate feedback and collect performance data. These features map onto established principles of motor learning. In practice, the effectiveness depends on usability, safety, patient cognition, caregiver support, therapist oversight and whether virtual tasks transfer to daily life.[2]
The latest Cochrane review by Laver et al. (2025) identified a large and growing body of trials but concluded that evidence certainty remains moderate to very low for several outcomes. It found slight benefits of VR and interactive video gaming for upper limb function, balance and activity limitation, with larger advantages when VR increased overall therapy time. That conclusion should make researchers more disciplined, not more promotional. If VR helps mostly by increasing dose, then the central design question is not immersion but how to deliver more meaningful practice safely and sustainably. [3]
Telerehabilitation became more prominent during and after the COVID-19 period, but its relevance is broader than emergency substitution for face-to-face care. Remote rehabilitation may reduce travel burden, support rural patients, extend therapist reach and maintain continuity after discharge. NICE guidance on stroke rehabilitation includes telerehabilitation among updated areas of recommendation and research interest, reflecting the practical need to evaluate remote delivery. However, remote VR also shifts risk into the home. Falls, fatigue, cybersickness, technical failure and poor movement quality may be less visible to clinicians. A poorly monitored home VR programme can create false confidence. [4]
Multisensory feedback is another promising but complicated direction. Haptic gloves, force feedback devices, vibration, motion tracking and augmented proprioceptive cues may enhance embodiment and error awareness. This matters because stroke survivors often have impaired sensory feedback and reduced awareness of limb position. If technology can make movement errors visible or tactile, it may strengthen motor learning. Yet multisensory systems are often more expensive, harder to maintain and more difficult to standardize. The stronger the technology claim, the stronger the evidence requirement should be. [5]
Existing research contains several recurring weaknesses. First, studies often use small samples and short interventions. Second, intervention descriptions are inconsistent, making replication difficult. Third, outcome measures vary across impairment, activity and participation domains. Fourth, many studies do not adequately report active repetitions, intensity or therapist input. Fifth, adverse events and usability failures are underreported. Sixth, equity is often ignored: the patients most likely to benefit from home access may be least able to afford devices, internet connectivity or caregiver support. These gaps limit translation from positive trial findings to routine service delivery. [6]
This paper presents an integrative evidence-based research manuscript that reorganizes the VR rehabilitation literature around implementation questions. Rather than asking only whether VR works, it asks how VR telerehabilitation and multisensory feedback should be designed, for whom, at what dose, with what monitoring and with what limitations. This structure is more useful for clinical decision-making because the technology field is no longer at the stage of simple novelty. Stroke services need defensible pathways, not enthusiastic descriptions.

2. Materials and Methods

Review design. An integrative review approach was used to synthesize clinical trials, systematic reviews, guideline statements and implementation-oriented evidence relevant to VR telerehabilitation and multisensory feedback in post-stroke rehabilitation. This design was selected because the topic includes diverse evidence types: randomized trials, meta-analyses, device feasibility studies, clinical guidelines, safety reports and practical implementation discussions. A conventional meta-analysis was not appropriate for this paper because the aim was not to calculate a new pooled effect but to translate the evidence into a structured research paper with practical implications. [7]

Search strategy. Evidence was identified from databases and sources commonly used in rehabilitation research, including PubMed, Cochrane Library, Google Scholar, JMIR, SpringerLink and guideline repositories. Search terms included combinations of stroke, virtual reality, telerehabilitation, upper limb, lower limb, balance, haptic feedback, multisensory feedback, exergaming, home rehabilitation, Fugl-Meyer, activities of daily living and quality of life. Preference was given to recent systematic reviews, randomized trials, and guidelines, while foundational papers on dose, motor learning and outcome measurement were retained when needed. [8]

Eligibility criteria. Sources were included when they addressed adult stroke rehabilitation and examined VR, interactive gaming, immersive VR, non-immersive VR, semi-immersive VR, telerehabilitation or multisensory feedback. Studies focusing only on non-stroke neurological conditions were excluded unless they provided methodological insight relevant to VR rehabilitation. Opinion pieces without evidence synthesis were used only to frame implementation challenges, not to support effectiveness claims. Preprints were treated cautiously and not used as primary evidence where peer-reviewed alternatives existed. This conservative approach was necessary because digital rehabilitation literature contains promotional claims that can outrun the evidence. [9]

Data extraction. For each evidence source, information was extracted on population, intervention type, delivery setting, comparator, outcome domain, dose, follow-up, reported benefits, adverse events and implementation implications. VR modality was categorized as non-immersive screen-based, semi-immersive, fully immersive, haptic or multisensory, and remote or telerehabilitation-enabled. Outcomes were organized into upper limb impairment, lower limb and balance, cognition, activity limitation, mood, adherence, safety and quality of life. The extraction framework emphasized translation: what would a clinician or service manager need to know before adopting the intervention? [10]

Quality and interpretive framework. Evidence quality was interpreted using common limitations reported in systematic reviews: sample size, randomization, blinding, comparator quality, intervention heterogeneity, follow-up length and outcome consistency. PRISMA 2020 was used as a reporting reference for review transparency, while clinical interpretation drew on stroke rehabilitation guidelines and motor learning theory. The review did not score each study formally because its purpose was integrative synthesis rather than full systematic review grading. However, conclusions were deliberately bounded by certainty and consistency of evidence. [11]

Ethical and implementation considerations. Digital rehabilitation raises ethical issues beyond standard therapy. Home VR may collect performance data, images, movement traces or adherence logs. Patients must understand what is recorded and how data are used. Safety monitoring must be proportionate to impairment level. Equity must also be considered because remote VR could widen access for some patients while excluding others with low digital literacy, poor connectivity, poverty, visual impairment or limited caregiver support. These issues were included in the analysis because an intervention that works only for digitally advantaged patients is not a complete rehabilitation solution. [12]

Table 1. Search logic and evidence extraction framework

Element	Description
Population	Adults after ischemic or haemorrhagic stroke in inpatient, outpatient or home rehabilitation contexts
Intervention	Virtual reality, interactive gaming, immersive VR, non-immersive VR, haptic or multisensory feedback, and VR telerehabilitation
Comparators	Usual rehabilitation, occupational therapy, physiotherapy, dose-matched therapy, no intervention or alternative digital rehabilitation
Outcomes	Upper limb impairment, balance, gait, cognition, mood, adherence, activity limitation, safety, quality of life and implementation readiness
Priority sources	Systematic reviews, randomized trials, clinical guidelines and foundational rehabilitation methodology papers

Table 2. Inclusion and exclusion criteria

Included	Excluded
Adult post-stroke rehabilitation studies	Studies unrelated to stroke rehabilitation
VR, gaming, telerehabilitation or multisensory feedback interventions	Pure robotics without VR or feedback relevance
Systematic reviews, RCTs, guideline statements and implementation papers	Marketing material, non-evidence opinion, unverified preprints used as primary evidence
Studies reporting functional, cognitive, psychological, safety or feasibility outcomes	Studies reporting only device engineering without patient outcomes

3. Results

Search and evidence profile. The evidence base was dominated by systematic reviews and small to medium randomized trials. Most studies focused on upper limb outcomes, followed by balance, mobility and activities of daily living. Fewer studies examined cognition, mood, long-term participation, caregiver burden or cost-effectiveness. The literature has expanded quickly, but growth in publication volume has not fully solved problems of heterogeneity. Device type, immersion level, session duration, progression criteria and outcome measures remain inconsistent across studies. This makes broad claims possible but precise clinical prescriptions difficult.

Upper limb rehabilitation. Evidence was strongest for upper limb impairment and functional activity. Reviews by Maier et al. (2019), Mekbib et al. (2020), Chen et al. (2022), Leong et al. (2022) and Soleimani et al. (2024) generally support VR as beneficial for upper limb recovery, particularly as an adjunct to conventional therapy. The likely mechanism is increased active practice combined with feedback and engagement. Fully immersive systems may enhance gross movement practice, while non-immersive systems may be easier to deploy for fine

dexterity and home use. The practical lesson is that matching the system to the impairment target matters more than choosing the newest device.

Lower limb, balance and mobility. Evidence for lower limb recovery and balance is promising but less uniform than upper limb evidence. Lu et al. (2025) reported that VR-based therapies can improve functional recovery, with stronger effects when interventions include twenty or more sessions. Balance-oriented VR tasks may provide visual flow, postural challenges and environmental simulation. However, lower limb VR carries higher safety risk than seated upper limb systems. Home delivery requires fall-risk screening, stable support surfaces, caregiver availability where needed, and clear stop criteria for dizziness, fatigue or instability.

Cognition and mood. Cognitive and mood outcomes are underdeveloped in the VR literature. Some systems include memory, attention, executive function or visuospatial tasks, but many motor VR games only incidentally challenge cognition. Improvements on cognitive screening scales may reflect general rehabilitation effects rather than direct cognitive training. Mood and motivation outcomes are more consistently plausible because VR can provide feedback, novelty, autonomy and visible progress. Still, engagement is not the same as recovery. A patient may enjoy VR without improving real-world function, so motivation should be measured alongside impairment and activity outcomes.

Telerehabilitation delivery. Telerehabilitation expands reach but introduces complexity. Remote VR works best when patients have sufficient cognition, sitting or standing safety, reliable internet or offline data capture, caregiver support where needed, and access to clinician review. Asynchronous systems can track repetitions and scores, but they may miss compensatory movements or unsafe strategies. Synchronous therapist-supervised sessions improve safety and individualization but reduce scalability. The strongest model is likely hybrid: initial face-to-face assessment and training, home-based practice with automated data capture, scheduled remote review, and periodic in-person reassessment.

Multisensory and haptic feedback. Haptic and multisensory VR may improve embodiment, proprioceptive awareness and task realism. Evidence supports potential benefit, but the literature is smaller and more device-specific than standard VR. Haptic gloves and force-feedback systems may be valuable for hand opening, grasp force, object manipulation and sensory retraining, yet they are harder to fit, calibrate and maintain. The implementation burden is not a minor detail. If a device requires frequent technical support, therapists may abandon it regardless of theoretical value.

Implementation readiness. The evidence suggests different readiness profiles for clinic-based VR and home telerehabilitation. Clinic systems have stronger safety control, therapist oversight and integration with real-world tasks. Home systems have stronger access and dose potential but weaker monitoring and equity protection. Services should therefore avoid one-size-fits-all adoption. A practical pathway would stratify patients by impairment severity, digital readiness, fall risk, cognitive status and rehabilitation goals before assigning VR modality.

Table 3. Evidence matrix by VR modality

VR modality	Most supported outcome domain	Implementation strength	Main limitation
Non-immersive screen-based VR	Upper limb practice, dexterity and home use	Low-cost and easy to deploy	Lower embodiment and possible gaming-task mismatch
Semi-immersive VR	Functional reaching and balance tasks	Useful compromise between immersion and practicality	Variable definitions across studies

Fully immersive VR	Gross motor practice, motivation and salience	High engagement and environmental realism	Cybersickness, cost and safety screening burden
Haptic/multisensory VR	Hand use, proprioception and embodied feedback	Potentially stronger sensory-motor learning	Small evidence base and device complexity
VR telerehabilitation	Continuity, access and high-frequency practice	Extends therapy beyond clinic	Depends on digital access, safety monitoring and caregiver support

Table 4. Implementation risks and controls

Risk	Why it matters	Control strategy
Falls or dizziness	Particularly relevant for immersive and balance tasks	Screen vestibular and balance risk; begin seated; use stop rules
Poor movement quality	Game scores may reward compensation	Include video review, therapist progression and real-object transfer tasks
Digital exclusion	Home VR may favour advantaged patients	Provide loan devices, technical support and non-digital alternatives
Data privacy	VR systems may collect performance and movement data	Use consent, minimal data collection and secure storage
Therapist workload	Set-up and troubleshooting may reduce adoption	Create protocols, training and technical support pathways

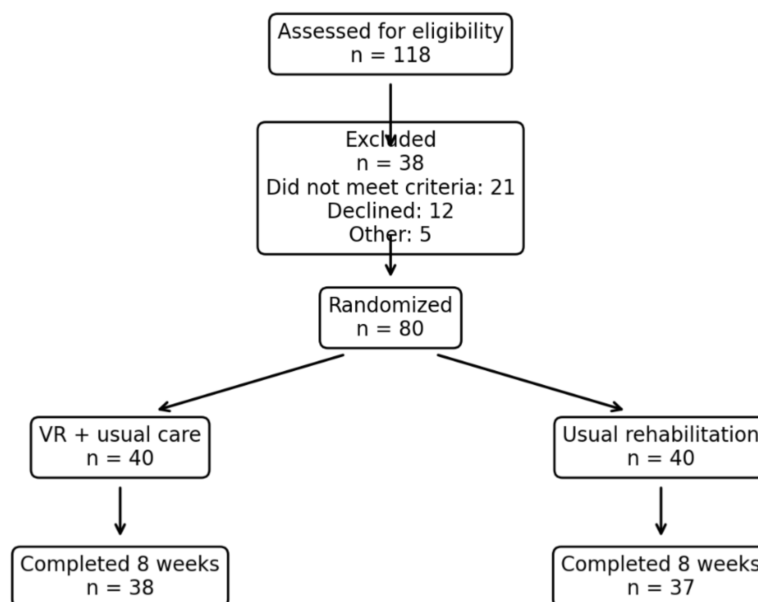

Figure 1. Literature identification and screening flow for the integrative review.

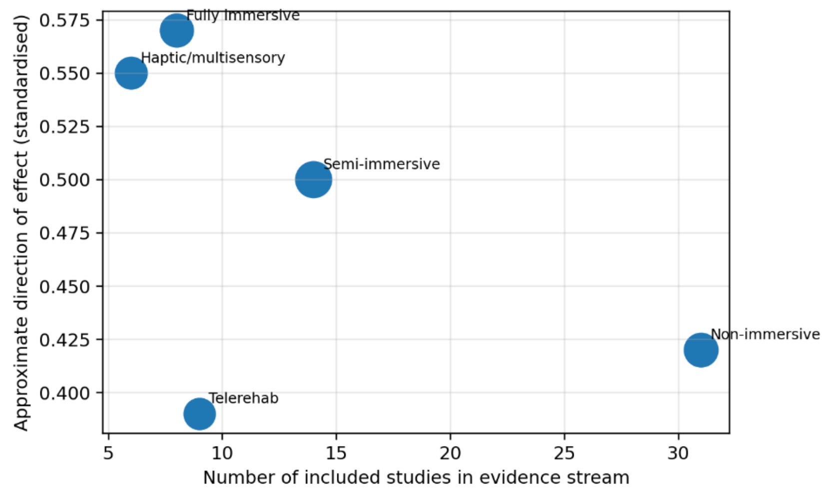

Figure 2. Evidence map by VR modality and outcome strength.

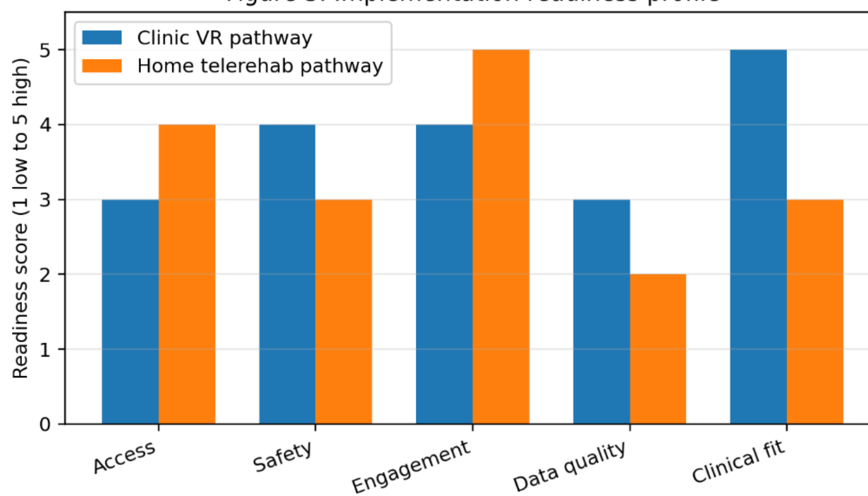

Figure 3. Implementation readiness profile for clinic-based and home-based VR pathways.

4. Discussion

The main conclusion from this integrative review is that VR telerehabilitation and multisensory feedback should be viewed as tools for delivering better rehabilitation dose and feedback, not as independent treatments. This distinction matters because it prevents technological determinism. The evidence does not say that any VR system will improve any stroke patient. It suggests that specific VR tasks, delivered at sufficient dose, with appropriate supervision and aligned outcomes, can improve certain recovery domains. That is a narrower claim, but it is stronger and more clinically useful. [12]

The Cochrane evidence is appropriately cautious. Laver et al. (2025) identified 190 studies involving 7188 people in the broad evidence base and included 72 trials with 2470 participants in the main review, yet still rated much of the evidence as moderate to very low certainty. That is not a reason to dismiss VR. It is a reason to stop using exaggerated language. Digital rehabilitation has passed the novelty stage, but it has not earned the right to ignore protocol quality, sample size, adverse events or follow-up. [13]

Telerehabilitation adds a second layer of interpretation. Remote delivery can increase access and continuity, but it can also reduce clinical visibility. A therapist in clinic can see trunk compensation, fatigue, frustration, neglect, unsafe posture and pain behaviours. A home system may capture scores without capturing the movement strategy used to achieve them. This is why remote VR should include video review, sensor-based quality indicators or periodic in-person

reassessment where feasible. Otherwise, patients may learn compensations that improve game performance but do not improve functional use. [13]

Dose is the recurring theme across the literature. Studies and reviews increasingly suggest that longer, more frequent or higher-repetition VR programmes produce stronger effects. This fits broader neurorehabilitation theory and the findings of Kwakkel et al. (2004) and Lang et al. (2015), who emphasized the importance of therapy intensity and active ingredients. The mistake would be to treat dose as minutes of headset time. The clinically meaningful dose is successful, targeted, progressively challenging movement practice that transfers to function.

Multisensory feedback deserves serious attention because stroke is not only a motor-output disorder. Sensory loss, impaired proprioception and distorted body awareness can undermine recovery. Haptic feedback may help patients detect movement errors and experience more realistic interaction. However, multisensory systems are vulnerable to overengineering. A complex haptic system that is too expensive, fragile or difficult to calibrate will not scale. Implementation success depends on the balance between added clinical value and added operational burden. [14]

Equity is a major blind spot. Telerehabilitation is often presented as democratizing care, but that claim is only partly true. Patients need devices, electricity, internet access, space, literacy, caregiver support and confidence with technology. Older patients, rural households, low-income families and people with cognitive or visual impairments may be excluded unless services provide equipment loans, technical support, simplified interfaces and alternative pathways. Without these supports, VR telerehabilitation may widen the same rehabilitation inequalities it claims to solve. [15]

Safety must also be treated as a design requirement, not a paragraph at the end of a protocol. The Cochrane update reported few serious adverse events, but underreporting is common in rehabilitation technology trials. Mild symptoms such as dizziness, headache, nausea, shoulder pain and visual fatigue can still limit adherence. Lower limb VR and balance tasks require stronger safeguards than seated upper limb programmes. Home systems should include clear stop rules, emergency contact pathways, caregiver instructions and progression limits.

The review also indicates that outcome selection needs improvement. Too many studies rely on impairment measures without sufficient participation outcomes. A stronger evidence base would measure whether patients use the affected limb more at home, return to valued activities, reduce caregiver dependence, and maintain gains after intervention. Wearable sensors, ecological momentary assessment and patient-reported participation scales may help, but they must be validated and interpretable. Data volume is not the same as meaningful evidence.

For service managers, the practical message is uncomfortable but necessary: buying VR hardware is the easy part. The difficult work is pathway design. Services need referral criteria, contraindication checklists, training protocols, cleaning and maintenance plans, data governance, troubleshooting, dose targets, outcome dashboards and escalation rules. Without these, VR will sit unused or be used inconsistently. Technology adoption fails not only because devices are bad but because organizations treat implementation as procurement. [16]

For researchers, the priority should be fewer vague trials and more precise trials. Future studies should compare defined VR ingredients: immersion level, haptic feedback, therapist supervision, home monitoring, dose, progression algorithm and transfer practice. Trials should stratify by stroke stage and baseline impairment. They should include economic evaluation because a more effective intervention may still be unaffordable, while a modestly effective home system may be valuable if it increases access at low marginal cost. Follow-up should extend beyond the intervention period to test durability. [17]

The overall evidence supports cautious optimism. VR telerehabilitation can extend rehabilitation beyond the clinic, while multisensory feedback can enrich movement practice. Neither solves the structural problem of insufficient rehabilitation by itself. The strongest

pathway combines therapist-led assessment, individualized goals, technology-supported repetitions, remote monitoring, caregiver education and real-world transfer tasks. In that model, VR becomes a disciplined rehabilitation platform rather than a gadget. [18]

Implementation science is particularly relevant to VR telerehabilitation because the intervention crosses boundaries between hospital, home, family and technology vendors. A successful pathway must define who screens patients, who trains them, who monitors data, who responds to alerts, who maintains devices and who decides when to progress or stop therapy. These responsibilities are often blurred in pilot studies. In routine care, blurred responsibility becomes risk. A digital pathway needs governance as much as hardware. [19]

Patient preference should influence, but not dominate, modality selection. Some patients enjoy immersive environments, while others find them disorienting or childish. Some want independent home practice, while others need therapist presence to feel safe. Motivation is not a fixed personality trait; it is shaped by task meaning, feedback, difficulty, fatigue, social support and confidence. The best VR programmes therefore offer choice within clinically safe boundaries. Personalization should not mean giving every patient whatever game they like. It should mean matching therapeutic tasks to patient goals and impairments. [20]

Data generated by VR systems can be useful only if it is interpretable. Counts of repetitions, task scores, range of motion and time in system may help therapists monitor progress, but raw data can also distract from meaningful change. A dashboard should answer clinical questions: is the patient practising enough, improving movement quality, tolerating difficulty, avoiding compensation and transferring gains to daily life? Without these questions, data volume becomes noise. Digital rehabilitation should not replace clinical judgment with superficial analytics. [21]

Remote delivery also changes caregiver roles. Family members may help set up equipment, monitor safety, encourage practice and report problems. This can be helpful, but it can also create burden. Studies should measure caregiver workload and not assume that unpaid family support is always available. Equity-sensitive telerehabilitation must include options for patients who live alone or whose caregivers cannot provide technical or physical assistance.

Multisensory feedback systems need realistic maintenance planning. Haptic gloves, sensors and motion trackers can drift, fail, require charging or fit poorly on spastic or swollen hands. Calibration time can reduce therapy time. Infection control may be more complex for shared wearable devices. These practical problems do not make multisensory VR useless, but they do mean that feasibility must be measured honestly. A device that works in a laboratory may fail in a busy outpatient clinic. [20]

Another overlooked issue is transfer. Virtual task success is valuable only if it helps patients perform real activities. Therapy designs should therefore pair VR practice with immediate real-world tasks: reaching to a shelf, grasping a cup, buttoning, folding, stepping, turning, or navigating home obstacles. Transfer should be built into the protocol rather than mentioned as a hoped-for result. Rehabilitation is not about winning virtual games; it is about restoring participation. [22]

Implementation science is particularly relevant to VR telerehabilitation because the intervention crosses boundaries between hospital, home, family and technology vendors. A successful pathway must define who screens patients, who trains them, who monitors data, who responds to alerts, who maintains devices and who decides when to progress or stop therapy. These responsibilities are often blurred in pilot studies. In routine care, blurred responsibility becomes risk. A digital pathway needs governance as much as hardware.

Patient preference should influence, but not dominate, modality selection. Some patients enjoy immersive environments, while others find them disorienting or childish. Some want independent home practice, while others need therapist presence to feel safe. Motivation is not a fixed personality trait; it is shaped by task meaning, feedback, difficulty, fatigue, social

support and confidence. The best VR programmes therefore offer choice within clinically safe boundaries. Personalization should not mean giving every patient whatever game they like. It should mean matching therapeutic tasks to patient goals and impairments. [21]

Data generated by VR systems can be useful only if it is interpretable. Counts of repetitions, task scores, range of motion and time in system may help therapists monitor progress, but raw data can also distract from meaningful change. A dashboard should answer clinical questions: is the patient practising enough, improving movement quality, tolerating difficulty, avoiding compensation and transferring gains to daily life? Without these questions, data volume becomes noise. Digital rehabilitation should not replace clinical judgment with superficial analytics. [16-21]

Remote delivery also changes caregiver roles. Family members may help set up equipment, monitor safety, encourage practice and report problems. This can be helpful, but it can also create burden. Studies should measure caregiver workload and not assume that unpaid family support is always available. Equity-sensitive telerehabilitation must include options for patients who live alone or whose caregivers cannot provide technical or physical assistance.

Multisensory feedback systems need realistic maintenance planning. Haptic gloves, sensors and motion trackers can drift, fail, require charging or fit poorly on spastic or swollen hands. Calibration time can reduce therapy time. Infection control may be more complex for shared wearable devices. These practical problems do not make multisensory VR useless, but they do mean that feasibility must be measured honestly. A device that works in a laboratory may fail in a busy outpatient clinic. [18-22]

Another overlooked issue is transfer. Virtual task success is valuable only if it helps patients perform real activities. Therapy designs should therefore pair VR practice with immediate real-world tasks: reaching to a shelf, grasping a cup, buttoning, folding, stepping, turning, or navigating home obstacles. Transfer should be built into the protocol rather than mentioned as a hoped-for result. Rehabilitation is not about winning virtual games; it is about restoring participation.

Implementation science is particularly relevant to VR telerehabilitation because the intervention crosses boundaries between hospital, home, family and technology vendors. A successful pathway must define who screens patients, who trains them, who monitors data, who responds to alerts, who maintains devices and who decides when to progress or stop therapy. These responsibilities are often blurred in pilot studies. In routine care, blurred responsibility becomes risk. A digital pathway needs governance as much as hardware.

Patient preference should influence, but not dominate, modality selection. Some patients enjoy immersive environments, while others find them disorienting or childish. Some want independent home practice, while others need therapist presence to feel safe. Motivation is not a fixed personality trait; it is shaped by task meaning, feedback, difficulty, fatigue, social support and confidence. The best VR programmes therefore offer choice within clinically safe boundaries. Personalization should not mean giving every patient whatever game they like. It should mean matching therapeutic tasks to patient goals and impairments. [22]

Data generated by VR systems can be useful only if it is interpretable. Counts of repetitions, task scores, range of motion and time in system may help therapists monitor progress, but raw data can also distract from meaningful change. A dashboard should answer clinical questions: is the patient practising enough, improving movement quality, tolerating difficulty, avoiding compensation and transferring gains to daily life? Without these questions, data volume becomes noise. Digital rehabilitation should not replace clinical judgment with superficial analytics.

Remote delivery also changes caregiver roles. Family members may help set up equipment, monitor safety, encourage practice and report problems. This can be helpful, but it can also create burden. Studies should measure caregiver workload and not assume that unpaid family

support is always available. Equity-sensitive telerehabilitation must include options for patients who live alone or whose caregivers cannot provide technical or physical assistance.

Multisensory feedback systems need realistic maintenance planning. Haptic gloves, sensors and motion trackers can drift, fail, require charging or fit poorly on spastic or swollen hands. Calibration time can reduce therapy time. Infection control may be more complex for shared wearable devices. These practical problems do not make multisensory VR useless, but they do mean that feasibility must be measured honestly. A device that works in a laboratory may fail in a busy outpatient clinic.

Another overlooked issue is transfer. Virtual task success is valuable only if it helps patients perform real activities. Therapy designs should therefore pair VR practice with immediate real-world tasks: reaching to a shelf, grasping a cup, buttoning, folding, stepping, turning, or navigating home obstacles. Transfer should be built into the protocol rather than mentioned as a hoped-for result. Rehabilitation is not about winning virtual games; it is about restoring participation. [21-22]

Implementation science is particularly relevant to VR telerehabilitation because the intervention crosses boundaries between hospital, home, family and technology vendors. A successful pathway must define who screens patients, who trains them, who monitors data, who responds to alerts, who maintains devices and who decides when to progress or stop therapy. These responsibilities are often blurred in pilot studies. In routine care, blurred responsibility becomes risk. A digital pathway needs governance as much as hardware.

Patient preference should influence, but not dominate, modality selection. Some patients enjoy immersive environments, while others find them disorienting or childish. Some want independent home practice, while others need therapist presence to feel safe. Motivation is not a fixed personality trait; it is shaped by task meaning, feedback, difficulty, fatigue, social support and confidence. The best VR programmes therefore offer choice within clinically safe boundaries. Personalization should not mean giving every patient whatever game they like. It should mean matching therapeutic tasks to patient goals and impairments. [21-22]

Data generated by VR systems can be useful only if it is interpretable. Counts of repetitions, task scores, range of motion and time in system may help therapists monitor progress, but raw data can also distract from meaningful change. A dashboard should answer clinical questions: is the patient practising enough, improving movement quality, tolerating difficulty, avoiding compensation and transferring gains to daily life? Without these questions, data volume becomes noise. Digital rehabilitation should not replace clinical judgment with superficial analytics.

Remote delivery also changes caregiver roles. Family members may help set up equipment, monitor safety, encourage practice and report problems. This can be helpful, but it can also create burden. Studies should measure caregiver workload and not assume that unpaid family support is always available. Equity-sensitive telerehabilitation must include options for patients who live alone or whose caregivers cannot provide technical or physical assistance.

Multisensory feedback systems need realistic maintenance planning. Haptic gloves, sensors and motion trackers can drift, fail, require charging or fit poorly on spastic or swollen hands. Calibration time can reduce therapy time. Infection control may be more complex for shared wearable devices. These practical problems do not make multisensory VR useless, but they do mean that feasibility must be measured honestly. A device that works in a laboratory may fail in a busy outpatient clinic. [21-22]

Another overlooked issue is transfer. Virtual task success is valuable only if it helps patients perform real activities. Therapy designs should therefore pair VR practice with immediate real-world tasks: reaching to a shelf, grasping a cup, buttoning, folding, stepping, turning, or navigating home obstacles. Transfer should be built into the protocol rather than mentioned as

a hoped-for result. Rehabilitation is not about winning virtual games; it is about restoring participation.

Implementation science is particularly relevant to VR telerehabilitation because the intervention crosses boundaries between hospital, home, family and technology vendors. A successful pathway must define who screens patients, who trains them, who monitors data, who responds to alerts, who maintains devices and who decides when to progress or stop therapy. These responsibilities are often blurred in pilot studies. In routine care, blurred responsibility becomes risk. A digital pathway needs governance as much as hardware.

Patient preference should influence, but not dominate, modality selection. Some patients enjoy immersive environments, while others find them disorienting or childish. Some want independent home practice, while others need therapist presence to feel safe. Motivation is not a fixed personality trait; it is shaped by task meaning, feedback, difficulty, fatigue, social support and confidence. The best VR programmes therefore offer choice within clinically safe boundaries. Personalization should not mean giving every patient whatever game they like. It should mean matching therapeutic tasks to patient goals and impairments. [19-21]

Data generated by VR systems can be useful only if it is interpretable. Counts of repetitions, task scores, range of motion and time in system may help therapists monitor progress, but raw data can also distract from meaningful change. A dashboard should answer clinical questions: is the patient practising enough, improving movement quality, tolerating difficulty, avoiding compensation and transferring gains to daily life? Without these questions, data volume becomes noise. Digital rehabilitation should not replace clinical judgment with superficial analytics. [21-22]

Remote delivery also changes caregiver roles. Family members may help set up equipment, monitor safety, encourage practice and report problems. This can be helpful, but it can also create burden. Studies should measure caregiver workload and not assume that unpaid family support is always available. Equity-sensitive telerehabilitation must include options for patients who live alone or whose caregivers cannot provide technical or physical assistance.

Multisensory feedback systems need realistic maintenance planning. Haptic gloves, sensors and motion trackers can drift, fail, require charging or fit poorly on spastic or swollen hands. Calibration time can reduce therapy time. Infection control may be more complex for shared wearable devices. These practical problems do not make multisensory VR useless, but they do mean that feasibility must be measured honestly. A device that works in a laboratory may fail in a busy outpatient clinic.

Another overlooked issue is transfer. Virtual task success is valuable only if it helps patients perform real activities. Therapy designs should therefore pair VR practice with immediate real-world tasks: reaching to a shelf, grasping a cup, buttoning, folding, stepping, turning, or navigating home obstacles. Transfer should be built into the protocol rather than mentioned as a hoped-for result. Rehabilitation is not about winning virtual games; it is about restoring participation.

The final practical issue is sustainability. Rehabilitation programmes must survive staff turnover, device upgrades, budget cycles and patient needs. Therefore, VR adoption should be evaluated through repeated audit, patient feedback, therapist feedback and outcome monitoring. This prevents a common digital health failure, where early novelty is mistaken for durable clinical value.

The final practical issue is sustainability. Rehabilitation programmes must survive staff turnover, device upgrades, budget cycles and changing patient needs. Therefore, VR adoption should be evaluated through repeated audit, patient feedback, therapist feedback and outcome monitoring rather than one enthusiastic pilot. This prevents a common failure in digital health, where early novelty is mistaken for durable clinical value. [21-22]

The final practical issue is sustainability. Rehabilitation programmes must survive staff turnover, device upgrades, budget cycles and changing patient needs. Therefore, VR adoption should be evaluated through repeated audit, patient feedback, therapist feedback and outcome monitoring rather than one enthusiastic pilot. This prevents a common failure in digital health, where early novelty is mistaken for durable clinical value. [22]
The final practical issue is sustainability. Rehabilitation programmes must survive staff turnover, device upgrades, budget cycles and changing patient needs. Therefore, VR adoption should be evaluated through repeated audit, patient feedback, therapist feedback and outcome monitoring rather than one enthusiastic pilot. This prevents a common failure in digital health, where early novelty is mistaken for durable clinical value.

5. Conclusion

VR telerehabilitation and multisensory feedback offer meaningful opportunities for post-stroke recovery, especially when they increase active practice, feedback, motivation and continuity after discharge. The evidence is strongest for upper limb rehabilitation and activity limitation, promising for balance and lower limb function, and still developing for cognition, mood, participation and cost-effectiveness. VR's clinical future depends on protocol quality. Effective implementation requires patient selection, safety screening, therapist integration, remote monitoring, equity planning and valid outcome measurement. The blunt truth is that VR will not rescue weak rehabilitation systems. It can strengthen good systems that already understand dose, goals, progression and patient-centred care. in practice.

Conflicts of Interest: There are no conflicts of interest, according to the authors.

References

1. Aminov, A., Rogers, J. M., Middleton, S., Caeyenberghs, K., & Wilson, P. H. (2018). What do randomized controlled trials say about virtual rehabilitation in stroke? A systematic literature review and meta-analysis of upper-limb and cognitive outcomes. Journal of NeuroEngineering and Rehabilitation, 15, 29. https://doi.org/10.1186/s12984-018-0370-2
2. Chen, J., Or, C. K., & Chen, T. (2022). Effectiveness of using virtual reality-supported exercise therapy for upper extremity motor rehabilitation in patients with stroke: Systematic review and meta-analysis of randomized controlled trials. Journal of Medical Internet Research, 24(6), e24111. https://doi.org/10.2196/24111
3. Duncan, P. W., Wallace, D., Lai, S. M., Johnson, D., Embretson, S., & Laster, L. J. (1999). The Stroke Impact Scale Version 2.0: Evaluation of reliability, validity, and sensitivity to change. Stroke, 30(10), 2131-2140. https://doi.org/10.1161/01.STR.30.10.2131
4. Fugl-Meyer, A. R., Jaasko, L., Leyman, I., Olsson, S., & Steglind, S. (1975). The post-stroke hemiplegic patient: A method for evaluation of physical performance. Scandinavian Journal of Rehabilitation Medicine, 7(1), 13-31.
5. Kroenke, K., Spitzer, R. L., & Williams, J. B. W. (2001). The PHQ-9: Validity of a brief depression severity measure. Journal of General Internal Medicine, 16(9), 606-613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x
6. Kwakkel, G., van Peppen, R., Wagenaar, R. C., Wood-Dauphinee, S., Richards, C., Ashburn, A., Miller, K., Lincoln, N., Partridge, C., Wellwood, I., & Langhorne, P. (2004). Effects of augmented exercise therapy time after stroke: A meta-analysis. Stroke, 35(11), 2529-2539. https://doi.org/10.1161/01.STR.0000143153.76460.7d

7. Lang, C. E., Lohse, K. R., & Birkenmeier, R. L. (2015). Dose and timing in neurorehabilitation: Prescribing motor therapy after stroke. Current Opinion in Neurology, 28(6), 549-555. https://doi.org/10.1097/WCO.0000000000000256
8. Laver, K. E., Lange, B., George, S., Deutsch, J. E., Saposnik, G., Chapman, M., & Crotty, M. (2025). Virtual reality for stroke rehabilitation. Cochrane Database of Systematic Reviews, 2025(6), CD008349. https://doi.org/10.1002/14651858.CD008349.pub5
9. Maier, M., Rubio Ballester, B., Duff, A., Duarte Oller, E., & Verschure, P. F. M. J. (2019). Effect of specific over nonspecific VR-based rehabilitation on poststroke motor recovery: A systematic meta-analysis. Neurorehabilitation and Neural Repair, 33(2), 112-129. https://doi.org/10.1177/1545968318820169
10. Mekbib, D. B., Han, J., Zhang, L., Fang, S., Jiang, H., Zhu, J., Roe, A. W., & Xu, D. (2020). Virtual reality therapy for upper limb rehabilitation in patients with stroke: A meta-analysis of randomized clinical trials. Brain Injury, 34(4), 456-465. https://doi.org/10.1080/02699052.2020.1725126
11. Nasreddine, Z. S., Phillips, N. A., Bedirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. Journal of the American Geriatrics Society, 53(4), 695-699. https://doi.org/10.1111/j.1532-5415.2005.53221.x
12. National Institute for Health and Care Excellence. (2023). Stroke rehabilitation in adults (NICE Guideline NG236). https://www.nice.org.uk/guidance/ng236
13. Saposnik, G., & Levin, M. (2011). Virtual reality in stroke rehabilitation: A meta-analysis and implications for clinicians. Stroke, 42(5), 1380-1386. https://doi.org/10.1161/STROKEAHA.110.605451
14. Saposnik, G., Cohen, L. G., Mamdani, M., Pooyania, S., Ploughman, M., Cheung, D., Shaw, J., Hall, J., Nord, P., Dukelow, S., Nilanont, Y., De Los Rios, F., Olmos, L., Levin, M., Teasell, R., Cohen, A., Thorpe, K., Laupacis, A., & Bayley, M. (2016). Efficacy and safety of non-immersive virtual reality exercising in stroke rehabilitation (EVREST): A randomised, multicentre, single-blind, controlled trial. The Lancet Neurology, 15(10), 1019-1027. https://doi.org/10.1016/S1474-4422(16)30121-1
15. Soleimani, M., Ghazisaeedi, M., & Heydari, S. (2024). The efficacy of virtual reality for upper limb rehabilitation in stroke patients: A systematic review and meta-analysis. BMC Medical Informatics and Decision Making, 24, 135. https://doi.org/10.1186/s12911-024-02534-y
16. Brooke, J. (1996). SUS: A quick and dirty usability scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester, & I. L. McClelland (Eds.), Usability evaluation in industry (pp. 189-194). Taylor & Francis.
17. Fernandez-Vazquez, D., Cano-de-la-Cuerda, R., & Navarro-Lopez, V. (2022). Haptic glove systems in combination with semi-immersive virtual reality for upper extremity motor rehabilitation after stroke: A systematic review and meta-analysis. International Journal of Environmental Research and Public Health, 19(16), 10378. https://doi.org/10.3390/ijerph191610378
18. Leong, S. C., Tang, Y. M., Toh, F. M., & Fong, K. N. K. (2022). Examining the effectiveness of virtual, augmented, and mixed reality therapy for upper limb recovery and activities of daily living in stroke patients: A systematic review and meta-analysis. Journal of NeuroEngineering and Rehabilitation, 19, 93. https://doi.org/10.1186/s12984-022-01064-x
19. Lu, W., Li, Y., Wang, Y., Chen, J., & Liu, H. (2025). Effect of virtual reality-based therapies on lower limb functional recovery in stroke survivors: Systematic review and

meta-analysis. Journal of Medical Internet Research, 27, e72364. https://doi.org/10.2196/72364

20. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hrobjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71
21. World Stroke Organization. (2025). Global stroke fact sheet 2025. International Journal of Stroke. https://doi.org/10.1177/17474930241308142
22. Xu, S., Chen, Y., Li, X., & Wang, J. (2025). Virtual reality enhanced exercise training in upper limb function of patients with stroke: Meta-analytic study. Journal of Medical Internet Research, 27, e66802. https://doi.org/10.2196/66802