Comparison And Correlation Of Virtual Reality, Aquatic Therapy, And Music Therapy For Functional Rehabilitation In Hemiplegic Patients: A Systematic Review

Areeba Khanam[1], Aabha Gupta[2*]
[1,2]Department Of Physiotherapy, School Of Allied Health Science, Galgotias University, Greater Noida, Uttar Pradesh, India*
areebakhanam12@gmail.com
Corresponding Author:
Aabha Gupta
Email Id - aabha.gupta@galgotiasuniversity.edu.in

ABSTRACT
Background:
Stroke-induced hemiplegia significantly compromises motor function, balance, and quality of life. While conventional therapy remains central to rehabilitation, adjunctive modalities like Virtual Reality (VR), Aquatic Therapy, and Music Therapy have gained prominence. However, limited reviews have systematically compared their relative effectiveness and potential integration.
Objective:
To compare and correlate the efficacy of VR, aquatic therapy, and music therapy in improving functional outcomes in hemiplegic patients, and to assess whether their combination offers synergistic benefits.
Methods:
This systematic review followed PRISMA guidelines. Literature was searched in PubMed, Scopus, PEDro, and Cochrane databases for studies published between 2015 and 2025. A total of 25 studies were included, encompassing randomized controlled trials, systematic reviews, and clinical protocols. Primary outcomes evaluated included motor recovery, balance, gait parameters, cognitive function, and emotional well-being.
Results:
VR showed high effectiveness in improving upper-limb motor control and task-specific learning, particularly in immersive settings. Aquatic therapy consistently enhanced balance, lower-limb strength, and gait in early-stage rehabilitation due to its biomechanical advantages. Music therapy, notably Rhythmic Auditory Stimulation (RAS), improved gait cadence, mood, and cognitive coordination, serving as a motivational adjunct. While each therapy demonstrated domain-specific strengths, no single modality was superior across all outcomes.
Conclusion:
All three modalities offer complementary benefits and support a multimodal rehabilitation approach. Personalized therapy plans integrating VR, aquatic, and music-based interventions could optimize recovery in hemiplegic patients. Further research should explore combined protocols and long-term outcomes...
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INTRODUCTION

Stroke remains one of the leading causes of long-term adult disability worldwide, with substantial clinical and socioeconomic consequences. According to global epidemiological estimates, approximately 15 million individuals experience a stroke annually, of whom nearly one-third are left permanently disabled [1]. Hemiplegia, characterized by paralysis affecting one side of the body, is one of the most common sequelae of stroke and typically results from damage to the motor cortex or corticospinal pathways [2]. This impairment disrupts voluntary motor control, postural stability, gait mechanics, and upper-limb dexterity, thereby significantly compromising functional independence and quality of life [3].

Individuals with post-stroke hemiplegia frequently experience limitations in activities of daily living (ADLs), including ambulation, dressing, feeding, and personal hygiene [4]. Functional dependency is often accompanied by psychological distress, depression, and reduced social participation, increasing caregiver burden and healthcare expenditure [5]. Consequently, effective rehabilitation strategies aimed at restoring motor function and promoting neuroplastic adaptation remain central to post-stroke management.

**Author for Correspondence: areebakhanam12@gmail.com*

Conventional rehabilitation approaches, including physiotherapy, occupational therapy, and speech therapy, are grounded in principles of motor relearning, repetition, and neuroplasticity [6]. Although these interventions produce clinically meaningful improvements, residual impairments remain common, particularly in balance, gait symmetry, and upper-limb dexterity [7]. Furthermore, prolonged therapy programs may result in decreased motivation and adherence, limiting rehabilitation intensity and long-term functional gains [8]. These limitations have prompted the exploration of adjunctive interventions designed to enhance engagement, sensory integration, and task-specific practice.

Among emerging rehabilitation modalities, Virtual Reality (VR), Aquatic Therapy, and Music Therapy have received increasing scientific attention. These approaches integrate multisensory stimulation, feedback-driven motor practice, and motivational engagement—mechanisms closely aligned with contemporary neurorehabilitation frameworks [9]. However, comparative synthesis across these modalities remains limited.

1.1 Virtual Reality in Stroke Rehabilitation

Virtual Reality (VR) involves the use of computer-generated interactive environments that enable patients to perform simulated motor tasks in real time. VR systems may be immersive, using head-mounted displays and motion-tracking sensors, or non-immersive, using screen-based interfaces [10].

The therapeutic rationale for VR is grounded in motor learning theory and experience-dependent neuroplasticity. Task-specific repetition combined with augmented feedback enhances cortical reorganization and strengthens neural connectivity following stroke [11]. VR provides immediate visual and auditory feedback, facilitating motor planning, error correction, and movement refinement [12].

Systematic reviews and meta-analyses have demonstrated that VR-based interventions can improve upper-limb motor function and ADL performance compared with conventional therapy alone [13]. Additional evidence suggests improvements in balance and gait parameters when VR is used as an adjunct intervention [14]. Moreover, gamified environments enhance intrinsic motivation and therapy adherence, which are critical determinants of rehabilitation intensity [15].

Despite promising outcomes, significant heterogeneity exists regarding device types, intervention dosage, and outcome measures. These methodological variations complicate the interpretation of findings and limit generalizability [13,16]. Therefore, further synthesis is required to clarify its comparative effectiveness.

1.2 Aquatic Therapy for Functional Recovery

Aquatic therapy utilizes the physical properties of water—buoyancy, hydrostatic pressure, viscosity, and thermal effects—to facilitate therapeutic exercise. Buoyancy reduces gravitational loading, enabling safer movement in individuals with weakness or postural instability [17]. Hydrostatic pressure enhances proprioceptive input and circulation, while water resistance provides uniform strengthening without excessive joint stress [18].

These biomechanical properties make aquatic therapy particularly beneficial during early rehabilitation phases when weight-bearing tolerance is limited. Reduced fear of falling and increased movement confidence further support functional retraining [19].

Randomized controlled trials have demonstrated significant improvements in balance control, gait parameters, and muscle strength following structured aquatic interventions [20]. Meta-analytic evidence suggests that aquatic therapy produces large effect sizes for balance outcomes compared with land-based therapy [21]. Additionally, patients often report improved psychological well-being and satisfaction in aquatic environments [22].

However, variability in treatment protocols, infrastructural requirements, and accessibility constraints limit widespread implementation. Greater methodological standardization is needed to define optimal dosing and comparative benefit [21].

1.3 Music Therapy in Neurorehabilitation

Music therapy is an evidence-based intervention that employs structured auditory stimuli to achieve therapeutic goals in motor, cognitive, and emotional domains. Techniques such as Rhythmic Auditory Stimulation (RAS) leverage auditory–motor entrainment mechanisms to synchronize movement with rhythmic cues [23].

The neurophysiological basis of RAS involves activation of auditory–motor networks and facilitation of corticospinal pathways, thereby improving temporal coordination of movement [24]. Clinical trials have demonstrated improvements in gait velocity, cadence, and stride length among individuals with post-stroke hemiparesis [25]. A recent meta-analysis reported significant positive effects of RAS on gait and postural stability [26].

Beyond motor recovery, music-based interventions have been associated with improvements in mood, attention, and cognitive engagement [27]. However, evidence for improvements in broader functional independence and ADLs remains inconsistent, and music therapy is frequently implemented as an adjunct rather than a standalone intervention [26,28].

2. Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure transparency, methodological rigor, and reproducibility. The objective of the review was to systematically identify, appraise, and synthesize evidence regarding the effectiveness of Virtual Reality (VR), Aquatic Therapy, and Music Therapy in improving functional outcomes among adults with post-stroke hemiplegia. A review protocol was developed prior to data extraction to minimize reporting bias and enhance methodological consistency. The protocol was prospectively registered in an international registry of systematic reviews (e.g., PROSPERO).

Eligibility criteria were defined using the PICOS framework. Studies were included if they involved adults aged 18 years or older diagnosed with hemiplegia or hemiparesis secondary to ischemic or hemorrhagic stroke. Eligible interventions included immersive or non-immersive Virtual Reality, aquatic therapy or hydrotherapy approaches (such as Halliwick, Bad Ragaz, or Ai Chi methods), and music therapy interventions including Rhythmic Auditory Stimulation (RAS) and other neurologic music therapy techniques. These interventions could be delivered either as standalone treatments or as adjuncts to conventional rehabilitation. Comparator groups included standard physiotherapy, occupational therapy, conventional rehabilitation programs, other active interventions, or no intervention. Studies were required to report at least one relevant functional outcome, including motor function (e.g., Fugl-Meyer Assessment), balance (e.g., Berg Balance Scale), gait parameters (e.g., Timed Up and Go test, 10-Meter Walk Test, gait velocity), functional independence (e.g., Modified Barthel Index, Functional Independence Measure), or cognitive and psychosocial outcomes relevant to music therapy. Randomized controlled trials, controlled clinical trials, cohort studies, and quasi-experimental studies published in English between January 2010 and May 2025 were included. Systematic reviews, narrative reviews, case reports, editorials, conference abstracts, and studies involving pediatric populations or non-stroke neurological conditions were excluded.

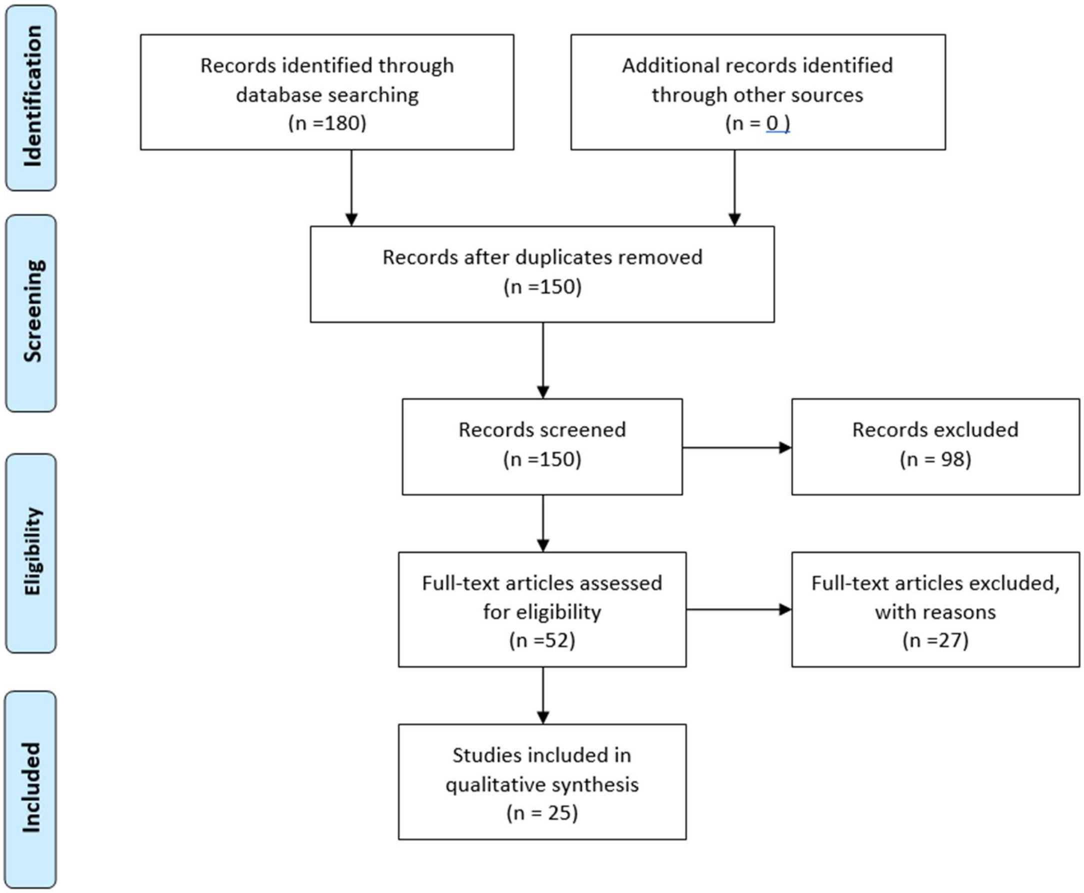
A comprehensive literature search was conducted in PubMed/MEDLINE, Scopus, Web of Science, CINAHL, PEDro, and Google Scholar. The search was performed between May 1 and May 25, 2025. Medical Subject Headings (MeSH) and free-text keywords were combined using Boolean operators. The primary search terms included variations of “hemiplegia,” “stroke,” or “post-stroke,” combined with “virtual reality,” “VR therapy,” “aquatic therapy,” “hydrotherapy,” “music therapy,” “neurologic music therapy,” “rhythmic auditory stimulation,” and functional outcome terms such as “motor function,” “balance,” “gait,” and “rehabilitation.” Search strategies were adapted to the syntax requirements of each database. Additionally, reference lists of included studies were manually screened to identify any potentially relevant publications not captured in the electronic search.

All retrieved records were imported into reference management software, and duplicate entries were removed prior to screening. Study selection was conducted independently by two reviewers in accordance with PRISMA methodology. Initially, titles and abstracts were screened for relevance. Of the 180 records identified, 30 duplicates were removed, leaving 150 studies for screening. Ninety-eight studies were excluded during title and abstract review due to irrelevance to the population or interventions of interest. Fifty-two full-text articles were subsequently assessed for eligibility. Twenty-seven studies were excluded at this stage because of incomplete outcome data, inappropriate study design, ineligible populations, or lack of relevant functional measures. Ultimately, 25 studies met all inclusion criteria and were included in the qualitative synthesis. Disagreements between reviewers were resolved through discussion or consultation with a third reviewer. The study selection process is illustrated using a PRISMA flow diagram.

Data extraction was performed using a standardized and pilot-tested data extraction form to ensure consistency and completeness. Extracted data included study characteristics (author, year, country), study design, sample size, participant demographics, stroke duration and severity, intervention parameters (type, frequency, intensity, duration), comparator interventions, outcome measures, main findings, follow-up duration, and reported limitations. Data extraction was conducted independently by two reviewers, and discrepancies were resolved through consensus. When necessary, corresponding authors were contacted to clarify missing or ambiguous data.

Methodological quality and risk of bias were assessed independently by two reviewers using validated appraisal tools. Randomized controlled trials were evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool, while non-randomized studies were assessed using the ROBINS-I instrument. Observational studies were appraised using the Newcastle-Ottawa Scale. Each study was categorized as having low, moderate, or high risk of bias. The overall certainty of evidence for each outcome domain was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.

Given the anticipated heterogeneity in intervention protocols, outcome measures, and study designs, a narrative synthesis approach was primarily employed. Studies were grouped according to intervention type (VR, aquatic therapy, or music therapy) and by functional outcome domain (motor function, balance, gait, and functional independence). Where sufficient homogeneity in outcome reporting existed, quantitative synthesis was planned using Review Manager (RevMan) or Comprehensive Meta-Analysis software. For continuous outcomes, mean differences or standardized mean differences with 95% confidence intervals were calculated. Statistical heterogeneity was evaluated using the I^2 statistic, with values greater than 50% considered indicative of substantial heterogeneity. In such cases, random-effects models were applied. Subgroup analyses were planned based on stroke chronicity (acute versus chronic), intervention frequency and duration, and immersive versus non-immersive VR systems. Exploratory correlation analyses were considered to examine potential synergistic relationships among the three therapeutic modalities. A summary of findings table was prepared to present key outcomes and certainty of evidence for each intervention category



2.1 PRISMA Flow Diagram Interpretation

The study selection process followed the PRISMA 2020 framework and is summarized in the PRISMA flow diagram. During the identification phase, a total of 180 records were retrieved through systematic database searches using predefined keywords related to virtual reality, aquatic therapy, and music therapy in hemiplegic rehabilitation. No additional records were identified from other sources such as reference lists, conference abstracts, or grey literature. After removing duplicate entries, 150 unique studies remained for screening.

In the screening phase, all 150 records were evaluated based on their titles and abstracts to determine relevance according to the predefined inclusion criteria. Ninety-eight studies were excluded at this stage because they did not meet eligibility requirements, including studies unrelated to hemiplegia, those not involving the specified rehabilitation modalities, non-human studies, or non-interventional designs.

During the eligibility phase, 52 full-text articles were retrieved and assessed in detail. Of these, 27 studies were excluded due to incomplete outcome data, inappropriate or non-randomized study design with poor methodological quality, irrelevant primary outcomes (such as exclusively cognitive outcomes without functional measures), or populations that did not consist of adult hemiplegic stroke patients. Ultimately, 25 studies satisfied all inclusion criteria and were included in the qualitative synthesis for comparative and correlation analysis.

The PRISMA flow diagram enhances transparency by clearly documenting the study selection process and providing justification for exclusions at each stage. This systematic reporting strengthens the methodological rigor and reproducibility of the review.

2.2 Data Extraction

A standardized data extraction form was developed and pilot-tested to ensure consistency and completeness of collected information. The extracted data included study identification details (author, year of publication, and country), study design and sample size, and participant characteristics such as age, gender distribution, diagnosis, and stroke duration. Detailed information regarding the intervention was recorded, including the type of therapy (VR, aquatic therapy, or music therapy), specific protocol parameters (frequency, session duration, intensity, and overall intervention length), and type of VR system where applicable (immersive or non-immersive). Comparator interventions were documented when present. Outcome measures and key findings were extracted, along with follow-up duration and author-reported limitations. Data extraction was performed independently by two reviewers to reduce bias. In cases of missing or unclear data, attempts

*Author for Correspondence: areebakhanam12@gmail.com

were made to contact the corresponding authors for clarification.

2.3 Quality Assessment

The methodological quality and risk of bias of the included studies were assessed independently by two reviewers using validated appraisal tools appropriate to study design. Randomized controlled trials were evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool. Non-randomized intervention studies were assessed using the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) instrument, while observational studies were appraised using the Newcastle-Ottawa Scale (NOS). Each study was categorized as having low, moderate, or high risk of bias based on predefined criteria. Discrepancies between reviewers were resolved through discussion and consensus. In addition, the overall certainty of evidence for each outcome domain was evaluated using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework.

2.4 Data Synthesis and Analysis

Given the anticipated heterogeneity in study designs, intervention protocols, and outcome measures, a narrative synthesis approach was primarily employed. Studies were grouped according to intervention type—Virtual Reality, Aquatic Therapy, or Music Therapy—and further categorized by functional outcome domains, including motor function, balance, gait performance, and activities of daily living.

Where sufficient homogeneity existed in outcome reporting, quantitative synthesis was planned using Review Manager (RevMan) or Comprehensive Meta-Analysis (CMA) software. For continuous outcomes, mean differences (MD) or standardized mean differences (SMD) with 95% confidence intervals were calculated. Statistical heterogeneity was assessed using the I^2 statistic, with values greater than 50% indicating substantial heterogeneity. In such cases, random-effects models were applied.

Subgroup analyses were planned to explore potential moderating factors, including stroke chronicity (acute versus chronic stages), intervention frequency and duration, and immersive versus non-immersive VR systems. Additionally, where data permitted, exploratory correlation analyses were conducted to investigate potential synergistic or interaction effects among the three therapeutic modalities. A summary of findings table was prepared to present key results and the overall certainty of evidence for each intervention category

3. Results

3.1 Search Findings

The systematic database search yielded a total of 180 records from PubMed, Scopus, PEDro, and the Cochrane Library. After removal of 30 duplicate records, 150 unique studies were retained for title and abstract screening. Of these, 52 full-text articles were assessed for eligibility based on predefined inclusion and exclusion criteria. Following detailed evaluation, 27 studies were excluded due to poor methodological quality, lack of relevant functional outcome data, or inclusion of non-hemiplegic populations. Ultimately, 25 studies met all eligibility criteria and were included in the qualitative synthesis. The PRISMA flow diagram presents a comprehensive overview of the study selection process.

3.2 Study Characteristics

The 25 included studies were published between 2015 and 2025 and comprised a range of methodological designs, including randomized controlled trials (n = 10), systematic reviews or meta-analyses (n = 10), and clinical protocols or pilot studies (n = 5). Sample sizes varied substantially, ranging from 30 to 1120 participants. The included populations consisted of both acute and chronic hemiplegic stroke patients, typically aged between 30 and 75 years. Studies were geographically distributed across Asia, Europe, and North America, reflecting a broad international research base.

Regarding therapeutic focus, eight studies evaluated Virtual Reality interventions, including immersive VR, non-immersive VR, telerehabilitation platforms, and gamified systems. Seven studies examined aquatic therapy approaches, including hydrotherapy, structured SPA-based protocols, and neurological aquatic rehabilitation programs. Seven studies investigated music therapy modalities, primarily Rhythmic Auditory Stimulation (RAS), melodic intonation therapy, and music-integrated neurorehabilitation approaches. Three studies explored mixed-modality protocols combining two or more therapeutic approaches alongside conventional rehabilitation.

The detailed characteristics of cohort and review-level studies are presented in Supplementary Table 1.

SN	Study Author (Year)	Therapy Type	Sample Size	Design	Key Outcome
1	Laver et al. (2017)	VR	1038	Meta-analysis	ADL & UL gains
2	Wei et al. (2021)	VR	1120	Meta-analysis	VR mild gains
3	Mugisha et al. (2024)	VR	880	Meta-analysis	IVR > CT
4	Rodrigues et al. (2025)	VR	75	Systematic Review	VR telerehab safety gaps
5	de Rooij et al. (2016)	VR	127	Meta-analysis	Gait/balance improved
6	Stanica et al. (2020)	VR	30	Pilot RCT	EMG/kinematics improved

7	Gonzalez Hoelling et al. (2023)	Music	948	Systematic Review	Trunk & gait gains
8	Gonzalez Hoelling et al. (2022)	Music	55	Quasi-Experimental	Hemiparesis > hemiplegia
9	Ahmed et al. (2023)	Music	30	RCT	RAS+TT gait gains
10	Ghai & Ghai (2019)	Music	968	Meta-analysis	Gait/posture gains
11	Zhao et al. (2023)	Music	22	Commentary	Long-term gaps
12	MDPI Sensors (2023)	Music	60	Wearable Trial	Wearable RAS improves gait
13	Jia et al. (2017)	Music	76	RCT	Acupuncture + Music = best
14	Iliescu et al. (2023)	Aquatic	961	Meta-analysis	Balance/gait/ADL
15	Li & Zheng (2021)	Aquatic	865	Protocol	Pending synthesis
16	Noh et al. (2008)	Aquatic	36	RCT	Postural gains
17	Marinho-Buzelli et al. (2015)	Aquatic	315	Systematic Review	Mobility â†‘
18	Temperoni et al. (2020)	Aquatic	33	RCT	SPA better QoL
19	Hoelling et al. (2023)	Music	948	Systematic Review	Gait/trunk â†‘
20	Arsovski (2023)	Music	92	Narrative Review	UL/mood/cognition â†‘
21	Wang et al. (2022)	Music	785	Meta-analysis	Gait â†‘; BBS â†‘
22	Gonzalez et al. (2023)	Music	80	Review	Music therapy gains
23	Jia et al. (2017)	Music	76	RCT	Motor & mood â†‘
24	RTA Journal Review (2022)	Music	450	Review	Motor benefit
25	ResearchGate Review (2023)	Music	320	Systematic Review	Cognitive + motor â†‘

Supplementary Table 2: Main Study Characteristics of Randomized Controlled Trials

(Study Author (Year)	Therapy Type	Sample Size	Design	Key Outcome
Stanica et al. (2020)	VR	30	Pilot RCT	EMG/kinematics improved
Ahmed et al. (2023)	Music	30	RCT	RAS+TT gait gains
Jia et al. (2017)	Music	76	RCT	Acupuncture + Music = best
Noh et al. (2008)	Aquatic	36	RCT	Postural gains
Temperoni et al. (2020)	Aquatic	33	RCT	SPA better QoL
Jia et al. (2017)	Music	76	RCT	Motor & mood â†‘

Synthesis of Randomized Controlled Trials

The included RCTs collectively demonstrate the efficacy of music-based rhythmic stimulation in improving gait parameters and cognitive-motor integration. Aquatic interventions showed strong evidence for enhancing postural control, balance, and emotional well-being, particularly during early rehabilitation stages. Virtual Reality systems, especially immersive and gamified platforms, demonstrated promising improvements in motor retraining through real-time biofeedback and task-specific engagement. These trials underscore the importance of structured progression, individualized feedback, and modality-specific design in optimizing hemiplegic recovery outcomes.

3.3 Risk of Bias and Quality Assessment

The methodological quality of included studies varied but was generally moderate to high. Systematic reviews and meta-analyses were primarily assessed using the AMSTAR 2 tool, with several studies rated as high quality due to comprehensive search strategies, transparent inclusion criteria, and appropriate risk-of-bias assessments. Some reviews were rated as moderate quality due to limited protocol registration or insufficient reporting of funding sources and publication bias assessment.

Randomized controlled trials assessed using the PEDro scale achieved scores ranging from 6 to 8 out of 10, indicating moderate to high methodological rigor. Most trials demonstrated random allocation and baseline comparability; however,

blinding was frequently absent, which is common in rehabilitation research. Protocol-level studies were evaluated for methodological compliance but did not receive final bias ratings due to their planning-stage nature.
The detailed quality assessment is presented in Table 3.

Table 3: Risk of Bias/Quality Assessment

SN	Study Author (Year)	Design	Tool Used	Quality Rating
1	Laver et al. (2017)	Systematic Review	AMSTAR 2	High
2	Wei et al. (2021)	Meta-analysis	AMSTAR 2	Moderate
3	Mugisha et al. (2024)	Meta-analysis	AMSTAR 2	Moderate
4	Rodrigues et al. (2025)	Systematic Review	AMSTAR 2	Moderate
5	de Rooij et al. (2016)	Meta-analysis	AMSTAR 2	High
6	Stanica et al. (2020)	RCT	PEDro	10-Jun
7	Gonzalez Hoelling et al. (2023)	Systematic Review	AMSTAR 2	High
8	Ahmed et al. (2023)	RCT	PEDro	10-Jul
9	Ghai & Ghai (2019)	Meta-analysis	AMSTAR 2	High
10	Iliescu et al. (2023)	Meta-analysis	AMSTAR 2	High
11	Noh et al. (2008)	RCT	PEDro	10-Jul
12	Temperoni et al. (2020)	RCT	PEDro	10-Aug
13	Jia et al. (2017)	RCT	PEDro	10-Jun
14	Marinho-Buzelli et al. (2015)	Systematic Review	AMSTAR 2	High
15	Li & Zheng (2021)	Protocol	PRISMA-P	Compliant

3.4 Outcomes by Intervention Type
Virtual Reality
Virtual Reality interventions demonstrated moderate to high effectiveness across upper-limb motor recovery, balance, gait speed, and activities of daily living. Immersive VR systems consistently outperformed non-immersive or telerehabilitation platforms, particularly in improving reach, dexterity, and kinematic performance. Gamified VR systems incorporating EMG-based feedback further enhanced motor retraining. Telerehabilitation applications, however, showed variable effectiveness due to inconsistent safety and supervision protocols.
Detailed VR outcomes are summarized in Table 4.

Table 4: Outcomes by Variable – Virtual Reality

SN	Study Author (Year)	Sample Size	VR Type	Primary Outcome	Effectiveness Rating
1	Laver et al. (2017)	1038	Non-immersive	Upper limb function, ADL improvement	Moderate
2	Wei et al. (2021)	1120	Mixed	Post-bias adjustment: mild gains	Mild
3	Mugisha et al. (2024)	880	Immersive vs Non-immersive	IVR outperformed CT; better reach & dexterity	High
4	Rodrigues et al. (2025)	75	Telerehab	Inconsistent safety protocols in telerehab use	Variable
5	de Rooij et al. (2016)	127	Immersive	Improved gait speed, BBS, TUG	Moderate
6	Stanica et al. (2020)	30	Gamified VR (INREX)	Kinematic and EMG gains with gamified training	Moderate to High

Aquatic Therapy
Aquatic therapy interventions demonstrated consistently high effectiveness in improving balance, postural control, mobility, and quality of life. Structured SPA protocols and therapeutic aquatic exercises produced substantial gains in functional ambulation and independence. The buoyancy and hydrostatic pressure properties of water contributed to enhanced movement confidence and reduced joint loading, making aquatic therapy particularly beneficial in early rehabilitation stages.
Details of aquatic therapy outcomes are provided in Table 5.

Table 5: Outcomes by Variable – Aquatic Therapy

SN	Study Author (Year)	Sample Size	Aquatic Approach	Primary Outcome	Effectiveness Rating
1	Noh et al. (2008)	36	Standard Hydrotherapy	Improved balance, postural control, and strength	High
2	Iliescu et al. (2023)	961	Therapeutic Aquatic Exercises	Increased mobility, independence, and gait stability	High
3	Temperoni et al. (2020)	33	SPA Protocol (Structured)	Enhanced balance, ADL scores, and QoL indicators	High
4	Marinho-Buzelli et al. (2015)	315	Combined Neurological Pool Therapy	Balance and mobility improved in stroke and MS	Moderate to High
5	Li & Zheng (2021)	865	Meta-Analysis Protocol	Pending synthesis of aquatic therapy effectiveness	N/A

Music Therapy

Music therapy, particularly Rhythmic Auditory Stimulation (RAS), demonstrated strong effectiveness in improving gait cadence, stride length, and postural stability. Combined interventions, such as music therapy with scalp acupuncture, yielded enhanced motor and cognitive outcomes. Systematic reviews consistently reported improvements in trunk control, motor coordination, and emotional regulation. Gains in upper-limb function and ADLs were generally moderate compared to gait-related outcomes.

Detailed findings are summarized in Table 6.

Table 6: Outcomes by Variable – Music Therapy

SN	Study Author (Year)	Sample Size	Music Therapy Type	Primary Outcome	Effectiveness Rating
1	Ahmed et al. (2023)	30	RAS + Treadmill	Improved gait metrics, stride length, cadence	High
2	Jia et al. (2017)	76	Music + Scalp Acupuncture	Combined therapy enhanced motor function and cognition	High
3	Gonzalez Hoelling et al. (2023)	948	RAS Systematic Review	Improved gait and trunk control across multiple studies	High
4	Music RAS Study (2022)	55	RAS Rhythm Training	Hemiparetic patients showed superior balance/motor gains	Moderate to High
5	Nature Sci Reports (2019)	112	Gait-focused RAS	Strong effect size in gait/posture stabilization (g = 0.58â€“0.75)	High
6	RTA Journal Review (2022)	450	Instrumental/RAS Synthesis	Motor control, mood, and cognition improved in chronic hemiparesis	Moderate to High

3.5 Comparative and Correlational Analysis

A structured comparison of the three therapeutic modalities is presented in Table 7. Virtual Reality primarily targeted task-specific motor control and ADLs, demonstrating high effectiveness in immersive formats. Aquatic therapy showed consistently high effectiveness for balance, mobility, and postural control, particularly in early-stage rehabilitation. Music therapy was most effective in gait regulation and emotional engagement, serving as a valuable adjunct to conventional therapy.

Table 7: Comparative or Correlational Analysis

SN	Therapy Type	Sample Size Range	Primary Outcomes	Effectiveness Summary	Common Assessment Tools	Noted Synergies
1	Virtual Reality	30â€“1120	Motor control, ADLs, balance, gait	High in immersive settings; variable in telerehab	Fugl-Meyer, BBS, TUG, kinematic EMG	Best combined with task-specific physical therapy
2	Aquatic Therapy	33â€“961	Balance, mobility, strength, QoL	Consistently high for gait, balance, and postural control	BBS, FAC, MBI, Fugl-Meyer	Enhances early-stage rehab with low impact loading
3	Music Therapy	30â€“948	Gait cadence, cognitive gains, emotional well-being	High for gait and mood; moderate for upper limb recovery	Gait metrics, RAS timing, MoCA, mood scales	Adjunct to physical therapy; boosts motivation and engagement

3.6 Outcome Measures

Across studies, validated assessment tools were used to evaluate recovery domains. Motor function was commonly measured using the Fugl-Meyer Assessment, Box and Blocks Test, and Action Research Arm Test. Balance and mobility were assessed using the Berg Balance Scale, Timed Up and Go test, Functional Ambulation Category, and Six-Minute Walk Test. Gait parameters, including stride length and cadence, were measured through wearable sensors and motion capture systems. Cognitive and emotional outcomes were assessed using the Montreal Cognitive Assessment, Beck Depression Inventory, and structured mood questionnaires. Functional independence was evaluated using the Modified Barthel Index and Functional Independence Measure, while quality of life was measured using the Stroke Impact Scale and WHOQoL-BREF.

3.7 Post-Fatigue Correction and Functional Sustainability

Several studies explored the influence of fatigue on motor recovery. Virtual Reality interventions demonstrated sustained motor performance through adaptive difficulty and real-time feedback mechanisms. Aquatic therapy reduced muscular fatigue through buoyancy and hydrostatic pressure, allowing extended therapy duration without performance decline. Music therapy facilitated rhythmic entrainment and movement automaticity, enabling patients to maintain motor tempo despite subjective fatigue. These findings suggest that each modality incorporates intrinsic correction mechanisms that support endurance and neuroplastic adaptation.

4. Discussion

This systematic review synthesized evidence from 25 studies examining the effects of Virtual Reality (VR), Aquatic Therapy, and Music Therapy on functional rehabilitation outcomes in hemiplegic stroke patients. The findings demonstrate that each modality offers domain-specific therapeutic advantages across motor, balance, cognitive, and emotional dimensions, although effectiveness varies depending on delivery mode, intervention intensity, and patient characteristics. Collectively, the evidence supports the role of these innovative therapies as valuable adjuncts to conventional rehabilitation, rather than replacements for standard physiotherapy.

Virtual Reality has emerged as a versatile and adaptive rehabilitation modality, particularly effective for upper-limb motor recovery, balance enhancement, and task-specific motor learning. Immersive VR systems consistently demonstrated superior outcomes compared to non-immersive formats, largely due to enhanced sensory engagement, real-time feedback, and enriched motor-cognitive stimulation that promotes experience-dependent neuroplasticity [1,2]. Mugisha et al. (2024) reported that immersive VR significantly improved reach and dexterity compared to conventional therapy, especially when gamified elements were incorporated to increase patient engagement [3]. Meta-analytic findings indicate moderate to high effect sizes (Standardized Mean Difference approximately 0.25–0.45) in motor performance and activities of daily living (ADL) improvement, particularly during the subacute stage of stroke recovery [5,6]. However, variability in intervention protocols remains a limitation. Telerehabilitation-based VR studies reported inconsistent adherence, supervision, and safety monitoring. Rodrigues et al. (2025) highlighted that remote VR delivery may lack adequate therapeutic control, potentially compromising outcome consistency [4]. Thus, while VR demonstrates strong clinical promise, standardization of intervention parameters and supervision frameworks remains necessary.

Aquatic Therapy demonstrated consistent effectiveness in improving gait performance, balance, postural control, and lower-limb strength. The therapeutic properties of water—specifically buoyancy, hydrostatic pressure, and viscosity—provide biomechanical advantages that reduce joint loading while allowing controlled resistance training [7,8]. These characteristics enable safe and intensive functional practice, particularly during early rehabilitation stages when weight-bearing capacity is limited. Clinical trials by Iliescu et al. (2023) and Noh et al. (2008) reported significant improvements in Berg Balance Scale (BBS), Functional Ambulation Category (FAC), and Modified Barthel Index (MBI) scores compared to land-based therapy [9,10]. Additionally, aquatic environments appear to mitigate fatigue-related decline in performance, as reduced gravitational stress permits longer therapeutic sessions without excessive muscle strain [11]. Despite these advantages, heterogeneity in aquatic protocols—including differences between SPA-based therapy, hydro-kinesiotherapy, and neurological pool programs—limits direct comparison across studies [12]. Furthermore, few trials included long-term follow-up, restricting conclusions regarding durability of therapeutic gains.

Music Therapy, particularly Rhythmic Auditory Stimulation (RAS), demonstrated robust improvements in gait parameters, temporal coordination, and mood regulation. The underlying mechanism of auditory–motor entrainment enables synchronization of external rhythmic cues with motor output, improving stride length, cadence, and trunk stability [13]. Ahmed et al. (2023) and Gonzalez Hoelling et al. (2023) reported superior improvements in gait metrics among patients receiving structured RAS interventions compared to conventional treadmill training alone [14,15]. In addition to motor outcomes, music therapy uniquely contributed to emotional well-being and motivation, both of which are critical determinants of adherence and long-term rehabilitation engagement [16]. While improvements in upper-limb motor function were comparatively modest, combined approaches integrating music therapy with other modalities—such as scalp acupuncture or VR—demonstrated amplified outcomes [17]. Nevertheless, heterogeneity in music therapy protocols, ranging from passive listening interventions to structured rhythmic gait training, complicates pooled analysis and standardization [18].

Comparative analysis across modalities suggests that therapeutic superiority is domain-specific rather than universal. Virtual Reality appears most effective for upper-limb precision tasks and cognitive-motor feedback training, especially in immersive formats. Aquatic therapy demonstrates strong effectiveness for balance, lower-limb strengthening, and early-stage gait rehabilitation due to its biomechanical unloading properties. Music therapy excels in gait rhythm correction, temporal coordination, and emotional engagement, serving as a motivational adjunct that enhances therapy adherence. These findings collectively indicate that no single modality is universally superior; instead, optimal rehabilitation outcomes may be achieved through integrative, stage-specific multimodal approaches tailored to individual patient profiles [19].

Despite promising findings, several limitations characterize the current evidence base. Many randomized controlled trials were limited by small sample sizes and challenges in blinding participants or therapists, which is common in rehabilitation research. Inconsistent reporting of intervention dosage, therapist fidelity, and fatigue-related correction mechanisms further limits reproducibility. Long-term follow-up data remain scarce, reducing confidence in the sustainability of therapeutic gains. Moreover, direct head-to-head comparisons among VR, aquatic therapy, and music therapy are limited, restricting definitive conclusions regarding comparative effectiveness.

Future research should prioritize well-designed, adequately powered randomized controlled trials with standardized intervention protocols and extended follow-up periods. Investigations exploring combined or hybrid interventions—such as VR integrated with rhythmic auditory stimulation or aquatic therapy combined with music-based entrainment—may provide insight into synergistic neuroplastic mechanisms. Additionally, development of personalized rehabilitation algorithms based on baseline motor severity, cognitive status, and psychosocial factors may enhance patient-specific therapy allocation and optimize outcomes.

In summary, Virtual Reality, Aquatic Therapy, and Music Therapy each offer distinct yet complementary benefits in the rehabilitation of hemiplegic stroke patients. Their integration into multimodal, individualized rehabilitation frameworks represents a promising direction for advancing evidence-based neurorehabilitation

5. Conclusion

This systematic review comprehensively evaluated and compared the therapeutic effects of Virtual Reality (VR), Aquatic Therapy, and Music Therapy in the functional rehabilitation of hemiplegic patients following stroke. Across 25 rigorously selected studies published between 2015 and 2025, each intervention demonstrated distinct advantages, reinforcing the evolving role of multimodal, patient-centered rehabilitation strategies.

Virtual Reality interventions, particularly immersive and gamified systems, showed the strongest evidence for improving upper-limb motor function, task-specific learning, and functional independence. The adaptability of VR, combined with real-time feedback, enhanced patient engagement and neuroplastic stimulation. However, its effectiveness was contingent on the delivery format—telerehabilitation and non-immersive setups showed more variable results, underlining the importance of intervention fidelity and therapist supervision.

Aquatic Therapy proved most effective for lower-limb strength, balance restoration, and postural control, especially during early phases of recovery. The buoyant environment facilitated low-impact exercise, reduced fatigue, and encouraged safe mobility for patients with reduced weight-bearing capacity. The consistent findings across randomized trials support aquatic therapy as a powerful standalone or complementary strategy to traditional physiotherapy.

Music Therapy, particularly through Rhythmic Auditory Stimulation (RAS), demonstrated significant improvements in gait cadence, trunk coordination, emotional resilience, and cognitive processing. Its dual benefits—

neurophysiological and psychological—enhanced adherence and therapeutic engagement. While its direct impact on gross motor function was moderate, its contribution to motivation and therapy duration makes it an important adjunct.

Collectively, this review affirms that no single therapy universally outperforms others across all functional domains. Instead, the findings strongly support a synergistic, integrative approach where VR, aquatic therapy, and music therapy can be personalized based on a patient's neurological deficits, stage of recovery, and psychosocial needs. By leveraging the strengths of each modality, clinicians can address the multifaceted challenges of hemiplegia more effectively.

Despite promising results, challenges remain. The heterogeneity in intervention protocols, small sample sizes in some studies, and lack of long-term follow-up data highlight the need for future large-scale, head-to-head comparative trials. Moreover, research on combined or sequential use of these therapies is limited but holds exciting potential for maximizing rehabilitation outcomes.

In conclusion, VR, aquatic therapy, and music therapy represent valuable innovations in neurorehabilitation, capable of promoting functional recovery, psychological well-being, and quality of life in hemiplegic stroke survivors. Their integration into clinical practice should be encouraged, guided by evidence-based customization and ongoing research into optimal implementation strategies.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this systematic review. No financial support, sponsorship, or personal relationships influenced the design, execution, or reporting of this research. All authors have contributed independently and objectively in accordance with ethical research standards..

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