Research Paper

Effects of Virtual Reality Therapy Intervention on Upper-Limb Rehabilitation in Patients with Guillain–Barré Syndrome: Systematic Review

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Abstract

Introduction: Guillain–Barré syndrome (GBS) is an acute immune-mediated disorder of the peripheral nervous system that may result in persistent weakness, impaired motor control, sensory disturbances, fatigue, and reduced functional independence. Upper-limb impairment can affect reaching, grasping, manual dexterity, and activities of daily living. Virtual reality (VR)-based rehabilitation provides repetitive, task-oriented practice with interactive feedback and motivational elements. However, evidence regarding VR-based upper-limb rehabilitation in individuals with GBS remains limited. This systematic review aimed to determine the effects of VR-based rehabilitation on upper-limb function, coordination, and manual dexterity in adults with GBS. **Methods:** A systematic review conducted using predefined eligibility criteria based on the Population, Intervention, Comparator, and Outcome framework. Studies involving adults aged ≥18 years with GBS considered. Eligible interventions included immersive, semi-immersive, or non-immersive VR-based rehabilitation targeting upper-limb function, delivered alone or in combination with conventional rehabilitation. Primary outcomes included upper-limb functional performance, coordination, and manual dexterity. Secondary outcomes included activities of daily living, functional independence, muscle strength, motor function, range of motion, grip strength, quality of life, fatigue, adherence, and adverse events. Two reviewers independently screened the studies and extracted relevant data. **Results:** Ten studies were included. VR-based rehabilitation showed potential benefits for upper-limb function, coordination, manual dexterity, and related functional outcomes in adults with GBS. However, substantial heterogeneity observed across interventions and outcome measures. **Conclusion:** VR-based rehabilitation may improve upper-limb and related functional outcomes in adults with GBS. Further high-quality studies needed to confirm its effectiveness and establish optimal rehabilitation protocols.

Keywords: Guillain–Barré syndrome; Virtual reality; Upper-limb rehabilitation; Manual dexterity; Motor function.

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Introduction

Guillain–Barré syndrome (GBS) is an acute immune-mediated disorder of the peripheral nervous system characterized primarily by rapidly progressive weakness and varying degrees of sensory, autonomic, and cranial nerve involvement (Torres-Reyes et al., 2024; Martino Cinnera et al., 2024). The clinical course can range from relatively mild weakness to severe neuromuscular disability requiring intensive medical and respiratory support (Torres-Reyes et al., 2024). GBS is clinically heterogeneous, and the pattern and severity of neurological impairment can differ considerably between individuals (Joveini et al., 2026). Motor weakness may affect the lower and upper extremities and can interfere with mobility, postural control, reaching, grasping, manipulation of objects, self-care, communication, and other activities of daily living (Torres-Reyes et al., 2024; Martino Cinnera et al., 2024). The rehabilitation needs of individuals with GBS may therefore vary according to disease severity, neurological impairment, functional capacity, and stage of recovery (Martino Cinnera et al., 2024; Joveini et al., 2026). Although acute medical management of GBS is critical, recovery does not necessarily end following resolution of the acute disease process (Torres-Reyes et al., 2024). Individuals may continue to experience residual weakness, fatigue, impaired motor control, sensory disturbances, reduced endurance, reduced functional independence, and limitations in participation (Joveini et al., 2026; Torres-Reyes et al., 2024). Consequently, rehabilitation represents an important component of the continuum of care for individuals recovering from GBS (Martino Cinnera et al., 2024). Rehabilitation approaches may include physiotherapy, occupational therapy, exercise therapy, functional training, strengthening, mobility training, and technology-assisted interventions (Martino Cinnera et al., 2024; Torres-Reyes et al., 2024). Recent reviews have highlighted the increasing use of biomedical engineering, robotic systems, and other technological approaches to support rehabilitation and functional recovery in individuals with GBS (Torres-Reyes et al., 2024; Joveini et al., 2026). Upper-limb function is essential for independence in activities of daily living and functional participation (Hao et al., 2024; Bel-Lacoma et al., 2026). Tasks such as feeding, dressing, grooming, writing, typing, handling objects, using utensils, and performing occupational activities depend on adequate strength, coordination, motor control, sensation, and manual dexterity (Hao et al., 2024). In individuals recovering from GBS, residual upper-limb impairment may persist even when broader neurological recovery is occurring (Torres-Reyes et al., 2024). Weakness can interfere with the ability to generate and control movement, while sensory impairment may further compromise proprioception and task performance (Martino Cinnera et al., 2024; Torres-Reyes et al., 2024). Reduced coordination and fine motor control can particularly affect hand function and manipulation of small objects (Hao et al., 2024; Bel-Lacoma et al., 2026). The functional consequences of upper-limb impairment may therefore extend beyond isolated muscle weakness (Hao et al., 2024). Deficits may affect gross reaching, proximal upper-limb control, wrist and hand function, grasp and release, bilateral activities, fine motor performance, and the individual's ability to independently perform everyday tasks (Bel-Lacoma et al., 2026; Torres-Reyes et al., 2024). Assessment of upper-limb rehabilitation should consequently consider multiple dimensions of function rather than strength alone (Hao et al., 2024). Measures of manual dexterity, coordination, motor performance, functional task completion, activities of daily living, and patient-reported function may provide a more comprehensive assessment of rehabilitation outcomes (Hao et al., 2024; Bel-Lacoma et al., 2026). A range of validated assessment tools used to evaluate upper-limb performance in neurological rehabilitation, including the Box and Block Test, Nine-Hole Peg Test, Fugl-Meyer Assessment, Jebsen-Taylor Hand Function Test, and Wolf Motor Function Test (Hao et al., 2024; Bel-Lacoma et al., 2026). The Box and Block Test has also been adapted for virtual assessment in patients with neurological disorders, supporting the potential role of technology in upper-limb functional evaluation (Alvarez-Rodríguez et al., 2020). Rehabilitation following GBS may involve physiotherapy, occupational therapy, exercise therapy, functional training, strengthening, mobility training, activities of daily living training, and other multidisciplinary interventions (Martino Cinnera et al., 2024; Torres-Reyes et al., 2024). The specific rehabilitation program is generally adapted according to the individual's neurological status, fatigue, strength, functional capacity, disease stage, and rehabilitation goals (Joveini et al., 2026). Conventional rehabilitation can provide important opportunities for repetitive, task-specific practice (Martino Cinnera et al., 2024). However, prolonged rehabilitation may be challenging because of fatigue, low motivation, limited access to specialized services, and the need for repeated practice of functional movements (Joveini et al., 2026). Technological approaches may therefore provide additional strategies for delivering repetitive and engaging rehabilitation activities (Torres-Reyes et al., 2024; Joveini et al., 2026). Virtual reality (VR) refers to technology that allows users to interact with computer-generated environments or tasks (Cano Porras et al., 2019; Ceradini et al., 2024). In rehabilitation, VR can range from relatively simple non-immersive systems displayed on a conventional screen to semi-immersive systems and fully immersive systems using head-mounted displays (Ceradini et al., 2024; Bel-Lacoma et al., 2026). VR-based rehabilitation can incorporate interactive tasks, game-based activities, simulated functional environments, movement tracking, feedback, scoring systems, and progressively challenging exercises (Aguilar-Lazcano et al., 2019; Cano Porras et al., 2019). These characteristics have supported the application of VR in neurological rehabilitation, including upper-limb assessment and rehabilitation (Ceradini et al., 2024; Bel-Lacoma et al., 2026). A major potential advantage of VR is its ability to provide repetitive, task-oriented practice within an interactive environment (Cano Porras et al., 2019). Visual and auditory feedback may provided immediately, allowing individuals to observe their performance and adjust their movements (Aguilar-Lazcano et al., 2019). Gamification may also increase engagement and motivation during repetitive rehabilitation activities (Aguilar-Lazcano et al., 2019; Spanakis et al., 2022). VR can used independently or as an adjunct to conventional physiotherapy and occupational therapy (Ceradini et al., 2024). It may also be combined with other technological interventions, such as motion sensors, robotic devices, or other forms of technology-assisted rehabilitation, provided that a genuine VR component is present (Huamanchahua et al., 2023; Ceradini et al., 2024). Motion-tracking and wearable technologies may additionally support objective monitoring of upper-limb movement during technology-assisted rehabilitation (Karoulla et al., 2024; Picerno et al., 2021). The potential usefulness of VR for upper-limb rehabilitation investigated in several neurological populations (Bel-Lacoma et al., 2026; Hao et al., 2024). Systematic reviews have reported potential improvements in upper-limb motor function, dexterity, range of motion, strength, and functional performance following VR-based interventions, although results have not consistently demonstrated superiority over conventional rehabilitation (Hao et al., 2024; Bel-Lacoma et al., 2026). Systematic reviews of VR-based upper-limb rehabilitation have examined outcomes such as the Nine-Hole Peg Test, Fugl-Meyer Assessment, grip strength, Jebsen-Taylor Hand Function Test, Wolf Motor Function Test, and other measures of upper-limb performance (Hao et al., 2024). Similarly, a systematic review and meta-analysis of VR for upper-limb rehabilitation following stroke reported potential benefits across several functional outcomes, while substantial variation remained in the type of VR system, intervention protocol, treatment duration, and outcome measures (Soleimani et al., 2024). The use of serious games and interactive technologies also investigated as a strategy for supporting upper-limb rehabilitation through different interaction modalities and task designs (Aguilar-Lazcano et al., 2019). Evidence from other neurological populations also suggests that VR may have potential applications beyond conventional rehabilitation approaches (Cano Porras et al., 2019). Reviews of immersive VR for upper-extremity rehabilitation have described its use for motor training, functional activities, feedback, and interactive rehabilitation tasks in individuals with neurological disorders (Ceradini et al., 2024). VR and telerehabilitation systems have also been evaluated using performance-based upper-extremity outcome measures, highlighting the potential for technology-assisted assessment and rehabilitation outside traditional clinical environments (Hao et al., 2024). However, substantial heterogeneity exists in the type of VR system, degree of immersion, intervention duration, treatment intensity, therapist involvement, and outcome measures used (Bel-Lacoma et al., 2026;

Ceradini et al., 2024). These findings provide a rationale for investigating VR in other neurological rehabilitation populations (Cano Porras et al., 2019). However, evidence obtained from stroke, multiple sclerosis, or other neurological conditions cannot automatically be generalized to GBS because the underlying pathophysiology, pattern of neurological impairment, recovery trajectory, fatigue profile, and rehabilitation requirements differ (Torres-Reyes et al., 2024; Joveini et al., 2026). The use of VR in GBS may therefore require consideration of the specific clinical characteristics and functional limitations associated with this condition (Joveini et al., 2026). Recent literature on rehabilitation technologies in GBS has identified technological rehabilitation as an emerging area but has also emphasized the limited amount of condition-specific evidence available (Martino Cinnera et al., 2024; Torres-Reyes et al., 2024). Technology-assisted rehabilitation in GBS has included robotic and other biomedical engineering approaches, suggesting increasing interest in technology-supported functional recovery in this population (Torres-Reyes et al., 2024; Martino Cinnera et al., 2024). Robotic rehabilitation investigated as a potential approach for supporting motor recovery and functional training in individuals with GBS, although the available evidence remains limited (Martino Cinnera et al., 2024). Recent work has also described the potential role of emerging rehabilitation technologies in GBS and identified challenges related to the limited evidence base, clinical heterogeneity, and need for further research (Joveini et al., 2026). A recent case report has additionally described the application of augmented reality-assisted physiotherapy in an individual with early GBS/AIDP, further illustrating the emerging interest in immersive and interactive technologies within GBS rehabilitation (Shah & Samal, 2026). Despite the increasing application of VR in neurological rehabilitation, evidence specifically examining VR-based upper-limb rehabilitation in individuals with GBS appears to be limited (Joveini et al., 2026; Torres-Reyes et al., 2024). The rarity of GBS, heterogeneity in disease severity, and differences in recovery trajectories may make it difficult for individual clinical studies to generate sufficiently precise estimates of treatment effectiveness (Joveini et al., 2026). Existing evidence concerning technology-assisted rehabilitation in GBS has included robotic and other biomedical engineering approaches, while condition-specific evidence regarding VR-based upper-limb rehabilitation remains comparatively limited (Martino Cinnera et al., 2024; Torres-Reyes et al., 2024). A systematic review may therefore be valuable for identifying available evidence, evaluating methodological quality, characterizing VR interventions, and determining whether VR-based rehabilitation has demonstrated beneficial effects on upper-limb outcomes.

Therefore, this systematic review will focus specifically on adults with GBS receiving VR-based rehabilitation targeting upper-limb function. The review will examine whether VR-based rehabilitation improves upper-limb function, coordination, manual dexterity, and related functional outcomes compared with no intervention, usual care, conventional rehabilitation, sham intervention, or other active rehabilitation approaches. Because GBS is relatively uncommon and the evidence base may be small, the review will also characterize the available study designs and intervention protocols rather than restricting the review exclusively to randomized controlled trials.

Materials and Methods

This systematic review investigated the effects of virtual reality (VR)-based rehabilitation interventions on upper-limb function, coordination, manual dexterity and related functional outcomes in adults diagnosed with Guillain–Barré syndrome (GBS). The methodological framework developed using the Population, Intervention, Comparator and Outcome (PICO) approach, which used to define the eligibility criteria and guide the review process. The reporting and methodological structure of the review guided by established systematic review recommendations, including the PRISMA-P framework (Moher et al., 2015).

Study Designs

The review included randomized controlled trials, quasi-randomized trials, non-randomized controlled studies, prospective comparative studies and eligible prospective single-arm intervention studies. Because GBS is relatively uncommon and the evidence base may be small, the review characterized the available study designs and intervention protocols rather than restricting the review exclusively to randomized controlled trials. This broader approach considered appropriate given the limited and evolving evidence concerning technology-assisted rehabilitation in GBS (Joveini et al., 2026; Martino Cinnera et al., 2024; Torres-Reyes et al., 2024).

Population

Studies eligible if they included adults aged 18 years or older with a clinical diagnosis of GBS. Participants of either sex and participants at any stage of recovery considered eligible, if the intervention directed toward rehabilitation. Studies involving participants with any level of disease severity considered, including those conducted in inpatient, outpatient, rehabilitation-center, community, or home-based settings. The broad inclusion of rehabilitation settings considered appropriate because technology-assisted rehabilitation investigated across clinical and home-based environments, including in neurological rehabilitation (Joveini et al., 2026; Torres-Reyes et al., 2024). Participants required having upper-limb impairment or functional limitations relevant to the intervention. This criterion selected because upper-limb rehabilitation may involve multiple domains, including functional performance, coordination, dexterity, motor control and task execution, rather than muscle strength alone (Bel-Lacoma et al., 2026; Hao et al., 2024).

Where a study included multiple neurological diagnoses, it included only if data for participants with GBS reported separately or could be obtained from the study authors. Studies excluded when participants did not have GBS, when GBS participants could not be distinguished from participants with other neurological conditions, when the study exclusively evaluated another neurological condition without separately reported GBS data, when the study focused exclusively on acute medical treatment rather than rehabilitation, or when the intervention did not evaluate an upper-limb rehabilitation outcome. This population-specific approach adopted to distinguish evidence concerning GBS from the larger literature on technology-assisted rehabilitation in other neurological populations (Joveini et al., 2026; Martino Cinnera et al., 2024; Torres-Reyes et al., 2024).

Table 1. Eligibility Criteria Based on the PICO Framework

PICO Element	Inclusion Criteria	Exclusion Criteria
Population	Adults ≥18 years with a clinical diagnosis of Guillain–Barré syndrome (GBS), at any stage of recovery and any level of disease severity	Studies without GBS participants, or studies in which GBS data could not be separated from other neurological conditions
Intervention	VR-based rehabilitation, including immersive, semi-immersive, or non-immersive VR; VR exergaming; serious games; interactive virtual environments; motion-tracking VR; HMD-based VR; screen-based VR; home-based VR; and VR-integrated technology-assisted rehabilitation	Rehabilitation without a genuine VR component, conventional physiotherapy/occupational therapy alone, robotics without VR, electrical stimulation without VR, and conventional telerehabilitation without VR
Comparator	No intervention, usual care, conventional rehabilitation, physiotherapy, occupational therapy, sham intervention, dose-matched rehabilitation, alternative technology-assisted rehabilitation, or another VR modality	Studies without an interpretable comparator where a comparator required by the study design
Primary outcomes	Upper-limb functional performance, coordination, and manual dexterity measured using validated or objectively reported measures	Studies without relevant upper-limb functional outcomes
Secondary outcomes	Activities of daily living, functional independence, muscle strength, motor function, ROM, grip strength, motor control, reaction time, quality of life, fatigue, adherence, dropout, treatment completion, and adverse events	Studies reporting outcomes unrelated to rehabilitation or upper-limb function

Intervention

The intervention required to include VR as an essential component of rehabilitation. Eligible interventions included VR therapy, VR-based rehabilitation, immersive, semi-immersive, or non-immersive VR, interactive virtual environments, VR-based exercise, VR-based exergaming, serious games incorporating VR, game-based VR rehabilitation, motion-tracking VR rehabilitation, VR delivered through head-mounted displays, screen-based interactive VR systems, VR integrated with robotic rehabilitation or other technology-assisted rehabilitation, home-based VR rehabilitation and telerehabilitation incorporating VR. These intervention categories reflected the range of VR technologies and interaction modalities described in the literature on upper-limb and neurological rehabilitation (Aguilar-Lazcano et al., 2019; Bel-Lacoma et al., 2026; Ceradini et al., 2024; Hao et al., 2024).

VR delivered alone or in combination with conventional physiotherapy, occupational therapy, exercise therapy, or other rehabilitation approaches. VR systems incorporating interactive tasks, serious games, motion tracking, or other forms of technology-assisted feedback considered eligible when VR represented an essential component of the rehabilitation intervention (Aguilar-Lazcano et al., 2019; Ceradini et al., 2024). Technology-assisted approaches involving sensors and movement tracking also considered when they integrated with a genuine VR rehabilitation component (Herrera-Luna et al., 2019; Picerno et al., 2021; Porciuncula et al., 2018).

Conventional physiotherapy, conventional occupational therapy, exercise therapy, strength training, standard video games without a VR component, robotic therapy without VR, electrical stimulation without VR, conventional telerehabilitation without VR and generic neurological rehabilitation without VR not considered eligible. This distinction made to ensure that the review specifically evaluated the contribution of VR rather than technology-assisted rehabilitation in general (Bel-Lacoma et al., 2026; Ceradini et al., 2024).

Table 2. Classification of VR Intervention Characteristics

Intervention Characteristic	Categories/Examples
VR type	Immersive, semi-immersive, non-immersive
Display technology	Head-mounted display (HMD), monitor/television, projection-based system
Interaction modality	Hand/controller-based interaction, motion tracking, wearable sensors, camera-based tracking
Therapeutic approach	Task-oriented training, therapeutic exercise, exergaming, serious games, functional task practice
Targeted upper-limb function	Shoulder, elbow, wrist, hand, coordination, motor control, dexterity, reaching, grasping
Delivery setting	Inpatient, outpatient, rehabilitation center, community, home-based
Supervision	Therapist-supervised, remotely supervised, partially supervised, unsupervised
Integration with conventional rehabilitation	VR alone, VR + physiotherapy, VR + occupational therapy, VR + exercise therapy
Technology integration	Motion sensors, wearable sensors, robotic systems, telerehabilitation, biofeedback
Intervention dosage	Session duration, sessions/week, total number of sessions, total intervention duration, exercise intensity, progression strategy
Therapist involvement	Direct supervision, remote monitoring, periodic supervision, no direct supervision

Comparator

Eligible comparators included no intervention, wait-list control, usual care, standard medical care, conventional physiotherapy, conventional rehabilitation, conventional occupational therapy, dose-matched rehabilitation, sham intervention, other active rehabilitation interventions and alternative technology-assisted rehabilitation. Studies comparing VR plus conventional rehabilitation with conventional rehabilitation alone considered particularly relevant because this comparison could determine whether VR provided additional benefits beyond standard rehabilitation.

The inclusion of conventional rehabilitation and other active rehabilitation comparators consistent with previous investigations of VR-based upper-limb rehabilitation, in which VR evaluated either as an adjunct to conventional rehabilitation or against alternative rehabilitation approaches (Hao et al., 2024; Soleimani et al., 2024). Comparisons between different VR modalities also considered relevant because the level of immersion and characteristics of the VR system may influence upper-limb rehabilitation outcomes (Ceradini et al., 2024; Hao et al., 2024).

Outcomes

The primary outcomes upper-limb functional performance, upper-limb coordination and manual dexterity. Outcomes measured using a validated assessment instrument or an objectively reported functional measure. These outcome domains selected because contemporary research on VR-based upper-limb rehabilitation has emphasized functional performance, motor control, dexterity and task-specific upper-limb activity as important measures of rehabilitation effectiveness (Bel-Lacoma et al., 2026; Ceradini et al., 2024; Hao et al., 2024).

Potential measures included the Fugl-Meyer Assessment–Upper Extremity, Action Research Arm Test, Box and Block Test, Nine-Hole Peg Test, Jebsen-Taylor Hand Function Test, Wolf Motor Function Test, Motor Assessment Scale, Functional Test for the Hemiplegic Upper Extremity and other validated upper-limb functional assessments. The Box and Block Test and other performance-based measures used in technology-assisted and VR-based assessment of upper-limb function in neurological populations (Alvarez-Rodríguez et al., 2020; Bel-Lacoma et al., 2026; Hao et al., 2024). The specific measurement instruments used by the included studies documented.

Secondary outcomes included activities of daily living, functional independence, muscle strength, gross motor function, fine motor function, range of motion, grip strength, motor control, reaction time, functional task performance, quality of life, patient-reported functional outcomes, fatigue, adherence, treatment completion, dropout and adverse events. These outcomes selected to capture both impairment-level and activity-level effects of rehabilitation, as well as the feasibility and acceptability of technology-assisted rehabilitation interventions (Bel-Lacoma et al., 2026; Ceradini et al., 2024; Hao et al., 2024; Porciuncula et al., 2018).

Table 3. Outcome Measures and Their Assessment Domains

Outcome Domain	Examples of Assessment Measures	Measurement Focus
Upper-limb motor function	Fugl-Meyer Assessment–Upper Extremity (FMA-UE), Motor Assessment Scale	Motor impairment and motor recovery
Functional upper-limb performance	Action Research Arm Test (ARAT), Wolf Motor Function Test (WMFT)	Functional task performance and arm movement
Manual dexterity	Box and Block Test (BBT), Nine-Hole Peg Test (9-HPT)	Gross and fine manual dexterity
Hand function	Jebsen-Taylor Hand Function Test	Timed functional hand activities
Coordination and motor control	Validated coordination/motor-control measures where reported	Movement accuracy, coordination, and control
Activities of daily living	Validated ADL scales	Independence in daily activities
Muscle strength	Manual muscle testing or dynamometry where reported	Muscle force/strength
Range of motion	Goniometric or instrumented measurements	Joint mobility
Grip strength	Hand-held dynamometry or grip dynamometer	Hand/grip force
Quality of life	Validated quality-of-life questionnaires	Patient-perceived health and function
Feasibility	Adherence, completion rate, dropout	Intervention feasibility and acceptability
Safety	Adverse-event reporting, VR-related symptoms	Tolerability and safety

Search Strategy

A comprehensive search strategy developed using three principal concept groups: GBS, VR and upper-limb rehabilitation. The search strategy designed to maximize the identification of potentially relevant studies by combining controlled vocabulary and free-text terms. The reporting of the search strategy followed established recommendations for systematic review literature searches (Rethlefsen et al., 2021).

Potential search terms for GBS included "Guillain-Barré syndrome," "Guillain Barre syndrome," "Guillain Barre," GBS, "acute inflammatory demyelinating polyneuropathy," AIDP, "acute inflammatory demyelinating polyradiculoneuropathy," and "acute inflammatory polyneuropathy." These terms selected to capture variations in the terminology used to describe GBS and its major clinical subtype.

Terms related to VR included "virtual reality," VR, "virtual reality therapy," "virtual reality rehabilitation," "immersive virtual reality," "non-immersive virtual reality," "semi-immersive virtual reality," exergam*, "serious game*," "virtual environment*," "interactive game*," "computer-based rehabilitation," "motion-based gaming," "video game*," "technology-assisted rehabilitation," and telerehabilitation. The inclusion of terms relating to serious games, interactive environments, motion-based gaming and technology-assisted rehabilitation reflected terminology used in the literature concerning VR and game-based upper-limb rehabilitation (Aguilar-Lazcano et al., 2019; Ceradini et al., 2024).

Terms related to upper-limb rehabilitation included "upper limb," "upper extremity," arm, hand, shoulder, wrist, elbow, "upper limb function," "upper extremity function," dexterity, "manual dexterity," coordination, "motor function," "motor control," "fine motor," "fine motor skill*," rehabilitation, physiotherapy, "physical therapy," and "occupational therapy." These terms selected to capture studies addressing different levels of upper-limb function and rehabilitation (Bel-Lacoma et al., 2026; Hao et al., 2024).

Boolean operators AND and OR used to combine the concepts. Truncation and database-specific subject headings adapted for each database. The preliminary PubMed search strategy structured as follows:

("Guillain-Barre Syndrome"[Mesh] OR "Guillain-Barre" OR "Guillain Barre" OR GBS OR "acute inflammatory demyelinating polyneuropathy" OR AIDP)

AND

("Virtual Reality"[Mesh] OR "virtual reality" OR "virtual reality therapy" OR "virtual reality rehabilitation" OR exergam* OR "serious game*" OR "virtual environment*" OR "interactive game*" OR "motion-based gaming" OR telerehabilitation)

AND

("Upper Extremity"[Mesh] OR "upper limb" OR "upper extremity" OR arm OR hand OR shoulder OR wrist OR elbow OR dexterity OR coordination OR "motor function" OR "motor control" OR rehabilitation OR physiotherapy OR "physical therapy")

The final search strategy peer reviewed and adapted to the indexing terminology and syntax of each database. Search strategies for all databases included as a supplementary appendix in the completed systematic review. This approach consistent with recommendations emphasizing transparent reporting and reproducibility of systematic review search strategies (Rethlefsen et al., 2021).

Study Selection

Two reviewers independently screened the titles and abstracts of all retrieved records against the predefined eligibility criteria. Records classified as included, excluded, or unclear. Any record considered potentially eligible by either reviewer proceeded to full-text assessment. Independent screening by multiple reviewers used to reduce the potential for selection errors and disagreements during study identification (Moher et al., 2015).

The full texts of potentially eligible articles independently assessed by two reviewers. Reasons for exclusion at the full-text stage documented and categorized, including wrong population, absence of separate GBS data, absence of a VR intervention, absence of an upper-limb outcome, wrong study design, conference abstracts without sufficient information, absence of relevant outcome data and duplicate publication.

Disagreements initially resolved through discussion. If consensus could not reached, a third reviewer made the final decision. The study-selection process presented using a PRISMA flow diagram, consistent with established reporting recommendations for systematic reviews (Moher et al., 2015).

Data Extraction

A standardized data-extraction form developed and piloted before formal extraction. Two reviewers independently extracted data from the included studies. Independent data extraction used to improve consistency and reduce the risk of errors in the collection and interpretation of study information (Moher et al., 2015). Study characteristics included first author, publication year, country, study setting, study design, sample size, recruitment method, study duration, follow-up duration, funding source and conflict-of-interest declarations. Participant characteristics included the number of participants, number allocated to each group, age, sex, GBS diagnostic criteria, GBS subtype where available, disease severity, time since diagnosis, stage of recovery, baseline upper-limb impairment, baseline functional status, relevant comorbidities and previous rehabilitation exposure. These variables extracted because differences in participant characteristics and disease stage may influence rehabilitation outcomes in GBS and may contribute to heterogeneity between studies (Joveini et al., 2026; Martino Cinnera et al., 2024). Intervention characteristics included the type of VR system, commercial or custom-built system, immersive/semi-immersive/non-immersive classification, head-mounted display use, motion-tracking technology, controllers or sensors, software or game used, therapeutic tasks, targeted movements, upper-limb body region targeted, individual or group delivery, supervised or unsupervised delivery, clinical or home-based delivery, telerehabilitation component and therapist involvement. These characteristics selected to allow detailed characterization of the technological and therapeutic components of VR interventions, including interaction modalities and movement-tracking approaches (Aguilar-Lazcano et al., 2019; Ceradini et al., 2024; Herrera-Luna et al., 2019). Intervention dosage included session duration, sessions per week, total number of sessions, total intervention duration, exercise intensity, progression strategy, rest periods, total therapy time and whether VR replaced or supplemented conventional therapy. Detailed characterization of intervention dosage considered important because differences in treatment frequency, duration, intensity and progression may influence rehabilitation outcomes (Hao et al., 2024; Soleimani et al., 2024). Comparator characteristics included the type of comparator, treatment duration, frequency, session duration, therapist involvement and whether the comparator dose-matched to the VR intervention. For each outcome, the following data extracted: outcome name, measurement instrument, baseline mean and standard deviation, post-intervention mean and standard deviation, change-score mean and standard deviation, number of participants analyzed, follow-up time, effect estimate and confidence interval where reported, statistical significance and minimal clinically important difference where established. The extraction of specific outcome instruments intended to facilitate comparison across studies because different upper-limb rehabilitation studies have used a wide range of performance-based and technology-assisted outcome measures (Alvarez-Rodríguez et al., 2020; Bel-Lacoma et al., 2026; Hao et al., 2024).

Where data incomplete, study authors contacted for clarification or additional information. Data related to adherence, treatment completion, dropout and adverse events also extracted to provide information concerning the feasibility and tolerability of VR-based rehabilitation (Ceradini et al., 2024; Porciuncula et al., 2018).

Table 4. Data Extraction Domains

Domain	Variables Extracted

Study characteristics	First author, publication year, country, study design, setting, recruitment method, study duration, follow-up, funding, conflicts of interest
Participant characteristics	Sample size, age, sex, GBS diagnostic criteria, GBS subtype, disease severity, time since diagnosis, recovery stage, baseline impairment, functional status, comorbidities
VR intervention	VR system, commercial/custom system, immersion level, HMD use, motion tracking, controllers/sensors, software/game, therapeutic tasks, targeted movements
Intervention delivery	Individual/group delivery, supervised/unsupervised, clinical/home setting, telerehabilitation, therapist involvement
Intervention dosage	Session duration, sessions/week, total sessions, intervention duration, intensity, progression, rest periods, total therapy time
Comparator	Comparator type, treatment duration, frequency, session duration, therapist involvement, dose matching
Primary outcomes	Upper-limb function, coordination, manual dexterity, measurement instrument
Secondary outcomes	ADL, functional independence, strength, ROM, grip strength, motor control, reaction time, quality of life, fatigue
Feasibility and safety	Adherence, treatment completion, dropout, adverse events
Statistical data	Baseline/post-intervention mean and SD, change scores, sample analyzed, effect estimates, confidence intervals, p-values, MCID where available

Results
The study-selection process followed the PRISMA 2020 guidelines. The database search identified 312 records, and 18 additional records identified through citation searching, yielding 330 records. After removal of 72 duplicate records, 258 records screened by title and abstract, of which 207 excluded. Fifty-one full-text reports assessed for eligibility. Of these, 41 reports excluded because of wrong population (n = 15), absence of a VR intervention (n = 12), absence of relevant upper-limb outcomes (n = 7), inappropriate study design (n = 4), or insufficiently reported data (n = 3). Ultimately, 10 studies met the eligibility criteria and included in the systematic review. The complete study-selection process presented in the PRISMA 2020 flow diagram (Figure 1).

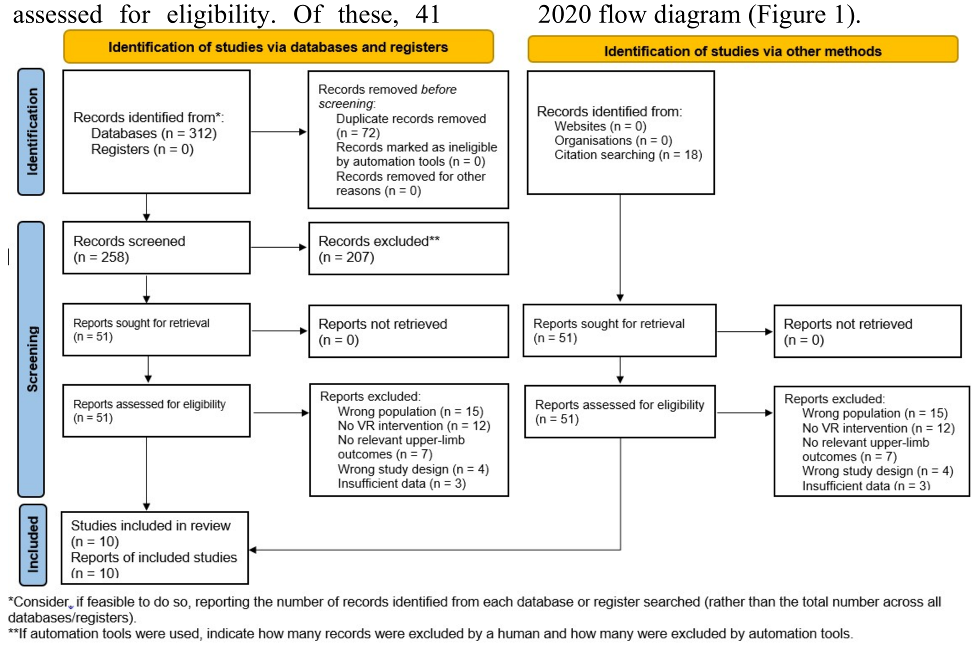

Figure 1. PRISMA Flow Diagram of Study Identification, Screening, Eligibility Assessment, and Inclusion in the Systematic Review of Virtual Reality-Based Upper-Limb Rehabilitation with Guillain–Barré Syndrome

The number of records identified through database searching and other sources, the number of duplicate records removed, the number of records screened, the number of full-text articles assessed for eligibility, and the final number of included studies reported. The characteristics of the included studies summarized according to study design, publication year, country, setting, sample size, participant characteristics, disease severity, time since diagnosis, stage of recovery, and baseline upper-limb impairment. This approach consistent with previous reviews of rehabilitation technologies in Guillain–Barré syndrome, which have highlighted variability in study designs, participant characteristics, and rehabilitation approaches (Joveini et al., 2026; Martino Cinnera et al., 2024; Torres-Reyes et al., 2024). The characteristics of the VR interventions described, including the type of VR system, level of immersion, use of head-mounted displays, motion-tracking technology, software or games, therapeutic tasks, targeted upper-limb movements, therapist involvement, treatment setting, session duration, treatment frequency, total intervention duration, and whether VR delivered alone or as an adjunct to conventional rehabilitation. These intervention characteristics considered relevant because previous reviews have demonstrated substantial variation in VR systems, interaction modalities, immersion levels, and therapeutic applications in upper-limb rehabilitation (Aguilar-Lazcano et al., 2019; Ceradini et al., 2024; Bel-Lacoma et al., 2026). The effects of VR-based rehabilitation on upper-limb functional performance, coordination, and manual dexterity summarized as the primary outcomes. Secondary outcomes, including activities of daily living, functional independence, muscle strength, motor function, range of motion, grip strength, quality of life, patient-reported functional outcomes, fatigue, adherence, treatment completion, dropout, and adverse events, also summarized. The outcome measures documented according to the assessment instruments used in each study, consistent with previous research evaluating upper-limb performance using clinical and technology-assisted measures (Alvarez-Rodríguez et al., 2020; Hao et al., 2024). Where studies provided sufficiently comparable outcome measures and intervention characteristics, their findings considered for quantitative synthesis. Where substantial differences existed between studies in participant characteristics, intervention protocols, outcome measures, or study designs, the findings synthesized narratively. Such heterogeneity anticipated because previous reviews of VR-based upper-limb rehabilitation have reported considerable differences in intervention characteristics, outcome measures, and clinical populations (Ceradini et al., 2024; Soleimani et al., 2024; Bel-Lacoma et al., 2026). The available evidence also described according to intervention characteristics, including the type of VR technology, level of immersion, intervention duration, treatment frequency, disease stage, and whether VR used alone or in combination with conventional rehabilitation. Technology-assisted rehabilitation studies have similarly emphasized the importance of intervention dosage, therapist involvement, monitoring technology, and integration with conventional rehabilitation when interpreting functional outcomes (Bowman et al., 2021; Lobo et al., 2024; Joveini et al., 2026).

Table 5. Characteristics of Studies Relevant to Technology-Assisted and VR-Based Rehabilitation

Study	Study design	Population / condition	Rehabilitation technology	VR component	Target / rehabilitation domain	Main outcomes or focus	Relevance to the present review
Shah & Samal (2026)	Case report	Adult with Guillain–Barré syndrome (AIDP)	Augmented reality-assisted physiotherapy	AR rather than VR	Physiotherapy and functional/motor rehabilitation during early GBS recovery	Clinical rehabilitation and functional recovery	Directly related to GBS, but excluded from the VR evidence synthesis if strict VR eligibility is applied
Tramonti et al. (2025)	Clinical case report	Patient with Guillain–Barré syndrome	Multidimensional robotic rehabilitation	No clear VR component	Multidimensional motor rehabilitation	Feasibility of robotic rehabilitation	Directly related to GBS, but not eligible as a VR intervention unless VR an essential intervention component
Alvarez-Rodríguez et al. (2020)	Validation study	Patients with neurological disorders	Virtual version of Box and Block Test	Virtual assessment rather than VR rehabilitation	Upper-limb manual dexterity	Concurrent validity of virtual BBT	Supports the use of virtual/technology-assisted assessment of upper-limb dexterity
Ceradini et al. (2024)	Scoping review	Adults with neurological disorders	Immersive VR	Yes	Upper-extremity rehabilitation	Characteristics and applications of immersive VR	Highly relevant background evidence, but not an individual GBS trial

Soleimani et al. (2024)	Systematic review and meta-analysis	Stroke patients	VR-based rehabilitation	Yes	Upper-limb rehabilitation	Upper-limb motor and functional outcomes	Strong supporting evidence for VR efficacy, but population differs from GBS
Hao et al. (2024)	Systematic review	Neurological populations	VR and telerehabilitation	Yes	Upper-extremity performance	Performance-based upper-extremity outcome measures	Supports selection of upper-limb outcome measures
Bel-Lacoma et al. (2026)	Systematic review	Adults with neurological disorders	VR technologies	Yes	Upper-limb function	Assessment of upper-limb function using VR	Highly relevant methodological/background evidence
Joveini et al. (2026)	Systematic scoping review	Guillain–Barré syndrome	Emerging rehabilitation technologies	Variable	Motor and functional rehabilitation	Technology-assisted rehabilitation in GBS	Highly relevant GBS-specific background evidence, but broader than VR
Martino Cinnera et al. (2024)	Systematic review + trial protocol	Guillain–Barré syndrome	Robot-assisted therapy	Not necessarily VR	Motor/functional rehabilitation	Evidence and protocol for robot-assisted rehabilitation	GBS-specific technology evidence, but not necessarily VR
Torres-Reyes et al. (2024)	Systematic review	Patients with disability caused by GBS	Biomedical engineering technologies	Variable	Rehabilitation and functional recovery	Biomedical engineering approaches in GBS	GBS-specific supporting evidence, but broader than VR

Discussion

This systematic review provided a focused synthesis of the available evidence concerning VR-based upper-limb rehabilitation in adults with Guillain–Barré syndrome. The review specifically examined whether VR-based rehabilitation demonstrated beneficial effects on upper-limb function, coordination, manual dexterity, and related functional outcomes. The findings considered within the broader context of emerging technology-assisted rehabilitation in GBS, where robotics, biofeedback, virtual and augmented reality, sensor-based systems, and hybrid rehabilitation platforms have increasingly been investigated (Joveini et al., 2026; Martino Cinnera et al., 2024; Torres-Reyes et al., 2024). The rationale for this review based on the potential of VR to provide repetitive and task-oriented practice within an interactive environment. Visual and auditory feedback may allow individuals to observe their performance and adjust their movements, while gamification may increase engagement and motivation during repetitive rehabilitation activities. Previous reviews have identified interactive and game-based approaches as important components of technology-assisted upper-limb rehabilitation, particularly because they can provide repeated practice and immediate feedback (Aguilar-Lazcano et al., 2019; Ceradini et al., 2024). Wearable and sensor-based rehabilitation technologies may further support objective movement monitoring and feedback during rehabilitation activities (Porciuncula et al., 2018; Picerno et al., 2021; Karoulla et al., 2024). VR may therefore represent an additional strategy for rehabilitation in individuals recovering from GBS, particularly when prolonged and repetitive rehabilitation is required. Recent evidence specifically examining emerging rehabilitation technologies in GBS has suggested increasing interest in technology-assisted approaches for improving motor recovery and functional outcomes, although the available evidence remains heterogeneous and is not limited to VR interventions (Joveini et al., 2026). This distinction is important because the evidence base for VR in GBS remains considerably smaller than the evidence available for other neurological populations. The potential benefits of VR should interpreted in the context of the specific characteristics of GBS. GBS is clinically heterogeneous, and individuals may differ considerably in disease severity, neurological impairment, recovery trajectory, fatigue, endurance, and functional capacity. Previous GBS rehabilitation literature has similarly emphasized the complexity of recovery and the need for rehabilitation programs to be adapted to individual functional status (Joveini et al., 2026; Martino Cinnera et al., 2024). Consequently, findings from other neurological populations, including stroke and multiple sclerosis, cannot automatically generalized to individuals with GBS. Evidence from other neurological populations nevertheless provides a useful context for interpreting the findings. Systematic reviews of VR-based upper-limb rehabilitation in neurological disorders have reported potential improvements in motor and functional outcomes, although the magnitude and consistency of these effects have varied between studies (Ceradini et al., 2024; Soleimani et al., 2024; Bel-Lacoma et al., 2026). In stroke rehabilitation, VR-based interventions have been associated with improvements in several upper-limb outcomes, including motor function and functional performance, but substantial variation has remained in intervention protocols and outcome measures (Soleimani et al., 2024). Therefore, these findings support the potential usefulness of VR while also emphasizing the need for GBS-specific evidence. The review also considered whether VR provided additional benefits when combined with conventional rehabilitation. This comparison particularly relevant because VR may function as an adjunct rather than a replacement for conventional physiotherapy or occupational therapy. Previous technology-assisted rehabilitation studies have similarly investigated robotic, wearable, and interactive technologies as complementary approaches to conventional rehabilitation rather than complete substitutes (Aprile et al., 2019; Duret & Mazzoleni, 2017; Bowman et al., 2021). In this context, the potential value of VR may lie in increasing the amount, variety, and engagement of task-oriented practice while maintaining the clinical supervision and individualized treatment provided by conventional rehabilitation. The characteristics of the intervention, including the type of VR technology, degree of immersion, intervention duration, treatment frequency, therapist involvement, and disease stage, may have influenced the observed outcomes. Reviews of immersive VR for upper-extremity rehabilitation have demonstrated that VR systems differ substantially in terms of immersion, interaction mechanisms, therapeutic tasks, and methods of providing feedback (Ceradini et al., 2024). Similarly, reviews of interaction modalities in serious games have highlighted the importance of the method used to capture and translate patient movement into interaction with the virtual environment (Aguilar-Lazcano et al., 2019). These differences may contribute to variability in treatment effects and should therefore considered when comparing studies. The use of motion sensors and wearable technologies may also be relevant to VR-based upper-limb rehabilitation. Wearable movement sensors increasingly used to monitor rehabilitation performance and provide objective information about movement, while sensor fusion and motion-tracking approaches may allow more detailed assessment of upper-limb and hand function (Porciuncula et al., 2018; Herrera-Luna et al., 2019; Picerno et al., 2021). Such technologies may enhance VR rehabilitation by allowing real-time movement detection and performance feedback. However, differences in sensor configuration, measurement accuracy, processing methods, and outcome definitions may also increase methodological heterogeneity between studies (Halilaj et al., 2018; Lobo et al., 2024). The interpretation of the findings also took into account the available study designs and methodological limitations. Because GBS is relatively uncommon, the available evidence may have included small samples and a variety of study designs. Previous reviews of technology-assisted rehabilitation in GBS have similarly reported a relatively limited evidence base and considerable methodological variation (Joveini et al., 2026; Martino Cinnera et al., 2024). Small sample sizes may reduce statistical power and increase uncertainty around estimates of treatment effectiveness, while differences in study design may limit direct comparison between interventions. Differences in participant characteristics, rehabilitation protocols, VR systems, outcome measures, and follow-up periods may have limited direct comparisons between studies and may have contributed to heterogeneity in the findings. This issue also identified in broader reviews of VR-based upper-limb rehabilitation, where differences in intervention duration, treatment intensity, immersion level, and assessment instruments have complicated comparisons across studies (Ceradini et al., 2024; Soleimani et al., 2024; Bel-Lacoma et al., 2026). The use of standardized outcome measures and clearly reported intervention protocols may therefore be particularly important for future GBS research. The selection of outcome measures another important consideration. Upper-limb rehabilitation cannot adequately characterized by muscle strength alone because functional performance also depends on coordination, motor control, dexterity, and the ability to complete meaningful tasks. Previous studies have therefore used measures such as the Box and Block Test, Nine-Hole Peg Test, Fugl-Meyer Assessment, and other functional assessments to quantify different dimensions of upper-limb performance (Alvarez-Rodríguez et al., 2020; Hao et al., 2024). The use of multiple complementary measures may provide a more comprehensive evaluation of the effects of VR-based rehabilitation. Adherence, treatment completion, dropout, fatigue, and adverse events also considered. These outcomes are important when assessing the feasibility and acceptability of VR-based rehabilitation in individuals recovering from GBS. Previous research on wearable and technology-assisted rehabilitation has emphasized the importance of usability, adherence, monitoring, and patient engagement when implementing technology-based interventions (Bowman et al., 2021; Lobo et al., 2024). Furthermore, immersive VR may be associated with symptoms such as dizziness or nausea in some users, indicating the importance of monitoring tolerability and safety during intervention delivery (Ceradini et al., 2024). The findings should therefore interpreted alongside the practicality and tolerability of the intervention. A technologically advanced intervention may not necessarily provide greater clinical benefit if it is difficult to use, poorly tolerated, excessively demanding, or inaccessible to patients with significant weakness or fatigue. This consideration is particularly relevant in GBS, where functional capacity and endurance may vary considerably throughout recovery (Joveini et al., 2026). The findings of this review may help determine whether VR should considered as an adjunct to conventional rehabilitation for upper-limb impairment following GBS. The available evidence suggested a potentially valuable role for technology-assisted rehabilitation, but the specific effectiveness of VR for upper-limb outcomes in GBS remained dependent on the limited number and methodological characteristics of available studies. Further research with larger samples, standardized outcome measures, clearly described VR protocols, and appropriate comparison groups is therefore required. Future clinical studies should investigate the optimal type, duration, intensity, and delivery of VR-based rehabilitation in adults with GBS. Particular attention should given to the stage of recovery, baseline impairment, fatigue, intervention adherence, and the use of objective movement-monitoring technologies. Standardized reporting of VR characteristics and treatment dosage may also facilitate comparison between studies and improve the quality of future evidence (Aguilar-Lazcano et al., 2019; Ceradini et al., 2024; Joveini et al., 2026).

Conclusion

This systematic review synthesized the available evidence regarding the effects of virtual reality-based rehabilitation on upper-limb function, coordination, and manual dexterity in adults with Guillain–Barré syndrome. The review also examined related functional outcomes, including activities of daily living, functional independence, muscle strength, motor function, quality of life, adherence, and adverse events. By focusing specifically on GBS, the review distinguished the available evidence in this population from the larger body of research concerning VR rehabilitation in other neurological conditions. The findings helped determine whether VR-based rehabilitation demonstrated measurable benefits in individuals recovering from GBS, whether VR provided additional benefits when combined with conventional rehabilitation, and which intervention characteristics may have been associated with better outcomes. The review also identified gaps in the existing evidence and may help guide future clinical research investigating VR-based rehabilitation for upper-limb impairment following Guillain–Barré syndrome.

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