



Balance and gait rehabilitation in stroke survivors: An analytical review of functional mobility and postural control

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Abstract

Stroke is a major neurological condition that frequently results in persistent impairments in balance, postural control, gait, and functional mobility. These problems can affect everyday activities, reduce independence, and increase the likelihood of falls. Rehabilitation therefore needs to address not only the ability to walk but also the underlying postural and balance problems that support safe functional movement. This analytical review examines the role of physiotherapy in the rehabilitation of balance and gait following stroke, with particular attention to postural control and functional mobility. The review considers commonly used approaches such as balance exercises, task-specific gait training, strengthening and functional exercises, treadmill training, proprioceptive training, dual-task activities, and selected technology-assisted interventions. It also discusses commonly used clinical measures, including the Berg Balance Scale, Timed Up and Go Test, 10-Meter Walk Test, 6-Minute Walk Test, and Functional Ambulation Category, for evaluating changes in balance, walking ability, and mobility. The reviewed evidence suggests that rehabilitation is more meaningful when exercises are progressive, repetitive, function-oriented, and adapted to the individual needs of the stroke survivor. Improvements in postural stability and walking performance can contribute to better functional mobility and greater independence. However, rehabilitation outcomes may differ according to the severity and stage of stroke, associated impairments, treatment intensity, and individual patient characteristics. Overall, an integrated physiotherapy approach that combines balance, postural control, and gait training appears important for improving functional mobility after stroke. Further research is needed to establish effective long-term rehabilitation strategies that translate clinical improvements into safer and more independent mobility in daily and community settings.

Keywords: Stroke, balance rehabilitation, gait rehabilitation, postural control, functional mobility, physiotherapy

Introduction

Stroke is a major neurological condition that can produce long-lasting limitations in movement, balance, walking, and independence. The effects of stroke extend beyond the initial neurological event, as many survivors continue to experience difficulties in performing everyday activities and participating in family, social, and community life. Stroke may affect muscle power, muscle tone, sensory processing, coordination, motor control, and mobility, making rehabilitation an important part of long-term management [1]. The World Health Organization (WHO) recognizes rehabilitation as an essential component of health care and estimates that approximately 2.4 billion people worldwide are living with a health condition that may benefit from rehabilitation. WHO also emphasizes that rehabilitation should aim not only to reduce impairment but also to improve functioning, independence, and participation in everyday life.

Balance and gait problems are among the important functional consequences that require attention during stroke rehabilitation. Normal balance depends on the integration of sensory information, postural responses, muscle activity, and voluntary motor control. After stroke, disruption of these processes may lead to poor trunk control, asymmetrical weight distribution, difficulty shifting weight, delayed postural responses, and reduced ability to maintain

stability during movement [2]. These problems become particularly evident during activities such as rising from a chair, standing, turning, reaching, transferring, and walking on uneven or unfamiliar surfaces. Consequently, a person who may be able to walk independently in a controlled clinical environment may still experience considerable difficulty when performing more demanding activities in the home or community.

Gait impairment further contributes to limitations in functional mobility. Stroke survivors may demonstrate reduced walking speed, altered step length, gait asymmetry, impaired foot clearance, reduced endurance, and difficulty changing direction or adapting walking to environmental demands [3]. These limitations can restrict community ambulation and encourage dependence on family members or assistive devices. From a physiotherapy perspective, the practical goal is therefore not simply to improve the ability to produce a walking pattern, but to develop safe, efficient, adaptable, and meaningful mobility that can be used in daily life. This requires consideration of balance, postural control, lower-limb strength, motor learning, sensory input, endurance, and the individual's specific functional goals [4]. The clinical management of stroke has increasingly emphasized rehabilitation across the continuum of care. WHO's recent framework for stroke care describes a continuum extending from community awareness and acute

care to rehabilitation and ongoing management. Similarly, WHO's Package of Interventions for Rehabilitation includes stroke within its neurological rehabilitation programme and identifies the workforce, equipment, assistive products, and interventions required for planning rehabilitation services [5]. These recommendations are particularly relevant to physiotherapy because rehabilitation may need to continue across hospital, outpatient, home, and community settings rather than being restricted to the acute hospital period.

The Indian health system also recognizes rehabilitation as an important component of stroke management. Under the National Programme for Prevention and Control of Non-Communicable Diseases (NP-NCD), stroke management includes rehabilitation involving physiotherapy, occupational therapy, speech therapy, and vocational training. The current training material for medical officers describes acute-phase rehabilitation in terms of bed mobility, transfers, and prevention of complications, while subacute and chronic rehabilitation includes mobility, gait and balance training, activities of daily living, cognitive and perceptual rehabilitation, and appropriate assistive devices. India's stroke management guidance also describes different levels of physiotherapy rehabilitation according to available resources. Basic rehabilitation can be delivered with relatively simple equipment, while higher-level centres may use treadmills, functional electrical stimulation, body-weight-supported treadmill systems, robotics, force platforms, and balance and gait analysis systems [6]. This provides a practical framework for understanding that effective stroke rehabilitation does not necessarily depend on advanced technology; appropriately selected exercises and functional training can form the foundation of rehabilitation, with specialized technologies added when clinically indicated and resources permit.

Assessment is another essential component of effective physiotherapy practice. Measures such as the Berg Balance Scale, Timed Up and Go Test, 10-Meter Walk Test, 6-Minute Walk Test, and Functional Ambulation Category can provide clinically useful information about balance, walking speed, endurance, and mobility [7]. These measures help physiotherapists identify functional limitations, establish treatment goals, monitor progress, and determine whether improvements observed during therapy translate into meaningful changes in mobility. Assessment should therefore be linked directly to treatment planning rather than being used only to document outcomes.

Despite the availability of several rehabilitation approaches, important questions remain regarding which strategies are most appropriate for particular functional problems, how much rehabilitation is required, and how improvements achieved in clinical settings can be transferred to everyday and community environments. Differences in stroke severity, time since stroke, motor and sensory impairments, cognitive status, comorbidities, treatment intensity, and patient participation can influence rehabilitation outcomes [8]. In addition, access to rehabilitation remains uneven globally, particularly in settings where services, trained professionals, equipment, and referral pathways are limited. WHO identifies these factors as important barriers to meeting rehabilitation needs?

Against this background, the present analytical review examines balance and gait rehabilitation in stroke survivors, with particular emphasis on functional mobility and postural control. It reviews major physiotherapy approaches, clinically relevant assessment methods, and practical factors influencing rehabilitation outcomes. The review also considers the strengths and limitations of different rehabilitation strategies and the importance of individualized, progressive, and function-oriented physiotherapy in helping stroke survivors achieve safer and more independent mobility in everyday and community settings.

Balance, Postural Control and Gait Impairments Following Stroke

Stroke can affect several systems involved in normal movement, including muscle strength, coordination, sensation, muscle tone, and voluntary motor control. As a result, many survivors experience difficulty maintaining stability, transferring weight, standing, and walking. Functional mobility is influenced by the combined performance of these components rather than by muscle strength alone. For this reason, balance, postural control, gait, and mobility need to be considered together during physiotherapy assessment and rehabilitation [9].

Postural control plays an important role in maintaining body stability during both stationary positions and movement. After stroke, impaired sensory integration and reduced motor control may lead to poor trunk stability, delayed postural responses, uneven loading of the lower limbs and difficulty transferring body weight towards the affected side. A patient may therefore be able to stand without assistance but still struggle with activities such as reaching, turning, rising from a chair, or stepping over an object. The Berg Balance Scale (BBS) can be used to examine functional balance through a range of everyday tasks involving standing, transfers, reaching, and turning. The Functional Reach Test provides additional information about how far a person can move the centre of mass forward while maintaining stability [10].

Post-stroke balance limitations can occur during both static and dynamic activities. Static control is important for maintaining a stable position, while dynamic control is required when the body is moving or the base of support changes. Sensory and proprioceptive disturbances may make these activities more difficult, particularly when visual cues are reduced or the individual encounters an unfamiliar surface. The Timed Up and Go (TUG) Test is particularly useful in this context because it combines several components of mobility, including standing up, walking, turning, and sitting down. It can therefore provide a practical indication of functional mobility beyond isolated standing balance [11].

Walking difficulties are also common following stroke and may appear as slower gait, unequal step patterns, reduced foot clearance, altered cadence, and difficulty starting, stopping, or changing direction. These changes may result from a combination of lower-limb weakness, abnormal muscle activation, impaired coordination, sensory disturbances, and reduced selective motor control. The 10-

Meter Walk Test (10MWT) offers a simple method of measuring walking speed, while the 6-Minute Walk Test (6MWT) provides information about the individual's ability to sustain walking over a longer period. The Functional Ambulation Category (FAC) can be used to determine the degree of assistance a person requires to walk safely^[12].

Clinical gait assessment should also reflect the demands of everyday and community mobility. Walking in a rehabilitation corridor may not adequately represent the challenges encountered outside the clinic. Stroke survivors may need to negotiate stairs, obstacles, uneven ground, crowded areas, changes in direction, and different walking speeds. The Dynamic Gait Index (DGI) and Functional Gait Assessment (FGA) are useful for examining gait under more demanding conditions, including changes in speed, head movement, turning, and obstacle negotiation^[13].

These assessment measures help physiotherapists identify functional limitations, establish realistic treatment goals, monitor changes over time, and determine whether improvements are clinically meaningful. However, no single measure can adequately represent all aspects of post-stroke mobility. Combining measures of balance, functional mobility, walking speed, endurance, and dynamic gait provides a more complete understanding of the patient's abilities and limitations.

Overall, balance, postural control, and gait dysfunction after stroke are closely associated with reduced independence and participation in daily activities. Rehabilitation should therefore be based on individual assessment findings and functional goals. Interventions may include progressive balance activities, weight-transfer exercises, task-oriented gait practice, strengthening, and functional mobility training. The primary aim of physiotherapy should be to convert improvements in body function into meaningful gains in everyday mobility, enabling stroke survivors to move with greater safety, confidence, efficiency, and independence.

Physiotherapy Approaches for Balance and Gait Rehabilitation

Physiotherapy is an essential part of post-stroke rehabilitation, particularly for individuals who have difficulty maintaining balance, walking safely or performing routine functional activities. The rehabilitation programme should be planned according to the patient's motor control, muscle strength, sensory function, endurance and existing mobility level. The emphasis should extend beyond walking practice inside the clinic and gradually prepare the patient for real-life activities. The overall aim is to improve functional independence, movement safety and confidence.

Balance and Postural Control Training

Balance training helps stroke survivors improve control of their body during sitting, standing and movement. Common therapeutic activities include supported standing, weight-shifting, reaching, sit-to-stand practice and controlled stepping. For example, a patient who avoids placing weight on the affected leg may be guided to transfer weight gradually towards that side while maintaining a stable posture.

As the patient's ability improves, the therapist can reduce external support, increase reaching distance or introduce different foot positions^[14]. These exercises are directly applicable to daily activities such as getting up from a chair, reaching for objects and maintaining stability while changing position.

Task-Specific Gait Training

Walking rehabilitation should involve repeated practice of activities that are actually required during walking. Depending on the patient's functional capacity, treatment may include gait initiation, stopping, turning, changes in speed, directional changes and obstacle negotiation.

For instance, a patient who walks adequately on a straight path but becomes unstable while turning can repeatedly practise controlled turns under supervision. A patient with inadequate foot clearance may practise stepping over appropriately sized obstacles^[15]. Such activities help connect clinical gait training with practical mobility at home and in the community.

Strengthening and Functional Exercise

Lower-limb weakness may affect standing, transfers, stair climbing and walking after stroke. Physiotherapy may therefore include resisted exercises, sit-to-stand repetitions, step-up activities and other functional strengthening exercises. Sit-to-stand practice is particularly useful because it combines lower-limb muscle activation with postural control and functional transfer training. However, strengthening should not be considered sufficient on its own. Improved muscle force needs to be incorporated into balance and gait activities to produce meaningful functional benefits. Exercise intensity should be increased gradually while considering fatigue, cardiovascular tolerance and the patient's response to treatment^[16].

Treadmill and Supported Gait Training

Treadmill training provides repeated walking practice within a controlled environment. Walking speed and therapist assistance can be adjusted according to the patient's ability. For individuals with substantial weakness or difficulty supporting body weight, body-weight-supported treadmill training may facilitate stepping practice while reducing the physical demands of walking. As functional control improves, treadmill practice should be complemented by overground walking. Patients should practise turning, walking on different surfaces, negotiating obstacles and adjusting their speed because these situations more closely represent community mobility^[17].

Proprioceptive and Dual-Task Training

Proprioceptive activities may be useful for patients who have difficulty recognizing or controlling the position of the affected limb. Controlled weight transfer, targeted stepping and accurate foot-placement exercises can be incorporated into treatment. For example, the patient may be asked to place the affected foot on specific floor targets while maintaining balance. When basic walking becomes sufficiently safe, dual-task activities can be introduced. Walking while carrying an object, answering simple

questions or responding to directional instructions can provide a more realistic challenge^[18]. Such training reflects everyday a situation in which walking commonly occurs alongside another activity.

Integrated Clinical Approach

Post-stroke mobility limitations usually result from several interacting impairments; therefore, no single intervention is appropriate for every patient. A comprehensive programme may combine balance exercises, strengthening, task-specific gait training, endurance activities and progressively challenging functional tasks. However, Treatment should advance from simple, well-supported activities towards complex situations that resemble home and community mobility. Progress can be monitored through measures such as the Berg Balance Scale (BBS), Timed Up and Go (TUG), 10-Meter Walk Test (10MWT) and Functional Ambulation Category (FAC)^[19].

The practical purpose of physiotherapy is to convert improvements in physical function into meaningful mobility. Effective rehabilitation should help stroke survivors walk more safely, perform daily activities with less assistance and participate more confidently in their home and community environments.

Assessment of Balance, Gait and Functional Mobility

A systematic assessment is necessary in post-stroke physiotherapy to understand the patient's movement limitations and to select appropriate rehabilitation strategies. Difficulties in balance, walking and functional mobility may occur together, but each reflects a different aspect of physical performance. For this reason, assessment should combine standardized outcome measures with clinical observation of functional activities. Regular reassessment is also important for identifying changes in performance and determining whether the treatment programme needs modification^[20].

Assessment of Balance

Balance assessment provides information about a patient's ability to maintain stability during different postural and functional tasks. The Berg Balance Scale (BBS) is widely used in stroke rehabilitation and evaluates activities such as standing, transferring, reaching and maintaining different body positions. In clinical practice, it can help the physiotherapist identify limitations that may affect safe mobility and follow changes in balance over the course of rehabilitation.

Another useful measure is the Functional Reach Test, which assesses the distance a person can reach forward while maintaining a stable standing position. It provides an indication of the individual's limits of stability during reaching^[21]. In addition to formal testing, the therapist should observe posture, weight distribution between the lower limbs, control of the affected side and the patient's ability to respond to changes in body position.

Assessment of Gait

Post-stroke gait assessment should consider not only how fast a person walks but also the quality and safety of movement. The 10-Meter Walk Test (10MWT) is commonly used to determine walking speed over a standardized distance. Changes in walking speed can help indicate improvement in functional walking capacity and provide useful information about progression during rehabilitation. Moreover, walking endurance can be examined using the 6-Minute Walk Test (6MWT)^[22]. This measure is particularly useful for patients who can already walk but experience difficulty sustaining walking over longer distances. Along with standardized testing, physiotherapists should examine gait characteristics such as step length, symmetry, cadence, foot clearance, gait initiation, turning and the use of walking aids. These observations can reveal problems that may not be reflected by walking speed alone.

Assessment of Functional Mobility

Functional mobility involves the ability to move between different positions and perform common movement tasks safely. The Timed Up and Go (TUG) test is a practical measure in this context. It requires the patient to stand from a chair, walk a specified distance, turn, and return and sit down. Because several movement components are included within one task, the test can provide useful information about transfers, walking and turning ability. The Functional Ambulation Category (FAC) is another relevant measure for stroke rehabilitation. It focuses on the level of assistance a person requires while walking and can therefore be useful for documenting changes in ambulatory independence during treatment^[23].

Practical and Integrated Assessment

A single assessment tool cannot adequately represent all aspects of post-stroke mobility. For example, a patient may achieve an acceptable walking speed but still experience instability when turning, crossing an uneven surface or avoiding an obstacle. Therefore, standardized measures should be complemented by observation of activities that resemble everyday movement. Where clinically appropriate, assessment can include walking over different surfaces, changing direction, negotiating obstacles, performing repeated sit-to-stand movements and climbing or descending stairs^[24]. Such activities provide a better understanding of whether improvements observed in the clinic are likely to support mobility at home and in the community.

Conclusively, combining standardized outcome measures with functional observation provides a broader understanding of balance, gait and mobility following stroke. Repeated assessment enables the physiotherapist to identify persistent problems, establish appropriate treatment goals, evaluate functional changes and adjust the rehabilitation programme according to the patient's progress.

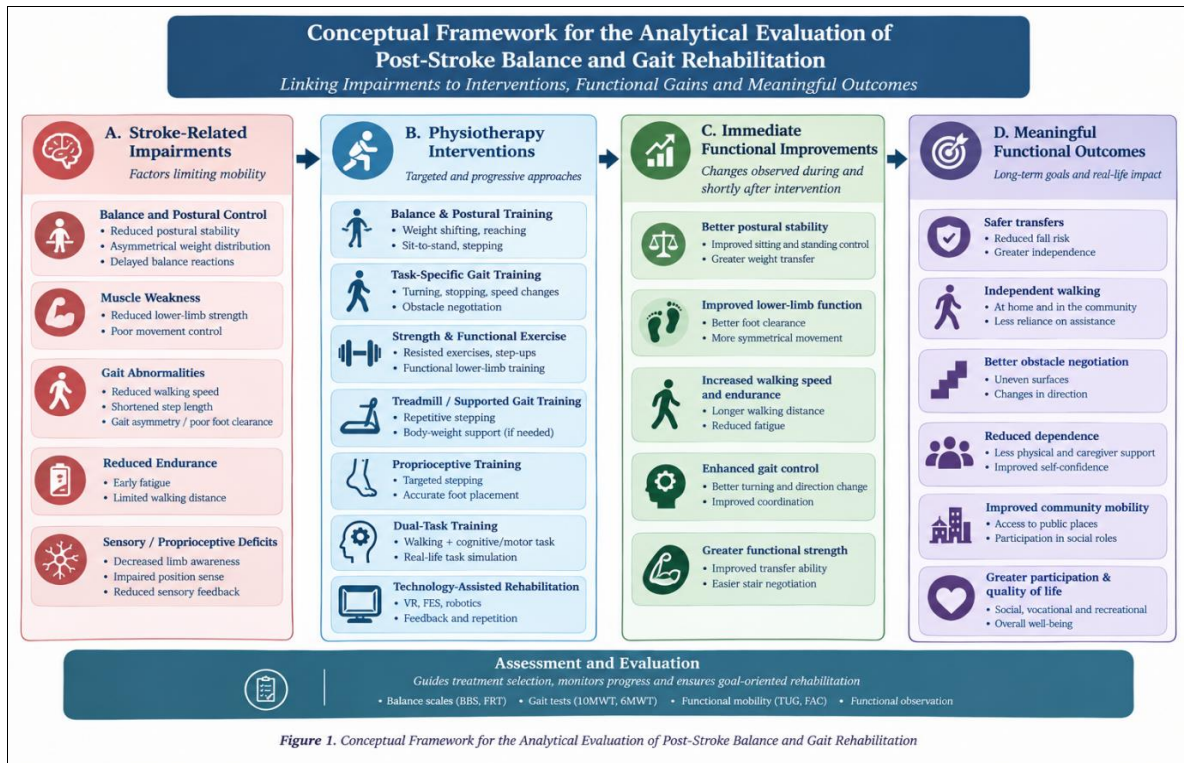


Fig 1: Conceptual Framework for the Analytical Evaluation of Post-Stroke Balance and Gait Rehabilitation

The framework presented in Figure 1 explains how post-stroke physical impairments can be addressed through targeted physiotherapy and subsequently translated into meaningful improvements in functional mobility. Stroke survivors may experience difficulties in postural stability, lower-limb strength, gait performance, walking endurance and sensory or proprioceptive control. These limitations can interfere with routine movements and restrict independent mobility.

Physiotherapy management is directed towards these impairments through a combination of balance and postural control exercises, task-oriented gait practice, functional strengthening, treadmill or body-weight-supported training, proprioceptive activities, dual-task exercises and technology-assisted rehabilitation. Rather than considering these interventions as isolated techniques, the framework emphasizes their complementary role in addressing different components of post-stroke mobility.

Improvements at the functional level may include better postural stability, more effective weight transfer, improved lower-limb control, increased walking speed and endurance, and greater control during gait-related activities. These changes are expected to support broader functional goals, including safer transfers, increased walking independence, and improved ability to negotiate obstacles and reduced reliance on physical assistance.

The framework further extends the rehabilitation pathway from clinical improvement to real-world participation. Enhanced community mobility, greater involvement in social and daily activities, increased self-confidence and improved quality of life represent important outcomes beyond changes observed during clinical testing. Standardized measures, including the Berg Balance Scale (BBS), Functional Reach Test (FRT), 10-Meter Walk Test (10MWT), 6-Minute Walk Test (6MWT), Timed Up and Go (TUG) and Functional Ambulation Category (FAC), provide objective support for identifying limitations,

monitoring progress and evaluating the functional relevance of rehabilitation.

Overall, the framework supports a patient-centred, progressive and function-oriented model of stroke rehabilitation, in which assessment guides intervention, intervention produces functional gains, and these gains are ultimately directed towards greater independence and participation in everyday life.

Challenges, Research Gaps and Future Directions

Although stroke rehabilitation has developed considerably, restoring stable balance, efficient gait and independent mobility continues to present clinical difficulties. Recovery is highly individual and may be influenced by the extent of neurological damage, type of motor and sensory impairment, age, associated health conditions, cognitive function and the availability of rehabilitation services. Consequently, a standardized treatment programme may not produce similar results across all stroke survivors, highlighting the need for individualized clinical decision-making.

A major practical concern is whether improvements achieved during supervised physiotherapy are maintained when patients return to their normal surroundings. For example, an individual may perform satisfactorily during a structured walking test but experience instability while walking on uneven ground, climbing stairs, moving through crowded places or responding to sudden changes in direction. Fatigue and fear of falling may further reduce confidence and discourage outdoor mobility. Rehabilitation should therefore gradually expose patients to varied and realistic movement situations rather than limiting practice to predictable clinical environments.

Access to continuous physiotherapy is another important concern. Treatment may be interrupted because of travel difficulties, financial limitations, and shortage of specialized rehabilitation professionals or inadequate follow-up

services. Advanced methods, including virtual reality, robotic systems and functional electrical stimulation, can expand therapeutic possibilities, but their application may be restricted by equipment costs, infrastructure requirements and the availability of appropriately trained personnel. This creates a need for rehabilitation models that are both clinically effective and feasible in different healthcare settings.

Important gaps also remain in the research evidence. More investigation is required into the appropriate dose, intensity, frequency and combination of interventions for patients at different stages of stroke recovery. Existing research often examines individual interventions, whereas clinical rehabilitation commonly involves several approaches delivered together. Future studies should therefore investigate how interventions can be combined and adapted according to the patient's specific impairments, functional goals and stage of recovery.

Another important research gap concerns long-term functional outcomes. Improvements recorded immediately after an intervention may not necessarily indicate sustained gains in everyday mobility. Future research should place greater emphasis on follow-up assessment of community walking, participation, independence, falls, confidence and quality of life. Outcomes that reflect actual daily functioning can provide a more meaningful indication of rehabilitation success than impairment measures alone.

Emerging technologies also offer opportunities for future research. Wearable sensors, tele-rehabilitation, virtual reality and remote monitoring may allow therapists to obtain information about walking and mobility beyond the conventional clinical setting. Such technologies could support individualized treatment and continuous monitoring, particularly when regular face-to-face therapy is difficult. However, technological solutions should complement clinical expertise and remain affordable, accessible and appropriate for the patient's needs. At the last, future stroke rehabilitation should move towards a personalized, progressive and function-centred model of care. Greater emphasis on real-world mobility, individualized treatment dosage, long-term follow-up, accessible rehabilitation services and clinically meaningful outcome measures may help narrow the gap between improvement observed during therapy and genuine independence in everyday life.

Conclusion

Post-stroke impairments in balance, postural control, gait and functional movement can substantially affect an individual's ability to perform daily activities independently. These difficulties are commonly associated with impaired motor control, muscle weakness, sensory changes, reduced endurance and impaired coordination. The literature reviewed in this paper indicates that these interacting impairments require rehabilitation strategies that are adapted to individual functional needs rather than reliance on a single treatment approach.

The reviewed evidence suggests that different physiotherapy interventions may contribute to different aspects of post-stroke recovery. Balance and postural exercises are commonly used to address stability and weight control, while task-specific gait training provides repeated practice of walking-related activities. Functional strengthening may support transfers and lower-limb performance, whereas treadmill and supported gait training can facilitate repetitive

stepping practice. Proprioceptive and dual-task activities may provide additional challenges related to sensory and cognitive-motor control. Technology-assisted approaches, including virtual reality, functional electrical stimulation and robotic rehabilitation, also show potential for providing intensive practice and feedback in appropriately selected patients. However, their clinical value may vary according to patient characteristics, treatment dosage, available resources and rehabilitation settings.

The reviewed literature also emphasizes the importance of systematic assessment. Measures such as the Berg Balance Scale, Timed Up and Go, 10-Meter Walk Test, 6-Minute Walk Test and Functional Ambulation Category can assist clinicians in identifying limitations and monitoring changes over time. However, standardized scores alone may not fully represent performance in everyday environments. Clinical observation of transfers, turning, obstacle negotiation, uneven surfaces and other task demands can provide additional information about functional performance.

A key limitation of this review is its literature-based and analytical design. No primary patient data were collected, no intervention was administered, and no independent statistical comparison of treatment effectiveness was undertaken. Therefore, this paper does not establish that one intervention is superior to another. The conclusions represent an interpretation of findings reported in the existing literature and should be considered within the limitations of that evidence base. Differences among studies in participant characteristics, stroke stage, intervention protocols, treatment intensity, outcome measures and follow-up periods also make direct comparison difficult. Future clinical research should address these variations through adequately designed comparative studies, standardized outcome measures and longer-term follow-up. The available literature supports an individualized, progressive and function-oriented approach to post-stroke balance and gait rehabilitation. The evidence does not indicate a single universally superior intervention; rather, it points towards the value of selecting and combining interventions according to specific impairments and functional goals. The central implication of this review is that rehabilitation gains are most meaningful when improvements identified through clinical assessment are connected with practical activities and participation in everyday life. Further high-quality research is needed to determine which combinations, treatment doses and delivery models produce the most sustained functional benefits for different groups of stroke survivors.

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