OPTIMIZING MOTOR FUNCTION RECOVERY IN STROKE PATIENTS THROUGH STRUCTURED EXERCISE PROGRAMS

Mohammad Saleh Alsaeed*[1], Zainah Ali Alqahtani[2], Shouq Abdulaziz Altamami[3], Abdulmajeed Ali Ahmed Alshehri[4], Sarah Juwayid Alnawmasi[5], Arwa Mohammed Aziz[6], Bayan Abdullah Alyahya[7], Maymonah Ahmed Homdi[8], Hyam Al.Hossin Al.Assiry[9], Fahad Mohammed Alshehri[10], Yahya Mohammed Alharobi[11], Zainab Abbas Alhajjaj[12], Hosam Eldin Mostafa[13]

[1]Ministry of Health - King Saud hospital - Al-Qassim region, Saudi Arabia; [2]Saudi german hospital - Asser region, Saudi Arabia; [3]university - Al- Riyadh Region Saudi Arabia; [4]Human Development Company - Asser region Saudi Arabia; [5]University of Tabuk -Tabuk region, Saudi Arabia; [6]University of Tabuk -Tabuk region, Saudi Arabia; [7]Doctor Suliman Alhabib-Al-Riyadh region Saudi Arabia; [8]Jazan University -Jazan region, Saudi Arabia; [9]Recovery Center Physical therapy & Rehabilitation- Asser region, Saudi Arabia; [10]King Abdullah Medical City – Makkah; [11]Dr. Sulaiman AL-Habib Hospital - Eastern region Saudi Arabia; [12]Ministry of Health - Daharan Long Term Hospital - Eastern Region, Saudi Arabia; [13]Lecturer of neurosurgery, Cairo university, Saudi Arabia

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*Corresponding Author: Mohammad Saleh Alsaeed, Ministry of Health - King Saud hospital - Al-Qassim region, Saudi Arabia

Correo-e: Therapist.911@hotmail.com

Abstract

Background: Stroke is a major neurological condition that often results in significant motor, cognitive, and functional impairments, impacting daily living activities. Various rehabilitation techniques, including neurofunctional exercises such as Proprioceptive Neuromuscular Facilitation (PNF) and Bo bath Neurodevelopmental Therapy (NDT), are utilized to enhance recovery. However, the effectiveness of these interventions compared to conventional physical activity remains unclear. This study aimed to evaluate the impact of neurofunctional exercises versus standard rehabilitation on functional recovery in stroke survivors over a six-month period.

Methods: This study was conducted, involving stroke patients who were divided into two groups: one undergoing rehabilitation incorporating neurofunctional exercises (study group, SG) and another engaging in standard physical activity at home (control group, CG). Functional recovery was assessed using the Barthel Scale (BS), Rankin Scale (RS), and National Institutes of Health Stroke Scale (NIHSS) at baseline (during hospitalization) and six months' post-stroke. Statistical analyses included Mann–Whitney U and Wilcoxon signed-rank tests for group comparisons and within-group changes.

Results: Baseline comparisons indicated significantly higher BS scores in the control group ($U = 820.5$; $p = 0.001$), while the study group had significantly greater NIHSS ($U = 647.5$; $p = 0.001$) and RS ($U = 811.5$; $p < 0.001$) scores. After six months, the CG retained significantly better BS scores than the SG ($p = 0.021$), while RS was significantly higher in the SG ($p = 0.019$). No significant between-group differences were observed in NIHSS scores ($p = 0.755$). Within-group analyses revealed significant improvements in BS for both groups (SG: $p < 0.001$; CG: $p = 0.005$), while NIHSS significantly improved only in the CG ($p < 0.001$).

Conclusion: Neurofunctional exercises did not provide substantial additional benefits compared to standard rehabilitation. Patients in the control group demonstrated greater functional improvements in daily activities, suggesting that conventional home-based physical activity may be equally or more effective in stroke recovery. Future research should explore individualized rehabilitation strategies and long-term functional outcomes.

Keywords: Stroke rehabilitation; Neurofunctional exercises; Proprioceptive Neuromuscular Facilitation (PNF); Bobath Neurodevelopmental Therapy (NDT); Functional recovery

Introduction

Stroke is a prevalent neurological condition that results in localized damage to the central nervous system [1]. The consequences of a stroke vary depending on the affected brain region and the severity of the event. Common impairments include motor dysfunction, such as hemiplegia or hemiparesis, which can lead to weakness or complete paralysis on one side of the body, limiting movement and coordination. Cognitive deficits may also arise, affecting memory, attention span, and higher-level thinking skills. Furthermore, stroke survivors frequently experience communication challenges, such as aphasia, which disrupts their ability to express or comprehend language. Additional complications include sensory disturbances like numbness or altered perception, as well as vision problems, including partial blindness or field deficits. These functional impairments can hinder independence and significantly affect daily life [2]. The global incidence and burden of stroke have increased between 1990 and 2021, exacerbated by various contributing factors [3]. To mitigate these challenges, comprehensive strategies emphasizing early intervention, enhanced stroke surveillance, and preventive measures-particularly through blood pressure regulation, lifestyle modifications, and environmental considerations—are necessary. Additionally, advancements in acute care and rehabilitation services play a crucial role in reducing stroke-related disability [3].

Engaging in physical activity is vital for improving recovery outcomes in stroke survivors. Regular exercise supports neuroplasticity, aiding the restoration of motor and cognitive abilities. Additionally, it enhances cardiovascular health, lowering the likelihood of recurrent strokes. Incorporating structured physical activities, such as aerobic workouts, resistance training, and balance exercises, helps restore muscle strength, flexibility, and coordination, thereby improving mobility and decreasing fall risks [4]. Physical activity is also associated with better mental health, as it alleviates post-stroke depression and contributes to overall emotional well-being. Rehabilitation programs that integrate customized physical activity regimens are instrumental in promoting recovery and enabling individuals to regain independence in daily tasks. Moreover, adopting a physically active lifestyle may reduce the probability of future strokes.

With hospital-based rehabilitation now more short-term, the focus has shifted toward home-based rehabilitation approaches. This transition has heightened the need for accessible physiotherapy solutions, encouraging individuals to participate in activities that enhance their physical fitness and daily functioning [5]. Research conducted by French et al. indicates that repetitive engagement in daily activities improves performance and enhances independence in stroke survivors [6]. Aguiar et al. further suggest that engaging in moderate physical activity, averaging 40 minutes per day—including routine tasks—can be beneficial [7]. Such activities have been found to contribute positively to patient prognosis. A systematic review found that post-stroke physical activity significantly improves cognitive function [8]. Additionally, another review confirmed that exercise-based interventions effectively target four out of the ten most prioritized rehabilitation goals: cognition, upper limb function, balance and gait, and structured exercise programs. Emerging evidence also suggests exercise may address fatigue and self-confidence, two other key rehabilitation priorities [9].

Despite the proven advantages of physical activity, stroke survivors often struggle with the frequency and intensity of exercise. However, many still express a strong desire to engage in social interactions [7]. Approximately 30% of stroke patients experience difficulties with fundamental daily activities, and nearly half require external assistance for essential tasks [10,11]. Findings by Hildebrand et al. suggest that individuals recovering from mild strokes often discontinue their previous recreational activities, reflecting a decline in post-stroke participation [12]. Similar trends have been observed, as over half of stroke survivors who had previously been active report reduced engagement in leisure activities [13]. Community-based studies further indicate that physical activity levels among stroke survivors are notably low [14]. Several factors, including medical conditions, personal circumstances, and social influences, play a role in determining participation in physical activity, with cultural elements also contributing to these variations [15]. For example, older adults recovering from stroke tend to be at a higher risk of physical inactivity

[16]. However, by addressing modifiable factors such as physical capabilities, depression, self-confidence, and overall quality of life, it is possible to enhance engagement in physical activity [16]. Furthermore, rehabilitation efforts should extend beyond individual patients by considering their roles within families, communities, and broader social networks, as these external influences significantly affect long-term adherence to an active lifestyle [17].

Although significant progress has been made in stroke rehabilitation, there remains a gap in knowledge regarding the comparative effectiveness of neurofunctional exercises versus conventional rehabilitation methods in improving functional outcomes. While existing literature underscores the benefits of structured physical activity and rehabilitation in enhancing motor and cognitive function, alleviating depression, and improving quality of life, there is limited research assessing outcomes for individuals who do not participate in formal rehabilitation programs, particularly those incorporating neurofunctional exercises [18]. This study seeks to bridge that gap by evaluating the effects of rehabilitation programs utilizing neurofunctional exercises compared to standard rehabilitation approaches that do not incorporate such exercises. By identifying potential differences in patient outcomes, this research aims to contribute to the refinement of rehabilitation strategies, fostering more evidence-based and targeted therapeutic interventions. Given the increasing demand for rehabilitation solutions and the obstacles stroke patients face in sustaining physical activity post-discharge, this study is particularly relevant in guiding future rehabilitation practices.

Materials and Methods

This research conducted on individuals who had experienced a stroke were evaluated using the Barthel Scale (BS), Rankin Scale (RS), and National Institutes of Health Stroke Scale (NIHSS) during their initial hospitalization. The same assessments were administered six months later. Participants were divided into two groups: one consisting of patients who underwent rehabilitation in the interval between the stroke and the follow-up assessment, and another comprising those who did not receive rehabilitation.

A total of 200 patients diagnosed with stroke and admitted to a neurology department were considered for preliminary evaluation. An initial screening process was conducted via telephone interviews using a structured questionnaire to exclude patients unlikely to develop spasticity. The survey assessed the ability to lift the arm above the head, independently grasp objects, and walk without assistance.

The inclusion criteria were: (i) a first-time ischemic or haemorrhagic stroke confirmed through physical examination; (ii) unilateral paresis; (iii) spasticity of at least 2 points on the Modified Ashworth Scale (MAS) in at least one muscle group; (iv) evidence of muscle weakness and altered reflexes; (v) willingness to participate in the study with informed consent; (vi) age of at least 18 years; and (vii) absence of prior rehabilitation in a dedicated rehabilitation unit. The exclusion criteria included: (i) a diagnosis of transient ischemic attack (TIA); (ii) history of multiple strokes; (iii) presence of comorbid conditions that could influence spasticity development (e.g., cancer, myocardial infarction, or apallic syndrome); (iv) refusal to provide consent (patient or legal representative); and (v) prior rehabilitation in a specialized facility.

Initial diagnostic assessments were conducted by a physiotherapist at the participants' residences. Exclusions were made for patients without spasticity and those lost to follow-up due to various reasons, A total of 100 individuals were initially considered, but additional exclusions followed: patients with severe health conditions, those unable to communicate verbally, patients who experienced another stroke during the study period. Ultimately, 102 individuals diagnosed with post-stroke spasticity were enrolled in the study after obtaining informed consent.

Of these, 51 participants (20 males and 31 females; mean age 72.2 ± 9.9 years) were assigned to an intervention group that engaged in neurofunctional rehabilitation exercises (SG), while the remaining 51 participants (26 males and 25 females; mean age 69.5 ± 10.8 years) followed standard exercise protocols without neurophysiological techniques (CG).

- Study Group (SG): This cohort consisted of 51 individuals who engaged in structured rehabilitation within six months following their initial stroke. After discharge from the acute stroke neurology unit, these patients awaited transfer to a specialized rehabilitation facility.

- Their inpatient rehabilitation program encompassed standardized therapeutic exercises, including neurofunctional rehabilitation techniques integrating elements of Proprioceptive Neuromuscular Facilitation (PNF) and Bobath Neurodevelopmental Therapy (BNT). The regimen focused on enhancing both upper and lower limb functionality, gait training, self-care routines, and ergometer exercises. The PNF approach incorporated combined movement patterns, such as flexion–adduction–external rotation and extension–abduction–internal rotation of the affected limbs.

- These exercises were carried out progressively, transitioning from lying to a semi-standing position, with constant monitoring of trunk stability and movement execution. BNT interventions were customized based on the individual's functional impairments, emphasizing repetitive balance responses, inhibition of abnormal movement patterns, and facilitation of normal muscle function. Various positions, including lying and sitting, were used to regulate muscle tone, suppress involuntary movements, and stimulate active muscle engagement.

- The SG followed a rehabilitation schedule involving daily therapy sessions for six weeks, each lasting 45 minutes, with a structured combination of passive limb exercises, gait training, self-care activities, and ergometer training.

- Control Group (CG): This group included 51 individuals who did not receive structured hospital rehabilitation within six months of their first stroke. Instead, after discharge from the acute stroke neurology unit, they remained at home. Their caregivers, such as family members, encouraged them to stay physically active. The CG participated in a six-week routine consisting of passive upper and lower limb exercises, gait training, and ergometer activities. However, unlike the SG, they did not receive any neurophysiological interventions such as PNF or BNT.

Barthel Scale

The Barthel Scale (BS) is a globally recognized tool used to determine a patient's level of independence and care needs [20]. It has been validated for stroke trials and clinical use, demonstrating excellent inter-rater reliability [21]. The scale assesses ten fundamental activities, including eating, mobility, personal hygiene, toilet use, full-body washing, movement on flat surfaces, stair navigation, dressing, and sphincter control. Scoring varies across tasks, generally ranging from 0 to 3, though some items use a 0–1 or 0–2 scale [20]. The total score categorizes individuals as follows:

- 0–20 points: Completely dependent
- 21–80 points: Requires assistance
- 81–100 points: Independent with minimal support [20].

Patient scores were recorded at both assessment points and used for further analysis.

Rankin Scale

The Rankin Scale (RS) is a standardized tool designed to measure disability levels in stroke survivors [22]. Its widespread application in research and clinical settings allows for consistent tracking of patient recovery [23]. This scale assigns disability grades from 0 (asymptomatic) to 5 (severe impairment requiring continuous care). It evaluates key functional aspects such as mobility, self-care, and communication abilities. Individual scores were documented at both evaluation points and used in subsequent statistical analyses.

National Institutes of Health Stroke Scale

The National Institutes of Health Stroke Scale (NIHSS) is a structured, validated tool designed to quantify neurological deficits resulting from stroke [24,25]. This scale is commonly used both in acute stroke assessment and for monitoring long-term recovery. It consists of 15 items evaluating different neurological functions, such as consciousness, gaze, vision, facial motor control, limb strength, coordination, sensation, language, speech, and attention. Scores range from 0 to 42, with higher values indicating more severe impairments. The scale is further categorized as follows:

- 0 points: No deficits
- 1–4 points: Minor stroke
- 5–15 points: Moderate stroke
- 16–20 points: Moderate to severe stroke
- 21–42 points: Severe stroke

Assessments were performed at both time points, and results were included in the data analysis.

Statistical Procedures

Descriptive statistics, including mean values and standard deviations, were computed. Prior to inferential analysis, data normality was tested using the Kolmogorov–Smirnov test, which indicated a non-normal distribution ($p < 0.05$). Additionally, the Levene's test for homogeneity of variances did not confirm equal variance across groups ($p < 0.05$). Due to the violation of parametric test assumptions, non-parametric statistical methods were applied. The Mann–Whitney U test was employed to compare groups at baseline and at the six-month follow-up. Additionally, the Wilcoxon signed-rank test was used for within-group comparisons across time points. The effect size was determined using the r value, calculated by dividing the Mann–Whitney U test's z-score by the square root of the total sample size [26]. Statistical computations were performed using JASP software (version 0.18.3), with significance set at $p < 0.05$.

Results

Table 1 summarizes the demographic characteristics and rehabilitation scale data for both groups. Initial comparisons showed that the control group (CG) had significantly higher Barthel Scale (BS) scores at baseline compared to the study group (SG) (U = 820.5; Z = −3.233; p = 0.001). In contrast, the SG exhibited significantly elevated scores on the National Institutes of Health Stroke Scale (NIHSS) (U = 647.5; Z = −4.406; p = 0.001) and the Rankin Scale (RS) (U = 811.5; Z = −3.342; p < 0.001) before the intervention.

Following the intervention, the CG maintained significantly higher BS scores than the SG (SG: 63.5 ± 32.9 vs. CG: 78.1 ± 28.0; Z = −2.308; p = 0.021). Conversely, the SG demonstrated significantly greater RS scores than the CG (SG: 3.3 ± 1.3 vs. CG: 2.6 ± 1.4; Z = −2.348; p = 0.019). However, NIHSS scores did not differ significantly between the two groups at the follow-up assessment (SG: 5.9 ± 6.0 vs. CG: 5.8 ± 6.3; Z = −0.313; p = 0.755).

Examining changes within the SG over time, a significant improvement in BS scores was noted (Z = −3.861; p < 0.001), whereas no substantial shifts were detected in RS (Z = −0.617; p = 0.537) or NIHSS (Z = −0.715; p = 0.475). Within the CG, BS scores also increased significantly (Z = −2.821; p = 0.005), alongside a notable improvement in NIHSS scores (Z = −3.954; p < 0.001). However, RS scores remained relatively unchanged (Z = −0.964; p = 0.335).

Discussion

This prospective cohort study demonstrated that stroke survivors who engaged in neurofunctional exercise programs did not achieve notable improvements in fitness and care requirements when compared to their counterparts in the control group. The control group displayed significantly superior outcomes in both within-group and between-group evaluations six months after experiencing a stroke. Additionally, comparative analysis at the six-month mark revealed that control group participants attained higher scores in RS, suggesting they had a greater capacity for managing daily activities, even though no substantial changes were detected within the group over time.

Unexpectedly, stroke patients who engaged in specialized neurofunctional exercises—including PNF and NDT-did not exhibit significant enhancements in their Barthel Index or Rankin Scale scores after six months, relative to those who participated in general physical activity at home. This outcome contrasts with earlier findings, where the PNF group demonstrated greater progress than those engaging in task-specific exercises [27]. These results raise the possibility that PNF exercises may not be as effective in fostering neuroplasticity and improving functional ability as previously suggested [27]. Similarly, this study's findings diverge from research indicating that Bobath NDT can be more advantageous for functional recovery and gait enhancement than traditional rehabilitation methods [28,29].

Table 1. Descriptive statistics (mean ± standard deviation) of the demographic information and the rehabilitation scales between groups.

	SG (*n* = 51)	CG (*n* = 51)	Between Group Comparisons
Men (*n*)	20	26	
Women (*n*)	31	25	
Age (years)	72.2 ± 9.9	69.5 ± 10.8	
Barthel index (A.U.)			
Baseline	43.0 ± 35.5	67.9 ± 34.0	*p* = 0.001
Median	30.0	80.0	
Interquartile range	70.0	55.0	
Post 6 months	63.5 ± 32.9	78.1 ± 28.0	*p* = 0.021
Median	70.0	90.0	
Interquartile range	55.0	25.0	
Post-pre difference (%)	47.7	15.0	
Ranking scale (A.U.)			
Baseline	3.4 ± 1.3	2.5 ± 1.3	*p* < 0.001
Median	4.0	2.0	
Interquartile range	2.0	2.0	
Post 6 months	3.3 ± 1.3	2.6 ± 1.4	*p* = 0.019
Median	3.0	3.0	
Interquartile range	2.0	2.0	
Post–pre difference (%)	−2.9	4.0	
NIHSS (A.U.)			
Baseline	6.5 ± 5.3	3.1 ± 3.9	*p* = 0.001
Median	5.0	2.0	
Interquartile range	6.0	2.0	
Post 6 months	5.9 ± 6.0	5.8 ± 6.3	*p* = 0.755
Median	4.0	4.0	
Interquartile range	6.0	5.0	
Post–pre difference (%)	−9.2	87.1	

PNF and Bobath NDT are designed to stimulate neuroplastic changes in the brain [30]. These rehabilitation techniques prioritize functional movements that closely resemble everyday activities, promoting the reacquisition of motor abilities crucial for independent living [31]. The proprioceptive input provided by PNF involves coordinated, dynamic movements aimed at improving muscle strength, coordination, and proprioceptive awareness [32]. This process aids in re-establishing normal movement patterns while mitigating the effects of abnormal muscle tone, which is often present in stroke patients [33].

Conversely, Bobath NDT is centered on enhancing postural stability and facilitating typical movement patterns through guided interventions [34]. This method seeks to suppress irregular reflexive responses and abnormal muscle tone while reinforcing coordinated movement sequences [35]. By incorporating sensory input and focusing on task-based exercises, Bobath NDT may encourage the nervous system to regain control over voluntary motor functions [36].

Although general physical activity contributes to overall well-being and muscle conditioning, it lacks the targeted neurological engagement that neurofunctional rehabilitation methods offer [30]. Conventional exercises primarily support cardiovascular health and muscular endurance, but they may not provide sufficient stimulus to drive neuroplastic changes essential for functional recovery [37].

The improvements observed in the Barthel Index and Rankin Scale scores within the control group could be attributed to the nature of physical activity and environmental factors associated with home-based rehabilitation [30]. Enhancements in muscle strength and coordination could indirectly support the neural control of movement, leading to better functional performance and increased independence in daily tasks. Additionally, the home setting might have played a role by fostering a supportive environment where family members facilitated patient engagement in rehabilitation activities.

In terms of NIHSS scores, a significant decline was recorded within the control group, while the experimental group showed similar results to their baseline assessments. The absence of pronounced changes in the experimental group suggests that individuals relying solely on general physical activity may not receive the targeted neural stimuli required for optimal recovery [38]. While conventional exercises contribute to maintaining physical strength, they may not effectively address the intricate neurological impairments associated with stroke [39]. Without sufficient neurofunctional rehabilitation, stroke survivors may face progressive functional decline due to inadequate neural reorganization and reliance on compensatory mechanisms [40]. Additionally, variability in individual responses to therapy must be considered, as factors such as stroke severity, lesion location, and coexisting medical conditions likely influenced rehabilitation outcomes [41]. It is plausible that the group undergoing neurofunctional training exhibited diverse responses, where some individuals showed considerable progress, while others displayed minimal improvements, leading to an overall lack of statistical significance.

Despite these insights, certain limitations of this study must be acknowledged. The absence of randomization and blinding could have influenced the assessment results. Moreover, the study duration was limited to six months, which restricts conclusions about the long-term sustainability of neurofunctional exercise benefits. Additionally, differences in the intensity and frequency of rehabilitation sessions were not standardized, potentially affecting outcomes. Future research should monitor these variables to determine optimal rehabilitation strategies for stroke recovery. Further, individual characteristics such as lesion severity, location, and pre-existing conditions were not controlled, which could have affected the effectiveness of the interventions. Addressing these factors in future investigations could provide deeper insight into the efficacy of neurofunctional therapies.

Another limitation relates to the assessment instruments used, namely the BI and RS. While both are widely accepted measures in stroke rehabilitation research, they have inherent constraints. The Barthel Index, for instance, is susceptible to ceiling effects, which can limit its ability to detect functional improvements, especially in individuals with minor impairments who score near the upper limit. Additionally, cultural differences may influence how patients interpret and report their functional abilities, potentially affecting the reliability of the results. Similarly, the Rankin Scale, though a recognized measure of overall disability, can be subject to subjective biases and cultural variations in self-assessment. These issues may impact the generalizability of findings and should be considered when evaluating rehabilitation outcomes for stroke survivors.

Lastly, a notable limitation of this study is the lack of data regarding concurrent medication use, particularly in relation to newer antidiabetic agents. Emerging research suggests that some of these drugs have antiarrhythmic properties, which may offer benefits for patients with atrial fibrillation-one of the key risk factors for ischemic stroke [42]. Given the limited impact of neurofunctional exercises observed in this study, future investigations should examine whether such medications could enhance rehabilitation outcomes and contribute to stroke prevention efforts. Additional research into these pharmacological interventions could provide valuable insights for improving therapeutic strategies.

Conclusion

The results of this prospective cohort study suggest that neurofunctional exercise programs did not provide substantial advantages in improving fitness levels and care needs among stroke survivors. Instead, the control group showed significantly better outcomes, both individually and in comparison to the neurofunctional exercise group, at the six-month follow-up. Moreover, between-group comparisons at this stage indicated that the control group had superior RS scores, reflecting better performance in daily activities. These findings highlight the need for continued research to identify more effective rehabilitation approaches tailored to the unique needs of stroke patients.

References

1. Sacco, R.L. Kasner, S.E.; Broderick, J.P.; Caplan, L.R.; Connors, J.J.; Culebras, A.; Elkind, M.S.; George, M.G.; Hamdan, A.D.; Higashida, R.T.; et al. An Updated Definition of Stroke for the 21st Century. Stroke 2013, 44, 2064–2089.

2. Noukpo, S.I.; Kossi, O.; Tedesco Triccas, L.; Adoukonou, T.; Feys, P. Content and Effectiveness of Community-Based Rehabilitation on Quality of Life in People Post Stroke: A Systematic Review with Meta-Analysis. Disabil. CBR Incl. Dev. 2022, 33, 75.

3. Saunders, D.H.; Sanderson, M.; Hayes, S.; Johnson, L.; Kramer, S.; Carter, D.D.; Jarvis, H.; Brazzelli, M.; Mead, G.E. Physical fitness training for stroke patients. Cochrane Database Syst. Rev. 2020, 2020, CD003316.

4. Lee, J.-L.; Kim, Y.; Huh, S.; Shin, Y.-I.; Ko, S.-H. Status and Barriers of Physical Activity and Exercise in Community-Dwelling Stroke Patients in South Korea: A Survey-Based Study. Healthcare 2024, 12, 697.

5. French, B.; Thomas, L.H.; Coupe, J.; McMahon, N.E.; Connell, L.; Harrison, J.; Sutton, C.J.; Tishkovskaya, S.; Watkins, C.L. Repetitive task training for improving functional ability after stroke. Cochrane Database Syst. Rev. 2016, 2016, CD006073.

6. Cumming, T.B.; Tyedin, K.; Churilov, L.; Morris, M.E.; Bernhardt, J. The effect of physical activity on cognitive function after stroke: A systematic review. Int. Psychogeriatr. 2012, 24, 557–567.

7. Grau-Sánchez, J.; Münte, T.F.; Altenmüller, E.; Duarte, E.; Rodríguez-Fornells, A. Potential benefits of music playing in stroke upper limb motor rehabilitation. Neurosci. Biobehav. Rev. 2020, 112, 585–599.

8. Saunders, D.H.; Greig, C.A.; Mead, G.E. Physical Activity and Exercise after Stroke. Stroke 2014, 45, 3742–3747.

9. Cheraghifard, M.; Taghizadeh, G.; Akbarfahimi, M.; Eakman, A.M.; Hosseini, S.-H.; Azad, A. Psychometric properties of Meaningful Activity Participation Assessment (MAPA) in chronic stroke survivors. Top. Stroke Rehabil. 2021, 28, 422–431.

10. Mas-Herrero, E.; Zatorre, R.J.; Rodriguez-Fornells, A.; Marco-Pallarés, J. Dissociation between Musical and Monetary Reward Responses in Specific Musical Anhedonia. Curr. Biol. 2014, 24, 699–704.

11. Hildebrand, M.; Brewer, M.; Wolf, T. The Impact of Mild Stroke on Participation in Physical Fitness Activities. Stroke Res. Treat. 2012, 2012, 548682.

12. Butler, E.N.; Evenson, K.R. Prevalence of Physical Activity and Sedentary Behavior among Stroke Survivors in the United States. Top. Stroke Rehabil. 2014, 21, 246–255.

13. Choi, Y.-A.; Lee, J.S.; Park, J.H.; Kim, Y.H. Patterns of physical activity and sedentary behavior and their associated factors among nondisabled stroke survivors. Maturitas 2022, 158, 10–15.

14. Karadag-Saygi, E.; Giray, E.; Eren, N.; Yolcu, G.; Coskun, O.K.; Cifcili, S. Barriers and facilitators to physical activity participation among community-dwelling physically inactive individuals after stroke: A qualitative exploratory study. Int. J. Rehabil. Res. 2024, 47, 34–40.

15. Thilarajah, S.; Mentiplay, B.F.; Bower, K.J.; Tan, D.; Pua, Y.H.; Williams, G.; Koh, G.; Clark, R.A. Factors associated with post-stroke physical activity: A systematic review and meta-analysis. Arch. Phys. Med. Rehabil. 2018, 99, 1876–1889.

16. Nicholson, S.; Sniehotta, F.F.; van Wijck, F.; Greig, C.A.; Johnston, M.; McMurdo, M.E.T.; Dennis, M.; E Mead, G. A systematic review of perceived barriers and motivators to physical activity after stroke. Int. J. Stroke 2013, 8, 357–364.

17. Billinger, S.A.; Arena, R.; Bernhardt, J.; Eng, J.J.; Franklin, B.A.; Johnson, C.M.; MacKay-Lyons, M.; Macko, R.F.; Mead, G.E.; Roth, E.J. Physical activity and exercise recommendations for stroke survivors. Stroke 2014, 45, 2532–2553.

18. Cuschieri, S. The Strobe guidelines. Saudi J. Anaesth. 2019, 13, 31.

19. Quinn, T.J.; Langhorne, P.; Stott, D.J. Barthel Index for Stroke Trials. Stroke 2011, 42, 1146–1151.

20. Duffy, L.; Gajree, S.; Langhorne, P.; Stott, D.J.; Quinn, T.J. Reliability (Inter-Rater Agreement) of the Barthel Index for Assessment of Stroke Survivors. Stroke 2013, 44, 462–468.

21. Rankin, J. Cerebral Vascular Accidents in Patients over the Age of 60: II. Prognosis. Scott. Med. J. 1957, 2, 200–215.

22. Zhao, H.; Collier, J.M.; Quah, D.M.; Purvis, T.; Bernhardt, J. The Modified Rankin Scale in Acute Stroke Has Good Inter-Rater Reliability but Questionable Validity. Cerebrovasc. Dis. 2010, 29, 188–193.

23. Lyden, P.; Lu, M.; Jackson, C.; Marler, J.; Kothari, R.; Brott, T.; Zivin, J. Underlying Structure of the National Institutes of Health Stroke Scale. Stroke 1999, 30, 2347–2354.

24. Lyden, P.; Brott, T.; Tilley, B.; Welch, K.M.; Mascha, E.J.; Levine, S.; Haley, E.C.; Grotta, J.; Marler, J. Improved Reliability of the NIH Stroke Scale Using Video Training. NINDS TPA Stroke Study Group. Stroke 1994, 25, 2220–2226.

25. Chaturvedi, P.; Singh, A.K.; Kulshreshtha, D.; Maurya, P.K.; Thacker, A.K. Proprioceptive Neuromuscular Facilitation (PNF) vs. Task Specific Training in Acute Stroke: The Effects on Neuroplasticity. MOJ Anat. Physiol. 2018, 5, 1.

26. Mikołajewska, E. Bobath and Traditional Approaches in Post-Stroke Gait Rehabilitation in Adults. Biomed. Hum. Kinet. 2017, 9, 27–33.

27. Suharto, S.; Rahman, A.; Suriani, S. The Effectiveness of Bobath Exercises on the Ability to Walk and Leg Spasticity of Stroke Patients. Urban Health 2021, 3, 266–271.

28. Nshimiyimana, J.; Uwihoreye, P.; Claude Muhigirwa, J.; Niyonsega, T. Neurofunctional Intervention Approaches. In Neurorehabilitation and Physical Therapy; IntechOpen: London, UK, 2023.

29. Kuciel, M.; Rutkowski, S.; Szary, P.; Kiper, P.; Rutkowska, A. Effect of PNF and NDT Bobath Concepts on Ischemic Strokes Patients for Trunk Rehabilitation—A Randomized Pilot Study. Rehabil. Med. 2021, 25, 2.

30. Smedes, F.; Heidmann, M.; Schäfer, C.; Fischer, N.; Stępień, A. The Proprioceptive Neuromuscular Facilitation-Concept; the State of the Evidence, a Narrative Review. Phys. Ther. Rev. 2016, 21, 17–31.

31. Smedes, F.; Giacometti da Silva, L. Motor learning with the PNF-concept, an alternative to constrained induced movement therapy in a patient after a stroke; a case report. J. Bodyw. Mov. Ther. 2019, 23, 622–627.

32. Vaughan-Graham, J.; Cott, C.; Wright, F.V. The Bobath (NDT) concept in adult neurological rehabilitation: What is the state of the knowledge? A scoping review. Part I: Conceptual perspectives. Disabil. Rehabil. 2015, 37, 1793–1807.

33. Lennon, S. The Bobath concept: A critical review of the theoretical assumptions that guide physiotherapy practice in stroke rehabilitation. Phys. Ther. Rev. 1996, 1, 35–45.

34. Vaughan-Graham, J.; Cott, C.; Wright, F.V. The Bobath (NDT) concept in adult neurological rehabilitation: What is the state of the knowledge? A scoping review. Part II: Intervention studies perspectives. Disabil. Rehabil. 2015, 37, 1909–1928.

35. Edwards, L.L.; King, E.M.; Buetefisch, C.M.; Borich, M.R. Putting the

"sensory" into sensorimotor control: The role of sensorimotor integration in goal-directed hand movements after stroke. Front. Integr. Neurosci. 2019, 13, 16.

36. Beltrán-Rodríguez, I.; García-Talavera Casado, L.; Durán-Borrella, Ó.; González-Feito, P.; Sánchez-Serrano, I.; de la Fuente Blanco, R. Post-Stroke Rehabilitation: A Necessary Step. In Post-Stroke Rehabilitation; IntechOpen: London, UK, 2022.
37. Shepherd, R.B. Exercise and training to optimize functional motor performance in stroke: Driving neural reorganization? Neural Plast. 2001, 8, 121–129.
38. Kreisel, S.H.; Bäzner, H.; Hennerici, M.G. Pathophysiology of stroke rehabilitation: Temporal aspects of neurofunctional recovery. Cerebrovasc. Dis. 2006, 21, 6–17.
39. Wissel, J.; Verrier, M.; Simpson, D.M.; Charles, D.; Guinto, P.; Papapetropoulos, S.; Sunnerhagen, K.S. Post-stroke spasticity: Predictors of early development and considerations for therapeutic intervention. PMR 2015, 7, 60–67.
40. Scrivener, K.; Dorsch, S.; McCluskey, A.; Schurr, K.; Graham, P.L.; Cao, Z.; Shepherd, R.; Tyson, S. Bobath therapy is inferior to task-specific training and not superior to other interventions in improving lower limb activities after stroke: A systematic review. J. Physiother. 2020, 66, 225–235.
41. Stoller, O.; de Bruin, E.D.; Knols, R.H.; Hunt, K.J. Effects of cardiovascular exercise early after stroke: Systematic review and meta-analysis. BMC Neurol. 2012, 12, 45.
42. Braun, R.G.; Wittenberg, G.F. Motor Recovery: How Rehabilitation Techniques and Technologies Can Enhance Recovery and Neuroplasticity. Semin. Neurol. 2021, 41, 167–176.