Effect of neurophysiotherapy intervention on the restoration of hemiparetic and ataxic gait pattern

Učinak neurofizioterapijske intervencije na obnovu hemiparetičkog i ataksičnog obrasca hoda

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Abstract

Introduction: One of the main motor deficits in neurological patients is gait impairment. Normal gait occurs as an automatic activity involving symmetrical synergy of walking speed and step length. Changes in the central nervous system manifest in the motor activities of neurological patients, causing difficulties and deviations in balance and coordination, base of support width, muscle weakness, and muscle tone, which lead to pathological patterns in the stance and swing phases during gait. Each pathological gait pattern reduces the efficiency and economy of walking and requires excessive energy expenditure, resulting in an asymmetric pattern, reduced speed, and reduced step length.

Aim: To determine the effect of neurophysiotherapy intervention on the restitution of hemiparetic and ataxic gait patterns in neurosurgical patients.

Materials and methods: This non-randomized pre–post intervention study was conducted on a sample of 30 participants. They were divided into two groups: the first group (G1) included participants with a hemiparetic gait pattern (N = 15), while the second group (G2) included participants with an ataxic gait pattern (N = 15). To assess the effectiveness of the neurophysiotherapy intervention on gait restoration, the Berg Balance Scale, Dynamic Gait Index, and Timed Up and Go test were used. Participants were tested at the beginning and at the end of therapy.

Results: The effect of the neurophysiotherapy intervention in the hemiparetic gait group was statistically significant (BBS = 0.005; DGI = 0.004; TUG = 0.001; $p < 0.01$), as well as in the ataxic gait group. (BBS = 0.001; DGI = 0.001; TUG = 0.001; $p < 0.01$). There was no statistically significant difference between the two groups ($p > 0.05$).

Conclusion: Early, individualized, and targeted neurophysiotherapy intervention effectively improves balance and gait in neurosurgical patients with hemiparetic and ataxic gait patterns. The observed positive clinical trends and statistically significant improvements confirm the importance of facilitation approaches and problem-oriented therapy in early neurorehabilitation. Further research with larger samples and advanced outcome assessment methods is needed.

Key words: balance, neurophysiotherapy, gait restitution, hemiparetic gait, ataxic gait

Sažetak

Uvod: Jedan od glavnih motoričkih deficita kod neuroloških bolesnika je poremećaj hoda. Normalni hod odvija se kao automatska aktivnost koja uključuje simetričnu sinergiju brzine hodanja i duljine koraka. Promjene u središnjem živčanom sustavu manifestiraju se na motoričkim aktivnostima bolesnika, uzrokujući poteškoće i odstupanja u balansu i koordinaciji, širini baze oslonca, slabost mišića i tonusu mišića, što dovodi do patoloških obrazaca u fazama oslonca i njihanja tijekom hoda. Svaki patološki obrazac hoda smanjuje učinkovitost i ekonomičnost hodanja te zahtijeva prekomjernu potrošnju energije, što rezultira asimetričnim obrascem, smanjenom brzinom i kraćom duljinom koraka.

Cilj: Utvrditi učinak neurofizioterapijske intervencije na restituciju hemiparetičnog i ataksičnog obrasca hoda kod neurokirurških bolesnika.

Materijali i metode: Ova nerandomizirana studija pre–post intervencije provedena je na uzorku od 30 ispitanika. Ispitanici su podijeljeni u dvije skupine: prva skupina (G1) uključivala je ispitanike s hemiparetičnim obrascem hoda (N = 15), dok je druga skupina (G2) uključivala ispitanike s ataksičnim obrascem hoda (N = 15). Za procjenu učinkovitosti neurofizioterapijske intervencije na restituciju hoda korišteni su Berg Balance Scale (BBS), Dynamic Gait Index (DGI) i Timed Up and Go test (TUG). Ispitanici su testirani na početku i na kraju terapije.

Rezultati: Učinak neurofizioterapijske intervencije u skupini s hemiparetičnim hodom bio je statistički značajan (BBS = 0,005; DGI = 0,004; TUG = 0,001; $p < 0,01$), kao i u skupini s ataksičnim hodom (BBS = 0,001; DGI = 0,001; TUG = 0,001; $p < 0,01$). Nije bilo statistički značajne razlike između dviju skupina ($p > 0,05$).

Zaključak: Rana, individualizirana i ciljana neurofizioterapijska intervencija učinkovito poboljšava balans i hod kod neurokirurških bolesnika s hemiparetičnim i ataksičnim obrascem hoda. Uočeni pozitivni klinički trendovi i statistički značajna poboljšanja potvrđuju važnost facilitacijskih pristupa i problemski orijentirane terapije u ranoj neurorehabilitaciji. Potrebna su daljnja istraživanja s većim uzorcima i naprednijim metodama procjene ishoda.

Ključne riječi: balans, neurofizioterapija, restitucija hoda, hemiparetični hod, ataksični hod

Introduction

Walking is the most important learned motor skill that enables movement through the coordinated interaction of various central nervous system structures responsible for the fundamental prerequisites of gait: vertical body alignment, adequate postural control, and postural orientation and stability.[1] According to the patterns and mechanisms of normal neurophysiology of motor function and gait, clinical medicine classifies diseases causing gait disturbance into disorders of the upper motor neuron, lower motor neuron, extrapyramidal system, and cerebellum.[2]

Gait disorders significantly affect patient mobility and verticalization, which is crucial in the acute phase of treatment to prevent cardiorespiratory complications of prolonged bed rest, as well as the development of contractures and general muscle hypotonia. Additionally, the level of mobility and independence in activities of daily living greatly influences the psychological state of patients and their motivation for recovery, and is directly related to the risk of falls, which frequently prolongs hospitalization.[3]

Gait restitution is one of the most demanding goals of neurophysiotherapy intervention because it requires modification of numerous components whose coordinated activity must be maximally normalized with reduced pathological patterns, compensatory strategies, and associated reactions. Restitution and facilitation of gait focus on the phases of normal gait and rely on several prerequisites: normalization of muscle and postural tone, and selective mobility of the trunk, pelvis, and extremities. Gait facilitation includes stimulation of the stability and mobility phases of the lower extremities with appropriate postural stability and adaptation of other body segments.[4]

Research has also confirmed the positive influence of cyclic and repetitive physical activities on the production of brain-derived neurotrophic factor (BDNF), a key factor responsible for promoting neuroplasticity. [5]

The quality of neurophysiotherapy outcomes and restitution of pathological toward normal gait patterns depends on several factors, such as the location and extent of neurological damage, timely and high-quality intervention, and individual patient characteristics including age, comorbidities, complication development, and cognitive abilities.[6]

Gait disorders in neurological patients are classified into low-level disorders, which include neuromuscular diseases and gait disturbances caused by sensory system damage; mid-level disorders, which encompass hemiparetic gait, ataxic gait, and disturbances caused by extrapyramidal symptomatology; and high-level disorders caused by subcortical imbalance, Parkinsonian gait, frontal gait, and frontal disequilibrium gait.[7]

The clinical picture of hemiparetic gait is most commonly dominated by weakness of the hip extensors and abductors, quadriceps, and pretibial muscles, resulting in insufficient postural control and pelvic instability due to abdominal and trunk stabilizer weakness, as well as impaired weight shifting.[8] In the stance phase, there is reduced hip extension, altered knee extension, decreased ankle plantar flexion, and lateral pelvic displacement. In the swing phase, there is reduced hip and knee flexion and decreased ankle dorsiflexion, preventing proper foot–ground contact.[9]

Ataxic gait is characterized by dysfunction of postural control mechanisms, sensorimotor balance processing, impaired coordination of body segments, and loss of spatial orientation relative to gravity.[10] Observing basic gait parameters, ataxic gait features reduced step width and length, decreased gait speed, and reduced peak flexion during the swing phase, accompanied by insufficient multijoint coordination and decreased ankle dorsiflexion at swing onset, which prevents proper foot contact with the ground and increases fall risk.[11]

However, despite growing evidence supporting neurophysiotherapy in neurological rehabilitation, there is still limited research comparing the effects of neurophysiotherapy interventions across different pathological gait patterns in neurosurgical patients during early postoperative rehabilitation.

The aim of this study was to examine the effectiveness of neurophysiotherapy intervention on balance, gait restitution, and fall risk in neurosurgical patients with hemiparetic and ataxic gait patterns.

Materials and methods

The research was conducted from February to September 2023 as a non-randomized pre–post intervention study on a sample of 30 participants. All participants had a history of neurosurgical operations and were hospitalized at the Department of Neurosurgery of the University Hospital Centre Zagreb, where postoperative neurophysiotherapy intervention was performed.

Inclusion criteria were. adult patients who underwent neurosurgical procedures. Presence of a hemiparetic or ataxic gait pattern, confirmed and diagnosed by a neurologist and physiotherapist. Exclusion criteria were: severe cognitive impairment, cardiorespiratory instability, musculoskeletal conditions affecting gait.

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of the University Hospital Centre Zagreb (Approval Number.: 8.1-20/125-2). All participants provided written informed consent prior to inclusion in the study.

Participants and Group Allocation

Participants were divided into two groups according to their gait pattern: the hemiparetic gait group (n = 15) and the ataxic gait group (n = 15).

In the hemiparetic gait group, 5 paticipants underwent surgery due to cerebral artery aneurysm, while 10 underwent brain tumour ablation.

In the ataxic gait group, 2 participants were operated on due to aneurysm, and 13 underwent brain tumour ablation.

Neurophysiotherapy Intervention

In both groups, neurophysiotherapy intervention was applied five times per week, 45 minutes per session, during the two-week hospitalization period. The intervention was based on facilitation of normal movement through specific sensory input adapted to the task and environment. The protocol included exercises tailored to each gait pattern and was administered by a licensed Bobath therapist.

Intervention in hemiparetic gait group, G1, included strengthening and activation of affected musculature, facilitation of sit-to-stand with symmetrical weight transfer, facilitation of stepping and gait, and motor learning activities aimed at selective movement, postural tone, and alignment.

Intervention in ataxic gait group, G2, included, strengthening of abdominal and back musculature, coordination exercises, facilitation of static and dynamic balance, gait training on a narrower base of support, and motor learning aimed at improving postural control and extremity coordination.

Outcome Measures

To assess the effectiveness of the neurophysiotherapy intervention, the following validated tools were used: Berg Balance Scale, Dynamic Gait Indeks and Timed Up and Go test.

Berg Balance Scale (BBS): evaluates stability, postural adjustments, and balance reactions. It includes fourteen functional tasks graded 0–4, where 0 indicates inability to perform the task and 4 indicates task performance without difficulty (maximum score = 56).[12-13]

Dynamic Gait Index (DGI): assesses gait, balance, and fall risk. It includes eight tasks scored 0–3, where 0 indicates severe impairment and 3 indicates normal performance (maximum score = 24).[14]

Timed Up and Go (TUG) test: measures functional mobility, static and dynamic balance, gait speed, and fall risk. Time is recorded in seconds: ≤10 s = normal mobility; 11–20 s = within normal limits and independently mobile; >20 s = mobility deficits and need for assistance; ≥30 s = not independently mobile with increased fall risk.[15]

Initial testing was performed on the first day of patient admission, and final testing was conducted on the last day of hospitalization.

Statistical Analysis

Statistical analyses were performed using MedCalc® Statistical Software version 22.006 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2023). Categorical data were presented as absolute and relative frequencies. Normality of numerical variables was assessed using the Shapiro–Wilk test. Numerical data were described using median and interquartile range. Differences between two independent groups were tested with the Mann–Whitney U test, and differences between two measurements were tested with the Wilcoxon test. All p-values were two-tailed, and the significance level was set at $\alpha = 0.05$.

Results

The study included 30 participants with a mean age of 55 years, 22 were women and 8 were men.

The BBS results for participants with a hemiparetic gait pattern (G1) were significantly higher in the second measurement compared to the first ($p = 0.005$). The DGI results also showed significant improvement in the second measurement ($p = 0.004$). The TUG test showed a reduction in the time required to perform the task ($p < 0.001$). Overall, participants demonstrated improved static and dynamic balance following the neurophysiotherapy intervention (Table 1).

In group G2, the BBS results showed significant improvement in the second measurement compared to the first ($p = 0.001$). DGI results were also significantly higher in the second measurement ($p < 0.001$). TUG results improved, with a reduction in execution time ($p < 0.001$) (Table 2).

Comparison of G1 and G2 on BBS, DGI and TUG showed differences in medians, but none of these differences were statistically significant (Table 3).

Table 1. *Results of BBS, DGI and TUG tests in Group G1*

G1		Measurement (Median, IQR)	Difference	95% CI	p-value
BBS	1st Measurement	34 (18 – 41)	9	4 to 14	0.005
	2nd Measurement	41 (32 – 46)			
DGI	1st Measurement	12 (6 – 16)	3	1 to 5	0.004
	2nd Measurement	14 (10 – 20)			
TUG	1st Measurement	37 (35 – 52)	-5,5	-12 to -3	<0.001
	2nd Measurement	34 (30 – 37)			

Legend: BBS – Berg Balans Scale; DGI – Dynamic Gait Index; TUG – Timed Up and Go test

Table 2. *Results of BBS, DGI and TUG tests in Group G2*

G2		Measurement (Median, IQR)	Difference	95% CI	p-value
BBS	1st Measurement	29 (8–38)	11	8 to 15	0.001
	2nd Measurement	41 (28–45)			
DGI	1st Measurement	10 (4–14)	4	3 to 6	0.001
	2nd Measurement	14 (9 – 19)			
TUG	1st Measurement	38 (35–63)	-6	–13 to –4	<0.001
	2nd Measurement	33 (32–40)			

Legend: BBS – Berg Balans Scale; DGI – Dynamic Gait Index; TUG – Timed Up and Go test

Table 3. *Comparison of G1 and G2 in BBS, DGI and TUG (First and Second Measurements)*

Test	Group	Measurement (Median, IQR)	Difference	95% CI	p-value
BBS 1st Measurement	G1	34 (18–41)	–4	–15 to 8	0.42
	G2	29 (8-38)			
BBS 2nd Measurement	G1	41 (32-46)	-2	-11 to 9	0.59
	G2	41 (28-45)			
DGI 1st Measurement	G1	12 (6-15)	-1	-6 to 4	0.60
	G2	10 (4-14)			
DGI 2nd Measurement	G1	14 (10-20)	0	-4 to 5	0.95
	G2	14 (9-19)			
TUG 1st Measurement	G1	37 (35–52)	1	–5 to 12	0.53
	G2	38 (35-63)			
TUG 2nd Measurement	G1	34 (30–37)	1	-3 to 6	0.69
	G2	33 (32-40)			

Legend: BBS – Berg Balans Scale; DGI – Dynamic Gait Index; TUG – Timed Up and Go test

Discussion

The results of this study confirmed the positive effect of neurophysiotherapy intervention on the restitution of balance and gait in participants with hemiparetic and ataxic gait patterns. In the group of participants with a hemiparetic gait, improvements in balance were confirmed on the BBS, while DGI results demonstrated enhanced gait performance. In the group of participants with an ataxic gait pattern, statistically significant improvements were likewise observed on both the BBS and DGI. These improvements are likely the result of a combination of posture facilitation, activation of segmental musculature, and repetitive, targeted motor tasks—principles that support motor learning and adaptation. This approach aligns with neuroplasticity theories, which propose that repeated, functionally relevant tasks can induce reorganization of neural networks and improve motor control. Supporting this, Matsugi et al. indicate that multimodal neurophysiotherapy interventions may reduce ataxia symptoms, despite moderate overall evidence strength.[24] Our findings corroborate this, demonstrating that participants with ataxic gait achieved significant improvements on both BBS and DGI, indicating that targeted neurophysiotherapy interventions can enhance functional control and gait in neurosurgical patients with ataxia.

Analysis of test variables suggests that participants with a hemiparetic gait pattern achieved optimization of the affected leg's function, characterized by improved weight shifting to the affected side during stance and shortened swing phase duration. These changes directly influenced step length, width, symmetry, and walking speed. Enhanced postural stability and balance reactions were reflected in improved ability to perform more demanding motor tasks. These findings are consistent with previous studies, which demonstrated positive effects of facilitation techniques and strengthening of the affected musculature, as well as gait re-education, particularly in the acute phase after hemiparesis.[16-18]

Similarly, analysis of results in the group with an ataxic gait pattern indicates improvements in coordination of body segments, postural control, static and dynamic balance, balance reactions, reduced lateral weight shifting, narrower base of support, increased step length, and improved gait speed. These results align with findings from other studies where therapeutic exercise interventions yielded improvements in balance and gait in individuals with ataxia.[19-21]

The effect of neurophysiotherapy intervention on walking speed and fall risk was evaluated using the TUG test, and a positive clinical trend was observed in both groups, with reduced performance time; however, statistical significance was not reached. Although the differences were not statistically significant, the trend of functional gait improvement is evident. The lack of statistical significance may be partly attributed to categorization thresholds (10-second increments) and the short time interval between assessments, which may limit sensitivity. Furthermore, the limited sensitivity of the TUG test in detecting subtle changes after a relatively short therapeutic period may also explain this outcome. While TUG is widely used for evaluating gait and fall risk, studies suggest that simple timing may not capture subtle yet clinically relevant gait changes in individuals with neurological disorders.[25] Therefore, future assessments would benefit from incorporating tools capable of more detailed analysis, including spatiotemporal gait parameters, step quality, stability, and postural control.

Comparison of BBS, DGI, and TUG outcomes between the hemiparetic and ataxic groups revealed no statistically significant differences, suggesting that the individualized neurophysiotherapy approach—adapted to each pathological gait pattern—successfully equalized outcomes despite differing neurological mechanisms. This underscores the value of problem-oriented interventions rather than a universal treatment model. Similar findings were reported by Winser et al., who demonstrated that therapeutic exercise alone does not significantly improve balance and functional independence unless specific, goal-directed physiotherapy strategies are implemented.[23]

Cassidy et al. recommend specialized additional training for physiotherapists working with individuals with ataxia to achieve better treatment outcomes.[23] This aligns with our findings, as the neurophysiotherapy intervention in this study was delivered by a therapist with specific training and expertise in neurological rehabilitation.

Overall, our results strongly indicate that rehabilitation of neurosurgical patients should begin early, be structurally planned, and individually tailored. Neurofacilitation and targeted therapeutic exercises should form the foundation of the therapeutic approach. Such interventions promote faster gait restitution, reduced fall risk, improved independence, and better patient quality of life—key goals of neurophysiotherapy intervention.

Although the results indicate effectiveness, several limitations must be considered: the relatively small sample size, the short follow-up period and the limited sensitivity of the TUG test for detecting subtle changes.

Future research should include larger samples, longer follow-up periods, and advanced gait analysis methods that allow detailed evaluation of spatiotemporal gait parameters, postural stability, and walking speed, particularly during longer distances.

Conclusion

Early, structured, and individualized neurophysiotherapy promotes functional gait restoration, balance improvement, and fall prevention in neurosurgical patients. Tailoring interventions to the specific gait pattern and functional needs of each patient supports neuroplasticity, motor learning, and faster recovery. These findings highlight the translational value of early, problem-oriented neurorehabilitation for clinical practice.

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Author Contribution:

M.V.: conception and design of the study; data acquisition, analysis and interpretation of data; drafting of the manuscript; M.T.: conception and design of the study; interpretation of data; drafting of the manuscript; L.J.: conception and design of the study; interpretation of data; drafting of the manuscript; G.G.Č.: conception and design of the study; interpretation of data; drafting of the manuscript; D.K.: conception and design of the study; interpretation of data; drafting of the manuscript; M.H.T.: conception and design of the study; interpretation of data; drafting of the manuscript; M.G.: conception and design of the study; interpretation of data; drafting of the manuscript; N.Ž.: conception and design of the study; analysis and interpretation of data; drafting of the manuscript;

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