International
Journal of Medical and Exercise Science
(Multidisciplinary, Peer Reviewed and Indexed Journal)

ORIGINAL ARTICLE

THE EFFECT OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION (PNF) EXERCISES ON POST-STROKE CONDITIONS ON CHANGES IN BDNF, POSTURAL BALANCE AND GAIT PATTERNS- NARRATIVE REVIEW

Search engine: www.ijmaes.org

James WH Manik[1], Beriman Rahmansyah[2]

Corresponding author:
[1]Physiotherapy Program, Faculty of Vocational Studies, Universitas Kristen, Indonesia, Jakarta, Indonesia, Mail id: jamesmanik@uki.ac.id
Co Author:
[2]Physiotherapy Program, Faculty of Vocational Studies, Universitas Kristen Indonesia, Jakarta, Indonesia. Mail id:

ABSTRACT

Background: Re-teaching functional abilities lost in stroke as early as possible with specific exercises systematically and repeatedly will produce beneficial effects on BDNF expression and balance. This study aims to determine the effect of proprioceptive neuromuscular facilitation (PNF) training in post-stroke conditions on changes in brain-derived neurotrophic factor (BDNF), postural balance and gait patterns through a narrative literature review". The research method used is a narrative review based on previous studies published in English data was obtained from PubMed, Google Scholar, Research Gate and other sources. Results: BDNF as a neurotrophic factor involved in motor learning, recovery and neurorehabilitation after stroke. BDNF levels in the acute phase of ischemic stroke are one of the prognostic considerations for the patient's functional status. Providing specific types of training can improve impaired motor function and functional abilities in stroke conditions and in line with the increase in BDNF concentrations that enhance the process of synaptogenesis in the central nervous system. Proprioceptive neuromuscular facilitation (PNF) training with minimal resistance and carried out intensively in stroke conditions can increase BDNF levels in the blood and improve balance and improved gait patterns. Conclusion: Studies on the effect of training with PNF techniques on BDNF concentrations in stroke conditions have not been widely conducted, however, several studies have shown an increase in BDNF levels and balance and gait patterns.

Keywords: Stroke; PNF, BDNF, Balance

Received on 04th May 2026; Revised on 20th May 2026; Accepted on 25th May 2026
DOI:10.36678/IJMAES.2026.V12I02.05

INTRODUCTION

Stroke is one of the factors causing disability with common symptoms of weakness of one half of the body. This condition arises from disruption of blood supply to the brain caused by ischemia or hemorrhage or sometimes both[2]. Inflammatory reactions often occur in stroke, even in the absence of infection, and induce the activation of microglia and astrocytes, peripheral infiltration of immunocytes, and the production of proinflammatory mediators, leading to necrosis and ultimately brain damage[3]. Stroke damages the body's structures and functions necessary for functional movement, therefore, motor recovery is one of the focuses of post-stroke rehabilitation[4]. Re-teaching functional abilities lost in stroke conditions as early as possible through exercise will produce a better impact. Active and passive exercise therapy with functional movement patterns systematically and repeatedly is one intervention that can be given in stroke conditions that aims to provide correct information to the brain, restoring the function of limbs lost due to neurological deficits[5].

Although functional limitations and disability aspects caused by stroke vary depending on the area and level of damage, stroke patients generally exhibit cognitive impairment, motor and sensory impairments and lower extremity dysfunction[6]. Impaired response to stimuli is caused by damage to motor pathways that cause difficulties in postural control, balance disorders, body stabilization against gravity, and disorientation accompanied by abnormal movements due to muscle weakness[7]. Saeys et al., (2012)[8] reported that trunk exercises are also performed in general physical therapy, it is more effective for balance and mobility in standing posture due to the smooth anticipatory posture performance and harmonization of the extremities by increasing postural strength. Decreased muscle strength and postural control (balance) are the main factors in limitations in activities of daily living[9].

Brain-derived neurotrophic factor (BDNF) is a neurotrophin widely expressed in the central nervous system (CNS) and plays a crucial role in synaptic plasticity, memory, and cognition[10]. Low serum BDNF levels in humans are a risk factor for stroke, while high serum BDNF levels cause hyperintensities in white matter and visual memory[11].

Providing specific types of exercise can address impaired movement and function in stroke, as increased BDNF concentrations enhance synaptogenesis in the central nervous system. This finding is consistent with research by Chaturvedi et al. (2018)[12], which demonstrated proprioceptive neuromuscular fasciculation (PNF) exercises in stroke patients immediately after the stroke. This study demonstrated increased BDNF levels, movement, and limb function in both the PNF (treatment) and specific upper and lower limb (control) exercise groups.

METHOD

The method used in this study is a narrative review with a search for national and international published literature in the form of experimental research or literature reviews/systematic reviews whose data is taken from PubMed, Google Scholar, Research gate and several other sources until 2025 using the keywords: stroke, PNF, BDNF, postural balance, gait pattern.

Brain derived neurotrophic factor (BDNF): Brain-derived neurotrophic factor (BDNF) is one of four neurotrophins belonging to the neurotrophic factor group, along with nerve growth factor (NGF), neurotrophin 3 (NT-3), and neurotrophin-4 (NT-4)[13]. BDNF is synthesized within cells as a precursor molecule called pro-BDNF, converted to the mature form by post-translational cleavage, and then secreted into the extracellular space[14]. BDNF, as a neurotrophic factor, is involved in motor learning, recovery, and neurorehabilitation after stroke[15].

Long-time potentiation (LTP) and long-time depression (LTD) are prototypical cellular models of synaptic plasticity in which specific types of synaptic stimulation result in a long-term increase (potentiation) or decrease (depression) in the strength of synaptic transmission. A growing body of research suggests that spinal structural plasticity and synaptic processes such as LTP or LTD are causally linked to memory[16]. Many studies have shown that BDNF is secreted during LTP induction and is functionally important for the acute signaling cascade leading to LTP, although BDNF is not required for all forms of LTP or the mechanisms leading to LTP[17].

Blocking TrkB during and after LTP induction confirms the critical phases required for the early and late phases in the BDNF-dependent components of LTP that begin with LTP induction and end in the range of 10 to 60 minutes after LTP initiation[18]. In addition, there is strong evidence that memory strengthening requires persistent action of BDNF over a longer period of up to 24 hours[19]. BDNF in LTP formation is better understood in the hippocampus, but the effects of BDNF differ greatly depending on the type of synapse.

DISCUSSION

Brain-derived neurotrophic factor (BDNF) profile in ischemic stroke

Brain-derived neurotrophic factor (BDNF) is produced in high amounts in the hippocampus, cerebral cortex, and spinal cord. In ischemic stroke, changes in BDNF levels correlate with mobility in post-stroke patients. Examination of ischemic stroke patients within 24 hours of the onset showed that BDNF levels during the first 24 hours of stroke were significantly higher in patient's less than 65 years of age compared to individuals older than 65 years. Furthermore, low BDNF concentrations were associated with clinical signs and symptoms observed over 90 days[20]. This suggests that BDNF levels in the acute phase of ischemic stroke are a prognostic factor for the patient's functional status[21].

Concurrent studies suggest that BDNF deficits may be an indicator of more severe stroke pathophysiology, as BDNF plays a crucial role in nervous system development and enhances neural differentiation, cellular survival, and neurogenesis[22,23]. Damage to the primary motor cortex (M1) and corticospinal cortex in stroke, resulting in loss of function in these areas, can replace the ipsilesional premotor area (PMA). This is likely due to the adaptive plastic potential of brain cells, which can accelerate stroke rehabilitation[11].

Effect of exercise on BDNF levels: Regular exercise at certain intensity will cause changes in epigenetic regulation through DNA methylation that leads to increased mRNA expression, BDNF in the hippocampus. BDNF is secreted in response to neural activity induced during acute and long-term exercise, which plays a crucial role in inducing cortical neuroplastic changes[24,25]. However, repetition of certain movements during training can also increase neuronal expression of BDNF, facilitating LTP in the pathways and circuits involved. The interaction of mature BDNF and TrkB leads to the growth of neural networks, nerve growth, synaptogenesis, and, possibly, motor recovery in patients. The effect of motor training is related to systematic and long-term practice in making movements[26]. High-intensity/extreme exercise will increase reactive oxygen levels and increase cell death. At the same time, increased BDNF expression is related to the regularity of exercise and not to the intensity of exercise[27].

Proprioceptive Neuromuscular Facilitation: Proprioceptive Neuromuscular Facilitation (PNF) is a physiotherapy approach used to improve neuromuscular abilities through proprioceptive, tactile, verbal, and visual stimulation. This concept was developed to facilitate functional movement patterns through diagonal and spiral movements that mimic everyday activities. PNF is widely used for neurological, musculoskeletal, and other movement disorders because it can improve coordination, muscle strength, flexibility, balance, and motor control. This approach emphasizes integration between the nervous system and the musculoskeletal system so that patients can obtain more efficient and controlled movement patterns[28].

In improving balance and gait, PNF has also been reported to be effective in reducing spasticity in stroke patients. This mechanism occurs through proprioceptive stimulation, which helps normalize muscle tone and improve neuromuscular coordination. The contraction-relaxation technique in PNF can help reduce stretch reflex hyperactivity, resulting in more controlled and efficient movements. Although several studies have noted that PNF has a positive effect on reducing spasticity, research with higher methodological quality is still needed[29,30].

Effect of PNF on BDNF levels: The effect of proprioceptive neuromuscular fasciculation (PNF) training on increasing BDNF levels in acute stroke conditions has been proven in a study by Chaturvedi et al., (2018)[12] which used 90 stroke patients as subjects consisting of 2 groups, namely the treatment group (PNF training) and control (special training).

The training was carried out for 30 minutes, 2x daily for 4 weeks. BDNF levels were examined before the intervention, after completing the training program and 6 months later. The results of the study showed an increase in serum BDNF levels in the treatment group (PNF) higher than the control group. Another similar study was conducted on 208 stroke patients. Regardless of stroke type and the presence of risk factors, significant increases in BDNF levels and FIM scale scores were seen in all subjects receiving PNF training in this study[24].

Furthermore, several researchers have suggested that BDNF levels are influenced by many factors besides physiotherapy interventions, such as post-stroke depression, inflammatory status, medication use, sleep quality, and the patient's daily physical activity. Post-stroke depression is known to decrease BDNF levels, leading to significant variation in research findings regarding BDNF increases after exercise. These factors may explain why some studies have not found consistent increases in BDNF after rehabilitation interventions[31].

The effect of PNF on postural balance and gait patterns: Postural balance is the ability to control the center of mass (COM) in relation to the base of support (BOS). Core muscles, including the trunk and pelvic muscles, are essential components for maintaining spinal and pelvic stability[32,33].

Previous research with PNF exercises in stroke conditions focused on the pelvic area combined with core muscle strengthening exercises and trunk flexibility exercises in two groups showed significant improvements in postural balance (Mini-BESTest), walking patterns (Wisconsin Gait Scale)[34,35]. Furthermore, the ankle is also a crucial factor in balance. Among chronic movement disabilities, foot and ankle proprioception deficits are most common and are strongly associated with the risk of falls in stroke[35].

Related to this, research by Donghwan Park et al, (2021)[36] which combines PNF exercises from extension to flexion, adduction, external rotation patterns with kinesio tapping on weak muscles (tibialis anterior, extensor hallucis and extensor toes) to increase ankle stabilization by improving ankle dorsiflexion ability which has a major impact on postural balance. The results of the study noted an increase in postural balance through the assessment of the time up & go test (TUG) and dynamic gait index (DGI).

Examining the timing of PNF-based exercise after a stroke, a study showed that early mobilization 24 hours after the attack had a better impact on balance and functional ability compared to 48 hours after the attack using the Barthel Index (BI) instrument for measuring functional ability and the Berg Balance Scale (BBS) for balance[37]. Improvements in balance and gait patterns in stroke conditions were also recorded in the research of Kyoung Kim et al., (2015)[38] with PNF coordination movement training with sprinter and skate patterns, 10x repetitions of each set of 5 sets carried out in water with a water depth of 100m and a temperature of 32º-34ºC.

Balance dysfunction includes postural instability and swaying, decreased gait speed, hemiplegic gait pattern and weight loss on the weaker leg[39]. Research by Shin Jun Park et al., (2020) using chopping and lifting pattern techniques in PNF exercises consisting of 10 movements performed on stroke patients showed improved posture control, balance and walking patterns using the Trunk Impairment Scale (TIS), Berg Balance Scale (BBS), Meters Walk Test (10 MWT), Walking Measurement Equipment (G-Walk) as examination instruments[40].

In terms of gait speed and cadence, Stephenson et al., (2014)[41] reported significant improvements in gait speed and cadence in both the PNF group and the body weight-supported treadmill training (BWSTT) group. It was also found that only the PNF group had a significant effect on gait improvement as measured by the Wisconsin Gait Scale (WGS) compared to the control group.

Seo et al., (2012)[42] reported that both PNF and control groups improved their stride time, with the PNF group improving significantly more than the control group. In terms of bipedal support, stance phase, and average speed, only the PNF group showed significant improvements after training. For distance parameters, both groups increased in stride length, with a more significant increase in the PNF group. Therefore, further research with a randomized controlled trial design and more specific biomarker measurements is still needed to confirm the direct relationship between PNF training and changes in BDNF expression in stroke conditions.

A systematic review and meta-analysis of the benefits of very early mobilization in acute stroke patients showed conflicting results, concluding that very early mobilization was not associated with beneficial effects when performed in patients 24 or 48 hours after stroke onset. There was no significant difference in Bartel index scores at 3 months, but the length of hospital stay in the early mobilization group (24 hours after stroke) was shorter than in the late mobilization group (48 hours after stroke)[43].

Although most studies show positive results, some studies have shown inconsistent results. A meta-analysis by Nguyen et al. noted that there are still some differences between studies regarding the type of PNF technique, intervention duration, exercise frequency, and characteristics of stroke patients. The researchers stated that the quality of evidence is still limited, so studies with better methodology are needed to generate a strong consensus regarding the effectiveness of PNF on balance and gait[28].

CONCLUSION

This study shows that PNF is an effective form of exercise for improving gait patterns in stroke patients. Therefore, PNF techniques should be considered in the management of stroke patients, combined with other specific exercise techniques. The primary factor that needs improvement in gait ability is postural balance.

BDNF is a neurotrophic factor involved in motor learning, recovery, and neurorehabilitation after stroke. Several studies have shown a link between BDNF levels and stroke severity. Increased BDNF levels during specific exercises, such as PNF and non-specific exercises have been demonstrated in some studies, but this has not been widely studied.

REFERENCE

1. Radak, Z. et al. Physical exercise, reactive oxygen species and neuroprotection. Free Radic. Biol. Med. 98, 187–196 (2016).
2. Sacco, R. L. et al. An updated definition of stroke for the 21st century: A statement for healthcare professionals from the American heart association/American stroke association. Stroke 44, 2064–2089 (2013).
3. Jin, R., Yang, G. & Li, G. Inflammatory mechanisms in ischemic stroke: role of inflammatory cells. J. Leukoc. Biol. 87, 779–789 (2010).
4. Langhorne, P., Bernhardt, J. & Kwakkel, G. Stroke rehabilitation. Lancet 377, 1693–1702 (2011).
5. Krisnawati, D. & Anggiat, L. Exercise Therapy in stroke: literature review. J. Fisioter. Terap. Indones. 1, 1–10 (2021).
6. Rafsten, L., Meirelles, C., Danielsson, A. & Sunnerhagen, K. S. Impaired motor function in the affected arm predicts impaired postural balance after stroke: A cross sectional study. Front. Neurol. 10, 1–7 (2019).
7. Mentiplay, B. F., Clark, R. A., Bower, K. J., Williams, G. & Pua, Y. H. Five times sit-to-stand following stroke: Relationship with strength and balance. Gait Posture 78, 35–39 (2020).

8. Saeys, W. et al. Randomized controlled trial of truncal exercises early after stroke to improve balance and mobility. Neurorehabil. Neural Repair 26, 231–238 (2012).
9. Feigin, V. L. et al. Global and regional burden of stroke during 1990-2010: Findings from the Global Burden of Disease Study 2010. Lancet 383, 245–255 (2014).
10. Minichiello, L. TrkB signalling pathways in LTP and learning. Nat. Rev. Neurosci. 10, 850–860 (2009).
11. Plow, E. B., Cunningham, D. A., Varnerin, N. & Machado, A. Rethinking stimulation of the brain in stroke rehabilitation: Why higher motor areas might be better alternatives for patients with greater impairments. Neuroscientist 21, 225–240 (2015).
12. 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. 5, (2018).
13. de Assis, G. G. & de Almondes, K. M. Exercise-dependent BDNF as a modulatory factor for the executive processing of individuals in course of cognitive decline. A systematic review. Front. Psychol. 8, 1–8 (2017).
14. Gibon, J., Barker, P. A. & Séguéla, P. Opposing presynaptic roles of BDNF and ProBDNF in the regulation of persistent activity in the entorhinal cortex. Mol. Brain 9, 1–13 (2016).
15. Ploughman, M., Austin, M. W., Glynn, L. & Corbett, D. The Effects of Poststroke Aerobic Exercise on Neuroplasticity: A Systematic Review of Animal and Clinical Studies. Transl. Stroke Res. 6, 13–28 (2015).
16. Hayashi-Takagi, A. et al. Labelling and optical erasure of synaptic memory traces in the motor cortex. Nature 525, 333–338 (2015).
17. Edelmann, E. et al. Theta Burst Firing Recruits BDNF Release and Signaling in Postsynaptic CA1 Neurons in Spike-Timing-Dependent LTP. Neuron 86, 1041–1054 (2015).
18. Harward, S. C. et al. Autocrine BDNF-TrkB signalling within a single dendritic spine. Nature 538, 99–103 (2016).
19. Panja, D. et al. Two-Stage Translational Control of Dentate Gyrus LTP Consolidation Is Mediated by Sustained BDNF-TrkB Signaling to MNK. Cell Rep. 9, 1430–1445 (2014).
20. Lasek-Bal, A. et al. Low concentration of BDNF in the acute phase of ischemic stroke as a factor in poor prognosis in terms of functional status of patients. Med. Sci. Monit. 21, 3900–3905 (2015).
21. Mirowska-Guzel, D. et al. Impact of BDNF -196 G>A and BDNF -270 C>T polymorphisms on stroke rehabilitation outcome: sex and age differences. Top. Stroke Rehabil. 21 Suppl 1, (2014).
22. Wang, J., Huang, Q., Ding, J. & Wang, X. Elevated serum levels of brain-derived neurotrophic factor and miR-124 in acute ischemic stroke patients and the molecular mechanism. 3 Biotech 9, 2–7 (2019).
23. Zhou, H. et al. Electroacupuncture Alleviates Brain Damage Through Targeting of Neuronal Calcium Sensor 1 by miR-191a-5p after Ischemic Stroke. Rejuvenation Res. 20, 492–505 (2017).
24. Chaturvedi, P., Singh, A. K. & Tiwari, V. Post - stroke BDNF concentration changes following proprioceptive neuromuscular facilitation (PNF) exercises. (2020) doi:10.4103/jfmpc.jfmpc.

25. Morais, V. A. C. de et al. A single session of moderate intensity walking increases brain-derived neurotrophic factor (BDNF) in the chronic post-stroke patients*. Top. Stroke Rehabil. 25, 1–5 (2018).
26. Blank, A. A., French, J. A., Pehlivan, A. U. & O'Malley, M. K. Current Trends in Robot-Assisted Upper-Limb Stroke Rehabilitation: Promoting Patient Engagement in Therapy. Curr. Phys. Med. Rehabil. Reports 2, 184–195 (2014).
27. Liu, W. A narrative review of gait training after stroke and a proposal for developing a novel gait training device that provides minimal assistance. Top. Stroke Rehabil. 25, 375–383 (2018).
28. Nguyen, P. T. & Chou, L. Proprioceptive Neuromuscular Facilitation-Based Physical Therapy on the Improvement of Balance and Gait in Patients with Chronic Stroke : A Systematic Review and Meta-Analysis. (2022).
29. Alasram, A. R. A. A. A. E. P. & G. A. Efficacy of proprioceptive neuromuscular facilitation on spasticity in patients with stroke: a systematic review. Phys. Ther. Rev. 26, 168–176 (2021).
30. Yucekaya, B. et al. The effect of proprioceptive neuromuscular facilitation techniques on pain, motor functions, fatigue and health related quality of life in individuals with multiple sclerosis: a randomized, single-blind study. Natl. Libr. Med. 7, 537–549 (2025).
31. Mojtabavi, H., Shaka, Z., Momtazmanesh, S., Ajdari, A. & Rezaei, N. Circulating brain - derived neurotrophic factor as a potential biomarker in stroke : a systematic review and meta - analysis. J. Transl. Med. 1–20 (2022) doi:10.1186/s12967-022-03312-y.
32. Lee, K. The Relationship of Trunk Muscle Activation and Core Stability : A Biomechanical Analysis of Pilates-Based Stabilization Exercise. (2021).
33. Stretanski, M. F., Collier, S. A. & Ampat, G. Lumbar Stabilization. (national library of medicine, 2026).
34. Sharma, V. & Kaur, J. Effect of core strengthening with pelvic proprioceptive neuromuscular facilitation on trunk, balance, gait, and function in chronic stroke. J. Exerc. Rehabil. 13, 200–205 (2017).
35. Gorst, T. et al. The prevalence, distribution, and functional importance of lower limb somatosensory impairments in chronic stroke survivors: a cross sectional observational study. Disabil. Rehabil. 41, 2443–2450 (2019).
36. Park, D. & Bae, Y. Proprioceptive Neuromuscular Facilitation Kinesio Taping Improves Range of Motion of Ankle Dorsiflexion and Balance Ability in Chronic Stroke Patients. Healthcare 9, 1426 (2021).
37. Rahayu, U. B., Wibowo, S. & Setyopranoto, I. The effectiveness of early mobilization time on balance and functional ability after ischemic stroke. Open Access Maced. J. Med. Sci. 7, 1088–1092 (2019).
38. Kim, K., Lee, D. K. & Jung, S. I. Effect of coordination movement using the PNF patern underwater on the balance and gait of stroke patients. J. Phys. Ther. Sci. 27, 3699–3701 (2015).
39. Cha, H. G., Shin, Y. J. & Kim, M. K. Effects of the Bad Ragaz Ring Method on muscle activation of the lower limbs and balance ability in chronic stroke: A randomised controlled trial. Hong Kong Physiother. J. 37, 39–45 (2017).
40. Park, S. J. & Oh, S. Effect of diagonal pattern training on trunk function, balance, and gait in stroke patients. Appl. Sci. 10,

(2020).

41. Stephenson, J. B., Maitland, M. E., Beckstead, J. W. & Anemaet, W. K. Locomotor Training on a Treadmill Compared With Pnf Training in Adults With Chronic Stroke. Technol. Innov. 15, 325–332 (2014).
42. Seo, K. C., Lee, J. H. & Lee, S. Y. Impact of PNF-based walking exercise on a ramp on gait performance of stroke patients. J. Phys. Ther. Sci. 24, 1243–1246 (2012).
43. Xu, T. et al. Efficacy and Safety of Very Early Mobilization in Patients with Acute Stroke: A Systematic Review and Meta-analysis. Sci. Rep. 7, 1–8 (2017).

James WH Manik, Beriman Rahmansyah (2026). The effect of proprioceptive neuromuscular facilitation (PNF) exercises on post-stroke conditions on changes in BDNF, postural balance and gait patterns, ijmaes, 12(2), 2863-2871.