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REVIEW ARTICLE (META-ANALYSIS)

Effectiveness of the Proprioceptive Neuromuscular Facilitation Method on Gait Parameters in Patients With Stroke: A Systematic Review

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Abstract

Objective: To review the current evidence for the effectiveness of proprioceptive neuromuscular facilitation (PNF) techniques on gait parameters in patients with stroke.

Data Sources: The electronic platforms of CINAHL, MEDLINE, PubMed, and the Physiotherapy Evidence Database were searched using the relevant search terms.

Study Selection: Intervention studies that had gait parameters as an outcome and in which PNF techniques were used in a poststroke population were reviewed. The studies were reviewed by both authors and a consensus was reached. The literature search identified 84 studies. Following screening, there were 5 studies that met the inclusion criteria for this review.

Data Extraction: Data were extracted from the studies by both authors and independently reviewed. Methodological quality was assessed with the Physiotherapy Evidence Database scale of randomized controlled trials and with the Quality Assessment Tool for Quantitative Studies for nonrandomized controlled trials.

Data Synthesis: Treatment using the PNF method led to a statistically significant improvement in gait outcome measures in patients with stroke in all the studies. Three of the studies also found that groups treated with PNF techniques had a significantly greater improvement in outcome measures than groups that received routine physiotherapy treatment.

Conclusions: Although some limitations were identified in the methodological quality of the studies, current research suggests that PNF is an effective treatment for the improvement of gait parameters in patients with stroke. Further research is needed to build a robust evidence base in this area.

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The proprioceptive neuromuscular facilitation (PNF) approach was originally developed in the 1940s by Dr Herman Kabat and Margaret Knott, when it was used to treat patients suffering from poliomyelitis.[1] Following its development, the PNF concept evolved into a rehabilitation approach used for a number of conditions of neurologic and musculoskeletal origin.[2] Voss, Ionta, and Meyers[3] defined PNF as "methods of promoting or hastening the response of the neuromuscular mechanism through stimulation of the proprioceptors." The PNF approach consists of an overarching philosophy, a defined set of basic principles and procedures, and a description of techniques for use in rehabilitation.[2] It has long been used in rehabilitation of stroke patients[4]; however, it remains an area that is underresearched, and the existing evidence for its efficacy is often ambiguous.[5]

A review of the current evidence and guidelines on the use of PNF was completed. The Scottish Intercollegiate Guidelines Network[6] report that there is insufficient evidence to recommend one treatment approach over another for patients with stroke, and therapists should select their treatment approach according to the needs of the patient. According to guidelines from Winstein et al,[7] it has not been established that neurophysiological approaches such as PNF are more effective than other treatment approaches for motor retraining after an acute stroke. This guideline suggests that neurophysiological approaches may be considered but further studies are needed to establish their efficacy.

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There are currently 3 narrative reviews that looked at the overall efficacy of the PNF concept as a rehabilitation approach. Smedes et al[2] completed a review of the evidence on the effectiveness of PNF techniques in a variety of subject populations, including patients with neurologic, musculoskeletal, geriatric, and pulmonary disorders. In the second narrative review, Westwater-Wood et al[5] evaluated the evidence on the effectiveness of PNF techniques for functional rehabilitation and increasing range of movement in neurologic and nonneurologic patients. Finally, Chaturveti[4] carried out a review of the effectiveness of PNF for functional recovery of patients with stroke. All of the reviews reported that PNF has been used safely in many different patient populations and demonstrates positive results. However, they also highlighted a need for studies of high methodological quality.

Smedes et al[2] reported that the results of studies using PNF on gait-related outcome measures in different patient groups show a positive result on step frequency and gait speed. To our knowledge, there has been no review of the literature that specifically investigated the efficacy of PNF techniques on gait parameters in people with stroke.

Method

Search strategy

A literature search was conducted in June 2018. Electronic platforms and databases including CINAHL, MEDLINE, PubMed, and Physiotherapy Evidence Database (PEDro) were searched using a combination of search terms related to stroke, PNF, and gait parameters. The search strategy used is presented in table 1. Bibliographies of identified studies were manually searched for additional references, and a gray literature search was conducted using Internet search engines and websites.

Study selection

The following criteria were used to include studies for the review: (1) published clinical trials that have an experimental group receiving PNF treatment and a control group, (2) studies including a stroke population, (3) studies using outcome measures related to gait, and (4) studies in English.

Both authors of this review conducted the searching, screening, and data extraction independently. The authors then met to compare findings and discuss discrepancies. When disagreements occurred, they were discussed and resolved without need for a third party.

Methodological quality

To evaluate the quality of the studies, the PEDro rating scale was used. When interpreting the scores, studies of high quality score between 6 and 10, studies of fair quality score between 4 and 5, and studies of poor quality score 3 or below.[8] The scale is considered a valid measure of the methodological quality of clinical trials[9] and has fair to good levels of reliability for rating the quality of randomized controlled trials (RCTs).[10] The PEDro scale has been used in previous systematic reviews in rehabilitation.[11,12] The final study by Morreale at al[13] was not an RCT and, therefore, was assessed with the Quality Assessment Tool for Quantitative Studies.[14] This tool meets acceptable standards of validity and reliability[15] and is suitable for use in quantitative studies. It has been used in previous systematic reviews in rehabilitation.[16,17]

List of abbreviations:

BWSTT	**body weight–supported treadmill training**
PEDro	**Physiotherapy Evidence Database**
PNF	**proprioceptive neuromuscular facilitation**
RCT	**randomized controlled trial**

Results

Study selection

The search produced 12 studies. Of these, 2 studies[18,19] were excluded because they used PNF in combination with other treatments within the same experimental group; thus, the results of the trial could not be attributed to PNF treatment alone. Three additional studies[20-22] were excluded because they used PNF interventions in all study arms, in other words, there was no group that did not receive PNF for comparison of effect. Finally, 2 studies[23,24] were excluded because they did not include a control group. There were 5 remaining studies that met the criteria for inclusion in the systematic review.[13,25-28] Of these studies, 4 are RCTs, and the fifth[13] is a prospective multicenter blinded interventional study. A description of the search using a Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram is available in figure 1.

Population of studies

The sample sizes in the RCTs ranged in number from 18-40. None of these studies reported a power calculation to inform the number of people needed to show a significant effect of treatment. The study by Morreale et al[13] was a larger multicenter trial with 340 patients. Of the 5 studies, 3 studies[25-27] had patients with chronic stroke (>6mo poststroke), and 2 studies[13,28] had patients who were <6 months poststroke.

Types of intervention

Although all of the included studies used PNF as the primary intervention, the treatment techniques in individual studies varied. In the study of Stephenson et al,[25] the intervention group received PNF mat activities, including resisted pelvic and lower extremity movement patterns, and gait training. The gait training involved resistance applied to the patient's pelvis during weight shifting, followed by manual resistance applied at the pelvis during continuous walking. Gait training was also used by Seo et al,[26] where the intervention group received PNF-based walking exercise on a ramp. This intervention involved PNF gait training with resistance applied and walking on a ramp in opposition to pressure applied by the therapist.

In the trial carried out by Kumar et al,[28] the intervention group received 3 PNF techniques of rhythmic initiation, slow reversal, and agonistic reversal for pelvis. A combination of PNF techniques was also used by Ribeiro et al,[27] where the intervention group received basic PNF procedures and movement patterns in standing and sitting. The treatments included resisted sit and rise,

Table 1 Search terms

Platform	Databases	Search Terms	Limiters	No. of Items
EBSCO	CINAHL	(MM "stroke+") OR (stroke) OR (CVA) OR (cerebrovascular accident) AND (MM "neuromuscular facilitation") OR (PNF) OR (proprioceptive neuromuscular facilitation) AND (MM "gait+") OR (MM "gait analysis") OR (walking) OR (gait) OR (mobility)	Articles in English	32
EBSCO	MEDLINE	(MM "stroke+") OR (stroke or CVA or cerebrovascular accident) AND (MM "muscle stretching exercises") OR (PNF or proprioceptive neuromuscular facilitation or proprioceptive neuromuscular technique) AND (MM "gait+") OR (gait or walking or stepping or mobility)	Articles in English	23
	PubMed	(stroke or CVA or cerebrovascular accident) AND (PNF or proprioceptive neuromuscular facilitation) AND (gait or walking or mobility or stepping)	Articles in English	20
	PEDro	Stroke, proprioceptive neuromuscular facilitation, gait	Articles in English	7

standing weight transfer with resisted pelvic movement, and resisted pelvic movement during gait.

In the final study by Morreale et al,[13] the PNF group received PNF techniques and postural alignment. The PNF intervention consisted of a bedside and out-of-bed intervention with proximal joint passive/active mobilization according to Kabat's schemes. No further detail is described in this study as to the exact PNF treatment used. Because of this variation in the interventions used in the studies, it is difficult to make direct comparisons between them, but the main element of all of the interventions was use of PNF techniques.

The dose of treatment also differed between studies (table 2). The recommended dose of rehabilitation therapy following stroke is a minimum of 45 minutes of each appropriate therapy at least 5 days a week for as long as the patient continues to benefit from therapy and can tolerate it.[29] Not all of the studies met this recommendation with their described intervention.

Control groups

In 4 of the studies,[13,25,27,28] PNF was compared directly with other treatments. In the first of these, it was reported that treatment with PNF resulted in significantly more improvement in gait outcome measures than conventional exercises. In the description of the conventional exercises by Kumar,[28] the types of exercise and overall treatment duration are given; however, the number of repetitions and intensity of the exercises are not described. This has limitations as a comparator arm in an RCT because of the potential for inconsistency and difficulty in reproducing the treatment. In the study by

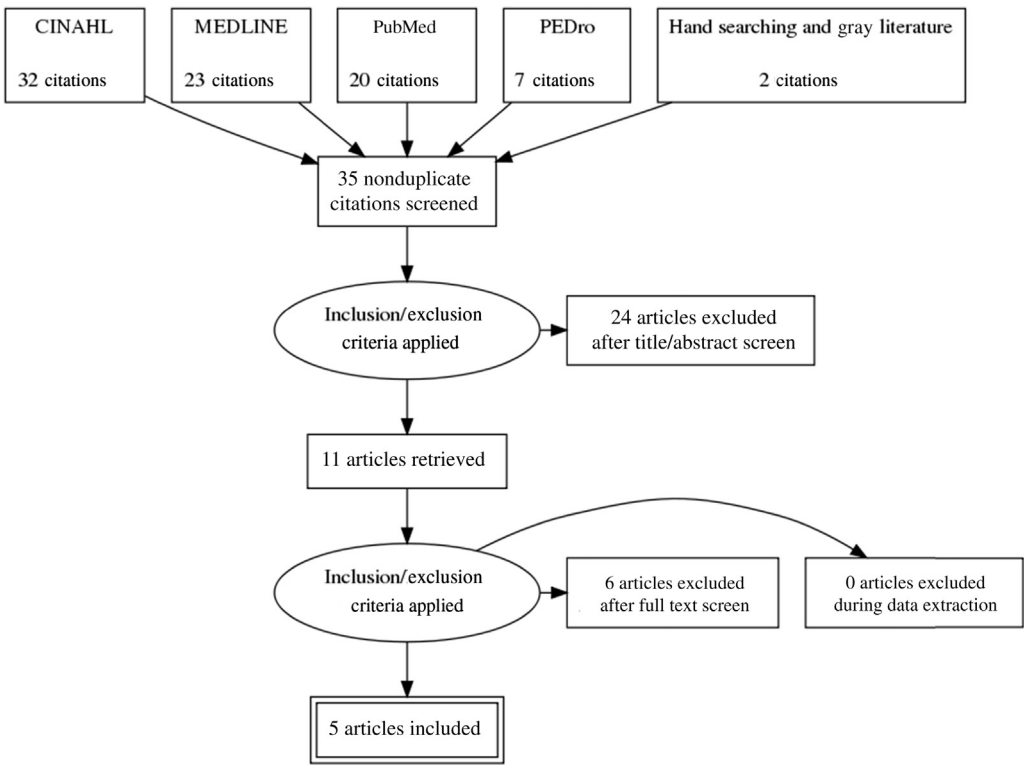

Fig 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart.

Table 2 Summary

Study	Sample	Intervention	Outcome Measures	Results
Stephenson et al[25] RCT	18 subjects with chronic stroke (>6mo)	PNF group: PNF mat activities and gait training × 30 min × 3 times/wk × 4 wk BWSTT group: BWSTT × 20 min × 3 times/wk × 4 wk Control group: no intervention	Measured preintervention and postintervention Gait velocity: 10-m walk test, gait cadence, Wisconsin Gait Scale, Perry's classification system	Both PNF and BWSTT improve gait velocity, cadence, and Wisconsin Gait Scale vs control group ($P<.05$)
Seo et al[26] RCT	40 subjects with chronic stroke (>6mo)	PNF group: 30-min PNF-based walking exercise on a ramp × 5 times/wk × 4 wk Control group: 30-min walking exercise on a ramp × 5 times/wk × 4 wk	Measured preintervention and postintervention Gait performance: temporal, spatial, and functional ambulation performance measured using GAITRite system	PNF-based walking on a ramp improved temporal and spatial parameters and improved functional ambulation performance vs control group ($P<.05$)
Kumar et al[28] Two-group pretest-posttest design	Convenience sample of 30 subjects (<6mo poststroke)	PNF group: 3 PNF techniques × 30 min × 3 d/wk × 4 wk Control group: stretching, strengthening and weight-bearing × 30 min × 3 d/wk × 4 wk	Measured preintervention and postintervention Stride length, cadence, gait velocity, functional mobility: Rivermead Mobility Index	PNF group improved in stride length, cadence, gait velocity, and Rivermead Mobility Index vs control ($P<.05$)
Ribeiro et al[27] RCT	Convenience sample of 23 subjects (>6mo poststroke)	PNF group: basic PNF procedures and facilitation patterns in standing and sitting × 30 min × 3 times/wk × 4 wk TPBWS group: gait trainer with treadmill and manual assistance × 30 min × 3 times/wk × 4 wk	Measured pre- and postintervention Functional Ambulation Category, NIHSS, Muscle tone: MAS, STREAM, FIM (motor); Gait: Qualisys System	Both groups improved in STREAM, motor FIM, and symmetry ratio of swing time ($P<.05$) PNF group only improved in maximum ankle dorsiflexion during swing phase ($P<.05$)
Morreale[13] Prospective multicenter blinded interventional study	340 patients post first time subcortical ischemic stroke	Early PNF: (starting day 1 poststroke) 45 min daily PNF and 15 min postural alignment and positioning Early CTE: (starting day 1 poststroke) 45-min guided movements during an attention task and 15 min postural alignment and positioning Both early groups then had 2.15 h/d of their assigned treatment from 5th-60th day poststroke. Then 1.30 h/d of treatment for a mean of 38 wk in total. Delayed treatment group: 60 min of postural alignment and positioning in the first 4 days. They were then randomized into the PNF or CTE groups to continue treatment for the rest of the trial.	Measured at baseline, at 3 mo and at 12 mo Disability, MRS, BI, safety, immobility-related adverse events, 6MWT, MI, MMSE, Beck Depression Inventory	MRS and BI improved in all groups ($P<.05$) with some more improvement in the early groups (not statistically significant) 6MWT improved in all groups ($P<.05$) At 12 mo early groups improved more in 6MWT than delayed groups ($P<.05$)

Abbreviations: 6MWT, 6-minute walk test; BI, Barthel Index; MAS, Modified Ashworth Scale; MI, myocardial infarction; MMSE, Mini-Mental State Examination; MRS, Modified Rankin Score; NIHSS, National Institutes of Health Stroke Scale; STREAM, Stroke Rehabilitation Assessment of Movement; TPBWS, treadmill training with partial body-weight support.

Morreale at al,[13] PNF and cognitive therapeutic exercise groups both showed significant improvement with no difference between the groups. Cognitive therapeutic exercise has limitations as a comparator arm because it is an approach that consists of different types of treatment techniques, and its protocol is not described in enough detail to allow replication of the treatment.

Table 3 PEDro rating scale for included RCTs

Study	Kumar et al[28]	Ribeiro et al[27]	Stephenson et al[25]	Seo et al[26]
Eligibility criteria	Yes	Yes	Yes	Yes
Random allocation	No	Yes	Yes	Yes
Concealed allocation	No	No	No	No
Groups similar at baseline	Yes	Yes	Yes	Yes
Subject blinding	No	No	No	No
Therapist blinding	No	No	No	No
Assessor blinding	No	No	Yes	No
Key outcomes ≥85%	No	No	Yes	No
All subjects received treatment	No	Yes	Yes	No
Between-group statistics	Yes	Yes	Yes	Yes
Point measure and variability	Yes	Yes	Yes	Yes
Total Score	3	5	7	4

PNF showed slightly more improvement than body weight–supported treadmill training (BWSTT) in 2 studies.[25,27] BWSTT is an appropriate choice of treatment for a comparison because it has been recommended with level A evidence in recent stroke guidelines to facilitate recovery of mobility in patients with stroke.[7] A favorable result for PNF in comparison with BWSTT could be interpreted as evidence that it is also an effective treatment for recovery of mobility in patients with stroke.

In the study by Seo et al,[26] PNF with walking on a ramp was compared with walking on a ramp only. The addition of the PNF treatment was the only difference between the groups, and, therefore, the improved outcomes in this group could be attributed to the PNF treatment. However, it could be argued that it was the combination of 2 treatments (walking on a ramp+PNF) that led to greater improvement in the PNF group and not PNF treatment alone.

Quality of the studies

The scoring of the quality of the studies with the PEDro scale is detailed in table 3. It suggests that 1 of the studies[28] is of low quality, 2 of the studies[26,27] are of fair quality, and 1 study[25] is of high quality. The most common reasons for lower scores in the assessment of these studies are the lack of concealed allocation and blinding of the therapists, subjects, and assessors. Analysis of the final study by Morreale et al[13] with the Quality Assessment Tool for Quantitative Studies suggested that the global rating for study methodology is strong. The study scored a strong rating in 4 out of 6 categories. The remaining 2 categories are scored as moderate because the study participants were aware of the study objectives and the study did not describe the validity and reliability of the outcome measures used.

Outcome measures

All of the studies used outcome measures related to gait. However, these outcome measures were different in every study. A full record of the outcome measures used relating to gait in the studies is presented in table 2. Because of this variation in outcome measures, results cannot be directly compared, but a comparison can be made of the overall improvements in gait parameters. All studies reported results in terms of statistical significance, and, although sample sizes were generally small, statistically significant differences were found in all the studies. None of the studies reported minimal clinically important difference, a significant consideration in person-centered care, because it measures the changes that are meaningful for the patient.[30]

Stephenson et al[25] reported a significant improvement in gait velocity and cadence in both the PNF group and the BWSTT group in comparison with the control group. Only the PNF group had a significant improvement in the Wisconsin Gait Scale compared with the control group. Seo et al[26] reported that, in temporal parameters, both the PNF and the control group improved their step time, with the PNF group improving significantly more than the control group. In terms of double support, stance phase, and mean velocity, only the PNF group showed a significant improvement post treatment. For the spatial parameters, both groups improved in step length, with significantly more improvement in the PNF group. Only the PNF group had significant improvements in heel-to-heel base of support and step/extremity ratio. Only the PNF group also had a significant improvement in Functional Ambulation Performance. This demonstrates that the PNF group had significantly more improvement in temporal and spatial gait parameters and functional ambulation performance than the control group.

Kumar et al[28] found that both the PNF and the control group improved their stride length, cadence, gait velocity and Functional Mobility Index. The PNF group had a significantly greater improvement in all measures than the control group. Significant changes were also found in the trial by Ribeiro et al.[27] This study reported that both groups improved significantly in the Stroke Rehabilitation Assessment of Movement and symmetry ratio of swing time. The only gait parameter in which the PNF group showed a greater improvement than the control group was in maximum ankle dorsiflexion during swing phase.

Finally, Morreale et al[13] found that scores on the 6-minute walk test significantly improved in all groups. They found that at 12 months, the groups that began rehabilitation within 24 hours of their admission (early groups) improved more than the groups that began rehabilitation 4 days after admission (delayed groups), but there was no difference in improvement of 6-minute walk test scores between the PNF and control groups.

Discussion

The aim of this review was to assess the effectiveness of the PNF approach on gait parameters in patients poststroke. Five studies were narratively analyzed and the results reviewed. The methodological quality of the included studies is variable, with most studies scoring a fair or high rating on the PEDro scale, 1 study scoring a strong rating on the Quality Assessment Tool for Quantitative Studies, and only 1 study scoring a low-quality rating on the PEDro scale. Four of the 5 studies were RCTs, and sample sizes were generally low.

All of the studies reviewed found that treatment using the PNF approach led to a statistically significant improvement in gait outcome measures in patients with stroke, with most of the studies finding that the PNF group improved more than the

control group. The findings must be interpreted carefully because these studies had small sample sizes and varying methodological quality; therefore, we cannot conclude that PNF is superior to other treatments. The best quality study with the largest sample size[13] did not show that PNF was more effective than the control treatment. However, it did show that PNF improved gait parameters and might be as effective as alternative physiotherapy treatments.

With the available evidence suggesting that the PNF approach is an effective intervention for the improvement of gait parameters in patients with stroke, its benefits over alternative treatments should be considered. Many therapists will have a basic level of knowledge of PNF from their core training program, and further training is available to certify therapists as PNF practitioners if desired. In the current health care climate, cost of treatment is a necessary consideration in choice of intervention. PNF may present a more cost-effective intervention than treatments such as BWSTT because there is no requirement to invest in expensive equipment for the PNF approach.

Study limitations

This review was limited by the number of studies available for inclusion. Limitations of the review also included the small sample size in the majority of the included studies and treatment protocols and outcome measures that varied in each study, meaning that the results cannot be pooled for meta-analysis.

Recommendations for future research

Future studies should include RCTs of high methodological quality, with blinding of therapists and patients. These studies should have larger sample sizes and use standardized outcome measures so that results could be compared in a meta-analysis. There is a need for long-term follow-up of the subjects of the trials, with most of the current studies only measuring outcomes at baseline and post intervention. The control groups in future studies would ideally include treatments that are known to be effective for improvement of gait parameters in people with stroke. Using these treatments in control groups would aim to show that PNF is as effective as or more effective than these established treatments.

The small number of studies identified in this area may stem from the difficulties in carrying out RCTs of a rehabilitation approach consisting of many different components. Future trials may benefit from assessing a specific treatment protocol using PNF methods, in order to have a standardized treatment program that can be assessed and reproduced. One preliminary small-scale trial[31] has already been completed in which a PNF-based treatment protocol was described in detail. This type of program would need to be evaluated in an RCT setting to assess its effectiveness.

Conducting large-scale studies is a wider issue that would need to be addressed by funding providers and collaboration between institutions. Considering the need for robust evidence in a pay-for-treatment, cost-competitive health care environment, this is an issue that needs to be addressed to provide proof of efficacy of the PNF approach. Producing this higher quality of evidence is important in future studies because the power and quality of the evidence dictates its inclusion in clinical guidelines and its continued use and relevance in physiotherapy practice.

Conclusion

The current research suggests that PNF is an effective treatment for the improvement of gait parameters in patients with stroke. In each of the reviewed studies, there was a statistically significant improvement in gait parameters in patients with stroke with the use of PNF. Therefore, PNF techniques should be considered by therapists as part of their treatment program for suitable patients. The results of this systematic review were affected by the small study numbers and varying methodological quality. Further research is needed to build a robust evidence base in this area.

Keywords

Gait; Muscle stretching exercises; Rehabilitation; Stroke

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