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

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

Abstract

Objective: The aim of this paper is to review the current evidence on the effectiveness of PNF techniques on gait parameters in patients with stroke.

Data Sources: The electronic platforms of CINAHL, MEDLINE, PubMed, and PEDro 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 post stroke 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 which met the inclusion criteria for this review.

Data extraction: Data was extracted from the studies by both authors and independently reviewed. Methodological quality of randomised controlled trials (RCTs) was assessed with the Physiotherapy Evidence Database (PEDro) scale and for non-RCTs with the Quality Assessment Tool for Quantitative Studies.

Data Synthesis: It was found that 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.

Key Words: proprioceptive neuromuscular facilitation, PNF, stroke, CVA, gait

Abbreviations: BWSTT- Body Weight Supported Treadmill Training; PEDro- Physiotherapy Evidence Database; PNF- Proprioceptive Neuromuscular Facilitation; RCT- Randomised Controlled Trial; STREAM – Stroke Rehabilitation Assessment of Movement; WGS – Wisconsin Gait Scale; 6MWT – Six Minute Walk Test.

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. Following its development, the PNF concept evolved into a rehabilitation approach used for a number of conditions of neurological and musculoskeletal origin. Voss, Ionta, and Meyers 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.
has long been used in rehabilitation of stroke patients, however, it remains an area which is under-researched and the existing evidence for its efficacy is often ambiguous.

A review of the current evidence and guidelines on the use of PNF was completed. The Scottish Intercollegiate Guidelines Network 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., 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 that further studies are needed to establish their efficacy.

There are currently three narrative reviews which looked at the overall efficacy of the PNF concept as a rehabilitation approach. Smedes et al. completed a review of the evidence on the effectiveness of PNF techniques in a variety of subject populations, including patients with neurological, musculoskeletal, geriatric, and pulmonary disorders. In the second narrative review, Westwater-Wood et al. evaluated the evidence on the effectiveness of PNF techniques for functional rehabilitation and increasing range of movement in neurological and non-neurological patients. Finally, Chaturveti 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.\textsuperscript{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 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 grey literature search was conducted using internet search engines and websites. [Table 1 near here]

Study Selection
The following criteria were used to include studies for the review.

**Inclusion Criteria:**

- Published clinical trials which have an experimental group receiving PNF treatment and a control group
- Studies including a stroke population
- Studies using outcome measures related to gait
- 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. Where disagreements occurred, they were discussed and resolved without need for a third party.

**Methodological quality**

To evaluate the quality of the studies, the Physiotherapy Evidence Database Rating Scale (PEDro) was used. When interpreting the scores, it is considered that 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. The scale is considered a valid measure of the methodological
quality of clinical trials,\textsuperscript{9} and has fair to good levels of reliability for rating the quality of RCTs.\textsuperscript{10} The PEDro scale has been used in previous systematic reviews in rehabilitation.\textsuperscript{11,12} The final study by Morreale at al.\textsuperscript{13} was not an RCT, and therefore, was assessed with the Quality Assessment Tool for Quantitative Studies.\textsuperscript{14} This tool meets acceptable standards of validity and reliability,\textsuperscript{15} and is suitable for use in quantitative studies. It has been used in previous systematic reviews in rehabilitation.\textsuperscript{16,17}

Results

Study selection

The search produced 12 studies. Of these, two\textsuperscript{18,19} were excluded as 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\textsuperscript{20,21,22} were excluded as they used PNF interventions in all study arms, i.e. there was no group that did not receive PNF for comparison of effect. Finally, two studies\textsuperscript{23,24} were excluded as they did not include a control group. There were five remaining studies which met the criteria for inclusion in the systematic review.\textsuperscript{25,26,27,28,13} Of these studies, four are RCTs, and the fifth\textsuperscript{13} is a prospective multicenter blinded interventional study. A description of the search using a PRISMA flow diagram is available in Figure 1. [Figure 1 near here]
Population of studies

The sample sizes in the RCTs ranged in number from 18 to 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.\textsuperscript{13} was a larger multicenter trial with 340 patients. Of the five studies, three\textsuperscript{25,26,27} had patients with chronic stroke (>6 months after stroke), and two\textsuperscript{28,13} had patients who were <6 months post stroke.

Types of Intervention

Although all of the included studies used PNF as the primary intervention, the treatment techniques in individual studies varied. In Stephenson et al.\textsuperscript{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.,\textsuperscript{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., the intervention group received three PNF techniques of rhythmic initiation, slow reversal, and agonistic reversal for pelvis. A combination of PNF techniques was also used by Ribeiro et al., where the intervention group received basic PNF procedures and movement patterns in standing and sitting. The treatments included resisted sit and rise, standing weight transfer with resisted pelvic movement, and resisted pelvic movement during gait.

In the final study by Moreale et al., 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 mobilisation according to Kabat’s schemes. No further detail is described in this study as to the exact PNF treatment used. Due to 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 (see 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. Not all of the studies met this recommendation with their described intervention. [Table 2 near here]
The Control Groups

In four of the studies,\textsuperscript{25,27,28,13} 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,\textsuperscript{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 due to potential for inconsistency and difficulty reproducing the treatment. In the study by Morreale at al.,\textsuperscript{13} PNF and cognitive therapeutic exercise (CTE) groups both showed significant improvement with no difference between the groups. CTE has limitations as a comparator arm as it is an approach which consists of different types of treatment techniques, and its protocol is not described in enough detail to allow replication of the treatment.

PNF showed slightly more improvement than Body Weight Supported Treadmill Training (BWSTT) in two studies.\textsuperscript{25,27} BWSTT is an appropriate choice of treatment for a comparison as it has been recommended with ‘level A’ evidence in recent stroke guidelines to facilitate recovery of mobility in patients with stroke.\textsuperscript{7} A favourable 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., PNF with walking on a ramp was compared to 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 two treatments (walking on a ramp +PNF) which 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 one of the studies is of low quality, two of the studies are of fair quality, and one study 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. 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 four out of six categories. The remaining two categories are scored as moderate due to the study participants being aware of the study objectives, and the study not describing the validity and reliability of the outcome measures used. [Table 3 near here]
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. Due to 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-centred care, as it measures the changes which 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 body weight supported treadmill training (BWSTT) group in comparison to the control group. It was also found that only the PNF group had a significant improvement in the Wisconsin Gait Scale (WGS) 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 improved functional ambulation performance than the control group.

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

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

\textbf{Discussion}
The aim of this review was to assess the effectiveness of the PNF approach on gait parameters in patients post-stroke. Five studies were narratively analysed, and the results reviewed. The methodological quality of the included studies is variable, with the majority of studies scoring a fair or high rating on the PEDro scale, one study scoring a strong rating on the Quality Assessment Tool for Quantitative Studies, and only one study rated as low quality on the PEDro Scale. Four of the five 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 the majority of the studies finding that the PNF group improved more than the control group. The findings must be interpreted carefully as these studies had small sample sizes and varying methodological quality, so we cannot conclude that PNF is superior to other treatments. It should be noted that the best quality study with the largest sample size 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 programme, and further training is available to certify therapists as PNF practitioners if desired. In the current healthcare 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, as 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 which 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 standardised
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 which 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 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 standardised treatment programme which can be assessed and reproduced. One preliminary small scale trial has already been completed where a PNF based treatment protocol was described in detail. This type of programme 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 healthcare environment, this is an issue that needs to be addressed in order to provide proof of efficacy of the PNF approach. Producing this higher quality of evidence is important in future studies as 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 programme 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.

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### Results

Both PNF and BWSTT improve gait velocity, cadence and Wisconsin Gait Scale vs control group (p<0.05). PNF group improved in stride length, cadence, gait velocity, and Rivermead Mobility Index vs control (p<0.05).

### Outcome Measures

Measured pre-intervention and post-intervention:
- Gait velocity – 10m walk test, gait cadence, Wisconsin Gait Scale, Perry’s Classification System

### Intervention

**PNF group** – PNF mat activities and gait training x 30 mins x 3 times a week x 4 weeks
- Body Weight Supported Treadmill Training (BWSTT) group – BWSTT x 20mins x 3 times a week x 4 weeks
- Control group – no intervention

**Stephenson et al. 2014**
- 18 subjects with chronic stroke (>6 months)

**Seo et al. 2012**
- 40 subjects with chronic stroke (>6 months)

**Kumar et al. 2012**
- Convenience sample of 30 subjects (<6 months post stroke)

### Table 2: Summary

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Intervention</th>
<th>Outcome Measures</th>
<th>Results</th>
</tr>
</thead>
</table>
| Stephenson et al. 2014 | 18 subjects with chronic stroke (>6 months) | PNF group – PNF mat activities and gait training x 30 mins x 3 times a week x 4 weeks  
- Body Weight Supported Treadmill Training (BWSTT) group – BWSTT x 20mins x 3 times a week x 4 weeks  
- Control group – no intervention | Measured pre-intervention and post-intervention  
- Gait velocity – 10m 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<0.05) |
| Seo et al. 2012        | 40 subjects with chronic stroke (>6 months) | PNF Group – 30mins PNF based walking exercise on a ramp x 5 times a week x 4 weeks  
- Control Group – 30mins walking exercise on a ramp x 5 times a week x 4 weeks | Measured pre-intervention and post-intervention  
- 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<0.05) |
| Kumar et al. 2012      | Convenience sample of 30 subjects (<6 months post stroke) | PNF group – 3 PNF techniques x 30mins x 3 days a week x 4 weeks  
- Control group – stretching, strengthening and weightbearing x 30mins x 3 days a week x 4 weeks | Measured pre-intervention and post-intervention  
- 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<0.05) |
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Intervention</th>
<th>Outcome Measures</th>
<th>Results</th>
</tr>
</thead>
</table>
| Ribeiro et al. 2013 RCT      | Convenience sample of 23 subjects (>6 months post stroke)              | PNF group – Basic PNF procedures and facilitation patterns in standing and sitting x 30mins x 3 times a week x 4 weeks
TPBWS group – Gait trainer with treadmill and manual assistance x 30mins x 3 times a week x 4 wks | Measured pre and post intervention
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<0.05)
PNF group only improved in max ankle dorsiflexion during swing phase (p<0.05) |
| Morreale 2016 Prospective multicenter blinded intervention study | 340 patients post first time subcortical ischaemic stroke              | Early PNF – (starting day 1 post stroke) 45mins daily PNF and 15mins postural alignment and positioning
Early CTE – (starting day 1 post stroke) 45mins guided movements during an attention task and 15mins postural alignment and positioning
Both early groups then had 2.15hrs a day of their assigned treatment from 5th to 60th day post stroke. Then 1.30hrs a day of treatment for a mean of 38 weeks in total.
Delayed treatment group – 60mins 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 months and at 12 months
Disability, Modified Rankin Score (MRS), Barthel Index (BI), Safety, Immobility related adverse events, 6MWT, MI, MMSE, Beck Depression Inventory | MRS and BI improved in all groups (p<0.05) with some more improvement in the early groups (not stat sig)
6MWT improved in all groups (p<0.05)
At 12 months early groups improved more in 6MWT than delayed groups (p<0.05) |
Table 3- PEDro Rating Scale for Included RCTs

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Figure 1 – PRISMA flowchart

CINAHL: 32 Citation(s)  
MEDLINE: 23 Citation(s)  
PubMed: 20 Citation(s)  
PEDro: 7 Citation(s)  
Hand searching and grey literature: 2 Citation(s)

35 Non-Duplicate Citations Screened

Inclusion/Exclusion Criteria Applied

24 Articles Excluded After Title/Abstract Screen

11 Articles Retrieved

Inclusion/Exclusion Criteria Applied

6 Articles Excluded After Full Text Screen

0 Articles Excluded During Data Extraction

5 Articles Included