The Efficacy of Proprioceptive Neuromuscular Facilitation Techniques in Improving Range of Motion and Strength: A Systematic Review

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KEYWORDS

Proprioceptive Neuromuscular Facilitation, Range of Motion, Muscle Strength, Rehabilitation.

ABSTRACT

Background: Proprioceptive Neuromuscular Facilitation (PNF) is a therapeutic approach widely used in rehabilitation to enhance range of motion (ROM) and muscle strength. By combining resistance, stretching, and contract-relax techniques, PNF aims to stimulate the neuromuscular system to facilitate functional movement patterns. While PNF has shown potential for improving ROM and strength in various patient populations, conflicting evidence necessitates a comprehensive review of its effectiveness.

Method:A systematic search was conducted using electronic databases, including PubMed, Cochrane, Google Scholar, Medline, and BioMed Central. Search terms included "Proprioceptive Neuromuscular Facilitation," "PNF techniques," "range of motion," and "muscle strength." Studies published between 2014 and 2020 in English were included. Inclusion criteria focused on randomized controlled trials (RCTs) examining the effects of PNF on ROM and strength. Exclusion criteria included studies lacking a focus on these outcomes or without control groups. Data extraction adhered to PRISMA guidelines, and quality assessment was performed using the Cochrane risk of bias tool.

Result: The initial search yielded 15,900 articles, narrowed to 10,900 upon refining the search period. After applying inclusion and exclusion criteria, 14 RCTs were deemed eligible. These studies involved diverse interventions targeting various muscle groups, with sample sizes ranging from 9 to 40 participants. PNF interventions demonstrated improvements in both active and passive ROM as well as muscle strength in most studies, with variations based on technique, intensity, and duration.

Conclusion: PNF techniques appear effective for enhancing ROM and muscle strength in various populations. However, heterogeneity in study designs, participant characteristics, and intervention protocols limits generalizability. Future research should standardize PNF protocols to establish evidence-based guidelines for clinical application. Additionally, factors such as therapist expertise, patient compliance, and baseline functional status should be considered to optimize outcomes.

Introduction

Proprioceptive Neuromuscular Facilitation (PNF) techniques are known to be widely used methods in rehabilitation, specifically in managing an increased range of motion (ROM) and strength1. This therapeutic application integrate resistance, stretching, and contract-relax techniques in the stimulation of the neuromuscular system to facilitate functional movement patterns2. Range of motion and muscle strength are one of the most significant variables of rehabilitation which may lead to joint stiffness, soft tissue injuries, and neurological impairments. The improvement of these components is part of achieving functionality, pain relief, and a better quality of life (QoL)3. Many researchers have investigated various PNF techniques concerning their role in enhancing range of motion in a variety of disorders involving muscle tightness or joint stiffness, such as post-surgical rehabilitation and musculoskeletal disorders4. It has been found that these exercises usually lead to marked improvements in both active and passive ROM, thus offering a practical option for a wide array of patients, including those recovering from injuries or surgeries. Besides ROM, PNF techniques help to improve muscle strength: through muscle contraction with resistance. In patients with muscle atrophy due to disuse or injury, such as the lower limb after surgery, activation of hypertrophy can be facilitated by muscle recruitment through PNF exercises5. Hence, PNF has become a further assistant in musculoskeletal rehabilitation since it simultaneously tackles strength and mobility.

A review of related studies has proved that PNF is effective in strength improvement, especially concerning muscle recruitment and motor learning enhancement. The ability of PNF for enhancement of neuromuscular coordination is particularly relevant for patients with neurological conditions, as coordinated movement patterns trained by PNF include agonist and antagonist muscles coaction. Functional dynamic movements are encouraged in PNF application, as these are part of the major activities in daily life. Furthermore, PNF practices contain active - passive elements that encourage flexibility, coordination, and strength gains, thus making it a holistic approach to rehabilitation6. PNF is generally effective for improving ROM and strength, but results from different studies are inconclusive. Some research showed impressive gains, while others noted little or no improvement in strength or ROM following PNF intervention. Such differences could be attributed to the various study design, characteristics of participants, and PNF techniques. Also, the duration, intensity, and frequency of PNF interventions correlate with the outcomes indicated, which means that further studies are essential to ascertain the most effective protocol for specific populations of patients. The PNF success will also depend on several factors such as the abilities of the therapist, patient cooperation, and it will also depend on the individual baseline function. The therapist requires extensive experience in PNF to be able to apply adequate resistance, the movement patterns, and the timing of muscle contraction. Motivation and compliance by the patient are also very important factors in the effective use of the method7-8.

This systematic review aims at collating evidence regarding the efficacy of the proprioceptive neuromuscular facilitation techniques in enhancing the range of movement and strength. Hence analyzing previous studies, this review can also clarify the advantages and disadvantages of PNF and examine what the mechanisms may be leading to its effects while identifying factors that could oversee its success or failure. As most clinical practice applies PNF, it is quite relevant in understanding its effectiveness in optimizing treatment and improving patient outcomes. This review, therefore, shall give recommendations for further studies and create a guide for clinical practice to use the PNF techniques most effectively and the most evidence-based way.

Methods

Electronic Databases and Search Strategies

A complete survey of literature databases was undertaken, such as PubMed, Cochrane, Google Scholar, Medline, and BioMed Central. The terms of reference were: "Proprioceptive Neuromuscular Facilitation," "PNF techniques". In addition to the terms above, the search included "range of motion," "muscle strength," "rehabilitation," and "musculoskeletal disorders." Ultimately, this entire exercise was geared toward identifying all studies evaluating the efficacy of PNF techniques for improvement in range of motion and strength. Inclusion criteria included studies published from 2014 to 2020 and those published in English language journals concerning the application of PNF for increasing ROM and muscle strength in multiple patient populations. The study did not include research that, while it involved PNF techniques for rehabilitation, did not concentrate on any of these specific outcomes, or that did not employ a control. The exclusion criteria also included co-morbidity for participants, full text not available. Data extraction and quality assessment were performed with conventional methodological practice. The relevant information on studies, including names of the authors, information about publication year, sample size, and study design as well as those regarding intervention, was systematically retrieved using a data mining form, as provided in Table 1. The work followed the PRISMA guidelines.

Risk of Bias

The risk of bias in each of the included studies was assessed by Cochrane risk of bias tool assessment. This tool addresses an important aspect of study design-to determine its random sequence generation, allocation concealment, blinding of participants or outcome assessors, incomplete outcome data, and selective outcome reporting.

Data Extraction

Data extraction was carried out independently by two researchers using separate Excel spreadsheets (Microsoft Office 2010). The extracted data included study characteristics such as the names of the authors, publication year, study design, sample size, participant age range, intervention type, and primary outcomes (range of motion and muscle strength). Specific details regarding the duration and frequency of the PNF interventions were also recorded. Discrepancies in data extraction were resolved through discussion between the researchers to ensure consistency and accuracy.

Results

In primary search, we found 15,900 articles based on keywords related to our topic that were “PNF AND range of motion AND strength” from 2010 to 2020. Hence the search strategy was changed and the topic were then search between 2014 till 2020. In the search, we found, 10,900 articles related to the above mentioned key words. Out of these articles, 4850 were obtained after excluding the topics. After exclusion of study design, population, and outcome measures, 14 articles were found to be eligible that were comparing the effects of hydro therapy on quality of life among rheumatoid arthritis patients. The number of initial studies and the detailed process for selecting appropriate studies followed PRISMA guidelines16 shown in Figure 1.

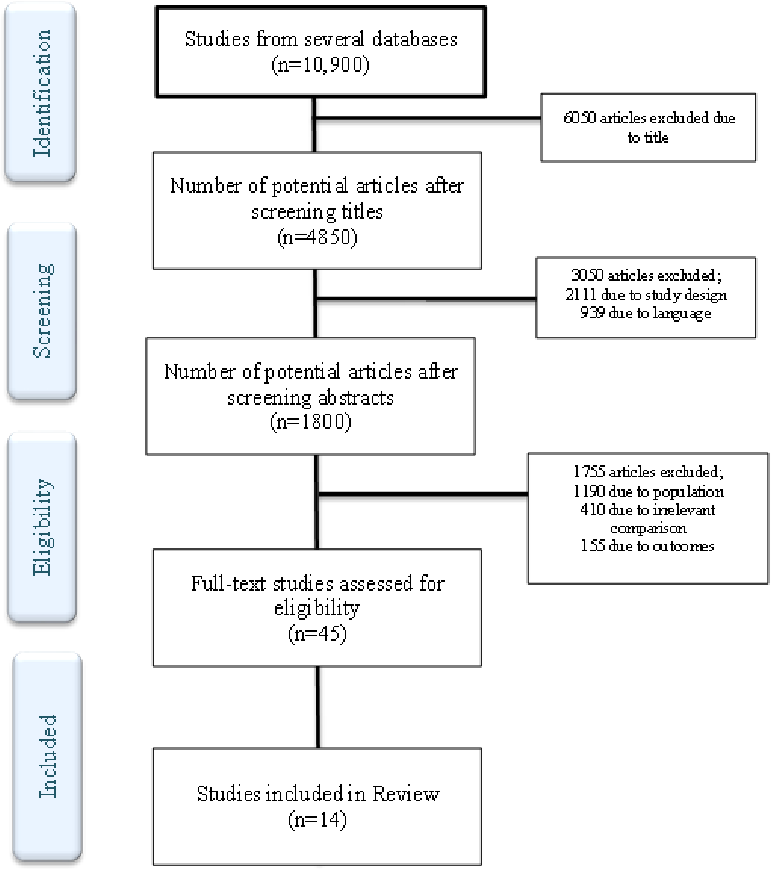

Figure 1: PRISMA flow of studies

The characteristics of participants across multiple studies investigating the effects of Proprioceptive Neuromuscular Facilitation (PNF) techniques on range of motion and muscle strength are summarized in Table 1. Each study employed a randomized controlled design, with variations in participant age ranges, sample sizes, interventions, and outcomes. Data collection procedures included the application of PNF techniques, either as standalone therapy or in combination with other rehabilitation modalities, and were compared with alternative treatments such as traditional strengthening exercises or passive range of motion exercises.

Table 1. Summary of Characteristics of the Selected Studies

Author	Age Mean±SD	Group Sizes	Intervention Type	Targeted Muscles	Frequency	Outcome Measure
Cini et al. (2020)	24 ± 2.0 (E1), 32 ± 14.2 (E2)	E1: 6, E2: 6, Control: Not reported	E1: Evaluator-performed passive stretching held for 30 seconds. E2: PNF combining hip flexion, maximal isometric contraction, and a static stretch held for 30 seconds. Control: No intervention provided.	Hamstrings	3 sessions/ week for 4 weeks	Hip range of motion improved during passive stretching

Gunn et al. (2019)	24 ± 2.0 (E1), 32 ± 14.2 (E2)	E1: 17, E2: 23, Control: Not reported	E1: Therapist-applied passive stretching for 30 seconds with 1-minute intervals, repeated 4 times. E2: Self-stretching for 30 seconds with 15-second rest intervals, repeated 4 times. Control: No stretching intervention provided.	Hip flexors	Single session	Hip flexion
Arjang et al. (2018)	12.2 ± 1.81 (E1), 12 ± 2.62 (E2)	E1: 10, E2: 10, Control: Not reported	E1: Therapist-assisted hamstring lengthening involving 30-second holds followed by 30-second rests, repeated 5 times. E2: Same intervention as E1. Control: No intervention specified.	Hamstrings (bilateral)	Single session	Active knee extension (AKET); no significant changes observed
Nakamura et al. (2015)	21.7 ± 1.2	E1: 30, E2: 30	E1: Assisted hold-relax PNF lasting 2 minutes with alternating static and isometric phases. E2: Static stretching held for 2 minutes. Control: No intervention provided.	Unilateral plantar flexors	Single session	Ankle dorsiflexion (passive) measured with dynamometer
Balle, Magnusson, and McHugh (2015)	31.1 ± 8.2	E1: 20, E2: 20	E1: Static stretching with six repetitions of 60-second holds. E2: PNF combining a 10-second isometric contraction followed by a 50-second static stretch. Control: No stretching intervention provided.	Unilateral hamstrings	Single session	Knee flexion (passive) measured using dynamometer
Kay et al. (2015)	25.6 ± 8.8	E1: 17, E2: 17, E3: 17	E1: Assisted contract-relax PNF. E2: Static stretching. E3: Maximal isometric contraction. Control: No intervention provided.	Gastrocnemius and triceps surae	Single session	Ankle dorsiflexion (passive) measured using dynamometer

Konrad, Gad, and Tilp (2015)	Not reported	E1: 20, E2: 18	E1: Self-applied contract-relax contract (CRC) PNF totaling 144 seconds with alternating static, isometric, and antagonist contraction phases. Control: No intervention provided.	Ankle muscles (unspecified side)	5 sessions/ week for 6 weeks	Ankle dorsiflexion (active) measured using goniometer
Yildirim et al. (2016)	E1: 21.4 ± 0.8, E2: 21.8 ± 1.3, E3: 21.6 ± 1.68, Control: 21.4 ± 1.8	E1: 5, E2: 6, E3: 8, Control: 7	E1: Static stretching with ten 30-second holds. E2: Self-applied PNF with alternating contraction and relaxation phases. E3: Mulligan traction straight leg raise. Control: No intervention provided.	Hamstrings (bilateral)	3 sessions /week for 4 weeks	Straight leg raise (passive) using goniometer
Demoulin et al. (2016)	E1: 22.5 ± 2.85, E2: 21.5 ± 1.9, Control: 22 ± 2.4	E1: 30, E2: 25, Control: 34	E1: Self-applied PNF at the hip involving a 6-second isometric contraction at 75% MVC followed by static stretch. E2: Self-applied PNF targeting the knee. Control: No intervention provided.	Hamstrings (bilateral)	5 sessions/ week for 8 weeks	Passive knee extension and straight leg raise using goniometer
Moesch et al. (2014)	20.2 ± 2.74	E1: 14, E2: 14, Control: 12	E1: Self-applied static stretching for 32 seconds. E2: Assisted PNF with a 5-second isometric contraction, relaxation, and a 32-second static stretch. Control: Kinesio-stretching combining static, active-assisted, and isometric phases.	Lumbar paravertebral and hamstrings (bilateral)	3 sessions/ week for 6 weeks	Knee extension (active/passive) using goniometer
Lim, Nam, and Jung (2014)	E1: 22.38 ± 2.31, E2: 22.25 ± 2.29, Control: 23.50 ± 2.16	E1: 16, E2: 16, Control: 16	E1: Static stretching held for 30 seconds. E2: Assisted PNF with three cycles of 6-second isometric contraction followed by 5-second rests. Control: No stretching performed.	Hamstrings (unilateral)	Single session	Hip ROM (active, passive, dynamic) using goniometer

Beltrão et al. (2014)	E1: 23.1 ± 3.7, Control: 22 ± 3.2	E1: 30, Control: 40	E1: Assisted PNF including a 30-second passive stretch, 6-second isometric contraction, and relaxation. Control: Static stretching held for 1 minute.	Knee extensors (unilateral)	Daily for 7 days	Active knee extension using goniometer
Minshull et al. (2014)	E1: 20.3 ± 2.2, Control: 20.7 ± 2.3	E1: 9, Control: 9	E1: Assisted contract-relax agonist PNF stretching for 60 seconds with intervals. Control: Static stretching for 60 seconds with intervals.	Knee flexors (unilateral)	3 sessions/ week for 8 weeks	Hip flexion (passive) using fleximeter
Wicke, Gainey, and Figueroa (2014)	Not reported	E1: 19, Control: 19	E1: Self-applied static stretching for 40 seconds. Control: Self-applied contract-relax PNF alternating between stretching and isometric contraction for 40 seconds.	Hamstring s (bilateral)	2 sessions/ week for 6 weeks	Hip flexion using goniometer

Risk of Bias in Studies

Random Sequence Generation

All studies10-13 showed a low risk of bias as they followed a randomization sequence.

Allocation Concealment

Seven studies10-13 showed a low risk of bias whereas the other seven showed high risk of bias.

Blinding of Participants and Personnel

Seven studies10-12 considered participant and personnel blinding, three studies13 did not provide detail and in four studies14 in which concealment was not done.

Blinding of Outcome Assessment

Six studies11, 12 showed low risk of bias, six studies10, 14 showed an unknown risk of bias, and two studies14 showed high risk.

Incomplete Outcome Data

All studies10-14 showed low risk of bias.

Selective Reporting

A low of risk of reporting bias was demonstrated in all five studies 10-14.

Table-2 Assessing Risk of Bias of Included Studies

Author	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Reporting Bias
Moesch et al. (2014)	+	+	+	-	+	+
Lim, Nam, and Jung (2014)	+	+	+	+	+	+
Beltrão, Ritti-Dias, Pitangui, and De Araújo (2014)	+	+	+	+	+	+
Minshull et al. (2014)	+	-	-	?	+	+
Wicke, Gainey, and Figueroa (2014)	+	+	+	?	+	+
Nakamura, Tokugawa, and Ichihashi (2015)	+	+	+	+	+	+
Balle, Magnusson, and McHugh (2015)	+	+	+	+	+	+
Kay, Husbands-Beasley, and Blazevich, (2015)	+	-	?	?	+	+
Konrad, Gad, and Tilp (2015)	+	+	+	?	+	+
Yildirim et al. (2016)	+	-	-	+	+	+
Demoulin et al. (2016)	+	+	+	+	+	+
Arjang et al, (2018)	+	-	?	?	+	+
Gunn et al, (2019)	+	-	-	-	+	+
Cini et al 2020	+	-	?	?	+	+

Discussion

The consistency among the results appears that the application of PNF techniques led to marked improvements in both ROM and muscle strength. For example, Moesch et al. (2014) showed that both active and passive knee extension were improved after 6 weeks of PNF intervention. Likewise, Lim et al. (2014) highlighted the immediate effect of PNF in improving flexibility and joint mobility since there was a significant change in the range of motion (ROM) of the hamstrings after a single session of PNF. These findings supplement with other studies such as those by Balle et al. (2015) and Konrad et al. (2015), which reported improvements in passive range of motion achieved with PNF in several muscle groups.

The protocols differed for administering interventions from one study to another, some utilized assisted techniques for proprioceptive neuromuscular facilitation (PNF), whereas others embraced forms of self-stretching or typical static stretching. For instance, in the 2014 study carried out in Brazil, Beltrão et al. used assisted contract-relax (CR) PNF and compared it against a protocol that leveraged a static stretch. Both intervention methods produced knee extension improvements. Differences in referral length were singe sessions to 8 weeks; frequency ranged between 1 and 5 times a week. These differences in intervention lengths and frequencies across different studies might be responsible for the differing levels of improvement seen from studies. A good example of this is the study by Demoulin et al. (2016), which made use of a protocol with 5 times per week sessions for an 8-week duration. Such interventions, as expected, demonstrated a more significant long-term effect than studies using shorter intervention periods. This suggests that frequency and duration may be fundamental in maximizing the benefits from PNF.

Moreover, sample size and participant demographics also differ per study. Some studies such as Yildirim et al., 2016; Konrad et al. ,2015 had considerably small groups (less than 20 participants), whereas Kay et al. ,2015 had large samples (over 30 participants per group). As a rule, large sample sizes are preferable for generalizing findings, and these consistent improvements in muscle strength and ROM among different studies with sample departure size suggest that PNF has a relevantly generalized application to physical function.

One notable observation from the included studies is the comparison of PNF with other interventions. Several studies, including those by Minshull et al. (2014) and Wicke et al. (2014), compared PNF with traditional stretching protocols or control groups. The results consistently favored PNF in improving ROM and muscle strength, particularly in participants with specific musculoskeletal impairments. In contrast, studies like that of Arjang et al. (2018) found no significant changes following the intervention, suggesting that PNF may be more effective in certain contexts or with certain populations.

The effectiveness of PNF seems to be also related to the specific muscle group on which it was applied. For example, whatever techniques of PNF were used, the studies using hamstrings and knee extensors consistently showed improvements in the range of motion (particularly passive ROM), while the studies using muscles such as the gastrocnemius (Nakamura et al., 2015) and hip flexors (Cini et al., 2020) showed a more varied outcome. These results suggest that muscle-specific factors such as muscle length and muscle type may influence how effects occur with the PNF. For instance, it could be that muscles with a higher percentage of slow-twitch fibers, which responds well to stretching techniques, would benefit more from PNF. Despite the promising results, there are several limitations in the current body of evidence. A significant concern is the lack of standardized protocols across studies. Differences in the type of PNF techniques (e.g., CR, HR, assisted, or self-stretching), duration, frequency, and intensity make it difficult to draw definitive conclusions regarding the most effective protocol. Moreover, the heterogeneity in outcome measures, including goniometric measurements of ROM and dynamometer assessments of strength, complicates the comparison of results across studies.

Additionally, while the studies included in this review predominantly focus on young, healthy adults, there is a need for more research examining the efficacy of PNF in clinical populations, such as those with chronic musculoskeletal disorders, neurological impairments, or age-related decline in muscle strength. Future studies should address these gaps by exploring the effects of PNF across diverse patient populations and incorporating standardized intervention protocols to improve the consistency and applicability of the findings.

Finally, it is important to note that while many of the studies reviewed demonstrated significant improvements in ROM and strength, the long-term effects of PNF remain uncertain. Few studies have followed participants beyond the intervention period, and the sustainability of the improvements after cessation of the intervention remains an important area for further investigation.

Conclusion

PNF techniques are generally effective in improving both ROM and muscle strength across various muscle groups. However, further research is needed to standardize PNF protocols, explore the long-term effects of the intervention, and assess its effectiveness in clinical populations. The current evidence suggests that PNF can be a valuable tool in rehabilitation and physical therapy, particularly when targeted at improving flexibility and muscle function in healthy individuals and those with musculoskeletal impairments.

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