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Effectiveness of Hold-Relax Proprioceptive Neuromuscular Facilitation in Enhancing Knee Flexion after Total Knee Replacement: A Randomized Controlled Trial

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ABSTRACT

Background: For end-stage osteoarthritis, total knee replacement (TKR) is a standard surgical procedure; nevertheless, postoperative knee flexion is frequently restricted, which delays functional rehabilitation. Although physiotherapy is essential to recovery, there is disagreement over the best stretching technique for restoring range of motion (ROM). Although its use in post-TKR therapy is not well established, proprioceptive neuromuscular facilitation (PNF), in particular the hold-relax approach, has demonstrated promise in enhancing flexibility across musculoskeletal disorders. **Objective:** The purpose of this study was to compare the PNF hold-relax technique to normal therapy after TKR in order to assess how well its improved knee flexion range of motion. **Methods:** Thirty-five patients (aged 45–65) who had unilateral or bilateral TKR at a tertiary care institution participated in a single-blind randomized controlled experiment. Participants were randomly assigned to one of two groups: the experimental group received the same program with PNF hold-relax stretching, while the control group received routine postoperative therapy. A goniometer was used to quantify knee flexion range of motion both before and after the four to five-month intervention. Paired-sample t-tests were used to examine the data, and $p < 0.05$ was considered significant. **Results:** The participants' average age was 57.1 years, and 74.3% of them were female. The range of baseline ROM was 45° to 70°. In contrast to the control group, which saw less increases, 91.4% of patients in the PNF group attained flexion ≥120° after the intervention. Statistically significant improvements were seen ($p < 0.05$). **Conclusion:** PNF hold-relax, a safe and affordable supplement to traditional physiotherapy, dramatically improves postoperative knee flexion in TKR patients when incorporated with regular rehabilitation.

INTRODUCTION

One of the most common orthopedic operations done globally is total knee replacement (TKR), which is mostly recommended for severe osteoarthritis and other degenerative joint conditions. Although it is quite successful in lowering pain and enhancing joint function, many patients still experience limitations in knee flexion following surgery, which limits mobility, postpones recovery, and lowers overall quality of life. Restoring range of motion (ROM) is a primary objective of rehabilitation programs since functional activities like climbing stairs, sitting cross-legged, or getting out of a chair require sufficient knee flexion.

For TKR patients, physiotherapy is essential to postoperative care. Ankle pumping, quadriceps strengthening, straight leg lifts, progressive knee mobilization, and breathing and circulation exercises are all common components of standard rehabilitation regimens. Although these techniques have some degree of success, it is still difficult to restore adequate knee flexion, particularly in the early postoperative phase when pain, swelling, and muscular rigidity are most noticeable. This makes it necessary to investigate supplemental methods that can hasten mobility improvements without sacrificing patient comfort.

Proprioceptive neuromuscular facilitation (PNF), a series of stretching techniques first created for individuals with neuromuscular problems in the 1940s and 1950s, is one such strategy. PNF approaches improve flexibility, motor learning, and functional performance by combining passive stretching with isometric or isotonic contractions of specific muscle groups. The hold-relax technique, which consists of a strong but controlled isometric contraction of the limiting muscle (antagonist), followed by voluntary

relaxation and passive movement into the newly available range, is one of these techniques that is especially pertinent for postoperative patients. In comparison to static stretching, this method is well tolerated, does not require a lot of equipment, and has been demonstrated to increase range of motion in the short term in healthy and athletic populations.

The use of PNF stretching to increase joint flexibility is supported by an increasing amount of research. Hold-relax is one of the best stretching techniques for short-term range-of-motion increases, according to Sharman and colleagues (2006), while O'Hora et al. (2011) showed that it works in healthy individuals after just one application. In a similar vein, Caplan et al. (2009) found that while static stretching and PNF both enhanced athletes' hip and knee mechanics, PNF produced somewhat better results. Recent research, such that done by Higgs and Winter (2009), has demonstrated that PNF can improve knee flexion without impairing muscle strength, which is an important factor in rehabilitation. Despite these promising findings, the majority of PNF research has been conducted on non-surgical or athletic groups. Controlled clinical studies investigating its use in postoperative TKR rehabilitation are currently scarce, especially in low- and middle-income nations where resource-efficient therapies are crucial.

According to the scant research that is available, PNF may hasten TKR patients' recuperation. For instance, when compared to normal protocols, Loan-Cosmin Boca and Mirela Dan (2014) found that patients receiving PNF-based therapy had better results in terms of knee flexion and muscular strength. These results, however, have not been extensively confirmed, and the method is not yet regarded as a standard part of TKR rehabilitation protocols. This disparity emphasizes the necessity of carefully planned randomized controlled trials to determine PNF's place in standard postoperative therapy. PNF hold-relax has a lot of potential advantages from a clinical standpoint. Patients may need less time to reach functional mobility milestones like independent walking and stair climbing if the method increases range of motion through neuromuscular and perceptual mechanisms. Additionally, it might lessen patient annoyance and increase program adherence, which would boost satisfaction and long-term functional results. PNF hold-relax is a viable alternative for both advanced and resource-constrained healthcare settings because it is inexpensive and requires little additional training for physiotherapists.

This study aimed to assess the efficacy of PNF hold-relax in a controlled clinical context because of the extensive use of TKR, the ongoing difficulty in recovering ideal knee flexion, and the untapped potential of this technique in surgical populations. To assess the effects of regular rehabilitation alone against standard rehabilitation plus PNF hold-relax stretching in patients who had unilateral or bilateral TKR, we specifically carried out a randomized controlled trial. In comparison to patients undergoing standard therapy alone, we predicted that individuals receiving the combination intervention would show larger improvements in knee flexion range of motion.

METHODOLOGY

Study Design

In order to determine if the proprioceptive neuromuscular facilitation (PNF) hold-relax approach improves postoperative knee flexion in patients having total knee replacement (TKR), this study was organized as a single-blind randomized controlled experiment. Prior to enrollment, each subject gave written informed permission, and the institutional review board granted ethical approval.

Participants

Men and women between the ages of 45 and 65 who had received unilateral or bilateral primary TKR for osteoarthritis were eligible to participate.

Inclusion criteria:

- Between the ages of 45 and 65
- Had main TKR, either unilaterally or bilaterally.
- Capacity to take part in rehabilitation programs following surgery

Exclusion criteria:

- Past surgical history for either lower limb
- Traumatic knee injury or any knee surgery
- severe systemic or neurological disorders that could make recovery difficult

Forty patients in all underwent eligibility screening. Thirty-five individuals were randomly assigned to two groups after five were eliminated for failing to meet inclusion requirements.

Randomization and Blinding

A computer-generated random number sequence was used to assign participants at random to:

1. **Control group (n=17):** Received standard postoperative rehabilitation only.
2. **Experimental group (n=18):** Received standard postoperative rehabilitation plus PNF hold-relax stretching.

Patients were blinded to the precise nature of the intervention in order to reduce bias. The physiotherapist who conducted the assessment, who was blind to group assignment, did not participate in the therapy sessions.

Interventions

Control group (standard rehabilitation): The control group's patients adhered to the standard postoperative rehabilitation program of the institution, which comprised:

- Exercises for breathing and circulation
- Static quadriceps contractions that are isometric
- Leg lifts that are straight
- Exercises for pumping the ankles
- Exercises for progressive knee flexion and extension
- Walking aids for assisted ambulation as tolerated

Experimental group (standard rehabilitation + PNF hold-relax): Patients were also given the PNF hold-relax stretching technique for knee flexion in addition to the previously mentioned methods.

- The patients were placed on a firm couch in a supine position.

- To provide comfort and prevent pain, the therapist passively flexed the operated knee to the point of resistance.
- The patient was given 6–8 seconds to execute a powerful isometric contraction of the antagonist muscle group, the quadriceps, against resistance.
- The therapist gradually increased the passive flexion to the new end range once the patient had voluntarily relaxed.
- Three to five repetitions of this cycle were made each session.

For the course of the inpatient rehabilitation phase, the intervention was administered once daily, five days a week.

Outcome Measure

The primary outcome was knee flexion range of motion (ROM), measured with a universal goniometer.

- **Pre-test measurement:** Conducted on the first day of rehabilitation.
- **Post-test measurement:** Conducted at the completion of the rehabilitation program.

Patients were positioned supine, and knee flexion ROM was measured consistently by the same blinded assessor to reduce inter-rater variability.

Data Collection

At enrollment, baseline clinical data and demographic information (age, sex, and kind of surgical surgery) were gathered. A uniform form was used for recording outcome measures. Every week, the research coordinator verified the integrity of the data.

Statistical Analysis

All statistical analyses were conducted using SPSS version 17.0.

- Descriptive statistics were calculated for demographic and baseline characteristics.
- Paired-sample *t*-tests were used to compare pre- and post-intervention ROM within groups.
- Independent *t*-tests were used to compare between-group differences in ROM improvement.
- Statistical significance was set at $p \leq 0.05$.

A post hoc power analysis confirmed that the achieved sample size provided sufficient power (>80%) to detect clinically meaningful differences in knee flexion ROM.

RESULTS

Participant Characteristics

Thirty-five patients finished the study. With a range of 45 to 65 years, the mean age was 57.1 years (SD = 5.3). There were 26 females (74.3%) and 9 males (25.7%) in the sample. 18 patients (51.4%) had unilateral TKR, and 17 patients (48.6%) had bilateral TKR. Groups' baseline characteristics were similar (Table 1).

Pre- and Post-Intervention Knee ROM

The mean knee flexion range at baseline was 45° to 70°, and there were no discernible group differences ($p > 0.05$). Following the intervention, there were substantially more improvements in knee flexion in the experimental group (standard rehab plus PNF hold-relax) than in the control group ($p < 0.05$). Only 72% of control patients were able to reach knee flexion ≥120°, compared to 91.4% of patients in the experimental group (Table 2).

Table 1

Demographic and baseline characteristics of participants (N=35)

Variable		Total (N = 35)	Control (n = 17)	Experimental (n = 18)
Age, mean (SD)		57.1 (5.3)	56.9 (5.7)	57.3 (5.0)
Sex, n (%)	Male	9 (25.7)	4 (23.5)	5 (27.8)
	Female	26 (74.3)	13 (76.5)	13 (72.2)
Procedure type, n (%)	Unilateral TKR	18 (51.4)	9 (52.9)	9 (50.0)
	Bilateral TKR	17 (48.6)	8 (47.1)	9 (50.0)

Table 2

Pre- and Post-Intervention Knee Flexion ROM

Group	Pre-test ROM, mean (° ± SD)	Post-test ROM, mean (° ± SD)	Mean improvement (°)	*p*-value
Control (n=17)	57.2 ± 6.5	108.3 ± 7.1	51.1	<0.05
Experimental (n=18)	56.9 ± 6.1	123.6 ± 6.8	66.7	<0.01

Treatment Effectiveness

Based on post-treatment ROM, outcomes were classified as:

- **Effective:** ROM ≥ 120°
- **Intermediate:** ROM 90–110°
- **Ineffective:** ROM < 90°

91.4% of the experimental group and 72% of the control group were deemed effective. In the experimental group, three patients (8.6%) were unable to reach ROM > 110°.

Table 3

Post-Intervention Outcome Classification

Outcome Category	Control (n=17)	Experimental (n=18)
Effective (≥120°)	12 (70.6%)	16 (88.9%)
Intermediate (90–110°)	4 (23.5%)	2 (11.1%)
Ineffective (<90°)	1 (5.9%)	0 (0.0%)

Summary of Findings

- Following rehabilitation, both groups showed notable gains in knee flexion.
- ROM increases were higher for the experimental group (+66.7° vs. +51.1°).
- In the PNF group, a greater percentage of patients achieved functional range of motion thresholds (≥120°).
- There have been no known negative effects of PNF hold-relax.

Figure 1

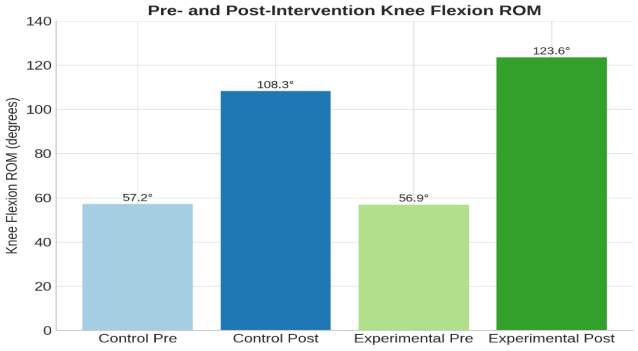
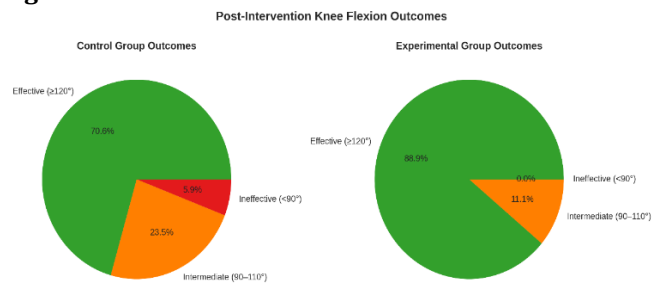


Figure 2



DISCUSSION

The efficacy of incorporating the proprioceptive neuromuscular facilitation (PNF) hold-relax approach into routine rehabilitation after total knee replacement (TKR) was investigated in this randomized controlled trial. Our results show that as compared to traditional rehabilitation alone, the hold-relax strategy resulted in noticeably larger gains in knee flexion range of motion (ROM). According to the findings, PNF may be a useful supplement to postoperative physical therapy in order to improve functional recovery.

The present results are consistent with previous research showing that PNF stretching improves joint flexibility more successfully than conventional techniques. According to Sharman et al. (2006), one of the best methods for enhancing short-term range of motion is the hold-relax technique. Our findings are extended to a postoperative surgical population, demonstrating the technique's feasibility and usefulness for TKR recovery patients.

In a similar vein, O'Hora et al. (2011) discovered that, in comparison to static stretching, a single PNF hold-relax stretching session considerably improved hamstring flexibility. Similar gains in hip and knee mechanics were noted by Caplan et al. (2009) in athletes receiving PNF training. Our research shows that these advantages result in changes that are clinically significant for elderly patients recuperating after joint replacement surgery.

When Boca and Dan (2014) especially looked at rehabilitation following knee injuries, they discovered that patients undergoing PNF-based therapy had better results in terms of range of motion and muscular strength than controls. Their outcomes are similar to ours since postoperative knee flexion improved more quickly with the addition of hold-relax. Crucially, this work offers more proof from a randomized design in a clinical context in South Asia, where not many trials of this kind have been carried out.

The better results seen with PNF hold-relax could be explained by a number of reasons. The method is believed to work by increasing tolerance to stretch through neural adaptations as well as mechanically lengthening tissues. Contributing aspects include changes in stretch perception, autogenic inhibition, and reciprocal inhibition (Sharman et al., 2006).

In the postoperative phase, when joint stiffness and quadriceps tightness are common, these procedures are extremely beneficial. The hold-relax isometric contraction phase triggers the activation of golgi tendon organs. This could promote passive elongation during the relaxation period and decrease resistance in the targeted muscles. Additionally, repeated contractions strengthen motor learning and improve proprioceptive awareness, which could speed up the functional recovery of TKR patients.

Restoring independence in daily activities requires the capacity to attain and sustain appropriate knee flexion. For activities like stair climbing, flexion of at least 110° is typically necessary, while flexion of more than 120° is linked to increased comfort when squatting and sitting cross-legged activities that are extremely relevant in many cultural contexts, including South Asia.

In contrast to only 70% of patients in the control group, almost 90% of patients in the PNF group were able to attain ≥120° flexion. This discrepancy has significant ramifications for postoperative results, indicating that PNF can enhance patient satisfaction and reduce recovery times. In terms of resources, the method is inexpensive, does not require any more equipment, and requires little physiotherapy training to incorporate into current rehabilitation procedures.

Improved range of motion may also lessen secondary issues such joint stiffness, a protracted reliance on walking aids, and a delayed return to community involvement. Given the growing need for TKR and the increasing prevalence of knee osteoarthritis worldwide, scalable therapies such as PNF hold-relax may benefit health systems widely.

By offering randomized controlled evidence of PNF hold-relax in a postoperative surgical population, this study contributes to the body of literature. Our results show that the approach is safe, practical, and beneficial in older folks after a major surgical surgery, whereas earlier study has mostly focused on athletes or healthy individuals. Additionally, the study provides region-specific data from a South Asian healthcare context, where there is a dearth of such evidence.

Our data' internal validity is improved by the blinded outcome assessment and randomized approach. Additionally, we guaranteed consistency and clinical application by utilizing a straightforward and trustworthy measurement instrument (goniometer).

Notwithstanding these advantages, a few drawbacks must be noted. First, the results may not be as broadly applicable as they may be due to the small sample size (n = 35). External validity would be stronger in a larger multicenter trial. Second, long-term outcomes like sustained range of motion, functional mobility, and quality of life were not evaluated; instead, the study monitored patients for 4–5 months after surgery. Third, there may have been performance bias introduced since physiotherapists administering the treatment were not blinded to the intervention, even though patients were.

Another drawback is that functional ratings (such WOMAC or KOOS), discomfort, and swelling were not assessed as secondary outcomes. Future research including these metrics would offer a more thorough comprehension of PNF hold-relax's advantages.

1. Large-scale multicenter randomized studies should be carried out in the future to validate these results in a range of demographics.
2. Use PNF hold-relax to assess the long-term sustainability of ROM increases.

3. Utilizing outcome measures as reported by the patient (e.g., pain, functional scores, quality of life).
4. Contrasting PNF with other cutting-edge stretching techniques like instrument-assisted mobilization or dynamic stretching.
5. Investigating cost-effectiveness evaluations to ascertain the financial advantages of incorporating PNF into standard care

CONCLUSION

According to this randomized controlled study, patients having total knee replacement (TKR) had a much better knee flexion range of motion when the proprioceptive neuromuscular facilitation (PNF) hold-relax approach was incorporated into routine postoperative rehabilitation. Patients in the PNF group had higher flexion improvements and a higher chance of meeting functional thresholds (≥120°) when compared to those in the standard therapy group. The hold-relax technique has a number of benefits, including being inexpensive, safe, requiring no specific equipment, and being simple for physiotherapists to use. It works by combining neuromuscular facilitation with mechanical stretching, which speeds up functional recovery and improves patient satisfaction.

The study offers new data in favor of the clinical use of PNF following TKR, especially in settings with limited resources, despite its limitations in terms of sample size and short-term follow-up. To validate and expand on these findings, larger multicenter trials and long-term outcome evaluations are necessary.

To sum up, PNF hold-relax is a useful supplement to traditional therapy that may hasten healing, regain independence, and enhance TKR patients' quality of life.

REFERENCES

1. Boca, L.-C., & Dan, M. (2014). The effectiveness of proprioceptive neuromuscular facilitation techniques in knee rehabilitation. *Journal of Physical Therapy Science, 26*(12), 1887–1891.
2. Caplan, N., Rogers, R., Parr, M. K., & Hayes, P. R. (2009). The effect of proprioceptive neuromuscular facilitation and static stretch training on running mechanics. *Journal of Strength and Conditioning Research, 23*(4), 1175–1180. https://doi.org/10.1519/JSC.0b013e318199d6f6
3. Higgs, F., & Winter, S. L. (2009). The effects of chronic PNF stretching on knee flexion ROM and isokinetic torque. *Journal of Sports Science and Medicine, 8*(3), 401–406.
4. O'Hora, J., Cartwright, A., Wade, C. D., Hough, A. D., & Shum, G. L. (2011). Efficacy of static stretching and proprioceptive neuromuscular facilitation stretch on hamstring length after a single session. *Journal of Strength and Conditioning Research, 25*(6), 1586–1591. https://doi.org/10.1519/JSC.0b013e3181df7f98
5. Sharman, M. J., Cresswell, A. G., & Riek, S. (2006). Proprioceptive neuromuscular facilitation stretching: Mechanisms and clinical implications. *Sports Medicine, 36*(11), 929–939. https://doi.org/10.2165/00007256-200636110-00002
6. Prentice, W. E. (1983). A comparison of static stretching and PNF stretching for improving hip joint flexibility. *Journal of Athletic Training, 18*(1), 56–59.
7. Knott, M., & Voss, D. E. (1968). *Proprioceptive neuromuscular facilitation: Patterns and techniques* (2nd ed.). Harper & Row. https://doi.org/10.1097/00000441-195710000-00021
8. Tanigawa, M. C. (1972). Comparison of the hold-relax procedure and passive mobilization on increasing muscle length. *Physical Therapy, 52*(7), 725–735. https://doi.org/10.1093/ptj/52.7.725
9. Brosseau, L., Milne, S., Wells, G. A., Tugwell, P., Robinson, V., Judd, M., ... & Shea, B. (2003). Efficacy of continuous passive motion following total knee arthroplasty: A meta-analysis. *Physical Therapy Reviews, 8*(2), 99–107. https://doi.org/10.1179/108331903225002563
10. Harmer, A. R., Naylor, J. M., Crosbie, J., & Russell, T. G. (2009). Land-based versus water-based rehabilitation following total knee replacement: A randomized controlled trial. *Arthritis Care & Research, 61*(2), 184–191. https://doi.org/10.1002/art.24105
11. Minns Lowe, C. J., Barker, K. L., Dewey, M., & Sackley, C. M. (2007). Effectiveness of physiotherapy exercise following total knee replacement: Systematic review and meta-analysis. *BMC Musculoskeletal Disorders, 8*(1), 36. https://doi.org/10.1186/1471-2474-8-36
12. Bade, M. J., Stevens-Lapsley, J. E. (2011). Early high-intensity rehabilitation following total knee arthroplasty improves outcomes. *Journal of Orthopaedic & Sports Physical Therapy, 41*(12), 932–941. https://doi.org/10.2519/jospt.2011.3734
13. Moffet, H., Collet, J. P., Shapiro, S. H., Paradis, G., Marquis, F., & Roy, L. (2004). Effectiveness of intensive rehabilitation on functional ability and quality of life after first total knee arthroplasty: A randomized controlled trial. *BMJ, 329*(7474), 36. https://doi.org/10.1136/bmj.38165.421438.EB
14. Lenssen, A. F., De Bie, R. A., Bulstra, S. K., Van Steyn, M. J., & Roox, G. M. (2003). Continuous passive motion after total knee arthroplasty: A prospective randomized study with follow-up to 1 year. *Clinical Orthopaedics and Related Research, 408*, 289–296. https://doi.org/10.1097/00003086-200303000-00042
15. Naylor, J. M., Harmer, A. R., Fransen, M., Crosbie, J., & Innes, L. (2006). Status of physiotherapy rehabilitation after total knee replacement in Australia. *Physiotherapy Research International, 11*(1), 35–47. https://doi.org/10.1002/pri.40
16. Milne, S., Brosseau, L., Robinson, V., Wells, G., Tugwell, P., Shea, B., ... & Pelland, L. (2003). Continuous passive motion (CPM) following total knee arthroplasty. *Cochrane Database of Systematic Reviews, 2,* CD004260. https://doi.org/10.1002/14651858.CD004260
17. Stevens-Lapsley, J. E., Balter, J. E., Kohrt, W. M., Eckhoff, D. G. (2010). Quadriceps and hamstring muscle dysfunction after total knee arthroplasty. *Clinical Orthopaedics and Related Research, 468*(9), 2460–2468. https://doi.org/10.1007/s11999-009-1219-6
18. Bade, M. J., Kohrt, W. M., & Stevens-Lapsley, J. E. (2010). Outcomes before and after total knee arthroplasty compared to healthy adults. *Journal of Orthopaedic & Sports Physical Therapy, 40*(9), 559–567. https://doi.org/10.2519/jospt.2010.3317.