

Acute Changes in Quadriceps Flexibility: PNF Versus Static Stretch in Senior Athletes

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Abstract:

Background: Flexibility is a crucial component of physical fitness, particularly among senior athletes, as it influences performance, injury prevention, and rehabilitation. The quadriceps muscle plays a pivotal role in functional mobility, and its flexibility can be improved through different stretching techniques. While static stretching is widely used, Proprioceptive Neuromuscular Facilitation (PNF) stretching has been proposed as a more effective method for improving range of motion (ROM). However, limited research exists comparing the acute effects of these two methods in senior athletes.

Objective: This study aims to compare the acute effects of PNF stretching and static stretching on quadriceps flexibility in senior athletes. The study evaluates changes in ROM and perceived muscle tightness immediately following stretching interventions.

Methods: A randomized controlled trial was conducted with 60 senior athletes (aged 50 years and older). Participants were randomly assigned to either a PNF stretching group or a static stretching group. Quadriceps flexibility was assessed using a goniometer, and muscle tightness was evaluated using the Visual Analog Scale (VAS). The PNF group performed the hold-relax technique, while the static stretching group held a passive stretch for 30 seconds. Pre- and post-intervention measurements were analyzed using paired and independent t-tests.

Results: Both groups exhibited significant improvements in ROM and reductions in muscle tightness post-intervention ($p < 0.001$). However, the PNF group showed a significantly greater increase in ROM (mean improvement: 15.47°) compared to the static stretching group (mean improvement: 7.33°). Similarly, the PNF group experienced a larger reduction in muscle tightness (mean VAS reduction: 2.87) compared to the static stretching group (mean VAS reduction: 1.20). Cohen's d effect size analysis indicated a large practical significance for both ROM and VAS improvements in the PNF group.

Conclusion: The results suggest that PNF stretching is more effective than static stretching in acutely increasing quadriceps flexibility and reducing muscle tightness in senior athletes. These findings support the integration of PNF stretching in athletic training and rehabilitation protocols to optimize performance and prevent musculoskeletal injuries. Future research should explore the long-term effects of PNF stretching on flexibility and functional performance in older adults.

INTRODUCTION

Flexibility is a critical component of musculoskeletal function and overall athletic performance. It is defined as the ability of a muscle or group of muscles to elongate, allowing a joint to move through its full range of motion (ROM) [1]. Adequate flexibility is essential for senior athletes as it contributes to efficient movement patterns, reduces the risk of musculoskeletal injuries, and supports overall functional independence [2]. Flexibility declines with age due to increased stiffness in connective tissues, alterations in collagen structure, and reductions in neuromuscular efficiency [3,4]. Consequently, limited flexibility can negatively impact athletic performance, restrict mobility, and elevate the risk of injuries such as strains and joint dysfunction [5,6].

The quadriceps muscle group, located in the anterior thigh, plays a crucial role in lower limb movements such as walking, running, and jumping. Reduced quadriceps flexibility is associated with increased joint stress, poor biomechanics, and decreased athletic endurance [7]. Stretching techniques, including static stretching and Proprioceptive Neuromuscular Facilitation (PNF) stretching, are widely used to enhance flexibility. Static stretching involves holding a muscle in a lengthened position for a specified duration, typically between 15 to 60 seconds, allowing for gradual elongation of the muscle fibers [8]. PNF stretching, on the other hand, incorporates an active contraction of the muscle followed by relaxation and passive stretching, leveraging neurophysiological mechanisms such as autogenic and reciprocal inhibition to enhance ROM [9]. Studies suggest that PNF stretching engages both mechanical and neural mechanisms, leading to increased ROM and improved muscle relaxation compared to static stretching alone [10,11].

Research has shown that stretching can influence neuromuscular control and proprioception, which are essential for maintaining postural stability and reducing the risk of falls in older adults [12,13]. PNF stretching has been found to improve not only ROM but also muscle coordination and force output, contributing to better athletic

performance [14]. Additionally, studies highlight the role of stretching in reducing muscle stiffness and enhancing circulation, which aids in post-exercise recovery and reduces delayed onset muscle soreness (DOMS) [15,16]. Evidence suggests that incorporating stretching interventions into training routines can optimize musculoskeletal function, improve movement efficiency, and delay age-related declines in flexibility [17].

Despite the evidence supporting PNF stretching as an effective intervention for improving flexibility, there remains a gap in literature specifically examining its acute effects in senior athletic populations. Most studies focus on younger individuals, leaving uncertainty regarding the applicability of findings to older athletes [9]. This study aims to address this gap by investigating the immediate impact of PNF versus static stretching on quadriceps flexibility in senior athletes. By understanding the efficacy of these stretching techniques, sports scientists and physiotherapists can better design warm-up and rehabilitation protocols to optimize performance and reduce injury risks in older athletes.

Methodology

This study employed a randomized controlled trial design to compare the effects of Proprioceptive Neuromuscular Facilitation (PNF) stretching and static stretching on quadriceps flexibility in senior athletes. The study was conducted over four weeks in a controlled laboratory environment to ensure uniform assessment conditions and minimize external variability.

A total of 60 senior athletes, aged 50 years and older, were recruited from local sports clubs and fitness centers. All participants engaged in regular physical activity at least three times per week and had no history of musculoskeletal injuries, lower limb surgeries in the past six months, or neuromuscular disorders affecting flexibility. Participants were randomly allocated into two groups: the PNF stretching group (n=30) and the static stretching group (n=30). Randomization was performed using a computer-generated allocation sequence to ensure equal distribution of participants.

Each stretching session was conducted under the supervision of a trained physiotherapist. The intervention lasted for four weeks, with participants engaging in five stretching sessions per week. The PNF stretching group performed the hold-relax technique, which included an initial isometric contraction of the quadriceps for six seconds at approximately 75% maximum voluntary contraction, followed by a passive stretch held for 10-15 seconds. This cycle was repeated three times for each leg, with a 30-second rest period between repetitions. The static stretching group performed a passive quadriceps stretch held for 30 seconds, repeated three times per leg, with a similar rest interval between repetitions.

Participants were instructed to perform all stretches in a controlled manner, ensuring no excessive discomfort or pain. To monitor compliance, a physiotherapist maintained attendance records and provided guidance during each session. Any adverse reactions or discomfort reported by participants were documented and addressed promptly.

The primary outcome measures included range of motion (ROM) and perceived muscle tightness. ROM was assessed using a standard goniometer, with knee flexion serving as the primary flexibility indicator. Participants were positioned in a standardized manner to ensure consistency in measurements. Muscle tightness was evaluated using the Visual Analog Scale (VAS), where participants rated their level of tightness on a scale from 0 (no tightness) to 10 (extreme tightness). Baseline measurements were taken before the intervention, and post-intervention measurements were recorded immediately after the final session.

All participants provided written informed consent before participation and were informed of their right to withdraw at any time. To ensure participant safety, all stretching sessions were conducted under professional supervision to minimize the risk of injury.

Statistical Analysis

All collected data were analyzed using SPSS version 26.0. Descriptive statistics, including means and standard deviations, were calculated for all outcome measures. Normality of data distribution was assessed using the Shapiro-Wilk test. A paired t-test was used to evaluate within-group differences in ROM and VAS scores before and after the intervention. An independent t-test was used to compare post-intervention changes between the PNF and static stretching groups.

Effect size calculations were performed using Cohen's d to assess the practical significance of the observed changes. A significance level of $p < 0.05$ was considered statistically significant. Data were presented in tables and graphs to illustrate the comparative effects of the interventions.

Additionally, inter-rater reliability for goniometer measurements was assessed using the intraclass correlation coefficient (ICC), ensuring consistency in ROM assessments. Missing data were handled using multiple imputation techniques to maintain statistical power and reduce potential biases. The findings were interpreted considering both statistical and clinical relevance, providing insights into the efficacy of PNF and static stretching for improving quadriceps flexibility in senior athletes.

Results

The study evaluated the effects of Proprioceptive Neuromuscular Facilitation (PNF) stretching and static stretching on quadriceps flexibility in senior athletes. A total of 60 participants completed the intervention, with no dropouts reported. Data analysis revealed significant improvements in both groups, with PNF stretching demonstrating superior outcomes compared to static stretching.

Pre- and post-intervention range of motion (ROM) measurements showed a statistically significant increase in flexibility for both groups. The PNF group exhibited a mean ROM improvement of $15.47^\circ \pm 2.31^\circ$, while the static stretching group showed a lesser improvement of $7.33^\circ \pm 1.89^\circ$. Independent t-test analysis confirmed that the PNF group had significantly greater gains in ROM ($p < 0.001$).

The Visual Analog Scale (VAS) scores for muscle tightness indicated a significant reduction in perceived discomfort post-intervention. Participants in the PNF group reported a mean reduction of 2.87 ± 0.85 , whereas the static stretching group reported a reduction of 1.20 ± 0.63 . Between-group analysis showed a statistically significant difference favoring the PNF group ($p < 0.001$).

Cohen's d effect size calculations demonstrated a large effect for ROM improvements in the PNF group ($d = 1.25$) and a moderate effect in the static stretching group ($d = 0.65$). The VAS reduction effect size was also larger in the PNF group ($d = 1.12$) compared to the static stretching group ($d = 0.58$), reinforcing the practical significance of PNF stretching.

Inter-rater reliability for ROM measurements was high, with an intraclass correlation coefficient (ICC) of 0.91, indicating excellent agreement between assessors.

No adverse events or injuries were reported during the study. Compliance was high, with 100% of participants completing the intervention sessions as prescribed. Participants in the PNF group reported greater satisfaction with the intervention compared to those in the static stretching group.

These findings suggest that PNF stretching is a more effective intervention for improving quadriceps flexibility and reducing muscle tightness in senior athletes compared to static stretching. The superior outcomes associated with PNF stretching highlight its potential applicability in rehabilitation and athletic performance enhancement programs.

Discussion

The results of this study indicate that Proprioceptive Neuromuscular Facilitation (PNF) stretching is significantly more effective than static stretching in improving quadriceps flexibility and reducing muscle tightness in senior athletes. These findings align with previous research that has demonstrated the superior effectiveness of PNF stretching in enhancing range of motion (ROM) and neuromuscular control [1,10]. The improvement in ROM observed in the PNF group can be attributed to the mechanisms of autogenic and reciprocal inhibition, which facilitate greater muscle elongation and relaxation compared to passive static stretching [9].

The reduction in muscle tightness observed in the PNF group further supports its clinical efficacy. Studies have shown that muscle tightness can contribute to decreased athletic performance and increased injury risk [8,18]. The greater reduction in Visual Analog Scale (VAS) scores for muscle tightness in the PNF group suggests that this technique may be more beneficial in alleviating muscle stiffness and discomfort. This is particularly relevant for senior athletes, who are more prone to age-related decreases in flexibility and increased musculoskeletal stiffness [2,3].

Furthermore, our findings are consistent with studies indicating that PNF stretching leads to longer-lasting improvements in flexibility and functional performance compared to static stretching alone [7,12]. The increased effectiveness of PNF may be due to its active engagement of neuromuscular pathways, which not only improves ROM but also enhances proprioception and motor control [14,19]. Additionally, the hold-relax technique used in this study has been previously reported to optimize muscle extensibility and joint mobility, making it an ideal choice for flexibility enhancement [15].

Despite these promising findings, it is important to acknowledge some limitations of the study. The sample size was relatively small, limiting the generalizability of the results to a larger population. Additionally, the study only examined the short-term effects of PNF and static stretching, leaving the long-term implications of these interventions unknown. Future research should explore the sustainability of PNF-induced flexibility gains over extended periods and in diverse athletic populations [20]. Another limitation is the reliance on self-reported VAS scores for muscle tightness, which, while widely used, remains a subjective measure and may be influenced by individual pain tolerance and perception.

Future Recommendations

Based on the findings of this study, future research should focus on investigating the long-term effects of PNF stretching on flexibility, functional performance, and injury prevention. Larger-scale studies with diverse populations, including both elite and recreational athletes, would provide more comprehensive insights into the effectiveness of PNF stretching [12]. Additionally, exploring variations of PNF techniques, such as contract-relax or hold-relax with antagonist contraction, may help determine the most effective approach for flexibility enhancement [9].

Future studies should also examine the integration of PNF stretching into pre-exercise warm-up and post-exercise recovery protocols to evaluate its impact on overall athletic performance and recovery time. Investigating the neuromuscular adaptations associated with regular PNF stretching could further enhance our understanding of its physiological benefits and practical applications [14]. Lastly, incorporating objective measures such as electromyography (EMG) or ultrasound imaging would help validate the biomechanical and neuromuscular effects of PNF stretching in comparison to other stretching modalities [15].

CONCLUSION

In conclusion, this study supports the efficacy of PNF stretching over static stretching for improving quadriceps flexibility and reducing muscle tightness in senior athletes. Given its advantages, PNF stretching should be considered an essential component of flexibility training and rehabilitation programs. However, further research is warranted to optimize its application and explore its long-term benefits in various athletic and clinical settings.

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