

## THE IMPACT OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION AND DYNAMIC STRETCHING ON LOWER LIMB FLEXIBILITY IMPROVEMENT: A SYSTEMATIC REVIEW

I Fadhilah<sup>1\*</sup>, Yanuar Kiram<sup>2</sup>, Padli<sup>3</sup>

Universitas Negeri Padang, Indonesia

Universitas Negeri Padang, Indonesia

Universitas Negeri Padang, Indonesia

E-mail: [fadhils13diamond@gmail.com](mailto:fadhils13diamond@gmail.com)<sup>1\*</sup>, [yanuarkiram@fik.unp.ac.id](mailto:yanuarkiram@fik.unp.ac.id)<sup>2</sup>, [padli85@fik.unp.ac.id](mailto:padli85@fik.unp.ac.id)<sup>3</sup>

Received : 20 September 2025

Revised : 10 October 2025

Accepted : 13 November 2025

Published : 13 December 2025

DOI : <https://doi.org/10.54443/morfai.v6i1.4706>

Link Publish : <https://radjapublika.com/index.php/MORFAI/article/view/4706>

### Abstract

A systematic review is therefore needed to consolidate existing evidence and identify the dominant factors. This systematic review was conducted to consolidate evidence on how proprioceptive neuromuscular facilitation (PNF) and dynamic stretching affect hamstring flexibility. Literature searches were carried out using the Scopus database. Two empirical studies up to the year 2025 were analyzed from an initial pool of 113 findings, including interventions combining PNF and dynamic/ballistic stretching. Thematic analysis focused on two main dimensions: the effectiveness of stretching techniques in improving hamstring flexibility and the acute impact of stretching on explosive performance. The synthesis results indicate that both dynamic stretching (including ballistic stretching) and PNF can improve hamstring flexibility in structured interventions, making them effective for reducing muscle stiffness and expanding the range of motion. In pre-activity contexts, dynamic or ballistic stretching tends to enhance neuromuscular readiness and supports the ability to generate power immediately after warm-up, making it suitable before activities that require high power output. Conversely, certain PNF variations ending with passive static stretching were found to decrease acute explosive performance despite improving muscle looseness, making them less appropriate as part of competitive warm-ups. Overall, this review emphasizes that the selection of stretching techniques should consider two primary goals: whether the priority is to improve hamstring flexibility or to maintain and even optimize explosive performance immediately after warm-up.

**Keywords:** *Hamstring flexibility, dynamic stretching, proprioceptive neuromuscular facilitation (PNF)*

### INTRODUCTION

Hamstring muscle flexibility plays a crucial role in maintaining athletic performance and preventing injuries in sports activities that involve stretching and lower-limb range of motion. Flexible hamstring muscles enable optimal movement range, enhance motion efficiency, and support faster recovery after training or competition. Tightness or stiffness in these muscles often becomes a major obstacle that affects performance and increases the risk of injuries, such as muscle strains or tears (Cai et al., 2023; Rudisill et al., 2023). Various training techniques and interventions have been developed to improve flexibility, including proprioceptive neuromuscular facilitation (PNF) and dynamic stretching, each with distinct mechanisms of action and effectiveness. A deep understanding of the biological processes and muscle adaptation mechanisms related to these stretching techniques is essential for designing optimal training programs. Previous studies have shown that stretching interventions can significantly improve flexibility; however, their success rates are influenced by factors such as exercise type, duration, intensity, and individual physical condition (Hosseini et al., 2025; Reiner et al., 2021; Zhang et al., 2025). Therefore, a systematic review of the effects of PNF and dynamic stretching whether used independently or in combination on lower-limb flexibility is necessary to obtain an accurate scientific overview and practical recommendations. A standardized approach and proper evaluation will contribute to the development of effective, efficient, and safe training methods for improving performance and preventing injuries in both athletes and physically active individuals.

## LITERATURE REVIEW

Hamstring muscle flexibility is an important factor in physical performance and injury prevention, especially in activities involving knee flexion and hip extension. Stiffness or limited flexibility of the hamstrings is associated with reduced range of motion, impaired movement efficiency, and an increased risk of injuries such as muscle strains. Improving hamstring flexibility is therefore a primary goal in both physical training and rehabilitation. This flexibility can be developed through various stretching approaches, including neuromuscular techniques and active stretching (Rudisill et al., 2023). One of the most widely used methods is Proprioceptive Neuromuscular Facilitation (PNF). PNF is a neuromuscular-based stretching technique that combines isometric contraction of the targeted muscle, followed by a relaxation phase and further passive stretching. This mechanism utilizes the activation of proprioceptors to reduce the muscle's protective tension, allowing it to lengthen further in a safe manner. Practically, PNF has been shown to significantly increase the joint range of motion (ROM) of the hamstrings while also contributing to joint stability and post-injury recovery. Another advantage of PNF is its relatively rapid improvement in flexibility when performed correctly and consistently (Ceyran et al., 2024; Reiner et al., 2021).

Dynamic stretching is also an important strategy for enhancing hamstring flexibility. Unlike static stretching, dynamic stretching involves controlled, repetitive active movements without holding extreme positions. The movement patterns typically resemble functional movements or sport-specific motions. Dynamic stretching progressively increases blood flow, muscle temperature, and tissue elasticity while preparing the neuromuscular system for high-intensity activity. Because of its functional nature, this technique is often used as part of warm-up routines to enhance performance readiness and reduce injury risk (Fenanlampir et al., 2024; Wang et al., 2024).

Both PNF and dynamic stretching contribute to improving lower-limb flexibility, particularly in the hamstrings. PNF primarily works through the modulation of neuromuscular reflexes and the inhibition of protective muscle responses, whereas dynamic stretching operates by increasing tissue temperature, mechanical elasticity, and functional motor activation. Several findings indicate that PNF tends to produce immediate improvements in passive flexibility or range of motion, while dynamic stretching is superior in enhancing functional movement readiness prior to physical activity. Thus, the choice of method depends on the objective: whether the goal is short-term flexibility and maximal range of motion, or immediate performance readiness. In training practice, these two methods can even complement each other to support performance, lower-limb movement efficiency, and hamstring injury prevention (Cai et al., 2023; Ghram et al., 2020; Hosseini et al., 2025; Pérez-Bellmunt et al., 2023). The purpose of this systematic review is to analyze and compare the effectiveness of Proprioceptive Neuromuscular Facilitation (PNF) and dynamic stretching techniques in improving hamstring flexibility and to examine their acute effects on explosive performance, in order to provide a more comprehensive understanding of the appropriate application of stretching within training and sports warm-up contexts.

## METHOD

This study employed a systematic literature review design to identify, evaluate, and synthesize empirical evidence regarding the effects of PNF and dynamic stretching on hamstring muscle flexibility. The systematic review approach was chosen to ensure methodological rigor, minimize bias, and provide a comprehensive understanding of the existing literature. The review process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). A structured and comprehensive literature search was conducted using electronic databases, including Scopus. The search included studies published up to the year 2025 to capture the latest developments in research on peripheral nerve stimulation, dynamic stretching, and lower-limb flexibility. The following keywords and Boolean operators were used: ("proprioceptive neuromuscular facilitation" OR "PNF stretching" OR "PNF stretch" OR "PNF technique") AND ("hamstring" OR "hamstring flexibility" OR "hamstring range of motion" OR "hamstring ROM") AND ("flexibility" OR "range of motion" OR "ROM" OR "muscle length") AND ("athlete" OR "athletes" OR "sport" OR "sports performance" OR "sport performance" OR "physical performance"). In addition, the reference lists of articles that met the inclusion criteria were manually examined (snowballing) to identify additional relevant studies that might not have been captured in the initial database search.

Studies were included if they met the following criteria:

1. Assessed the effects of PNF and dynamic stretching on hamstring muscle flexibility or range of motion parameters relevant to hamstring function (e.g., hamstring flexibility, knee extension angle, passive straight leg raise, hip flexion range of motion).

# THE IMPACT OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION AND DYNAMIC STRETCHING ON LOWER LIMB FLEXIBILITY IMPROVEMENT: A SYSTEMATIC REVIEW

Fadhilah et al

2. Involved human participants who were adults or late adolescents with measurable physical activity levels (e.g., athletes, physically active individuals, or subjects participating in lower-limb exercise/training/rehabilitation programs).
3. Employed an empirical research design, including quantitative experimental, quasi-experimental, pre-post clinical trials, or mixed-method approaches reporting flexibility measurements.
4. Published in English in peer-reviewed journals between 2018 and 2025.

Studies were excluded if:

1. They did not focus on the hamstrings, meaning they only assessed flexibility in other areas (e.g., lumbar spine, shoulder, or “general body flexibility” without specific analysis of the hamstrings/posterior lower limbs).
2. They did not implement both interventions according to inclusion criteria and failed to clearly describe the intervention methods of peripheral nerve stimulation/facilitation or dynamic stretching (e.g., missing details on protocol frequency, duration, or application site), or did not report outcomes related to hamstring flexibility/range of motion changes.
3. They were literature reviews, editorials, opinions, commentaries, conference abstracts without full data, or single case reports lacking objective hamstring flexibility measurements.
4. They were not available in English or were not peer-reviewed.

Two independent reviewers extracted data using a standardized form, recording study characteristics (authors, year, country, design, sample size, and instruments), main findings, and identifying the effects of PNF and dynamic stretching. Disagreements between reviewers were resolved through discussion and consensus. Data were analyzed using thematic synthesis, a process of coding empirical findings from each study and grouping them based on shared physiological and functional concepts. The results of the analysis were then organized into three main dimensions. First, the effects of PNF stimulation and dynamic stretching on hamstring muscle flexibility, including their influence on muscle tone, neuromuscular relaxation, stretch tolerance, and improvements in functional range of motion. Second, the complementary effects of combining peripheral nerve stimulation and dynamic stretching, particularly regarding their contribution to hamstring strain prevention, enhanced motor control, and sustained flexibility improvement in both training and rehabilitation contexts.

The methodological quality of the included studies was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist, appropriate to each study design. Studies were rated as high, moderate, or low quality based on criteria such as clarity of objectives, methodological consistency, validity, and relevance. Only studies rated as moderate or high quality were included in the synthesis to ensure credibility. As this research involved a review of published literature, ethical approval was not required. However, all included studies were assumed to have adhered to ethical standards as declared by their respective authors and institutions (Santos et al., 2018).

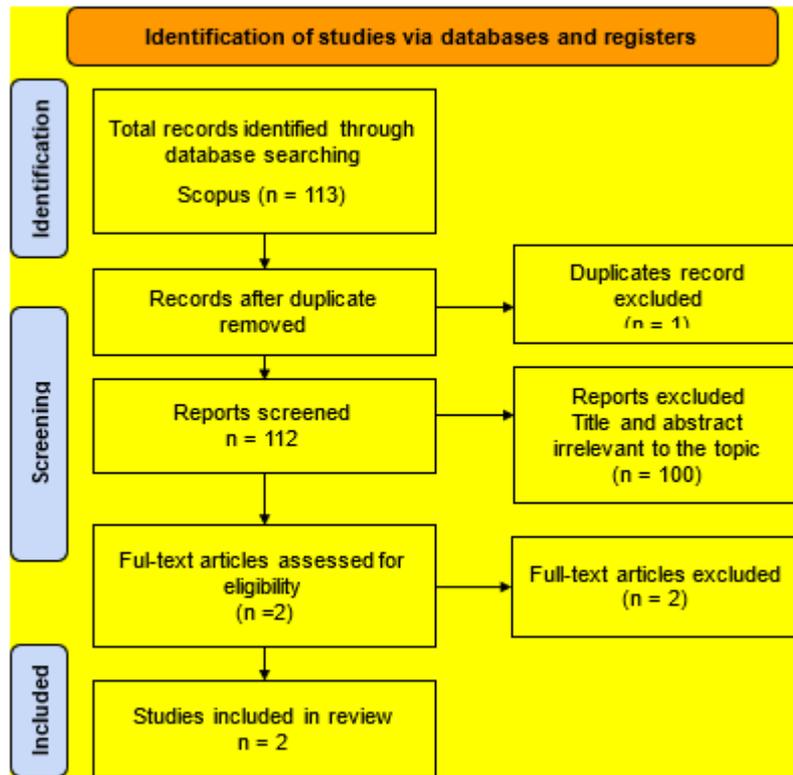


Figure 1. PRISMA Flowchart

**RESULTS AND DISCUSSION**

**Study Characteristics**

A total of two empirical studies published up to 2025 were included in the final analysis out of 113 initial findings. These studies examined the effects of various stretching techniques primarily PNF and dynamic stretching on hamstring muscle flexibility and their additional impact on physical performance. All studies employed quantitative experimental designs (n = 2); no qualitative or mixed-method studies were identified. In general, both PNF and dynamic/ballistic stretching were found to improve hamstring flexibility, although their effectiveness was influenced by factors such as isometric contraction duration, combination with other techniques, and length of the intervention period. The synthesis revealed three main themes regarding the effects of PNF and dynamic stretching on hamstring flexibility:

1. Effectiveness of stretching techniques in improving hamstring flexibility.
2. Acute impact of stretching on functional or explosive performance.

Table 1. Summary of Included Studies

No.	Authors and Year	Country/Region	Research Design	Sample Characteristics	Intervention Duration	Main Findings
1	Poor, A. S., Mohseni, H., Najafzadeh, N., Hemmati, M., & Najafi, A. (2014). <i>Research Journal of Pharmaceutical, Biological and Chemical Sciences</i>	Iran	Experimental with pre–post test between groups	30 male participants aged 18–24 years, physically active university students, divided into 3 groups (dynamic stretching, PNF 5-second	8 weeks	Compared three methods: dynamic stretching, PNF with 5-second static contraction, and PNF with 10-second static contraction over 8 weeks. All methods significantly improved

**THE IMPACT OF PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION AND DYNAMIC STRETCHING ON LOWER LIMB FLEXIBILITY IMPROVEMENT: A SYSTEMATIC REVIEW**

Fadhilah et al

				contraction, and PNF 10-second contraction)		hamstring flexibility in men aged 18–24. No significant difference was found among the three methods in the degree of flexibility improvement.
2	Kirmizigil, B., Ozcaldiran, B., & Colakoglu, M. (2014). <i>Journal of Strength and Conditioning Research</i>	Turkey	Experimental with crossover design among three stretching treatments	100 male athletes, grouped according to initial flexibility and performance levels	Single (acute) session	Compared the effects of three flexibility protocols during warm-up: (a) ballistic stretching (BS), (b) PNF + BS, (c) PNF + static stretching (SS), on countermovement jump performance. BS increased jump height especially in athletes with low/normal flexibility and lower initial performance. PNF + BS benefited athletes with high flexibility. PNF + SS decreased jump performance in most groups. BS was deemed most suitable before explosive activities.

**Effectiveness of Stretching Techniques on Hamstring Flexibility**

Based on the synthesis of empirical findings, the effectiveness of stretching techniques on hamstring flexibility is influenced by the mechanical and neuromuscular characteristics of each stretching method. In general, both dynamic or ballistic stretching (BS) and proprioceptive neuromuscular facilitation (PNF) aim to increase the range of motion of the hamstring muscles; however, they produce different functional consequences on physical performance immediately after warm-up (Kirmizigil et al., 2014; Poor et al., 2014). Ballistic stretching, which involves repeated active movements lasting approximately 5 seconds per muscle and performed over several sets, has been shown to enhance neuromuscular readiness and support explosive performance without compromising hamstring function. Among male athletes, ballistic stretching targeting the hamstrings, gluteus maximus, and lumbar

extensors was found to increase vertical jump height, particularly in individuals with low to moderate baseline flexibility (Kirmizigil et al., 2014). In contrast, the PNF approach involves an isometric contraction followed by a passive stretching phase, aiming to reduce reflexive muscle tension through neuromuscular inhibition and to enhance range of motion. When PNF was combined with ballistic stretching (PNF + BS), the effects appeared to be more individually specific: improvements in explosive performance were most evident among participants with high initial flexibility, suggesting that PNF can help optimize neuromotor control when the hamstring tissues are already relatively supple. However, when PNF was combined with static stretching held for approximately 30 seconds (PNF + SS), explosive performance decreased significantly in groups with moderate to high flexibility, despite the intervention's goal of improving flexibility (Kirmizigil et al., 2014). This finding reinforces that not all flexibility gains are functionally beneficial; certain stretching patterns may increase muscle length while simultaneously reducing acute power output (Dallas et al., 2014; Opplert & Babault, 2018).

On the other hand, a study on men aged 18–24 years showed that dynamic stretching and PNF with variations in isometric contraction duration (5 seconds and 10 seconds) were both able to significantly improve hamstring flexibility after a structured training period, with no significant difference between the three methods in terms of flexibility gains. This finding implies that for the purpose of improving hamstring range of motion in the short-to-medium term (several weeks of training), both dynamic stretching techniques and short-duration contract–relax PNF techniques can be effectively used (Poor et al., 2014). Overall, two key points emerge. First, both dynamic/ballistic stretching and PNF are equally effective in improving hamstring flexibility, indicating that increases in range of motion are not dependent on a single stretching technique (Kirmizigil et al., 2014; Poor et al., 2014). This is clinically important because it allows for individualization in young or athletic populations, coaches or physiotherapists can choose the technique best suited to the athlete's or patient's preference and tolerance without losing the basic benefit of increased flexibility (Donti et al., 2022; Stricker et al., 2020).

Second, the choice of stretching technique has different performance consequences. Ballistic or dynamic stretching not only enhances mobility but also helps maintain or even improve acute explosive performance such as vertical jump, making it ideal for pre-activity warm-ups before high-intensity exercise. Conversely, PNF followed by a relatively long-held static stretch may increase range of motion but potentially reduce power output immediately after warm-up (Kirmizigil et al., 2014). This means that PNF with a long static component may be more appropriate for structured flexibility training or rehabilitation sessions (focused on ROM goals) rather than pre-explosive activity warm-ups. Thus, the evidence indicates that hamstring stretching effectiveness should not only be measured by how much the muscle becomes more flexible but also by neuromuscular readiness after stretching to perform specific physical tasks (Kirmizigil et al., 2014; Poor et al., 2014).

### **Acute Effects of Stretching on Functional Performance (Explosive Performance)**

Analysis of pre-activity stretching interventions shows that the choice of stretching technique not only affects hamstring flexibility but also influences the ability to generate explosive power immediately after warm-up, particularly in activities such as vertical jumping. Ballistic stretching, performed through rapid, repetitive active movements of short duration (approximately 5 seconds per muscle, repeated in several sets), has been shown to enhance acute explosive performance. Male athletes who performed ballistic stretching targeting the hamstring, gluteus maximus, and lumbar extensors demonstrated increased vertical jump height (countermovement jump), especially among those with initially low-to-moderate flexibility and jump ability (Kirmizigil et al., 2014). This finding suggests that high-velocity dynamic stretching not only fails to “weaken” the muscles but actually enhances neuromuscular readiness for power production (Stojanovic & Ostojic, 2011).

A combination of stretching techniques involving a passive stretch component held for a relatively long duration can have negative effects on acute explosive performance. The PNF plus static stretching (PNF + SS) protocol consisting of isometric contraction followed by a static stretch held for about 30 seconds resulted in a decrease in vertical jump performance among athletes with moderate to high flexibility (Kirmizigil et al., 2014). This decline indicates that while the technique is useful for reducing tissue tension and improving range of motion, its side effect is a temporary reduction in power output immediately after stretching. Practically, this means that prolonged passive stretching during the warm-up phase may impair explosive performance, which is crucial in power-based sports (Lima et al., 2019). When the PNF technique is not concluded with a prolonged static hold but instead combined with a dynamic or ballistic component (PNF + BS), its effects become more specific to individual characteristics. Among athletes with initially high flexibility, the PNF and ballistic stretching protocol can support explosive performance without the decline observed in the PNF and static stretching combination (Kirmizigil et al., 2014). This suggests that PNF can function as a form of “neuromotor priming”, provided that its final phase remains

dynamic and does not hold the muscle in a prolonged passive relaxation state (Smedes & Giacometti da Silva, 2019). When compared with findings from multi-week training interventions, this pattern highlights an important distinction between acute effects and training-induced effects. Studies that evaluated dynamic stretching and PNF over planned training periods reported significant increases in hamstring flexibility across all groups but did not address the immediate consequences for explosive power output. In the context of short- to medium-term flexibility improvement programs, both PNF and dynamic stretching are effective for increasing range of motion (Poor et al., 2014). However, in the context of acute pre-activity for example, immediately before performing explosive movements not all techniques that improve flexibility are safe for performance (Kurak et al., 2024).

These findings emphasize that stretching before explosive activity should not be evaluated solely based on “whether flexibility increases,” but rather on “whether the muscle remains ready to generate power.” Ballistic or dynamic stretching appears most appropriate as part of a warm-up routine because it enhances neuromuscular readiness while also supporting vertical jump performance. Conversely, combining PNF with a prolonged static hold (PNF + SS) is less recommended for warm-up prior to explosive tasks, as it may reduce performance despite increasing range of motion (Kirmizigil et al., 2014). The choice of acute stretching technique should therefore align with the session goal: if the goal is immediate explosiveness, dynamic or ballistic stretching is more suitable; if the aim is range-of-motion improvement and temporary reduction of muscle tightness without immediate power demands, PNF with a static component remains relevant (Kirmizigil et al., 2014; Poor et al., 2014).

## CONCLUSION

This review indicates that the improvement of hamstring flexibility and explosive performance readiness is influenced by three main factors: the type of stretching technique, the intended purpose, and the context of application. Both dynamic or ballistic stretching and proprioceptive neuromuscular facilitation (PNF) techniques are effective in increasing hamstring flexibility, making them suitable for reducing muscle tightness and enhancing range of motion. However, their acute effects on performance differ. Dynamic or ballistic stretching tends to enhance neuromuscular readiness and support explosive power generation, making it more appropriate as part of a warm-up routine before high-intensity activity. In contrast, certain forms of PNF that conclude with a prolonged passive stretch may temporarily decrease explosive capability, even though they make the muscles feel looser. Thus, such PNF variations are better suited for flexibility training rather than for competitive warm-ups. Overall, hamstring stretching techniques should not be selected generically; rather, the choice must be aligned with the specific goal whether the aim is to increase range of motion or to maintain and optimize explosive performance immediately after warm-up.

## REFERENCES

- Cai, P., Liu, L., & Li, H. (2023). Dynamic and static stretching on hamstring flexibility and stiffness: A systematic review and meta-analysis. *Heliyon*, 9(8), e18795. <https://doi.org/10.1016/j.heliyon.2023.e18795>
- Ceyran, M., Pancar, Z., Ulema, M. S., Karaca, B., Tasdogan, A. M., Yilmaz, M., & Koyunlu, A. (2024). The Effect of Proprioceptive Neuromuscular Facilitation Stretching Exercises on Balance Circulatory Parameters and Motoric Adaptations in Futsal Players. *Annals of Applied Sport Science*, 12(4), 0–0. <https://doi.org/10.61186/aassjournal.1417>
- Dallas, G., Smirniotoy, A., Tsiganos, G., Tsopani, D., di Cagno, A., & Tsolakis, C. (2014). Acute effect of different stretching methods on flexibility and jumping performance in competitive artistic gymnasts. *The Journal of Sports Medicine and Physical Fitness*, 54, 683–690.
- Donti, O., Konrad, A., Panidi, I., Dinas, P. C., & Bogdanis, G. C. (2022). Is There a “Window of Opportunity” for Flexibility Development in Youth? A Systematic Review with Meta-analysis. *Sports Medicine - Open*, 8(1), 88. <https://doi.org/10.1186/s40798-022-00476-1>
- Fenanlampir, A., Lumba, A., Mutohir, T., & García-Jiménez, J. (2024). The differences between static stretching and proprioceptive neuromuscular facilitation stretching on flexibility: a gender review. *Jurnal Keolahragaan*, 12, 67–76. <https://doi.org/10.21831/jk.v12i1.72373>
- Ghram, A., Yahia, A., Damak, M., Safaei Motlagh, A., Jribi, S., & Costa, P. B. (2020). Effects of different types of proprioceptive neuromuscular facilitation stretching on dynamic balance control. *Sport Sciences for Health*, 16(3), 451–458. <https://doi.org/10.1007/s11332-020-00623-9>
- Hosseini, E., Alimoradi, M., Iranmanesh, M., Saki, F., & Konrad, A. (2025). The effects of 8 weeks of dynamic hamstring stretching or nordic hamstring exercises on balance, range of motion, agility, and muscle

- performance among male soccer players with hamstring shortness: a randomized controlled trial. *BMC Sports Science, Medicine and Rehabilitation*, 17(1), 187. <https://doi.org/10.1186/s13102-025-01216-0>
- Kirmizigil, B., Ozcaldiran, B., & Colakoglu, M. (2014). Effects of Three Different Stretching Techniques on Vertical Jumping Performance. *Journal of Strength and Conditioning Research*, 28(5), 1263–1271. <https://doi.org/10.1519/JSC.0000000000000268>
- Kurak, K., İlbak, İ., Stojanović, S., Bayer, R., Purenović-Ivanović, T., Pałka, T., Ambroży, T., Kasicki, K., Czarny, W., & Rydzik, Ł. (2024). The Effects of Different Stretching Techniques Used in Warm-Up on the Triggering of Post-Activation Performance Enhancement in Soccer Players. *Applied Sciences*, 14(11), 4347. <https://doi.org/10.3390/app14114347>
- Lima, C. D., Ruas, C. V., Behm, D. G., & Brown, L. E. (2019). Acute Effects of Stretching on Flexibility and Performance: A Narrative Review. *Journal of Science in Sport and Exercise*, 1(1), 29–37. <https://doi.org/10.1007/s42978-019-0011-x>
- Opplert, J., & Babault, N. (2018). Acute Effects of Dynamic Stretching on Muscle Flexibility and Performance: An Analysis of the Current Literature. *Sports Medicine*, 48(2), 299–325. <https://doi.org/10.1007/s40279-017-0797-9>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, n71. <https://doi.org/10.1136/bmj.n71>
- Pérez-Bellmunt, A., Casasayas-Cos, O., Ragazzi, P., Rodríguez-Sanz, J., Hidalgo-García, C., Canet-Vintró, M., Caballero-Martínez, I., Pacheco, L., & López-de-Celis, C. (2023). Foam Rolling vs. Proprioceptive Neuromuscular Facilitation Stretching in the Hamstring Flexibility of Amateur Athletes: Control Trials. *International Journal of Environmental Research and Public Health*, 20(2), 1439. <https://doi.org/10.3390/ijerph20021439>
- Poor, A. S., Mohseni, H., Najafzadeh, N., Hemmati, M., & Najafi, A. (2014). Comparing the effectiveness of an eight-week period stretching PNF, and dynamic stretching on hamstring muscle flexibility. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 5(6), 1246–1252. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84911171927&partnerID=40&md5=c27348dd5d86b4cb655db6731a8993a2>
- Reiner, M., Tilp, M., Guilhem, G., Morales-Artacho, A., Nakamura, M., & Konrad, A. (2021). Effects of a Single Proprioceptive Neuromuscular Facilitation Stretching Exercise With and Without Post-stretching Activation on the Muscle Function and Mechanical Properties of the Plantar Flexor Muscles. *Frontiers in Physiology*, 12. <https://doi.org/10.3389/fphys.2021.732654>
- Rudisill, S. S., Varady, N. H., Kucharik, M. P., Eberlin, C. T., & Martin, S. D. (2023). Evidence-Based Hamstring Injury Prevention and Risk Factor Management: A Systematic Review and Meta-analysis of Randomized Controlled Trials. *The American Journal of Sports Medicine*, 51(7), 1927–1942. <https://doi.org/10.1177/03635465221083998>
- Santos, W. M. dos, Secoli, S. R., & Püschel, V. A. de A. (2018). The Joanna Briggs Institute approach for systematic reviews. *Revista Latino-Americana de Enfermagem*, 26(0). <https://doi.org/10.1590/1518-8345.2885.3074>
- Smedes, F., & Giacometti da Silva, L. (2019). Motor learning with the PNF-concept, an alternative to constrained induced movement therapy in a patient after a stroke; a case report. *Journal of Bodywork and Movement Therapies*, 23(3), 622–627. <https://doi.org/10.1016/j.jbmt.2018.05.003>
- Stojanovic, M. D., & Ostojic, S. M. (2011). Stretching and Injury Prevention in Football: Current Perspectives. *Research in Sports Medicine*, 19(2), 73–91. <https://doi.org/10.1080/15438627.2011.556476>
- Stricker, P. R., Faigenbaum, A. D., McCambridge, T. M., LaBella, C. R., Brooks, M. A., Canty, G., Diamond, A. B., Hennrikus, W., Logan, K., Moffatt, K., Nemeth, B. A., Pengel, K. B., & Peterson, A. R. (2020). Resistance Training for Children and Adolescents. *Pediatrics*, 145(6). <https://doi.org/10.1542/peds.2020-1011>
- Wang, B., Wu, B., Yang, Y., Cai, M., Li, S., & Peng, H. (2024). Neuromuscular and balance adaptations following acute stretching exercise: a randomized control trial. *Frontiers in Physiology*, 15. <https://doi.org/10.3389/fphys.2024.1486901>
- Zhang, P., Chen, J., & Xing, T. (2025). Effects of post-exercise stretching versus no stretching on lower limb muscle recovery and performance: a meta-analysis. *Frontiers in Physiology*, 16. <https://doi.org/10.3389/fphys.2025.1674871>