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Effects of Dynamic, Static and Post-Activation Warm-Up Strategies on Athletic Performance: A Narrative Review

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Abstract: Warm-up is widely recognized as a fundamental component of athletic preparation and is commonly used to enhance performance and reduce injury risk. Various warm-up strategies have been investigated in recent years, including dynamic warm-up, static stretching, Post-Activation Performance Enhancement (PAPE), foam rolling, and plyometric exercises. However, the relative effectiveness of these approaches remains unclear. The aim of this narrative review was to synthesize current evidence regarding the effects of different warm-up strategies on athletic performance and injury prevention. A literature search was conducted using PubMed, Scopus, Web of Science, and Google Scholar databases, and studies published between 2015 and 2025 were considered. Twenty-two studies met the inclusion criteria. The findings indicated that dynamic warm-up produced the most consistent improvements in sprint performance, agility, jumping ability, and sport-specific skills. PAPE protocols were also associated with enhanced power output and explosive performance. Static stretching primarily improved flexibility and range of motion, whereas foam rolling showed limited effects on performance despite increasing mobility. Plyometric warm-up strategies yielded mixed results. In addition, structured warm-up programs incorporating balance, strength, and neuromuscular exercises contributed to injury prevention and improved postural control. Overall, the available evidence suggests that dynamic warm-up and PAPE protocols currently represent the most effective evidence-based strategies for enhancing athletic performance, while structured warm-up programs play an important role in injury prevention..

Keywords: warm-up; dynamic stretching; static stretching; PAPE; athletic performance; injury prevention

Introduction

Warm-up represents a fundamental component of athletic preparation and is widely recognized as an essential strategy for optimizing performance and reducing injury risk. Although the practice of warming up has been integrated into sports training for decades, recent research has highlighted that the effectiveness of a warm-up depends not only on its inclusion, but also on its structure, intensity, duration, and specificity to the subsequent athletic task (Afonso et al., 2024).

Current evidence suggests that warm-up protocols facilitate physiological, neuromuscular, and psychological adaptations that prepare athletes for training and competition. These adaptations include increases in muscle and core temperature, enhanced metabolic activity, improved nerve conduction velocity, increased joint mobility, and greater readiness of the neuromuscular system to generate force and power (Abreu et al., 2025; Afonso et al., 2024). Even small acute improvements resulting from an effective warm-up may have meaningful implications in competitive sport, where marginal gains can influence final outcomes (Afonso et al., 2024).

In recent years, considerable attention has been directed toward identifying the most effective warm-up strategies. Dynamic warm-up protocols have emerged as one of the most frequently recommended approaches due to their ability to improve explosive performance, sprint speed, agility, and lower-limb power. Recent evidence indicates that dynamic warm-ups lasting approximately 7–10 minutes can produce significant improvements in athletic performance while simultaneously enhancing range of motion and movement efficiency (Esteban-García et al., 2024; Sople & Wilcox, 2025). In contrast, prolonged static stretching performed immediately before explosive activities may negatively affect force and power production, although it remains useful for flexibility development and specific rehabilitation contexts (Esteban-García et al., 2024; Lucaciu et al., 2014).

Alongside traditional dynamic and static warm-up approaches, novel performance-oriented strategies have gained increasing popularity. Among these, Post-Activation Performance Enhancement (PAPE) has received substantial scientific interest. PAPE refers to the acute enhancement of muscular performance following a high-intensity conditioning activity and has been associated with improvements in strength, power output, sprinting, and jumping performance when appropriately implemented (Kasicki et al., 2024; Olsen et al., 2025). However, the effectiveness of PAPE appears to be influenced by several factors, including athlete training status, exercise selection, recovery duration, and sport-specific demands (Kasicki et al., 2024).

Despite the growing number of studies investigating warm-up strategies, the literature remains heterogeneous and, in some cases, contradictory. While several investigations report positive effects of dynamic warm-up and PAPE interventions on athletic performance, other studies have found minimal or non-significant differences when compared with traditional warm-up routines (Rappelt et al., 2024). Furthermore, the effectiveness of different warm-up approaches may vary according to sport discipline, competitive level, and the specific performance variables being evaluated.

Therefore, a comprehensive synthesis of the available evidence is required to better understand the relative effectiveness of contemporary warm-up strategies. The aim of this narrative review is to examine and critically analyze current scientific evidence regarding dynamic warm-up, static stretching, and post-activation performance enhancement strategies and their effects on athletic performance. Additionally, this review seeks to provide practical recommendations for coaches, athletes, and sport practitioners while identifying areas that warrant further investigation.

Methodology

Study Design

This study was conducted as a narrative review of the scientific literature investigating the effects of different warm-up strategies on athletic performance. Particular attention was given to dynamic warm-up, static stretching, and post-activation performance enhancement (PAPE) protocols. The review aimed to synthesize current evidence regarding the physiological and performance-related outcomes associated with these approaches in athletes and physically active individuals. This study was conducted as a narrative review following the recommendations of the Scale for the Assessment of Narrative Review Articles (SANRA) (Baethge et al., 2019).

Literature Search Strategy

A literature search was conducted between January and March 2025 using the electronic databases PubMed, Scopus, Web of Science, and Google Scholar. The search strategy combined keywords and Boolean operators related to warm-up interventions and athletic performance.

The following search terms were used individually and in combination: "warm-up" and "athletic performance";dynamic warm-up" and performance; "static stretching" and performance; "post-activation performance enhancement" or "PAPE"; "post-activation potentiation" and sport; "warm-up strategies" and athletes; "sports performance" and warm-up

Only studies published in English between 2015 and 2025 were considered for inclusion to ensure that the review reflected current scientific evidence.

Eligibility Criteria

Studies were included if they met the following criteria: Investigated warm-up interventions in athletes or physically active individuals;

1. Examined dynamic warm-up, static stretching, PAPE, or combinations of these strategies.
2. Reported outcomes related to athletic performance, including strength, power, sprint speed, agility, jumping ability, endurance, or sport-specific performance.
3. Were original research articles, systematic reviews, or meta-analyses published in peer-reviewed journals.

Studies were excluded if they:

1. Focused exclusively on rehabilitation or clinical populations.
2. Did not report performance-related outcomes.
3. Were conference abstracts, editorials, dissertations, or non-peer-reviewed publications.
4. Were published in languages other than English.

Study Selection

Titles and abstracts identified through the database searches were screened for relevance. Full-text articles were subsequently reviewed when the title and abstract suggested potential eligibility. Particular emphasis was placed on studies published during the last five years and on high-quality systematic reviews and meta-analyses.

Following the screening process, the selected studies were grouped according to the primary warm-up strategy investigated: Dynamic warm-up; static stretching; post-activation; performance enhancement (PAPE); combined warm-up approaches.

Data Extraction and Synthesis

Relevant information was extracted from each study, including participant characteristics, sport discipline, warm-up protocol, outcome measures, and principal findings. Due to the heterogeneity of study designs, participant populations, and performance outcomes, a quantitative meta-analysis was not performed.

Instead, findings were synthesized narratively, allowing comparison of the effectiveness of different warm-up strategies across various sports and performance contexts. Particular attention was given to identifying common trends, practical applications, and areas of disagreement within the literature.

Quality Considerations

To improve the scientific rigor of this review, priority was given to studies published in high-impact peer-reviewed journals, systematic reviews, and meta-analyses. Recent evidence was emphasized whenever available, while seminal studies were included when necessary to provide historical and theoretical context.

Results

A total of 22 studies met the eligibility criteria and were included in this narrative review. The studies investigated the effects of various warm-up strategies on athletic performance in different populations, including runners, swimmers, tennis players, basketball players, gymnasts, and recreationally active individuals. The characteristics and main findings of the included studies are presented in Table 1.

Table 1. Characteristics and main findings of studies investigating warm-up strategies and athletic performance

STUDY	PARTICIPANTS	WARM-UP STRATEGY	OUTCOME MEASURES	MAIN FINDINGS
Anderson et al. (2020)	91 active athletes	Dynamic warm-up vs. self-myofascial foam rolling (SMFR)	Sprint, jump performance, flexibility	Foam rolling did not improve performance beyond dynamic warm-up.
Lopez-Samanes et al. (2021)	11 elite tennis players	Dynamic warm-up vs. SMFR	CMJ, sprint, agility	Dynamic warm-up produced superior agility and sprint performance.
Morales-Artacho et al. (2016)	14 active males	Cycling vs. foam rolling	ROM, muscle stiffness	Cycling improved ROM more effectively than foam rolling.
Yuan et al. (2022)	11 basketball players	Dynamic stretching, foam rolling, combined protocol	Agility, jump performance	All methods improved performance, with dynamic warm-up showing the greatest benefits.
Warneke et al. (2023)	20 recreationally active participants	Foam rolling vs. sham rolling	Passive and active ROM	Increased passive ROM, with limited effects on dynamic performance.
Alves et al. (2023)	13 trained distance runners	High-intensity warm-up (PAPE) vs. low-intensity warm-up	5000-m performance, CMJ, lactate	High-intensity warm-up improved running performance by 0.5%.

Đurović et al. (2022)	10 swimmers	Swimming warm-up + drop jumps (PAPE)	Swim-start performance, CMJ	PAPE improved start efficiency and explosive performance.
Boullosa et al. (2018)	22 trained athletes	PAPE protocols	Power output, muscular performance	Significant acute enhancement of muscular performance.
Ullman et al. (2021)	Competitive runners	Dynamic vs. static stretching	VO_2, sprint, jump performance	Dynamic warm-up demonstrated superior performance benefits.
Faelli et al. (2021)	Endurance runners	Dynamic stretching, static stretching, no stretching	Running economy, RPE	Both dynamic and static stretching improved running economy and reduced perceived exertion.
Gelen et al. (2021)	26 tennis players	Static, dynamic, and plyometric warm-up	Serve velocity	Dynamic and plyometric warm-ups increased serve speed.
Kendall (2017)	10 recreational participants	Dynamic vs. static stretching	Wingate anaerobic test	Dynamic warm-up improved peak power output.
Yu et al. (2024)	Gymnasts (19 studies)	Static stretching, vibration platform, PAP	CMJ, squat jump	No significant differences among protocols.
Wei et al. (2020)	12 endurance athletes	Plyometric warm-up	Running economy, VO_2, leg stiffness	Running economy improved by 6.2%.
Tomlinson et al. (2020)	22 sprinters	Loaded plyometric warm-up	30-m sprint	No significant sprint improvements were observed.
Krzysztofik & Wilk (2020)	22 resistance-trained athletes	Plyometric push-ups	Bench press power	Performance improved only during the first set.
Ding et al. (2022)	Systematic review (15 studies)	Injury-prevention warm-up programs	Injury incidence	Injury rates were reduced by approximately 36%.
Munoz-Plaza et al. (2021)	Coaches and players (n = 42)	Basketball warm-up routines	Injury prevention practices	Considerable variability in warm-up implementation was observed.
Fradkin et al. (2010)	Systematic review (32 studies)	Various warm-up protocols	Physical performance	Most warm-up strategies improved performance outcomes.
Brighenti et al. (2020)	12 athletes	Cycling warm-up	Balance control	Balance improved after 10–20 minutes.
Ahmadabadi Et Al. (2015)	16 gymnasts	Dynamic warm-up protocol	Static and dynamic balance	Significant improvements in balance performance were reported.
Donti et al. (2014)	34 elite gymnasts	Stretching + tuck jumps	ROM, CMJ	Combined protocols improved flexibility and jump performance.

Overall, the evidence suggests that warm-up interventions generally have positive effects on athletic performance. However, the magnitude of these effects appears to depend on the type of warm-up, the characteristics of the participants, and the specific performance outcomes assessed. Dynamic warm-up and Post-Activation Performance Enhancement (PAPE) protocols demonstrated the most consistent positive effects, whereas foam rolling and some plyometric interventions produced more variable results (figure 1).

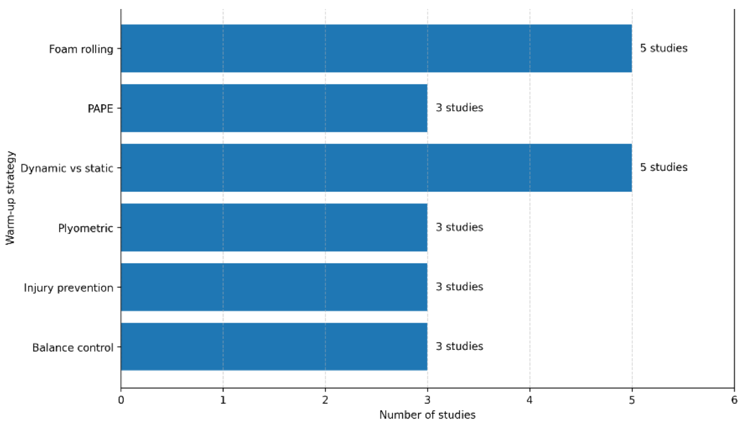

Figure 1. Distribution of included studies by warm-up strategy

Dynamic Warm-Up Strategies

Dynamic warm-up was the most frequently investigated strategy among the studies included in this review. These protocols typically involved jogging, dynamic mobility exercises, sport-specific movements, and progressive activation drills designed to increase muscle temperature and neuromuscular readiness.

Several studies reported superior performance outcomes following dynamic warm-up compared with other approaches. Lopez-Samanes et al. (2021) found that dynamic warm-up produced greater improvements in sprint and agility performance than self-myofascial foam rolling in elite tennis players (Lopez-Samanes et al., 2021). Similarly, Yuan et al. (2022) reported that although dynamic stretching, foam rolling, and combined protocols all improved performance, dynamic warm-up generated the greatest benefits in agility-related tasks (Yuan et al., 2023).

Studies comparing dynamic and static stretching also favored dynamic warm-up. Ullman et al. (2021) observed superior improvements in sprinting and jumping performance following dynamic protocols (Ullman et al., 2021), while Kendall (2017) reported higher peak power values after dynamic warm-up compared with static stretching (Kendall, 2017). Furthermore, Gelen et al. (2021) demonstrated that dynamic exercises enhanced tennis serve velocity more effectively than static stretching (Gelen et al., 2012).

Collectively, these findings suggest that dynamic warm-up is one of the most effective strategies for enhancing explosive performance, agility, and sport-specific skills.

Static Stretching

The effects of static stretching were less consistent across the reviewed studies. Although static stretching remains widely used to increase flexibility and range of motion, its influence on performance appears to depend on the characteristics of the activity performed afterward.

Faelli et al. (2021) reported that both static and dynamic stretching improved running economy and reduced ratings of perceived exertion in endurance runners (Faelli et al., 2021). However, studies focusing on explosive performance generally showed less favorable outcomes for static stretching. Ullman et al. (2021) and Kendall (2017) found that static stretching was less effective than dynamic warm-up for enhancing sprint, jump, and power-related performance variables (Kendall, 2017; Ullman et al., 2021).

In gymnasts, Yu et al. (2024) reported no significant differences between static stretching, vibration-based warm-up, and PAP protocols, suggesting that the effectiveness of static stretching may depend on the sport and performance task evaluated (Yu et al., 2024).

Overall, static stretching appears beneficial for flexibility development but may not represent the optimal strategy when maximal power, speed, or explosive performance is required immediately afterward.

Post-Activation Performance Enhancement (PAPE)

PAPE protocols were consistently associated with positive performance outcomes. These interventions typically involved high-intensity conditioning activities performed before the main performance task in order to acutely enhance neuromuscular function.

Alves et al. (2023) demonstrated that a high-intensity warm-up improved 5000-m running performance by approximately 0.5% compared with a low-intensity warm-up (Alves et al., 2023). Similarly, Đurović et al. (2022) reported significant improvements in swim-start efficiency and countermovement jump performance following the inclusion of drop jumps within the warm-up routine (Đurović et al., 2022).

The study by Boullosa et al. (2018) further highlighted the effectiveness of PAPE, reporting improvements in muscular power and performance following specific activation exercises (Boullosa et al., 2018). These findings support the notion that properly designed PAPE protocols can enhance both explosive and endurance-related performance when sufficient recovery is provided between the conditioning activity and the subsequent task.

Foam Rolling and Plyometric Warm-Up Strategies

Alternative warm-up approaches such as self-myofascial foam rolling and plyometric exercises have gained increasing popularity in recent years. However, the evidence supporting their effectiveness remains mixed.

Most foam rolling studies reported improvements in flexibility and passive range of motion but limited effects on athletic performance. Anderson et al. (2020) concluded that foam rolling did not improve performance beyond that achieved through dynamic warm-up alone (Anderson et al., 2020). Similar findings were reported by Morales-Artacho et al. (2016) and Warneke et al. (2023), who observed improvements in range of motion without corresponding increases in dynamic performance outcomes (Morales-Artacho et al., 2017; Warneke et al., 2023).

Plyometric warm-up protocols demonstrated more promising results. Wei et al. (2020) found that plyometric exercises improved running economy by 6.2% in endurance athletes (Wei et al., 2020). Likewise, Gelen et al. (2012) reported increases in tennis serve velocity following plyometric warm-up activities (Gelen et al., 2012). Nevertheless, not all studies observed significant benefits. Tomlinson et al. (2020) found no significant improvements in sprint performance following loaded plyometric exercises (Tomlinson et al., 2020), while Krzysztofik and Wilk (2020) reported positive effects that were limited to the initial set of exercise (Krzysztofik & Wilk, 2020).

These findings indicate that plyometric warm-up strategies may be beneficial in specific contexts, although their effectiveness appears to depend on exercise selection and athlete characteristics.

Warm-Up for Injury Prevention and Balance Enhancement

Several studies highlighted the role of warm-up programs in reducing injury risk and improving balance performance. Ding et al. (2022) reported that structured warm-up interventions reduced injury incidence by approximately 36% among young athletes (Ding et al., 2022). Similarly, Fradkin et al. (2010) found that the majority of warm-up protocols improved physical performance while simultaneously contributing to injury prevention (Fradkin et al., 2010).

Balance-related outcomes were also positively influenced by warm-up interventions. Brighenti et al. (2020) demonstrated significant improvements in balance control following a 10-minute cycling warm-up (Brighenti et al., 2022), while Ahmadabadi et al. (2015) observed improvements in both static and dynamic balance after dynamic warm-up protocols in gymnasts (Ahmadabadi et al., 2015). Additionally, Donti et al. (2014) reported enhanced flexibility and countermovement jump performance when stretching was combined with tuck jumps (Donti et al., 2014).

Taken together, these findings suggest that structured warm-up routines not only enhance athletic performance but also contribute to injury prevention and postural control, both of which are essential components of long-term athletic development.

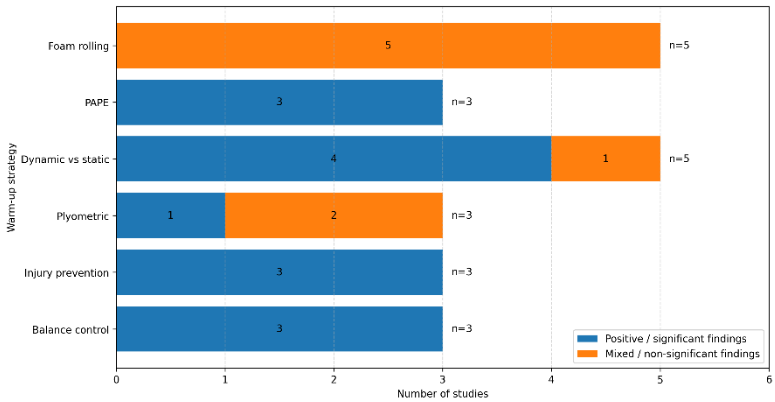

Figure 2. Summary of performance-related findings by warm-up strategy

Figure 2 illustrates the overall trends identified across the included studies. Dynamic warm-up and PAPE protocols demonstrated the most consistent positive effects on athletic performance. In contrast, foam rolling interventions primarily improved flexibility and range of motion, with limited evidence supporting improvements in performance outcomes. Plyometric protocols showed mixed findings, whereas injury-prevention and balance-oriented warm-up programs consistently reported beneficial effects.

Discussion

The primary aim of this narrative review was to examine the current evidence regarding the effects of different warm-up strategies on athletic performance. Overall, the findings indicate that warm-up interventions generally produce beneficial effects on performance-related outcomes, although the magnitude of these effects varies according to the type of warm-up, the characteristics of the athletes, and the specific physical capacities being assessed.

Among the strategies reviewed, dynamic warm-up demonstrated the most consistent positive effects on athletic performance. Studies included in this review reported improvements in sprint speed, agility, jumping ability, and sport-specific performance following dynamic warm-up interventions. These findings are consistent with recent literature suggesting that dynamic exercises increase muscle temperature, enhance neural activation, improve joint mobility, and stimulate sport-specific movement patterns before competition (Afonso et al., 2024; Sople & Wilcox, 2025). Furthermore, dynamic warm-up appears to optimize the balance between physiological preparation and fatigue, allowing athletes to perform explosive actions more effectively.

In contrast, static stretching produced less consistent results. Although several studies reported improvements in flexibility and running economy, static stretching was generally less effective than dynamic warm-up for maximizing power, sprint, and jumping performance. These findings support recent systematic reviews indicating that prolonged static stretching immediately before explosive activities may temporarily reduce force production and neuromuscular efficiency (Esteban-García et al., 2024). Nevertheless, static stretching should not be considered ineffective, as it remains valuable for increasing range of motion and may be particularly beneficial in sports requiring high levels of flexibility, such as gymnastics and dance.

Post-Activation Performance Enhancement (PAPE) emerged as one of the most promising warm-up approaches identified in this review. High-intensity conditioning activities, including sprint efforts, loaded exercises, and plyometric movements, consistently improved subsequent performance when appropriate recovery periods were provided. Recent evidence suggests that PAPE enhances performance through increased motor unit recruitment, improved muscle contractile properties, and greater neuromuscular readiness (Kasicki et al., 2024). However, the effectiveness of PAPE appears highly dependent on individual characteristics such as training status, strength level, and recovery duration. Consequently, practitioners should individualize PAPE protocols according to the specific needs of each athlete.

The findings related to self-myofascial foam rolling were less conclusive. Most studies reported improvements in flexibility and passive range of motion, but limited evidence supporting meaningful improvements in performance outcomes. Similar conclusions have been reported by Behm and Wilke (2019), who suggested that foam rolling may be useful as a mobility-enhancing strategy without negatively affecting subsequent performance. However, based on the current evidence, foam rolling alone does not appear to provide the same performance-enhancing effects as dynamic warm-up or PAPE protocols (Behm & Wilke, 2019).

Plyometric warm-up strategies produced mixed results across studies. While some investigations demonstrated improvements in running economy, jump performance, and sport-specific tasks, others reported minimal or non-significant effects. These discrepancies may be explained by differences in exercise selection, training status of participants, and recovery intervals. Nevertheless, plyometric exercises may serve as an effective complement to traditional dynamic warm-up routines, particularly in sports requiring explosive force production.

Another important finding of this review concerns injury prevention and balance enhancement. Structured warm-up programs incorporating aerobic activity, strength exercises, balance training, and movement preparation consistently reduced injury risk and improved postural control. These findings are supported by the systematic review of Ding et al. (2022), which reported a substantial reduction in injury incidence following structured warm-up interventions. Improved balance and neuromuscular control may contribute not only to injury prevention but also to enhanced movement efficiency and athletic performance.

The present review has several practical implications for coaches and sport practitioners. First, dynamic warm-up should be considered the foundation of most pre-competition preparation routines due to its consistent positive effects on performance. Second, PAPE protocols may provide additional performance benefits for trained athletes when appropriately individualized. Third, static stretching should be used strategically, particularly when flexibility is a priority. Finally, injury-prevention programs that integrate balance, strength, and movement-control exercises should be incorporated regularly into athletic preparation.

Future research should focus on identifying optimal combinations of warm-up strategies and investigating the individual factors that influence responsiveness to different protocols. Greater standardization of warm-up interventions and outcome measures would also facilitate comparisons across studies and improve the quality of evidence available to practitioners.

Overall, the evidence reviewed suggests that dynamic warm-up and PAPE protocols currently represent the most effective strategies for enhancing athletic performance, while structured warm-up programs also play an important role in injury prevention and balance development..

Conclusions

The present narrative review examined the current evidence regarding the effects of dynamic warm-up, static stretching, Post-Activation Performance Enhancement (PAPE), foam rolling, plyometric protocols, and injury-prevention warm-up programs on athletic performance.

Overall, the findings suggest that warm-up interventions play a fundamental role in preparing athletes for training and competition. Among the strategies reviewed, dynamic warm-up and PAPE protocols demonstrated the most consistent positive effects on performance-related outcomes, including sprint speed, agility, jumping ability, power production, and sport-specific performance. In contrast, static stretching was primarily associated with improvements in flexibility and range of motion, while its effects on explosive performance were less consistent. Foam rolling interventions generally improved mobility and passive range of motion but provided limited evidence of additional performance benefits. Plyometric warm-up strategies showed promising but variable results depending on the sport and protocol employed.

The reviewed evidence also highlights the importance of structured warm-up programs for injury prevention and balance enhancement. Warm-up routines that incorporate aerobic activity, dynamic movements, strength exercises, and neuromuscular control components appear to contribute not only to improved performance but also to reduced injury risk.

From a practical perspective, coaches and sport practitioners should prioritize dynamic warm-up as the foundation of pre-competition preparation while considering the inclusion of PAPE strategies when appropriate for the athlete's training level and performance demands. Future research should focus on identifying optimal combinations of warm-up methods and establishing standardized protocols for different sports and athletic populations.

In conclusion, warm-up remains an essential component of athletic preparation, with dynamic warm-up and PAPE currently representing the most effective evidence-based approaches for enhancing athletic performance.

Limitations

Several limitations of the present review should be acknowledged. First, the studies included differed substantially with regard to participant characteristics, sport disciplines, warm-up duration, exercise intensity, and performance outcomes assessed. Such heterogeneity limits direct comparisons between investigations and makes it difficult to identify a universally optimal warm-up strategy.

Second, the reviewed studies included athletes from various competitive levels, ranging from recreationally active individuals to elite performers. Consequently, the effectiveness of specific warm-up protocols may not be equally applicable across all populations.Third, despite the emphasis on recent evidence, some older studies were included to provide theoretical context and support the interpretation of findings. Therefore, some conclusions may reflect methodological approaches that have evolved over time.

Finally, this study was conducted as a narrative review and did not include a formal risk-of-bias assessment or meta-analytic procedures. As a result, the findings should be interpreted with caution and viewed as a synthesis of the current literature rather than definitive evidence regarding the superiority of a particular warm-up strategy.

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References

Abreu, M., Nakamura, F. Y., Carvalho, T., Silva, D., Vasconcellos, F., & Afonso, J. (2025). Warm-Up Strategies at Halftime: A Pilot Randomized Controlled Trial in a Professional Women's Soccer Team. *J Funct Morphol Kinesiol*, *10*(3). https://doi.org/10.3390/jfmk10030270

Afonso, J., Brito, J., Abade, E., Rendeiro-Pinho, G., Baptista, I., Figueiredo, P., & Nakamura, F. Y. (2024). Revisiting the 'Whys' and 'Hows' of the Warm-Up: Are We Asking the Right Questions? *Sports Med*, *54*(1), 23–30. https://doi.org/10.1007/s40279-023-01908-y

Ahmadabadi, F., Avandi, M., & Aminian Far, A. (2015). Acute versus Chronic dynamic warm-up on balance and balance the vault performance in skilled gymnast. *International Journal of applied exercise physiology*, *4*, 20–33.

Alves, M., Knechtle, B., Silva, D. D. S., Fernandes, M., Gomes, J. H., Thuany, M., Aidar, F. J., Weiss, K., & De Souza, R. F. (2023). Effects of High-Intensity Warm-Up on 5000-Meter Performance Time in Trained Long-Distance Runners. *J Sports Sci Med*, *22*(2), 254–262. https://doi.org/10.52082/jssm.2023.254

Anderson, B. L., Harter, R. A., & Farnsworth, J. L. (2020). The Acute Effects of Foam Rolling and Dynamic Stretching on Athletic Performance: A Critically Appraised Topic. *J Sport Rehabil*, *30*(3), 501–506. https://doi.org/10.1123/jsr.2020-0059

Baethge, C., Goldbeck-Wood, S., & Mertens, S. (2019). SANRA-a scale for the quality assessment of narrative review articles. *Res Integr Peer Rev*, *4*, 5. https://doi.org/10.1186/s41073-019-0064-8

Behm, D. G., & Wilke, J. (2019). Do Self-Myofascial Release Devices Release Myofascia? Rolling Mechanisms: A Narrative Review. *Sports Med*, *49*(8), 1173–1181. https://doi.org/10.1007/s40279-019-01149-y

Boullosa, D., Del Rosso, S., Behm, D. G., & Foster, C. (2018). Post-activation potentiation (PAP) in endurance sports: A review. *Eur J Sport Sci*, *18*(5), 595–610. https://doi.org/10.1080/17461391.2018.1438519

Brighenti, A., Noé, F., Stella, F., Schena, F., & Mourot, L. (2022). Warm-Up Improves Balance Control Differently in the Dominant and Non-Dominant Leg in Young Sportsmen According to Their Experience in Asymmetric or Symmetric Sports. *Int J Environ Res Public Health*, *19*(8). https://doi.org/10.3390/ijerph19084562

Ding, L., Luo, J., Smith, D. M., Mackey, M., Fu, H., Davis, M., & Hu, Y. (2022). Effectiveness of Warm-Up Intervention Programs to Prevent Sports Injuries among Children and Adolescents: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health*, *19*(10). https://doi.org/10.3390/ijerph19106336

Donti, O., Tsolakis, C., & Bogdanis, G. C. (2014). Effects of baseline levels of flexibility and vertical jump ability on performance following different volumes of static stretching and potentiating exercises in elite gymnasts. *J Sports Sci Med*, *13*(1), 105–113.

Đurović, M., Stojanović, N., Stojiljković, N., Karaula, D., & Okičić, T. (2022). The effects of post-activation performance enhancement and different warm-up protocols on swim start performance. *Scientific Reports*, *12*(1), 9038. https://doi.org/10.1038/s41598-022-13003-9

Esteban-García, P., Abián-Vicen, J., Sánchez-Infante, J., Ramírez-delaCruz, M., & Rubio-Arias, J. Á. (2024). Does the Inclusion of Static or Dynamic Stretching in the Warm-Up Routine Improve Jump

Height and ROM in Physically Active Individuals? A Systematic Review with Meta-Analysis. *Applied Sciences*, *14*(9), 3872.

Faelli, E., Panascì, M., Ferrando, V., Bisio, A., Filipas, L., Ruggeri, P., & Bove, M. (2021). The Effect of Static and Dynamic Stretching during Warm-Up on Running Economy and Perception of Effort in Recreational Endurance Runners. *Int J Environ Res Public Health*, *18*(16). https://doi.org/10.3390/ijerph18168386

Fradkin, A. J., Zazryn, T. R., & Smoliga, J. M. (2010). Effects of warming-up on physical performance: a systematic review with meta-analysis. *J Strength Cond Res*, *24*(1), 140–148. https://doi.org/10.1519/JSC.0b013e3181c643a0

Gelen, E., Dede, M., Bingul, B. M., Bulgan, C., & Aydin, M. (2012). Acute effects of static stretching, dynamic exercises, and high volume upper extremity plyometric activity on tennis serve performance. *J Sports Sci Med*, *11*(4), 600–605.

Kasicki, K., Rydzik, Ł., Ambroży, T., Spieszny, M., & Koteja, P. (2024). The Impact of Post-Activation Performance Enhancement Protocols on Vertical Jumps: Systematic Review. *Applied Sciences*, *14*(21), 9664.

Kendall, B. J. (2017). The Acute Effects of Static Stretching Compared to Dynamic Stretching with and without an Active Warm up on Anaerobic Performance. *Int J Exerc Sci*, *10*(1), 53–61. https://doi.org/10.70252/xylb7701

Krzysztofik, M., & Wilk, M. (2020). The Effects of Plyometric Conditioning on Post-Activation Bench Press Performance. *J Hum Kinet*, *74*, 99–108. https://doi.org/10.2478/hukin-2020-0017

Lopez-Samanes, A., Del Coso, J., Hernández-Davó, J. L., Moreno-Pérez, D., Romero-Rodriguez, D., Madruga-Parera, M., Muñoz, A., & Moreno-Pérez, V. (2021). Acute effects of dynamic versus foam rolling warm-up strategies on physical performance in elite tennis players. *Biol Sport*, *38*(4), 595–601. https://doi.org/10.5114/biolsport.2021.101604

Lucaciu, G., Marinau, M., Gavris-Stef, M., & Dragos, P. (2014). Changes in the group's social structure in mountain tourism. *Baltic Journal of Health and Physical Activity*, *6*. https://doi.org/10.2478/bjha-2014-0007

Morales-Artacho, A. J., Lacourpaille, L., & Guilhem, G. (2017). Effects of warm-up on hamstring muscles stiffness: Cycling vs foam rolling. *Scand J Med Sci Sports*, *27*(12), 1959–1969. https://doi.org/10.1111/sms.12832

Olsen, O. R., Bojsen-Møller, J., & Aagaard, P. (2025). Post-Activation Performance Enhancement in Strength and Power Sports-A Narrative Review. *Scand J Med Sci Sports*, *35*(11), e70162. https://doi.org/10.1111/sms.70162

Rappelt, L., Held, S., Wiedenmann, T., Micke, F., & Donath, L. (2024). Post-activation performance enhancement (PAPE) protocols do not further increase jumping performance beyond warm-up effects: findings from three acute randomized crossover trials. *Front Physiol*, *15*, 1447421. https://doi.org/10.3389/fphys.2024.1447421

Sople, D., & Wilcox, R. B., 3rd. (2025). Dynamic Warm-ups Play Pivotal Role in Athletic Performance and Injury Prevention. *Arthrosc Sports Med Rehabil*, *7*(2), 101023. https://doi.org/10.1016/j.asmr.2024.101023

Tomlinson, K. A., Hansen, K., Helzer, D., Lewis, Z. H., Leyva, W. D., McCauley, M., Pritchard, W., Silvestri, E., Quila, M., Yi, M., & Jo, E. (2020). The Effects of Loaded Plyometric Exercise during Warm-Up on Subsequent Sprint Performance in Collegiate Track Athletes: A Randomized Trial. *Sports*, *8*(7), 101.

Ullman, Z. J., Fernandez, M. B., & Klein, M. (2021). Effects of Isometric Exercises versus Static Stretching in Warm-up Regimens for Running Sport Athletes: A Systematic Review. *Int J Exerc Sci*, *14*(6), 1204–1218. https://doi.org/10.70252/fdtw6296

Warneke, K., Aragão-Santos, J. C., Alizadeh, S., Bahrami, M., Anvar, S. H., Konrad, A., & Behm, D. G. (2023). Are Acute Effects of Foam-Rolling Attributed to Dynamic Warm Up Effects? A Comparative Study. *J Sports Sci Med*, *22*(2), 180–188. https://doi.org/10.52082/jssm.2023.180

Wei, C., Yu, L., Duncan, B., & Renfree, A. (2020). A Plyometric Warm-Up Protocol Improves Running Economy in Recreational Endurance Athletes. *Front Physiol*, *11*, 197. https://doi.org/10.3389/fphys.2020.00197

Yu, W., Feng, D., Zhong, Y., Luo, X., Xu, Q., & Yu, J. (2024). Examining the Influence of Warm-Up Static and Dynamic Stretching, as well as Post-Activation Potentiation Effects, on the Acute Enhancement of Gymnastic Performance: A Systematic Review with Meta-Analysis. *J Sports Sci Med*, *23*(1), 156–176. https://doi.org/10.52082/jssm.2024.156

Yuan, H., Mao, J., Lai, C., Lu, H., Xue, Y., & Liu, Q. (2023). Acute effects of foam rolling and dynamic stretching on angle-specific change of direction ability, flexibility and reactive strength in male basketball players. *Biol Sport*, *40*(3), 877–887. https://doi.org/10.5114/biolsport.2023.121325