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The Influence of Pre-Competition Warm-Up Strategies on Athletes' Performance

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Abstract

Pre-competition warm-up, as an essential component of sports training, has a long history. With the development of modern competitive sports, pre-competition warm-up has gradually become systematized and scientific, becoming an indispensable part of various sports. Warm-up strategies are mainly divided into three categories: dynamic warm-up, static stretching, and sport-specific warm-up. Dynamic warm-up significantly enhances athletes' explosiveness, speed, and flexibility by increasing muscle temperature and core body temperature, boosting blood flow, stimulating nervous system excitability, and improving reaction speed, thereby enhancing overall athletic performance. Static stretching is effective in improving muscle flexibility and joint range of motion, but it may lead to short-term decreases in strength and explosiveness, so its application in pre-competition warm-ups needs to be approached with caution. Sport-specific warm-up, which simulates competition movements, improves technical performance and physical fitness levels, especially in projects requiring high technical proficiency and athletic skills. However, its specific effects are influenced by the complexity and intensity of the warm-up and the individual adaptability of the athletes. Different warm-up strategies have their own advantages and limitations in enhancing athletic performance and preventing sports injuries. Dynamic warm-up rapidly enhances athletes' cardiovascular and muscle temperature, making it suitable for most high-intensity and quick-response sports; static stretching significantly improves flexibility and joint range, making it ideal for sports requiring large movements and high flexibility; sport-specific warm-up is highly targeted and improves technical performance and athletic skills through simulated competition movements, making it suitable for highly technical sports. In practical applications, these warm-up strategies should be flexibly chosen and combined according to the specific sports and characteristics of the athletes to achieve the best results. Future research should continue to explore the specific mechanisms of different warm-up strategies and their application effects in various sports. By improving research methods, increasing sample size and diversity, and using multiple measurement indicators, the effectiveness of warm-up strategies can be comprehensively evaluated. Attention should also be given to the combination of new warm-up methods with traditional warm-up strategies, exploring their potential in improving athletic performance and preventing sports injuries. Through systematic research and scientific guidance, pre-competition warm-up strategies will continue to evolve and improve, providing athletes and coaches with more scientific and practical warm-up guidance, promoting the development of sports science, and enhancing athletes' competitive levels and health.

Keywords

Sports training; warm-up; sports competition; athletic performance; sports level.

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1. Introduction

Pre-competition warm-up, as an essential component of sports training, has a long history. In ancient Greece and Rome, athletes recognized the importance of warming up their bodies before competitions to prepare for various athletic events[1-3]. With the development of modern competitive sports, pre-competition warm-up has gradually become systematized and scientific, becoming indispensable in various sports[4]. In the early 20th century, scientists and coaches began to study pre-competition warm-up from the perspectives of physiology and kinesiology, exploring its impact on athletic performance. This stage of research focused on understanding the physiological changes during warm-up, such as increased muscle temperature, enhanced joint mobility, and improved nerve conduction speed.

Warm-up strategies are mainly divided into three categories: dynamic warm-up, static stretching, and sport-specific warm-up[5-6]. Dynamic warm-up includes a series of continuous, gradually intensifying exercises such as jumping, running, and high knees. The theoretical basis of this strategy is to gradually increase body temperature, heart rate, and respiratory rate, thereby improving muscle elasticity and joint flexibility, and reducing the risk of sports injuries. Static stretching involves lengthening the muscles and holding the position for a certain period to enhance muscle and joint flexibility. This method's theoretical basis is to reduce muscle stiffness and the risk of strains during exercise by elongating the muscles and tendons. Sport-specific warm-up is tailored for particular sports and aims to activate the relevant muscle groups and nervous system by simulating competition movements, thereby improving athletic efficiency and performance.

Pre-competition warm-up plays a crucial role in enhancing athletic performance and reducing sports injuries[7]. Warm-up increases muscle temperature and metabolic rate, boosts blood flow and oxygen delivery, and enhances muscle elasticity and contractile ability, thereby improving athletic performance. It enhances maximum strength output, speed, flexibility, and endurance. Additionally, warm-up improves nervous system function, increases reaction speed and coordination[8], allowing athletes to respond more quickly during competitions. Another important role is the prevention of sports injuries. Gradually increasing exercise intensity during warm-up allows muscles, joints, and ligaments to adapt to the intensity changes, reducing the incidence of common injuries like muscle strains and joint sprains.

This review aims to systematically summarize and analyze the existing literature on the impact of different pre-competition warm-up strategies on athletic performance, providing scientific guidance and reference for coaches, athletes, and sports science researchers. By comparing the effects of different warm-up strategies, it helps coaches select the most suitable warm-up methods for their athletes and sports, maximizing their performance. Additionally, this review provides scientific warm-up guidance for athletes, helping them prepare thoroughly before competitions and reduce the risk of injuries. It points out current research gaps and future research directions, promoting the further development and optimization of pre-competition warm-up strategies. Pre-competition warm-up holds a significant position in sports training, with each warm-up strategy having its own theoretical basis and practical effects. By systematically reviewing existing research, we can provide scientific guidance for athletes and coaches, enhancing athletic performance and reducing sports injuries.

2. Dynamic warm-up

Dynamic warm-up is a method that enhances the body's overall preparedness through a series of continuous and progressively intensifying exercises. Unlike static stretching, dynamic warm-up emphasizes continuity and dynamism, typically including actions such as jumping, fast running, high knees, and leg swings[9, 10]. These movements aim to simulate key actions of the

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upcoming sports activities, thereby more effectively activating the relevant muscle groups and nervous system. The distinctive feature of dynamic warm-up is its ability to raise muscle temperature, enhance blood circulation, increase heart rate and respiratory rate within a short time, contributing to improved overall athletic performance.

The theoretical foundation of dynamic warm-up mainly comes from studies in exercise physiology and sports neuroscience[11]. Dynamic warm-up significantly raises muscle temperature and core body temperature. This temperature increase reduces muscle viscosity, thereby improving muscle elasticity and contraction efficiency. This is crucial for enhancing athletic performance, as higher muscle temperatures enable muscles to perform more flexibly and powerfully during exercise[12]. Additionally, dynamic warm-up increases blood flow, particularly to the working muscles, which not only improves oxygen and nutrient supply but also accelerates the removal of metabolic waste, which is vital for extending exercise endurance and preventing fatigue. Moreover, dynamic warm-up can enhance nervous system excitability and reaction speed, promoting faster nerve conduction and improved motor coordination through the simulation of competitive actions, enabling athletes to respond quickly and effectively during competitions. Numerous studies have explored the effects of dynamic warm-up on different types of sports, covering endurance sports, strength sports, and explosive sports. Research generally indicates that dynamic warm-up significantly improves athletic performance. Fletcher and Jones (2004) found in their study on sprinters that athletes who performed dynamic warm-up showed significantly higher sprinting speeds compared to those who performed static stretching[14]. Previous studies have shown that dynamic warm-up can significantly increase maximum strength output and muscle explosiveness in strength sports. Behm and Chaouachi (2011) summarized in their review that dynamic warm-up can enhance vertical jump height and quick reaction ability, which is particularly important for sports requiring explosiveness and reaction speed, such as basketball and volleyball[13].

In summary, dynamic warm-up can effectively increase muscle temperature and core body temperature, boost blood flow and oxygen supply, and significantly enhance athletic performance in a short period. Additionally, it can improve nervous system excitability and reaction speed by simulating competitive actions, enhancing athletes' coordination and reaction speed, thereby making them perform better in competitions. Dynamic warm-up positively impacts various types of sports, especially those requiring strength and explosiveness[15]. However, studies also indicate that the specific effects of dynamic warm-up may be influenced by factors such as the duration of the warm-up, exercise intensity, and individual differences among athletes. Therefore, in practical applications, the content and intensity of dynamic warm-up should be flexibly adjusted based on the specific sports and athletes' characteristics to achieve the best results.

As an effective pre-competition preparation strategy, dynamic warm-up has significant advantages in enhancing athletic performance and preventing sports injuries[16]. Through systematic analysis of existing research results, it can provide scientific guidance for athletes and coaches, helping them select and implement the most suitable dynamic warm-up strategies before competitions to maximize performance. Future research should continue to explore the mechanisms of dynamic warm-up and its optimal application methods in different sports, providing a deeper and more detailed theoretical foundation and practical guidance for the development of sports science.

3. Static stretching

Static stretching is a method that involves lengthening the muscles and holding them in a fixed position for a period to improve muscle flexibility and joint range of motion. Typically, each static stretch is maintained for 15 to 60 seconds, with the muscles remaining stationary and

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without repetitive movements. The main characteristics of static stretching are its simplicity and ease of execution, requiring no special equipment, making it suitable for various settings and different types of athletes[17]. Despite its widespread use in sports training and rehabilitation, the role and effects of static stretching in pre-competition warm-up have always been controversial.

The theoretical foundation of static stretching mainly comes from studies in muscle physiology and exercise physiology. Stretching increases muscle and tendon length, enhancing muscle flexibility and joint range of motion, which is crucial for athletes' flexibility and range of motion. During stretching, muscle fibers are passively elongated, reducing muscle stiffness and lowering the risk of muscle strains and sprains during exercise. Static stretching also reduces muscle tension and improves blood circulation, promoting muscle recovery and reducing delayed onset muscle soreness. Additionally, static stretching can activate the Golgi tendon organs and muscle spindles, regulating the nervous system's reflex mechanisms, thereby improving muscle relaxation and coordination. Numerous studies have explored the effects of static stretching on athletic performance, but the results are mixed. Some studies suggest that static stretching positively impacts athletic performance. For instance, Taylor et al. (2009) found that static stretching significantly improves joint range of motion and muscle flexibility, which is particularly beneficial for sports requiring high flexibility, such as gymnastics and dance. However, other studies indicate that pre-competition static stretching might negatively affect certain types of athletic performance. Kay and Blazevich (2012) found that static stretching might lead to short-term decreases in strength and explosiveness, which is detrimental to sports requiring high-intensity explosiveness, such as sprinting and jumping.

Static stretching is effective in enhancing joint range of motion and muscle flexibility, which is beneficial for sports requiring high flexibility and large movement ranges[18]. Although static stretching can reduce muscle tension and improve blood circulation, promoting muscle recovery and reducing delayed onset muscle soreness, its role in pre-competition warm-up remains controversial. Particularly for sports requiring high-intensity strength and explosiveness, pre-competition static stretching might negatively impact performance in the short term. Therefore, in practical applications, coaches and athletes should carefully select and adjust the timing and intensity of static stretching based on specific sports and individual needs to avoid potential adverse effects. As an important training and rehabilitation method, static stretching plays a significant role in improving muscle flexibility and joint range of motion. Despite the controversy over its effects in pre-competition warm-up, reasonable application and scientific guidance can still provide beneficial support for athletes' overall athletic performance and rehabilitation.

4. Sport-Specific Warm-Up

Sport-specific warm-up is a method of preparing the body by simulating specific movements of the upcoming sport[19]. Unlike general dynamic warm-up or static stretching, sport-specific warm-up focuses on strengthening the muscle groups and movement patterns directly related to the target sport. Its main characteristic is high specificity, which can more effectively activate and mobilize the muscles and nervous system that athletes will use in competitions or training. Specific actions may include simulating the starting actions of runners, the shooting and jumping exercises of basketball players, or the strokes and turns of swimmers. This type of warm-up not only enhances the physiological readiness of athletes but also boosts their psychological preparedness for competition by familiarizing and reinforcing movement patterns, thus reducing feelings of unfamiliarity and anxiety.

The theoretical foundation of sport-specific warm-up mainly stems from research in kinesiology, neurophysiology, and biomechanics. First, sport-specific warm-up effectively

ISSN: 2710-0170

increases the temperature and blood circulation of specific muscle groups, enhancing muscle elasticity and power output[20]. This is particularly important for athletes about to engage in high-intensity sports, as raising muscle temperature can reduce the risk of strains and improve muscle response speed. Second, sport-specific warm-up enhances the adaptability and responsiveness of the nervous system through repeated specific movement patterns. Neural adaptability refers to the nervous system's ability to transmit signals more quickly and accurately through repeated actions, thereby improving exercise efficiency. Moreover, sport-specific warm-up optimizes athletes' technical movements through repetitive practice and adjustment of movement details, enabling athletes to better display their technical skills in competitions. Numerous studies have explored the effects of sport-specific warm-up on different types of sports, and results generally show that sport-specific warm-up significantly improves athletic performance[21]. Previous research indicates that golfers performing specific swing warm-ups before competitions can significantly increase driving distance and accuracy. Similarly, studies on soccer players have found that warm-ups simulating passing and shooting actions can effectively improve technical performance and physical fitness in competitions. Swimmers performing specific stroke and turn exercises before races can significantly reduce race completion times and improve performance. While most studies support the positive effects of sport-specific warm-up, some research suggests that overly complex and high-intensity sport-specific warm-ups may cause athletes to fatigue before competitions, thereby affecting performance.

Sport-specific warm-up significantly improves athletic performance, especially in sports requiring high technical proficiency and athletic skills. This warm-up method enhances technical performance and physical fitness levels by simulating competitive actions, increasing the nervous system's adaptability and responsiveness, and improving athletes' coordination and reaction speed, thereby making them perform better in competitions. However, the specific effects of sport-specific warm-up may be influenced by various factors, including the complexity and intensity of the warm-up and the individual adaptability of the athletes.

In practical applications, the content and intensity of sport-specific warm-ups should be flexibly adjusted based on the specific sport and the characteristics of the athletes to achieve the best results[22]. As an effective pre-competition preparation strategy, sport-specific warm-up has significant advantages in enhancing athletic performance and optimizing technical movements. By systematically analyzing existing research results, scientific guidance can be provided for athletes and coaches, helping them select and implement the most suitable sport-specific warm-up strategies before competitions to maximize performance.

5. Comprehensive comparison

5.1. Effect of dynamic warm-up

The impact of dynamic warm-up on athletic performance has been widely studied and confirmed. Numerous studies have shown that dynamic warm-up significantly enhances athletes' explosiveness, speed, and strength. Fletcher and Jones (2004) found that dynamic warm-up significantly increased sprint speed in sprinters[23]. Behm and Chaouachi (2011) pointed out that dynamic warm-up helps improve vertical jump height, which is crucial for sports like basketball and volleyball that require explosiveness[24]. Dynamic warm-up has also been shown to improve athletes' flexibility and coordination, thereby enhancing their athletic skills. Dynamic warm-up improves athletic performance through various physiological and neurological adaptations. It increases muscle temperature and core body temperature, thereby enhancing muscle elasticity and power output. Temperature increase reduces muscle and joint viscosity and enhances metabolic efficiency. Additionally, dynamic warm-up increases blood flow and oxygen supply, enhances muscle metabolic function, reduces lactate accumulation,

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and improves endurance levels. Dynamic warm-up also activates the nervous system by simulating competitive actions, increasing nerve conduction speed and improving motor coordination. Furthermore, dynamic warm-up raises heart rate and respiratory rate, promoting cardiovascular adaptation for high-intensity exercise. These mechanisms collectively enhance athletic performance.

5.2. Effects of static stretching

Static stretching has a significant effect on improving muscle flexibility and joint range of motion, but its impact on athletic performance is more complex. Some studies suggest that static stretching can effectively enhance athletes' flexibility and movement range, which is particularly important for sports requiring high flexibility, such as gymnastics and dance. Taylor et al. (2009) found that static stretching can significantly improve joint range of motion, thereby enhancing technical performance[25]. However, Kay and Blazevich (2012) pointed out that pre-competition static stretching might lead to short-term decreases in strength and explosiveness[26], which could be detrimental to sports requiring high-intensity strength and speed, such as sprinting and jumping. Overall, the impact of static stretching on athletic performance depends on the type of sport and specific requirements.

The potential mechanisms by which static stretching improves athletic performance mainly include the following aspects. First, static stretching increases muscle and tendon length, reducing muscle stiffness, and enhancing flexibility and joint range of motion. Second, static stretching can lower muscle tension by activating the Golgi tendon organs and muscle spindles, regulating the nervous system's reflex mechanisms, and improving muscle relaxation and coordination. Additionally, static stretching increases blood flow, promoting muscle recovery, and reducing delayed onset muscle soreness. However, static stretching might lead to a temporary decrease in muscle strength due to prolonged stretching, which can reduce neural excitability. Therefore, in practical applications, coaches and athletes need to reasonably schedule and adjust the timing and intensity of static stretching based on specific situations to avoid negative impacts on performance.

5.3. The Impact of Sport-Specific Warm-Up on Athletic Performance

The impact of sport-specific warm-up on athletic performance is particularly significant, especially in sports that require high technical proficiency and athletic skills. This warm-up method improves athletes' technical performance and physical fitness by simulating specific actions from the competition. Fradkin et al. (2010) found that golfers who performed specific swing warm-ups before competitions could significantly improve their driving distance and accuracy[28]. Vetter (2007) showed that soccer players who performed warm-ups simulating passing and shooting actions could effectively enhance their technical performance and physical fitness in matches[29]. Overall, sport-specific warm-up has a significant effect on improving athletes' coordination, reaction speed, and technical proficiency.

The potential mechanisms of sport-specific warm-up include physiological adaptation and neural adaptation. Sport-specific warm-up increases the temperature and blood circulation of specific muscle groups, enhancing muscle elasticity and power output while reducing the risk of injury. This warm-up method enhances the adaptability of the nervous system by simulating competitive actions, improving nerve conduction speed and motor coordination. Neural adaptation means that the nervous system can transmit signals more quickly and accurately through repeated actions, thereby improving exercise efficiency. Repetitive practice and adjustment of movement details optimize athletes' technical movements, improving the efficiency and effectiveness of their actions. These mechanisms work together to make sport-specific warm-up significantly advantageous in enhancing athletic performance and reducing sports injuries.

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Dynamic warm-up, static stretching, and sport-specific warm-up each have distinct features in improving athletic performance. Dynamic warm-up enhances overall athletic performance by increasing muscle temperature and nervous system excitability; static stretching improves muscle flexibility and joint range of motion, benefiting specific sports; sport-specific warm-up improves athletes' technical skills and coordination by simulating competitive actions. According to different sports and specific needs, choosing and combining these warm-up strategies can maximize athletic performance, reduce sports injuries, and provide scientific basis for athletes' pre-competition preparation.

6. Comparison of Different Warm-Up Strategies

When comparing different warm-up strategies, it is essential to consider their characteristics and impacts on athletic performance. The main advantage of dynamic warm-up is its ability to effectively increase muscle temperature, heart rate, and blood circulation, thereby enhancing muscle elasticity and power output. Through a series of continuous, progressively intense exercises, it can significantly improve athletes' explosiveness, speed, and flexibility. However, the disadvantage of dynamic warm-up is that it may cause fatigue in some athletes, especially those not accustomed to high-intensity warm-ups.

The advantage of static stretching lies in its simplicity and ease of execution, significantly improving muscle flexibility and joint range of motion, which is crucial for sports requiring extensive movements such as gymnastics and dance. Static stretching also reduces muscle tension, promoting relaxation and recovery. The primary disadvantage is that it may lead to short-term decreases in muscle strength and explosiveness, which can be detrimental to sports requiring high-intensity power, such as sprinting and weightlifting.

The advantage of sport-specific warm-up is its high specificity, which can improve athletes' technical performance and physical fitness by simulating specific actions from the competition. This strategy enhances the adaptability and responsiveness of the nervous system, making athletes perform better in competitions. Its disadvantage is the complexity in design and implementation, requiring in-depth knowledge of the sport and the athlete. Overly complex and high-intensity warm-ups may lead to fatigue before the competition begins.

Different warm-up strategies have varied impacts on endurance sports, strength sports, and flexibility sports. For endurance sports such as long-distance running, swimming, and cycling, dynamic warm-up is particularly important. By increasing heart rate and blood circulation, dynamic warm-up enhances the efficiency of oxygen and nutrient transportation, thereby extending athletes' endurance levels. Research indicates that endurance athletes can maintain higher exercise intensity and extend exercise duration after dynamic warm-up. For strength sports such as weightlifting, throwing, and sprinting, the choice of warm-up strategy needs to be more cautious. Dynamic warm-up effectively increases muscle temperature and power output, enhancing explosiveness and speed, making it a commonly used warm-up method for these sports. However, pre-competition static stretching may negatively impact power output, with research showing it temporarily reduces muscle strength and speed. Therefore, strength athletes should primarily use dynamic warm-up combined with minimal static stretching to ensure optimal performance. Flexibility sports such as gymnastics, dance, and yoga require warm-ups that emphasize flexibility and joint range of motion. Static stretching plays a critical role in these sports by increasing muscle length and joint range of motion, helping athletes perform high-difficulty flexibility movements. However, dynamic warm-up should not be overlooked as it can increase muscle temperature and heart rate, reducing muscle viscosity, thereby enhancing both flexibility and muscle response speed and coordination.

In practical applications, a single warm-up strategy often cannot meet the needs of all sports, so combined warm-up methods that integrate various strategies are becoming more popular.

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For most sports, coaches and athletes can flexibly choose and combine dynamic warm-up, static stretching, and sport-specific warm-up based on specific needs to achieve the best results. For example, soccer players can start with a period of dynamic warm-up to increase heart rate and muscle temperature, then incorporate appropriate static stretching to enhance muscle flexibility, and finally perform specific soccer drills to improve technical performance and nervous system adaptability. When designing a warm-up plan, the characteristics of the sport, the individual needs of the athlete, and the specific requirements of the competition should be considered. For instance, before long-duration endurance events, the duration of dynamic warm-up can be extended, while the time for static stretching should be controlled within a reasonable range to avoid negative impacts on strength and speed. Before high-intensity strength events, dynamic warm-up should be combined with minimal static stretching to ensure that muscles can maintain optimal power output and explosiveness under high-intensity loads.

Although existing research provides substantial evidence on the advantages and disadvantages of different warm-up strategies and their effects on various types of sports, future research should further explore the optimization and individualized application of warm-up strategies. Large-sample experimental studies can analyze the best combination methods and specific application effects of different warm-up strategies. As sports science progresses, new warm-up methods and technologies (such as vibration training and neuromuscular electrical stimulation) should also be included in research to provide more comprehensive and scientific warm-up guidance. By systematically comparing the advantages and disadvantages of different warm-up strategies and their impacts on various types of sports, scientific evidence and practical guidance can be provided to athletes and coaches, helping them design and implement the most suitable warm-up schemes to enhance performance, reduce injuries, and ensure optimal conditions during competitions and training.

7. Advantages and Disadvantages of Different Warm-Up Strategies and Their Applicability

This study reviews the definitions, theoretical foundations, and impacts on athletic performance of various warm-up strategies, including dynamic warm-up, static stretching, and sport-specific warm-up. Dynamic warm-up has been found to significantly enhance athletes' explosiveness, speed, and flexibility. This strategy involves a series of continuous and progressively intense exercises, increasing muscle temperature, blood circulation, and heart rate, thereby improving athletes' performance in both competitions and training. Static stretching mainly improves muscle flexibility and joint range of motion, which is particularly effective for sports requiring extensive movements such as gymnastics and dance. However, static stretching in pre-competition warm-ups may lead to short-term decreases in strength and explosiveness, which is detrimental to sports requiring high-intensity power. Sport-specific warm-up improves athletes' technical performance and physical fitness by simulating specific actions from the competition, making it especially suitable for sports that demand high technical proficiency and athletic skills.

By comparing the research results of different warm-up strategies, it is evident that each strategy has unique advantages and limitations in enhancing athletic performance. Dynamic warm-up is effective in overall physiological preparation by increasing muscle temperature and heart rate, placing athletes in an optimal state at the start of a competition. In contrast, static stretching performs better in increasing muscle flexibility and joint range of motion but may cause short-term decreases in strength and speed, limiting its application in certain high-intensity sports. Sport-specific warm-up enhances technical skills and coordination by

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simulating specific movements, making it particularly suitable for sports with high technical requirements.

The advantages, disadvantages, and applicability of different warm-up strategies vary based on the demands of the sport and the characteristics of the athletes. The main advantage of dynamic warm-up is its ability to rapidly enhance cardiovascular function and muscle temperature, boosting strength and explosiveness, making it suitable for most high-intensity and quick-response sports. However, its intensity needs to be reasonably controlled to avoid excessive fatigue. Static stretching significantly improves muscle flexibility and joint range of motion, suitable for sports requiring large movements and high flexibility, such as gymnastics and dance. However, its application in pre-competition warm-ups needs caution to avoid short-term decreases in strength and speed. The advantage of sport-specific warm-up lies in its high specificity, enhancing technical performance and athletic skills through simulated competition actions, making it suitable for sports with high technical and skill requirements.

8. Future Research Recommendations

Future research should continue to explore the specific mechanisms of different warm-up strategies and their application effects in various sports. Although existing research provides substantial evidence on the impacts of dynamic warm-up, static stretching, and sport-specific warm-up on athletic performance, many questions remain unresolved. For instance, further studies are needed to investigate the differential effects of warm-up strategies across different genders, ages, and training levels. Exploring the preventive effects of warm-up strategies on various types of sports injuries is also a critical research direction. Sport-specific warm-up particularly requires more research to determine its optimal implementation methods and specific actions, optimizing its application in competitions and training.

To achieve more comprehensive and precise research results, future studies need methodological improvements. Research designs should be more rigorous, employing randomized controlled trials (RCTs) and other high-quality designs to enhance the reliability and validity of the findings. Studies should expand sample sizes and diversity to ensure broader applicability of the results. Multiple measurement indicators should be used, including not only traditional performance metrics (e.g., speed, strength, explosiveness) but also physiological and psychological indicators (e.g., heart rate, blood lactate levels, subjective fatigue) to comprehensively assess the effects of warm-up strategies. Future research should also explore the combined application effects of different warm-up strategies. Although existing studies have evaluated the effects of individual strategies, there is relatively little research on their combined use. Studies could design various combination schemes (e.g., dynamic warm-up combined with static stretching, dynamic warm-up combined with sport-specific warm-up) to evaluate their specific effects in different sports. This research could provide more practical warm-up guidance, helping coaches and athletes select and adjust the most suitable warm-up schemes based on specific needs. Additionally, research should focus on the timing and intensity regulation of warm-up strategies to avoid excessive or insufficient warm-up, which could negatively impact performance and health.

With the advancement of sports science, new warm-up methods and technologies continue to emerge, such as vibration training, neuromuscular electrical stimulation, and infrared therapy. These new methods show potential in improving performance and preventing injuries. Future research should explore their specific effects and application methods. For example, vibration training stimulates muscles and the nervous system through mechanical vibrations, helping improve muscle strength and neural response speed. Neuromuscular electrical stimulation enhances muscle strength and endurance by stimulating muscle contractions with electrical currents. Infrared therapy promotes blood circulation and metabolism by heating muscles and

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joints with infrared rays. Combining these new methods with traditional warm-up strategies could provide athletes with more effective and comprehensive warm-up schemes. Future research should build on existing foundations to further explore and optimize the application effects and mechanisms of different warm-up strategies. By improving research methods, expanding sample sizes and diversity, and using multiple measurement indicators, the effects of warm-up strategies can be comprehensively evaluated. Research on combined warm-up strategies and new methods will help provide athletes and coaches with more scientific and practical guidance, enhancing performance, reducing injuries, and advancing the field of sports science.

9. Conclusion

Pre-competition warm-up strategies play a crucial role in enhancing athletic performance and reducing injuries. A systematic summary and analysis of existing literature reveal that dynamic warm-up significantly improves athletes' explosiveness, speed, and flexibility. This warm-up method, through a series of continuous and progressively intense exercises, effectively increases muscle temperature, heart rate, and blood circulation, enhancing muscle elasticity and power output. Dynamic warm-up aids in overall performance improvement, especially in sports requiring high-intensity power and explosiveness. Static stretching excels in increasing muscle flexibility and joint range of motion. This strategy involves lengthening muscles and holding them in a fixed position for some time, significantly improving muscle flexibility and joint range, reducing the risk of muscle strains and sprains. Although static stretching has positive effects on flexibility, its application in pre-competition warm-ups is controversial. Some studies suggest that pre-competition static stretching may lead to short-term decreases in strength and explosiveness, which is detrimental to sports requiring high-intensity power. Sport-specific warm-up, by simulating specific actions of the upcoming competition, effectively improves athletes' technical performance and physical fitness. This highly targeted warm-up method enhances the adaptability and responsiveness of the nervous system, improving athletes' coordination and reaction speed. Its effects are particularly significant in sports requiring high technical proficiency and athletic skills.

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