

Dynamic Warm-ups Play Pivotal Role in Athletic Performance and Injury Prevention



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Abstract: Dynamic warm-ups (DWs) are being increasingly used before athletic performance because of their perceived potential to promote readiness to play, enhance performance, and reduce injury across the recreational and elite athlete populations. There has been widespread adoption of warm-ups before athletic activity and evolving literature suggesting best practices including the role of static versus dynamic stretching and combination of pre-performance activities. DWs have gained traction as a preferred warm-up approach over static stretching because of the increased potential to improve athletic performance and reduce injury by enhancing the musculoskeletal, neurologic, cardiovascular, and psychological systems before performance. In this article, we aim to discuss the physiological and potential athletic performance benefits of DWs, key differences compared with prior widely adopted pre-activity static stretching, injury reduction benefits, and recommendations for implementing DWs into pre-athletic performance activities including crucial components of a multifaceted sport-specific approach. **Level of Evidence:** Level V, expert opinion.

Dynamic warm-ups (DWs) consist of active sport-specific joint movements and are recommended to have a multifaceted approach inclusive of active range-of-motion (ROM) activities including agility, plyometrics, functional strengthening, whole-body muscle activation, and challenges to core stability and balance control. DWs appear to be best performed just before athletic activity, at least twice a week, and should be performed for at least 7 to 10 minutes in duration, although there remains a need for further research on the duration and frequency of performance across different sports and activities.¹⁻⁵

DWs have been shown to have physiological benefits on the musculoskeletal, neurologic, cardiovascular, and psychological systems (Table 1).¹⁻³ Musculoskeletal system improvements include improved joint ROM, muscle flexibility, and force production; increased muscle temperature; and increased tissue

extensibility.^{1,2,6} Neurologic effects include improvements in nerve conduction velocity, as well as muscle activation via enhanced motor unit recruitment; improved joint proprioception; and enhanced central drive.^{1,2,7,8} Cardiovascular/systemic effects include increasing body temperature, heart rate, and circulation and enhanced muscle oxygen saturation in preparation for activity.⁹⁻¹¹ Psychologically, there has been research showing enhanced readiness to perform, increased enjoyment of activity, and reduced perception of effort after a DW performance.^{9,12} These physiological benefits have been linked to performance improvements and injury reduction risks associated with completing a DW program.

Athletic Performance

Several studies have shown short-term athletic improvements immediately after DW performance. Improvements in muscle force, power, and explosiveness have been observed, with performance gains seen in sprint time,^{2,13} vertical jump height,¹³⁻¹⁵ and baseball bat swing speed.¹⁶ One recent meta-analysis reported that a DW lasting between 7 and 10 minutes was able to significantly improve explosive athletic lower-limb performance.² However, there remains some disagreement in the literature over the degree to which DWs have a role in enhancing athletic performance. A 2016 systematic review recommended DWs for injury reduction and joint ROM benefits but with limited benefit to athletic performance.¹ Additional studies

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Table 1. Key Components of Effective Dynamic Warm-up Routine

	Description
Cardiovascular activation	Activities such as jogging, jumping jacks, or high knees increase the heart rate and circulation, preparing the cardiovascular system for exercise.
Dynamic stretching	Movements such as leg swings, arm circles, and walking lunges promote flexibility and joint mobility without the prolonged static holds that may reduce muscle power.
Sport-specific movements	Incorporating movements specific to the activity or sport helps athletes mentally and physically prepare for the demands they will face.
Progressive intensity	Gradually increasing the intensity of movements within the warm-up prepares the body for higher exertion levels, reducing the risk of sudden strain.

found no benefit of DW programs to athletic performance.^{17,18}

Conversely, whereas static stretching (SS) has been shown to improve joint ROM and flexibility,¹⁹ there are studies that have shown that SS performed in isolation might reduce athletic performance.² SS has been shown to have the potential for acute reductions in muscle force and power production, leading to decreased utilization in pre-athletic warm-up activities. These acute effects appear to be most pronounced with stretch durations lasting more than 60 seconds, whereas shorter-duration SS holds of less than 60 seconds seem to be well tolerated and have minimal, if any, impact on performance.^{1,20} More recent studies have noted the potential use of SS in combination with a DW to allow for the benefits of SS while minimizing any performance detriment; however, because of a relative lack of studies to date, further research has been recommended to assess the response to combined SS and DW routines.²

Injury Prevention

DWs have become a staple in the routines of athletes and fitness enthusiasts alike, largely because of their effectiveness in preparing the body for physical activity and preventing injuries. Research consistently supports the role of DWs in injury prevention across various sports and activities. Studies have shown that athletes who incorporate DWs into their routines experience fewer muscle strains, sprains, and overuse injuries than athletes who rely solely on SS or no warm-up at all. Injuries are a major concern in any sport, impacting player performance, team success, and long-term athlete health. The Fédération Internationale de Football Association (FIFA) 11+ program is an evidence-based injury prevention program, developed by the FIFA Medical Assessment and Research Centre as a comprehensive warm-up routine designed to reduce injuries in soccer players (Table 2, Figs 1-6).²¹

The FIFA 11+ program was developed in 2006 to address the growing trends in injuries among soccer players. It consists of a series of exercises aimed at improving strength, flexibility, agility, and neuromuscular control. The program is divided into 3 main parts:

running exercises; strength, plyometrics, and balance exercises; and running exercises with acceleration and deceleration:

1. Running exercises are designed to increase the heart rate and prepare the cardiovascular system for physical activity. They include jogging, running with changes in direction, and high-knee running.
2. Strength, plyometrics, and balance exercises focus on enhancing muscle strength, coordination, and balance. They include single-leg stance, walking lunges, and jumps.
3. Running exercises with acceleration and deceleration prepare players for the high-intensity demands of soccer, involving sprints, quick changes in direction, and deceleration.

Numerous studies have demonstrated the effectiveness of the FIFA 11+ program in reducing the incidence of injuries among soccer players. Key findings reported in the literature include a reduction in injury rates for teams implementing the FIFA 11+ program. Specifically, it has been reported by many publications that there is a decrease in overall injury rates, including lower-limb injuries such as hamstring strains and knee injuries.^{4,22-29}

DWs such as the FIFA 11+ routines have been shown to reduce upper-extremity injury rates and lower injury burden and severity in youth volleyball players³⁰ and to reduce joint load at the knee in dancers.³¹ In addition, an upper-extremity injury reduction of 50% has been reported in soccer goalkeepers who followed a FIFA 11+ program.³² Elite male basketball players have seen a reduction in injury rates as well following a FIFA 11+ DW routine.³³

In addition, several authors have shown improvements in various performance metrics after the implementation of the FIFA 11+ program. Players who regularly performed the FIFA 11+ exercises showed improvements in strength, agility, and balance, contributing to enhanced field performance.^{4,26-28,34-46}

In all these studies, players consistently performed their DWs and exercises. Hence, for maximal injury prevention and performance gains, players should consistently perform the prescribed exercises. Added injury reduction benefits have been seen in athletes who

Table 2. Exercises of FIFA 11+ Program

Exercise	Repetitions
Part 1: running exercises: 8 min (starting with warming up, in pairs; path consists of 6-10 pairs of parallel cones)	
Running: straight ahead	2
Running: hip out	2
Running: hip in	2
Running: circling partner	2
Running: shoulder contact	2
Running: quick forwards and backwards	2
Part 2: strength, plyometrics, and balance exercises	
Bench (static, raise/lower hip, and leg lift)	3 × 20-30 s each
Sideways bench (static, raise/lower hip, and leg lift)	3 × 20-30 s each
Hamstrings (beginner, intermediate, and advanced)	Up to 10
Single-leg stance (hold ball, throw and catch, and unstable surface)	3 × 20-30 s each
Squats (toe raise, lunges, and 1-leg squats)	2 × 30 s each
Jumping (vertical jumps, lateral jumps, and box jumps)	2 × 30 s each
Part 3: running exercises with acceleration and deceleration	
Across pitch	2
Bounding	2
Plant and cut	2

NOTE. The FIFA 11+ program includes 15 exercises, divided into 3 levels of increasing difficulty.

FIFA, Fédération Internationale de Football Association.

participate in both a pre- and post-training FIFA 11+ program.^{32,47} Low compliance of only 1 to 2 days per week may lead to no injury reduction benefits.⁴⁸ It has been reported that the FIFA 11+ program did not have

an impact on balance and proprioception when completed by amateur male futsal players over a 10-week period.⁴⁹ Likewise, no difference in performance has been reported with the use of the FIFA 11+ program in amateur female basketball players.⁵⁰

By incorporating DW exercises that enhance strength, flexibility, agility, and neuromuscular control, the FIFA 11+ program significantly reduces the risk of injuries. Effective implementation through education, regular incorporation, and continuous monitoring is essential for maximizing its benefits. The FIFA 11+ program represents a crucial tool for coaches, trainers, and players in promoting long-term athletic health and performance in soccer.

Practical Applications and Implementation

Incorporating DWs into both clinical and athletic routines requires careful planning and customization. Practitioners should consider the individual's needs and sport-specific demands, as well as any existing injuries. These exercises should be performed in a controlled manner, focusing on smooth, pain-free movements.

Practical recommendations for successful implementation include the following:

1. In terms of education and training, coaches and trainers should receive proper education on the DW exercises and their correct execution to effectively guide players.
2. In terms of regular incorporation, the program should be performed at least twice a week during training sessions to maintain its preventive benefits.

Fig 1. Running: hip out. The athlete walks or jogs easily, stopping periodically to lift the knee and rotate the hip outward. She alternates between the left and right legs. Two sets are performed.





Fig 2. Running: shoulder contact. The athlete and a partner run forward in pairs. They shuffle sideways by 90° to meet in the middle; then, the athlete jumps sideways toward the partner to make shoulder-to-shoulder contact. Two sets are performed.

3. In terms of progressive adaptation, exercises should be progressively adapted to match players' skill levels and physical conditions, ensuring continuous improvement and challenge.
4. In terms of monitoring and feedback, regular monitoring of players' performance and feedback can help maintain high compliance and correct technique, enhancing the effectiveness of the program.

Athletes and fitness enthusiasts alike can benefit from integrating DW routines into their pre-exercise rituals. The following practical recommendations enhance the effectiveness of DWs:

1. Regarding individualization, warm-up exercises should be tailored to match the specific movements and intensity levels of the upcoming activity or sport. Adding additional exercises to already established

Fig 3. Bench: static. In the starting position, the athlete lies on the ground, supporting herself on the forearms and toes. The elbows should be directly under the shoulders. To perform the exercise, the athlete lifts her body up, supported on her forearms; pulls the stomach in; and holds the position for 20 to 30 seconds. Three sets are performed.



Fig 4. Jumping: vertical jumps. In the starting position, the athlete stands with the feet hip-width apart with the hands on the hips. To perform the exercise, she bends the knees slowly until they are at approximately 90° and holds for 2 seconds. She keeps the knees facing forward. From this squat position, she jumps as high as she can. She lands softly on the balls of the feet with the hips and knees slightly bent. This is repeated for 20 seconds. Two sets are performed.



programs such as the FIFA 11+ program can provide additional gains.⁵¹

2. Regarding consistency, establishing a consistent warm-up routine helps condition the body over time, improving performance and reducing injury risk.
3. Regarding time efficiency, DWs can be completed in a relatively short period, making them feasible for inclusion in both training sessions and competitions.

4. Regarding educational awareness, coaches and trainers play a crucial role in educating athletes about the importance of DWs and proper execution techniques.

Physical therapists, athletic trainers, sports medicine physicians, and physician assistants should determine and consider whether the lack of a DW warm-up routine or an incomplete DW warm-up routine was a contributing factor to the athlete's current injury and/or



Fig 5. Hamstrings: intermediate. The athlete kneels on a soft surface. A partner holds the athlete's ankles firmly. To perform the exercise, the body should be completely straight from the shoulder to the knees. The athlete leans forward as far as she can while controlling the movement with the hamstrings and gluteal muscles. When she can no longer hold the position, she gently takes the weight on her hands, falling into a push-up position. She completes 7 to 10 repetitions over 60 seconds. One set is performed.



Fig 6. Running: plant and cut. The athlete jogs 4 to 5 steps and then plants on the outside leg and cuts to change direction. She accelerates and sprints 5 to 7 steps at a high speed before decelerating. Then, she performs another plant and cut. She keeps her knees facing forward. She repeats this across the space available. Two sets are performed.

recurrent injury history. If it is determined that the lack of a DW routine or an incomplete DW routine was a contributing factor, then education and counsel regarding the need to establish and be consistent with a DW routine are highly recommended to commence at the time of return to sport activities and continue through the athlete's sport-specific training and competition cycle. Future training and competition cycles should include a DW routine to minimize injury risk. Such return-to-play and -competition discussions among all sports medicine clinicians caring for the athlete should include a DW component. During the return-to-play and -competition guidance, discussion with coaches regarding a specific athlete is an optimal time to introduce and reinforce the injury prevention benefits of DW programs.

Future Directions

A preponderance of the available literature is based on acute changes after DW performance. Further investigation into the long-term effects of a well-implemented DW program remains a research gap. The future research should focus on large-scale longer-duration studies to further validate the benefits of neurodynamic warm-ups across different sports and populations. Additionally, exploring the integration of these warm-ups with other injury prevention strategies and performance enhancement techniques could provide valuable insights.

Conclusions

The DW exercises play a pivotal role in injury prevention by preparing the body both physically and

mentally for physical activity. The best available evidence details that a DW program should include agility, plyometrics, power, core, and balance activities that simulate sport- and activity-specific movements. By enhancing muscle flexibility, joint mobility, and neuromuscular activation, DWs help athletes perform at their best while minimizing the risk of injuries such as strains and sprains. Integrating these practices into training regimens can contribute greatly to long-term athletic success and well-being. A well-implemented and sport-specific DW program before athletic activity is recommended for injury prevention and the potential for performance gains. Sharing injury prevention knowledge with coaches regarding DWs is a key component of the return-to-play and -competition discussions. Ongoing research gaps exist; thus, additional long-term large-sample studies across diverse populations and skill levels are recommended.

Disclosures

Both the authors (D.S., R.B.W.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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