Dynamic Warm-Up

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It is important for all athletes to warm up before practice and competition. A well-designed warm-up can mentally and physically prepare athletes for the demands of sports training and athletic events by increasing blood flow to active muscles, raising core body temperature, enhancing metabolic reactions, and improving joint range of motion (26). These effects can boost athletic performance by enhancing oxygen delivery, increasing the speed of nerve-impulse transmissions, improving rate of force development, and maximizing strength and power (2, 5, 45). Moreover, a well-designed warm-up can set the tone for upcoming activities and establish a desired tempo for practice or competition. Indeed, warm-up procedures that are consistent with the needs, goals, and abilities of each athlete should be considered an integral component of every sport practice and competition.

Although well-designed warm-up procedures can enhance athletic performance, reduce the risk of injury, and lessen the potential for muscle soreness after exercise (1, 21, 26), it is important to realize that warming up and stretching are two different activities. A warm-up consists of preparatory activities and functionally based movements that are specifically designed to prepare the body for exercise or sport. In contrast, the primary goal of stretching is to enhance flexibility. These distinctions are important because long-held beliefs about traditional warm-up procedures have recently been questioned. Some scientists and practitioners now propose that it may be advantageous to exclude static stretching from warm-up routines prior to sport training and athletic competitions (32, 49, 52, 59).

Interest is growing in warm-up procedures that involve dynamic activities and sport-specific movements that maximize active ranges of motion at different movement-specific speeds while preparing the body for the demands of sport training and competition (10, 13, 15, 29, 55). This chapter reviews the components of a traditional warm-up and examines the potential benefits of a dynamic warm-up. Although it discusses different types
of warm-ups, this chapter focuses on the influence of dynamic warm-up protocols on athletic performance. It also discusses the proposed physiological mechanisms that may enhance the preparedness of athletes for sport practice and competition and outlines program design considerations for developing warm-up protocols that emphasize the movement requirements of the sport or activity.

A traditional warm-up usually consists of two components. The first is a general warm-up of 5 to 10 minutes of low- to moderate-intensity cardiorespiratory exercise, such as jogging or stationary cycling, followed by several minutes of static stretching. The second is a specific warm-up that involves less intense movements similar to the sport or activity about to be performed. The purpose of this type of warm-up is to allow the body to gradually adjust to the changing physiological demands of the exercise session without undue fatigue. A general warm-up of basic exercises for the major muscle groups increases heart rate, blood flow, muscle temperature, and core body temperature, as evidenced by the onset of sweating. Static stretching exercises, in which a body position is held stationary for a predetermined period of time (typically 10-30 seconds), are habitually recommended by some sport coaches to improve range of motion within joints, enhance performance, and reduce the risk of injury prior to activity (30, 36, 46). However, conventional beliefs regarding the routine practice of pre-event static stretching have recently been questioned (48, 50, 53).

**Static Stretching and Performance**

Although static stretching enhances flexibility, which is a well-recognized component of health-related fitness (1), there is little scientific evidence to suggest that pre-event static stretching prevents activity-related injury or enhances athletic performance (32, 47, 50, 53). Even athletes who compete in sports that require high levels of flexibility, such as gymnastics or diving, must consider both the potential benefits and the related concerns when deciding whether or not to include static stretching exercises in the warm-up routine.

A growing body of research evidence indicates that pre-event static stretching of the prime movers may actually have a negative effect on force production, power performance, strength endurance, reaction time, and running speed (4, 10, 11, 19, 34, 40, 41). In one research study that examined the effects of static stretching on sprint performance in collegiate track-and-field athletes, researchers reported a 3% decrease in sprinting performance at 40 m following pre-event static stretching (57). It has also been shown that pre-event ballistic stretching (i.e., bouncing movements) and stretching techniques for proprioceptive neuromuscular facilitation (PNF), which involve both passive movements and active muscle actions, can also inhibit strength and reduce explosive power (6, 39). Although
some data suggest that pre-event static stretching has no short-term effect on performance measures (23, 33), a majority of the available evidence indicates that it can have detrimental effects on subsequent performance.

This stretching-induced effect is thought to be related to a decrease in neural activation, reduced musculotendinous stiffness, or a combination of neural and muscular factors (3, 20, 24). Since static stretching can result in muscle damage (as evidenced by elevated levels of creatine kinase in the blood), it is also possible that tissue damage could explain, at least in part, stretching-induced decrements in performance (51). While the undesirable effects of an acute bout of static stretching on performance are increasingly apparent, additional research is needed to determine the precise mechanisms underlying the performance decrements, as well as the particular stretching protocols and performance conditions that produce this adverse effect.

Of note, the observed reductions in performance following static stretching may, in some cases, last up to one hour (20). Since even a 1% change in performance can have a noticeable influence on the outcome of an athletic event in both individual and team sports, the small but significant changes in performance following an acute bout of static stretching should be considered by sport coaches and strength and conditioning professionals. Indeed, several fitness and medical organizations, including the American College of Sports Medicine (1), the National Strength and Conditioning Association (28), and the President’s Council on Physical Fitness and Sports (32) contend that pre-event static stretching may adversely affect athletic performance, particularly in sports that involve strength and power.

This is not to say that static stretching should be eliminated from an athlete’s program, but it should be sensibly incorporated into the daily training regimen, since chronic stretching can enhance the range of motion around a joint and potentially improve strength and power performance (35, 52). Consequently, most athletes should perform static stretching during the cool-down or as part of a separate training session. In some cases, however, athletes who participate in sports that require high levels of flexibility may benefit from pre-event static stretching. For example, gymnasts who need to improve flexibility may perform pre-event stretching exercises after a general warm-up, provided that they perform a series of dynamic movements prior to training or competition.

Because static stretching has traditionally been a part of many warm-up routines, strength and conditioning professionals need to genuinely appreciate each athlete’s prior beliefs about pre-event static stretching when prescribing flexibility training protocols for sport teams. In some instances, athletes who routinely perform static stretching (and have strong beliefs about its value) may need to be educated about the undesirable consequences of an acute bout of static stretching on athletic performance. They should be gradually introduced to pre-event protocols that include dynamic activities.
Dynamic Warm-Up and Performance

Since the current practice of pre-event static stretching has been based more on intuition and tradition than on scientific evidence, dynamic warm-up protocols that simulate movements that occur in daily activities and sport have become more popular as we continue to better understand methods of training that enhance performance. This type of training typically includes movements of low, moderate, and high intensity that increase body temperature, enhance motor-unit excitability, develop kinesthetic awareness, and maximize active ranges of motion (10, 24, 28, 55). Instead of focusing on individual muscles, dynamic exercises emphasize the movement requirements of an exercise or sport. The term movement preparation is also used to describe this type of training because it actually prepares athletes to move (55).

Again, it is important to note that dynamic exercises do not involve the bouncing type movement that is characteristic of a ballistic stretch, but rather a controlled elongation of specific muscle groups. During this type of continuous movement, the muscles are stretched to a new range of motion. They then contract to perform the desired action. As such, the muscles do not relax during the dynamic movement, remaining active throughout the entire range of motion. For example, during the lunge walk (figure 3.1), the athlete exaggerates the length of each stride as the lunge movement is performed for the prescribed number of repetitions, keeping the lead knee over or slightly behind the toe and the back knee just off the floor.

Ideally, a seamless progression from dynamic movements that are less intense to more intense activities that resemble sport movements should occur during a dynamic warm-up routine. Higher intensity movements are needed to optimize performance; therefore, they should be recognized as an important component of the pre-event protocol (54). For example, track-and-field athletes, such as long jumpers, could begin their warm-up with side shuffles and then progress to power skips. Sprinters could begin with high steps and then perform
a series of sprint drills to better prepare to perform at maximal levels during sport practice and competition. Prior to a weightlifting workout, plyometric jumps and explosive exercises with medicine balls could be used to prepare athletes for the upcoming training session (37, 56). Regardless of the movement, strength and conditioning professionals must emphasize proper technique and highlight important mechanics in order to reinforce key skill factors that are required to perform the movement correctly. This type of pre-event warm-up can contribute to an acutely enhanced muscular performance effect. If dynamic warm-up protocols are well conceived and consistent with the needs and abilities of the athletes, some observers suggest that subsequent explosive performance may improve between 2% and 10% (54).

**Postactivation Potentiation**

In preparation for explosive sporting events, such as the long jump, pole vault, or high jump, a technique known as postactivation potentiation (PAP) may be used as part of the athlete's dynamic warm-up (44). Postactivation potentiation may create an optimal environment for athletic performance by increasing phosphorylation of the regulatory myosin light chains, enhancing neuromuscular function, or possibly changing pennation angle (54). Although the exact mechanisms of PAP are not totally understood, evidence exists that the response of skeletal muscle to the demands placed on it is influenced by its contractile history (43). A brief time of repetitive stimulation can result in an enhanced contractile response (potentiation), while continued stimulation can impair the contractile response (fatigue) (43).

Given that potentiation and fatigue can coexist in skeletal muscle during repetitive stimulation and for some time afterward (43), strength and conditioning professionals must consider the interaction between these two phenomena when designing and implementing warm-up procedures for athletes. In short, the net difference between potentiation and fatigue will determine the outcome of the pre-event protocol.

A number of studies involving youths and adults have examined the short-term effects of various warm-up procedures (static stretching versus dynamic) with respect to their effect on muscle force and power performance (7, 14, 18, 38, 42, 58, 60, 61). A majority of the existing literature suggests that a well-designed dynamic warm-up protocol can enhance acute muscle performance in athletic populations due, at least in part, to the effects of activity-related PAP. However, many factors need to be considered when applying the principles of PAP to athletic performance. Namely, training experience, individual power-strength ratio, intensity and volume of the pre-event activity, and the recovery period can influence the efficacy of any performance-enhancing stimulus. Additionally, individual variability should be considered when examining the application of PAP to activities that require dynamic muscle contractions.
An important issue regarding the practical application of PAP is the time between the cessation of the PAP activity and the start of training or competition. Although an optimal time probably exists when the muscle has recovered but is still potentiated, it is likely that this potential window of opportunity depends on a complex interaction of factors, including the fiber type of the athlete, training experience, and the design of the preload activity. Preliminary evidence suggests that the optimal time to maximize the PAP effect on power performance (such as during a high jump) is within 4 to 12 minutes after the preload stimulus (8, 17, 22, 31). Of note, fatigue tends to be more dominant in the early phase of recovery, but it subsides at a faster rate than PAP, so potentiation can be realized during subsequent sport activities (54). Limited data suggest that the effects of pre-event muscle activation may linger for several hours, possibly extending into the second half of a team game (12).

**Mental Preparation**

Although a well-designed warm-up increases body temperature and enhances flexibility, the incorporation of dynamic movement activities can also establish a desired tempo for upcoming events and set the tone for strength and conditioning activities. If the warm-up protocol is slow and monotonous (e.g., low-intensity jog around the field and static stretching), performance during the practice session or game that follows may be less than expected. On the other hand, if the pre-event protocol is dynamic, engaging, and diverse, performance during the practice session or game that follows may be enhanced. In short, a warm-up that includes dynamic flexibility exercises may help to better focus the athletes’ attention on listening, learning, and noting task-relevant cues.

**Developing a Dynamic Warm-Up Protocol**

Unlike a traditional warm-up protocol, a dynamic warm-up can result in noticeable improvements in fundamental movement skills. It also prepares the body for the vigorous, random movements that can occur during sports training and competition. As such, this phase of training can provide an opportunity for younger athletes to gain confidence in their abilities to perform movement skills. Additionally, warm-up activities that are active, engaging, and somewhat challenging are far more enjoyable than traditional stretch-and-hold activities.

A well-designed dynamic warm-up should turn on the neuromuscular system to prepare athletes for the demands of sports training and competition. The general idea is to (1) warm up, (2) activate, and (3) motivate. Warm up highlights the importance of increasing body temperature, activate refers to exciting or potentiating the neuromuscular system, and motivate draws attention to the need to psychologically prepare athletes for the demands of
sports practice and competition. Instead of jogging around the playing field, a general warm-up of jumping rope, body-weight calisthenics, medicine ball exercises, footwork patterns with an agility ladder, or sport-specific actions, such as dribbling a soccer ball around cones, can contribute to movement skill development and make a valuable contribution to the overall conditioning process. In one study, the incorporation of a four-week dynamic warm-up into the daily pre-season training regimen of college wrestlers positively influenced measures of strength, power, agility, muscular endurance, and flexibility as compared to an active control condition (25).

A fundamental principle of a dynamic warm-up is to perform large muscle group exercises that are similar to the movement patterns that will be performed during training or competition. Dynamic warm-up routines do not require equipment or a lot of space. Athletes typically perform each functionally based movement in place for a prescribed number of repetitions (e.g., 8 to 12) or cover a predetermined distance (e.g., 10 to 20 m). Normally, athletes complete 8 to 12 different exercises that progress from relatively simple movements to more challenging exercises, involving more complex movement patterns that require greater ranges of motion. To this end, a well-designed warm-up can enhance the physical fitness of athletes and contribute to the overall conditioning program in a time-efficient manner. However, it is important to keep in mind that the goal is to warm up, activate, and motivate without undue fatigue. Performance may deteriorate if the warm-up is too intense or if the muscles do not have an opportunity to recover from the fatigue induced during the pre-event dynamic warm-up protocol.

If appropriate, dynamic exercises can be combined to add variety to the warm-up routine in a time-efficient manner. For example, knee lifts can be added to the lunge walk to stretch more muscles in a shorter period of time. In any case, athletes should perform each movement while receiving instruction on correct exercise technique (e.g., vertical torso, up on toes, knee toward chest) in order to reinforce proper movement mechanics. Since literally hundreds of exercises can be incorporated into a dynamic warm-up, the sample exercises described in this chapter should be considered a general guide or starting point to help strength and conditioning professionals develop a 10- to 15-minute routine that is consistent with the fitness and skill level of their athletes.

Ideally, different dynamic warm-up protocols that are specific to the unique demands of strength and conditioning workouts, practice sessions, or games should be developed. Athletes who have limited or no experience performing dynamic exercises should be exposed to this type of training during the pre-season (or earlier) to limit any potential muscle soreness that can result from performing novel dynamic movements that maximize active ranges of motion. Additional ideas for incorporating dynamic flexibility exercises into warm-up protocols are available elsewhere (9, 16, 27, 55).