Smith, JC. The use of stretching as part of a thorough warm-up. J Sport Human Perf
2013;1(4):79-94. doi: 10.12922/jshp.0017.2013

JSHP
JOURNAL OF SPORT AND HUMAN PERFORMANCE

EXERCISE TECHNIQUE & PERFORMANCE ENHANCEMENT OPEN ACCESS

THE USE OF STRETCHING AS PART OF A THOROUGH WARM-UP

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ABSTRACT

The use of certain types of stretching as part of a warm-up has been shown to impair performances requiring strength, speed, agility, and power. Enhancing the athlete's range of motion and the perception about reducing the risk of injury are rationales for including flexibility exercises in the warm-up period. The focus of this paper is to discuss the different types of flexibility exercises in light of their impact on performance and range of motion. Based on a review of different types of flexibility exercises, this paper will offer some guidelines for the design of a warm-up that will minimize the potential for performance impairment while helping to enhance the athlete's range of motion.

Keywords: performance; ballistic; static; dynamic; PNF

INTRODUCTION

It is a generally accepted practice that a warm-up be completed prior to an athletic event with the intention of improving performance. In a review of the warm-up literature, Bishop (1) concluded that an active warm-up could improve short-term performance largely through an increase in muscle temperature, and improve intermediate- and long-duration performance if the athlete begins the activity with an elevated baseline of oxygen consumption and is not fatigued. Several physiological benefits associated with the increased muscle temperature include enhanced force production and shortening velocity due to increased metabolic activity, reduction in muscle and joint stiffness, and an increased speed of nerve transmission (2). Sometimes, flexibility exercises are included in the warm-up to help improve performance by increasing range of motion.

In addition, a thorough warm-up is used for the purposes of reducing the risk of injury (3). Stretching exercises may be included in the warm-up process for this reason as well. Several studies have demonstrated an acute increase in compliance for the musculotendinous unit due to stretching (4-11) which would allow for a greater absorption of energy, thus reducing the chance of injury (11). Unfortunately, there is limited and conflicting evidence about the effect of stretching on the incidence of injury (12-16). One possible explanation may be the differences in the total duration of stretching to induce alterations in the viscoelastic properties of the musculotendinous unit.

Acute increases in compliance require stretching durations greater than 45 s (11). More research is needed to establish a cause-and-effect relationship between the various methods of stretching and risk of injury.

The increased range of motion induced by stretching may facilitate less resistance throughout the movement, allowing for a fluid, more efficient movement and transfer of force. Stretching exercises are often incorporated into an active warm-up with the hopes of improving performance. However, performance may be impaired depending upon the method, duration, and intensity of stretching employed during the warm-up. In a recent survey of high school strength and conditioning coaches, the most commonly employed flexibility method is dynamic flexibility (35 out of 38 respondents) (17). However, 24 out of 38 respondents reported using static stretching and 10 out of 38 respondents reported using proprioceptive neuromuscular facilitation (PNF). In the same survey, the respondents reported "before practice", "before workout", and "after workout" as the top three answers when asked when flexibility exercises were employed. Unfortunately, the survey did not ask which type of flexibility exercise was employed immediately prior to the workout or practice. Another study that surveyed pre- and post-activity practices of division I and III college football programs found that 21 out of 23 (91%) respondents used some type of flexibility exercise during the pre-exercise period (18). Further, 13 of the respondents used a combination of PNF, static, and dynamic flexibility, 5 used dynamic flexibility, and only 1 respondent used static stretching only during the pre-exercise period. The type of flexibility exercise employed can have a direct impact on performance. Volume and intensity of stretching may also play a role in the impact on performance as well as the enhancement in the person's range of motion. Therefore, the purpose of this paper is to discuss the different types of flexibility exercises in light of their effect on performance and range of motion in healthy, young adults. In addition, the proposed physiological and mechanical mechanisms will be discussed with each mode of stretching.

Static Stretching and Performance

A traditional warm-up protocol consists of a low-intensity aerobic exercise followed by flexibility exercises and a higher-intensity, more sport-specific exercise. Of the basic types of flexibility exercises, static stretching and its impact on performance has been studied most extensively. In general, static stretching has been shown to impair sprinting (19-25), jumping (24, 26-34), indicators of golf performance (35, 36), cycling economy (37), and strength performances (38-45). The duration of static stretching is related to the magnitude of performance decrement with the smallest decrease occurring with less than 45 s of stretching (46). If the American College of Sports Medicine's guidelines are followed for stretching (i.e., at least 4 repetitions of 15-60 seconds of static stretching per muscle group) (47), performance is most likely to be impaired when performing static stretching prior to the workout or competition period.

However, the National Strength and Conditioning Association recommend a single static stretch for 30 s per muscle group (48). While this limited-duration stretching protocol has demonstrated an acute increase range of motion (44, 49), studies have shown either a decrease or no effect on leg extensor strength (44, 45, 49), acceleration (50), agility (50), and jump performance (31, 32, 50). Little and Williams (50) demonstrated an increase in 20 m maximum sprint speed, in professional soccer players when using the 30 s static stretch protocol. Fletcher and Jones found an increase in 20 m sprint speed in rugby union players when using a 20 s static stretch protocol (20). Kistler et al (22) showed an impairment in sprint performance over the 20 to 40 m interval of 60 and 100 m distances in male collegiate sprinters, jumpers, hurdlers, pole vaulters, and multievent athletes. The effect of this limited-duration stretching protocol on sprint speed may be distance specific and/or sport specific. This static stretching protocol is also sufficient to improve range of motion when utilized three times per week for 4 weeks (51). Despite the long-term and short-term benefits on range of motion, static stretching does not acutely enhance performance in a variety of athletic parameters when using this limited-duration stretching protocol.

Static Stretching Mechanism

The proposed mechanisms for the static stretch-induced decrement in performance are alterations in the musculotendinous unit and impairment of neural activation. Stojanovic (11) suggests that at least 45 s of static stretching is required to increase tissue compliance. Studies evaluating neuromuscular activation and static stretching have shown either no effect (28, 41) or a reduction in electromyographic (EMG) activity (52-54). These studies utilized stretching volumes between 120 and 180 seconds. Future studies may want to evaluate the effect of a shorter-duration static stretch on neuromuscular activation to determine its role, if any, in this performance decrement. In addition, there is no consensus on the duration of this reduced neuromuscular activation (41, 54). Any impairment in performance due to 30 s of static stretching could be due to impaired neural activation or a synergistic effect between minimal tissue compliance and impaired neural activation. Clearly, more research is needed to study the acute effects of this limited-duration static stretching protocol.

Dynamic Stretching and Performance

Dynamic stretching uses functional, sport-specific movements to increase the range of motion and improve balance and coordination (55). When incorporated into a warm-up, improvements in power (56, 57), jump performance (21, 24, 29, 31, 58-61), agility (21, 50, 56, 62, 63), sprint time (19-21), and the performance of soccer skills (50, 59, 64) have been documented. These increases in performance may be related to a greater transfer effect from the warm-up to competition or training due to the specificity of the movement patterns involved (65). The sport-specific nature of these flexibility exercises may be ideal in novice athletes not only for improving flexibility but also for learning the movement patterns required for the sport or skill. In advanced trained individuals, dynamic stretching combined with a high-intensity activity such as heavy squats that induces post-activation potentiation can further enhance performance (66). Therefore, it appears that dynamic stretching can be beneficial to novice and well-trained individuals when integrated into the warm-up procedure.

Dynamic Stretching Mechanisms

Fletcher (21) demonstrated an increase in jump performance using two different dynamic stretch velocities. The fast dynamic stretch had a greater improvement in jump performance than the slow dynamic stretch. Changes in core temperature were significantly greater in the two dynamic stretch conditions compared to the control condition. These changes in core temperature observed in the slow dynamic stretch condition may be an indirect indicator of local muscular changes in temperature that are consistent with a general warm-up. An increase in electromyography was attributed to the improved performance in the fast dynamic stretch condition. Several studies have identified an increase in neuromuscular activation as a mechanism for improvement in performance due to dynamic stretching (66, 67). Studies evaluating drop jumps and countermovement jumps (66-69) have shown an increase in performance following dynamic stretching suggesting a preservation of musculotendinous stiffness. Wilson et al (70) hypothesized that a stiff musculotendinous unit can enhance force production by altering the force-velocity and length-tension relationships and enhancing force transmission. Another possible mechanism is post-activation potentiation (31, 66). The mechanism for post-activation potentiation requires an increase in motor unit recruitment to lift the heavy loads performed in the pre-exercise activity. In addition, the mechanism responsible for post-activation potentiation is an increase in myosin light chain phosphorylation (71). The ability to improve performance via post-activation potentiation has been attributed to a high number of type II skeletal muscle fibers (72), strength and skill level (72-74). If dynamic stretching is performed at a fast velocity, an increase in the recruitment of type II fibers would take place, which would lead to an increase in neuromuscular activation as measured by electromyography. Given the high intensity requirements necessary to induce significant amounts of myosin light chain phosphorylation, it seems unlikely that post-activation potentiation would occur in sufficient magnitude to account for the performance enhancement that occurs with dynamic stretching alone. Future studies investigating role of post-activation potentiation in dynamic stretching should measure changes in local muscle temperature and myosin light chain phosphorylation to differentiate between the effects of a general warm-up and post-activation potentiation.

PNF Stretching and Performance

The two most commonly used types of PNF stretching are the contract-relax (CR), and contract-relax with antagonist contraction (CRAC). The CR method involves three phases. The first phase is a passive stretch. In the second phase, a brief concentric contraction of the previously stretched muscle is performed. The final phase is another passive stretch that is of greater magnitude than the previous stretch. The CRAC method is performed in an identical manner as the CR method with the exception that the antagonist muscle is contracted during the last phase (passive stretch). Studies evaluating CR method of PNF stretching have consistently documented no immediate effect on performance (34, 75-77). Bradley et al (27) demonstrated a decrease in drop jump performance as a result of this type of PNF stretching. This impairment may be attributed to the extensive passive stretching component (four sets of 25 seconds) of their PNF protocol. The static stretching condition showed similar results in their study. Pacheco et al (78) documented improvements in jump performance when utilizing the CR method of PNF stretching. However, they also demonstrated an improved jump performance when utilizing static stretching. Other methods of PNF stretching have shown a decrease in muscular endurance (79), angular velocity (80), movement time (80), peak torque (81), and mean power (81). Place et al (82) found no difference in maximum voluntary force production following PNF stretching. The authors contributed this to the limited duration and/or volume of stretching. Molacek et al (83) reported no effect of PNF stretching on bench press performance. However, PNF stretching was performed prior to 3-5 submaximal repetitions being performed, which was followed by a 3-5 minute rest and the 1-RM attempts. Each successful maximal effort attempt was followed by another 3-5 minute rest period. The authors state that their goal was to obtain 1-RM values within 3-5 maximal effort attempts. Since the impairment in performance occurs within 15 minutes of PNF stretching (27), the lack of effect on bench press performance may be due to having missed this critical time period. This time frame is most likely modified by the program design variables for the PNF stretching (e.g., duration and intensity of stretch and contraction).

PNF Stretching Mechanism

Substantial improvements in range of motion via PNF stretching have been attributed to autogenic and reciprocal inhibition as well as changes in the viscoelastic properties of the musculotendinous unit. Autogenic inhibition refers inhibition of the target muscle by way of a segmental reflex that is initiated by Golgi tendon organs located within the tendon of the target muscle. This inhibition of the target muscle will allow for a more efficient stretch. Reciprocal inhibition reduces activation of the target muscle when the opposing muscle is contracted. This, too, will allow for a more efficient stretch. The additive effect of autogenic and reciprocal inhibition during PNF stretching is likely to enhance the reduction in motorneuron excitability to the target muscle, thereby allowing for increased elongation of the muscle (84). There is a growing body of research that refutes autogenic and reciprocal inhibition as plausible mechanisms for improved flexibility (85-89). These studies documented an increase rather than a decrease in muscle activation. Combined with the static stretching component, PNF is likely to induce a decrease in stiffness of the musculotendinous unit in the short-term. However, Rees et al (90) showed an increase in musculotendinous unit stiffness as a result of a four-week PNF stretching program, suggesting an improvement in performance may be likely in the long-term.

Ballistic Stretching and Performance

Ballistic stretching utilizes the momentum of a bouncing body part to stretch the involved tissues. While ballistic stretching is effective in improving flexibility, there is an inherent risk of injury. Studies evaluating the effect of ballistic stretching on maximal strength are both limited and have conflicting results (91-93). Barroso et al (94) found an impairment in total lifting volume and total number of repetitions completed in all stretching conditions including ballistic stretching compared to the control condition. While still limited in their number, studies evaluating the acute effect of ballistic stretching on vertical jump have consistently demonstrated no adverse effect on performance (93, 95, 96). Bradley, Olsen, and Portas (27) reported a nonsignificant 2.7% decrease in vertical jump height when using a greater ballistic stretching duration (4 repetitions of 30 seconds) compared to other studies (single 30-second stretch). Interestingly, ballistic stretching increased vertical jump height following 20 minutes of basketball play (97), suggesting a delayed performance effect. Wallmann et al (98) reported no acute stretching (ballistic, dynamic, and static) effect on sprint performance. However, it is important to note that they only stretched the iliopsoas. Similar to the studies evaluating vertical jump performance, Wallmann et al (98) used a total ballistic stretching duration of 30 seconds. Therefore, the performance effect of ballistic stretching may depend upon the total stretching duration as well as other program design variables such as intensity and rate of bounce. Due to the perception of an increased risk of injury, ballistic stretching is not generally recommended despite the lack of scientific evidence. In fact, Covert et al (99) reported no stretching injuries during four weeks of ballistic or static stretching. Clearly, more research is needed in this area to fully understand the effects of ballistic stretching on performance and injury.

Ballistic Stretching Mechanism

Ballistic stretching may repeatedly activate the stretch reflex. A desensitization of the stretch reflex may occur, enabling participants to increase their range of motion. Another possible explanation for the acute increase in flexibility may be due to an increase in stretch tolerance. Due to the specificity principle utilized with ballistic stretching, any acute increase in performance may be attributed to activation of similar movement patterns much like the previously mentioned dynamic stretching mechanism.

SUMMARY

All four methods of stretching can acutely improve range of motion. Static stretching appears to impair performance in a variety of athletic parameters when the stretching duration or volume exceeds 45 seconds. More research is needed to evaluate the acute effects of static stretching using shorter stretching durations/volume on a variety of athletic parameters. PNF stretching also appears to acutely impair performance. While ballistic stretching does not appear to adversely affect performance, the perception of an increased risk of injury is associated with it despite the lack of scientific evidence. Dynamic stretching appears to be the optimal method to use during the pre-exercise activity in healthy, uninjured young adults to enhance performance and range of motion. Other forms of stretching can still be utilized at other times to avoid possible stretching-induced impairments in performance.

Before dynamic stretching should be used, it is important to have in an increase in temperature of the active tissues. This can be accomplished with low-intensity aerobic activity for 5-10 minutes. Bishop (1) recommends the intensity of this aerobic activity be ~40-60% maximal oxygen consumption (VO2max). Since most coaches may not have access to VO2max data, the Borg Ratings of Perceived Exertion scale can be used with ratings between 12 and 13 on the 6-20 scale (100). The dynamic stretching exercises selected should contain movement patterns similar to the sport or skill to be completed during training or competition. Following the dynamic stretching routine, a higher intensity and more sport specific activity should be completed prior to training or competition. Other stretching modes may be used at other times to enhance range of motion.

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