INVITED COMMENTARY

The Use of Static Stretching in Warm-Up for Training and Competition

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Static stretching (SS) is widely used in warm-ups before training and competition. A growing amount of research, however, has demonstrated that SS can impair muscle performance, leading to a reevaluation of optimal warm-up protocols. This commentary discusses many of the methodological issues that can influence conclusions about the acute effects of SS on performance. One difficulty in interpreting the literature is the lack of control or communication about the volume and intensity of the various stretching treatments used. Another major issue is the failure of many researchers to evaluate SS as it is used in practice, particularly the interaction with the other general and sport-specific components of the warm-up. Acute warm-up effects on performance should be considered in conjunction with potential effects on injury prevention. Future directions in research include optimizing general and sport-specific warm-ups, time course of physiological and performance effects, and individualization of warm-ups according to fitness and skill level.

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Warm-up before sports training or competition is universally accepted and is practiced with the intention of improving performance and reducing the risk of injury.1 A warm-up routine often includes a general component performed at submaximal intensity, such as jogging; a series of static stretches; and a specific component involving practice of the movements about to be performed. Static stretching (SS) is an activity in which a body position is adopted at the end of a joint’s range of motion and held stationary for a period of time, usually 10 to 30 seconds. In a typical warm-up before vigorous activity, such a stretch would be repeated after a brief recovery so that the total stretch duration per muscle group is 0.5 to 2.0 minutes. Static stretching has been a popular part of warm-up and has been recommended by professional organizations such as Sports Medicine Australia to reduce muscle tension, increase freedom of movement and therefore short-term flexibility, and reduce the risk of muscle and tendon injuries.2

A considerable amount of research has been conducted in recent years addressing the efficacy of SS in warm-up in relation to performance, with some investigators proposing eliminating this traditional part of the warm-up.3,4 The rationale for this view has emanated from findings indicating negative effects on various
measures of muscle strength and power. It is not the purpose of this commentary to review the mounting research in this area; rather, I will comment on some of the methodological issues facing researchers interested in exploring the utility of SS in warm-up for athletes. The design of warm-ups is clearly an important issue for both researchers and coaches.

There is accumulating evidence that an acute bout of SS can impair muscle strength,\textsuperscript{5} strength endurance,\textsuperscript{6} power,\textsuperscript{4,7} and components of sports performance.\textsuperscript{8,9} The mechanism controlling this effect is thought to be decreased neural activation,\textsuperscript{10} reduced musculotendinous stiffness,\textsuperscript{5} or combined neural and muscular influences.\textsuperscript{11}

**Methodological Issues**

In order to apply research findings on SS to precompetition or training warm-ups, it is important that SS be investigated using protocols that are realistic and reflective of athletic practices. One study imposed a stretch protocol lasting for 30 minutes on 1 muscle group, and the authors acknowledged that their findings might have limited application to sport.\textsuperscript{12} The volume or total time that a muscle is under stretch is an important variable because it has been demonstrated that longer doses of stretching can induce greater magnitudes of impairment to performance than shorter stretch durations.\textsuperscript{13,14} Although it is not always clear what stretch duration has been used, studies demonstrating a stretch-induced impairment of performance have tended to use at least 2 minutes of total time under stretch for a muscle group.\textsuperscript{5,7-9,13}

Another fundamental exercise variable that might influence the acute stretch-induced response is stretch intensity. This refers to how far the muscle is elongated for a given rate of stretch, and it has been poorly described and controlled in the research literature. This is likely a result of inconsistent instructions regarding “how far” to take a stretch. For example, researchers have described a stretch being taken to the “pain threshold,”\textsuperscript{15} until “pain was received,”\textsuperscript{16} and “just before discomfort,”\textsuperscript{17,18} while another gave no instructions about muscle lengthening.\textsuperscript{19} In addition, some stretching treatments are controlled entirely by the participant, whereas others include assistance from an investigator. The variability in muscle lengthening during stretching can have a significant influence on muscle performance. For example, a stretch treatment involving stretches of 10% less elongation than the “point just before pain” (as measured by joint angle)\textsuperscript{13} abolished the impairment of muscle power observed with a full stretch.

To understand the effects of SS on performance, investigators have compared a stretching protocol with a no-warm-up condition.\textsuperscript{16,19} Although this research design might isolate the effect of stretching, this is not the way SS is used by athletes—it overlooks the influence of the general component and the sport-specific phase of the warm-up. Some studies have attempted to assess various combinations of warm-up protocols with and without SS, in an attempt to apportion the contribution of each to performance. Unfortunately, the exact protocols used for each component of the warm-up are not always clearly described,\textsuperscript{9,20} or the SS is placed at the end of the warm-up,\textsuperscript{8} which is not usual in practice.

One study that explored the influence of the 3 warm-up elements\textsuperscript{21} compared no warm-up with a 4-minute run only (general component), SS only, run + SS, run + SS + practice jumps (all 3 warm-up components), and measured jumping
performance. Evidence was provided that the run-only warm-up was superior to no warm-up, and the run-only was superior to the run + stretch. Furthermore, the practice jumps (specific-movement component) produced an additive positive effect on some performance variables. Unfortunately, one combination that was not studied that might have yielded the best results is run + practice jumps.

In order to isolate the effects of SS in the context of an athletic warm-up, the ideal research design would appear to be a comparison of 2 protocols:

- General warm-up + SS + specific warm-up (traditional warm-up sequence)
- General warm-up + specific warm-up

The second warm-up protocol appears to contain the elements that have a positive effect on performance and potentially satisfies the objective of increasing muscle and core temperature, as well allowing specific motor units to be recruited before a particular sporting activity. This design would answer the question of whether the addition of SS significantly alters performance compared with a thorough warm-up not containing SS. The same design could also be used to ask a similar question regarding the acute effects of SS on joint range of motion and injury risk.

Two studies have used this research design to isolate the acute effects of SS. The first, involving professional soccer players, required the athletes to perform 4 minutes of jogging (general), followed by approximately 6 minutes of SS and finally 20-m sprints in a straight line, as well as with changes of direction (specific). The stretches consisted of one 30-second stretch for each of 4 muscle groups of the lower limb. On another day, players performed the general and specific components of the warm-up without the SS. After the warm-ups, the players were tested on vertical jump with no arm swing, sprint, and agility. The only statistically significant difference between the warm-up protocols was for a flying 20-m sprint, with the SS warm-up producing faster times. This result was in contrast to other research indicating sprint-performance decrements from SS warm-ups. It was also somewhat surprising because this performance test was conducted approximately 10 minutes after the completion of the warm-up, and the 2 tests conducted immediately after the warm-ups (vertical jump and 10-m sprint) did not reveal any differences between the warm-up conditions.

The second study investigated the influence of SS in warm-up on maximum foot speed in kicking in Australian Rules footballers. One warm-up consisted of a 5-minute run, SS, and 7 kicks with increasing effort (specific component). This protocol was compared with a warm-up comprising only the run and kicking practice. The SS stretches consisted of 3 × 30 seconds for each of the exercises targeting the quadriceps and hip-flexor muscle groups. There was no substantial difference (0.5%, effect size = 0.12) between the warm-ups in foot speed at impact with the ball, as measured from high-speed video analysis. Collectively, these findings and those of Little and Williams suggest that when a moderate volume of SS is performed between the general and specific components of the warm-up, it has a limited impact. This outcome might be attributable to the acute effects of SS being diluted by other warm-up components.

In conclusion, the acute effects of SS in warm-up remain equivocal because of variations in research-design protocols and methodologies. Apart from the SS dosage (volume and intensity) and placement of the stretching treatment in the sequence of warm-up components, other factors that might influence results include
the time from cessation of the warm-up to the performance test, the particular stretching exercises, and performance indicators used, as well as age, gender, and training experience of the athletes. An issue that has not been adequately addressed in the literature is the time course of any stretch-induced effects. Future research should determine whether warm-up effects persist beyond the first bout of activity lasting a few seconds in a sporting competition. For example, do the potential benefits of a warm-up effect extend into the second half of a game in team sports?

Implications for Warm-Up Design

If it is shown in well-designed research that SS impairs performance, practitioners should consider eliminating this component of the warm-up. This action, however, must be balanced against other potential acute effects of stretching on sports participation. For example, SS is practiced with the belief that it might reduce the risk of injury and increase the range of motion at various joints. It is beyond the scope of this commentary to discuss these effects. These issues are controversial and are the subject of ongoing research. To date there have been no studies that have systematically investigated (such as with randomized controlled trials) whether including SS in the warm-up influences the rate or severity of injuries from sports participation. If there is a prophylactic benefit of SS, practitioners could rationalize retaining SS in a warm-up despite any perceived impairment to performance. Similar to the effects of SS on performance, the question that should be asked in relation to injury reduction and flexibility is whether SS achieves a beneficial acute effect that is greater than that produced by the other components of the warm-up.

Given that SS is a traditional warm-up practice, suddenly eliminating this element might have a negative psychological effect on some athletes, especially if they have a history of using it and a belief in its benefits. A practical issue is whether clear instructions regarding the technique, volume, and intensity of stretches can be adequately supervised, especially with large numbers of athletes, for example, in team sports. Reports of muscle strains after stretching sessions have been reported in dancers,24 highlighting the importance of warm-up supervision. If SS is to be discontinued, should it be replaced by an alternative component of warm-up activity? The utility of dynamic or ballistic forms of stretching should also be explored.

Researchers should be encouraged to explore the optimal general and sport-specific warm-up protocols that influence performance. Finally, a challenge for researchers and coaches who design warm-ups is to individualize and optimize them according to factors such as fitness and skill level.

References


