STATIC STRETCHING IMPAIRS SPRINT PERFORMANCE IN COLLEGIATE TRACK AND FIELD ATHLETES

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ABSTRACT

Previous research has shown that static stretching (SS) can diminish the peak force output of stretch-shortening cycle actions while performing a dynamic warm-up (DW) protocol has been shown to enhance performance in similar activities. The purpose of this study was to establish whether the deleterious effects of SS would wash out the performance enhancements obtained from the DW. Eleven males and 11 females, who were athletes of a NCAA Division I track team, performed a DW followed with either a SS or rest (NS) condition. After warm-up was completed, three 40 m sprints were performed to investigate the effects of the SS condition on sprint performance when preceded by DW. Time(s) were obtained from timing gates placed at 0, 20, and 40 m respectively. Testing was conducted over 2 days with a 1 week washout period. Testing order was balanced to eliminate possible order effect. Time for the NS versus the SS group was significantly faster for the second 20 m with a time of 2.41 versus 2.38 seconds ($P \leq .05$), and for the entire 40 m with a time of 5.6 $\pm$ 0.4 versus 5.7 $\pm$ 0.4 seconds ($P \leq .05$). The results of this study suggest that performing a SS protocol following a DW will inhibit sprint performance in collegiate athletes.

KEY WORDS flexibility, sprinting, track & field, active warm-up

INTRODUCTION

Flexibility (joint range of motion) is promoted as an important component of physical fitness (26). It is widely conjectured that increasing flexibility will promote better performances and reduce the incidence of injury (29,31). Consequently, stretching exercises designed to enhance flexibility are regularly included in both the training programs, and the pre-event warm-up activities of many athletes (16).

Notwithstanding the widespread acceptance and use of stretching exercises as a major component of pre-event activities, the purported benefits of stretching upon performance and injury prevention have come into question in several review papers (13,38). In addition, recent research has established an adverse effect of acute static stretching upon various different maximal performances. For example, pre-event stretching has demonstrated an inhibitory effect on maximal force or torque production (3,11,23), vertical jump performance (40), and running speed (24).

The use of a dynamic warm-up protocol (DW) has garnered attention in the literature in recent years as an effective means of enhancing athletic performance and providing for a safe warm-up procedure (8). Young and Behm (40) found an increase in countermovement jump height and rate of force development (RFD) when using DW over performing a traditional, general warm-up. In addition, the same researchers reported a significant performance increase in drop jump height, countermovement jump, contact time, RFD, and peak force when using DW compared to static stretching (40). Similar results have been reported by Fletcher and Jones (10) with an increase in sprint performance, by Stewart et al. (32) improved power production, and Trimble and Harp (35) with a potentiation of the H-reflex. Additional research confirmed the above findings (8).

Given the deleterious effect of passive muscle stretching in a laboratory setting on skills relying on the rate of force production and peak force generation, one could assume that preperformance stretching would negatively influence the performance of explosive sports such as sprinting (24). What is found in the laboratory, however, does not always directly transfer to sport performances. For an example, one can look at the confounding results such as those reported in Little and Williams (19), who was able to demonstrate an improvement in sprint performance using both static and dynamic stretching protocols in a 20 m flying sprint start, but the dynamic stretch group only improved in a 10 m sprint from a standard start. Since preperformance stretching is still widely practiced by sport coaches, it was questioned whether the negative influence noted in earlier research would

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1533-4287/22(1)/13–18

Journal of Strength and Conditioning Research

manifest in an actual athletic performance. Given the explosive nature of the sprint start, sprinting performance could be negatively influenced by static stretching. Moreover, since each step during the sprint requires an explosive take off, any negative impact seen at the start could be carried through the whole race.

Therefore, it would appear upon examination of the literature that use of a DW like those performed in the above mentioned studies may represent a more effective method of preparing for athletic performance than traditional static stretching. However, more research is needed to solidify this relationship. In addition, insufficient data exists examining a possible deleterious effect of static stretching on the possible gains from using DW prior to physical activity. Therefore, it was the purpose of this study to ascertain whether the addition of pre-event stretching would have a negative impact on sprint performance when preceded by performance of a DW protocol.

Methods

Experimental Approach to the Problem

Subjects were tested as part of their normal Monday practice session. Two testing sessions were performed with one week of separation between each. Athletes performed their normal DW as part of a routine practice. Activities included in the DW were typical of those observed in track and field settings and included an 800 m slow jog, body weight squats, frontal and sagittal leg swings, arm swings, various sprint drills (i.e., A and B skips, high knees, butt kicks), multiple hurdle mobility drills, 30 m lateral shuffles, backwards reaching runs, and bodyweight tuck jumps. The entire DW procedure was completed by each athlete and took approximately 30 minutes to perform. Following the warm up session, athletes were separated into either a stretching (SS) or nonstretching (NS) group. Testing order was balanced to prevent the possibility of an order effect, and each athlete was used as their own control by participating in both the SS or NS condition in either the first or second testing session.

Following the DW and either the stretch or rest condition, each participant performed 3 timed 40 m sprints. To minimize climatic conditions, all sprints were done indoors on a rubberized track. The sprints were initiated from standard starting blocks set to individual preferences, and were timed with an electronic timing gate system with gates set at 0, 20, and 40 meters (Speedtrap II, Brower Timing Systems, Draper, UT). This timer utilized a pressure pad placed under the fingers of the sprinter's right hand in the starting position. The timing device started when the sprinter lifted the fingers off of the pressure pad, and stopped when the sprinter broke a single laser light beam projected across the track 40 m from the starting line. To control for error, the laser beam was positioned so the height above the ground approximated the height of the runners' waist.

Subjects

Subjects were recruited from members of the Louisiana State University's nationally ranked Track and Field team, who were all currently competing in the 2005 NCAA indoor season. Eleven men (Age = 20.2 ± 1.3 years, Mass = 81.0 ± 8.9 kg, and Height = 185.7 ± 8.1 cm) and 11 women (Age = 20.3 ± 1.2 years, Mass = 62.3 ± 8.6 kg, and Height = 170.9 ± 10.2 cm) completed the study. All were jumpers (high jump, long jump, triple jump, pole vault) or multi-event athletes (e.g., decathlon or heptathlon), were highly-skilled at performance of a sprint start, and had extensive previous experience using the timing gate system described below. Informed written and verbal consent was obtained from each participant prior to taking part in the experiment, and the appropriate institutional human participants review committee approved the study. The participants were not allowed to see the results until the study was completed.

Procedures

The stretching protocols included four passive (partner-assisted) activities designed to stretch the calf and thigh muscles. The duration of the stretching protocol was 10 minutes. The first activity was a hamstring stretch. The athletes adopted a supine position on the ground with the one leg extended. The other leg was flexed at the knee (~ 90°) and hip (~ 45°), and the sole of the foot was planted firmly on the ground. From this position, the extended leg was raised (hip flexion) to the vertical position or beyond. During the stretch, the buttocks remained in complete contact with the ground, and the knee of the stretched leg was fully extended. The second activity was a triceps surae stretch which was performed while the athlete's leg was in the vertical position. While the leg was vertical, the ankle was dorsi-flexed by pushing down on the ball of the foot. The third stretch again started with the person lying supine with one leg flexed and one extended. The extended leg was then flexed at both the knee and hip, simultaneously pushing the heel into the buttocks and the knee towards the chest. The fourth activity was a quadriceps stretch. For this stretch, the subject started by lying prone. At this point, the subject's partner passively flexed the knee and lifted the knee off of the ground, keeping the hip in contact with the floor. For each activity, the range of motion was increased until the person acknowledged a stretch-induced discomfort similar to that normally felt during their daily stretching activities. At the point of discomfort, the stretch was maintained for 30 seconds. The 4 activities were done in the order listed above, with a 10–20 second rest period separating each activity. Once one cycle of stretches was completed, the leg was rested for an additional 20–30 seconds and then the cycle was repeated until each of the 4 activities had been done 3 times. The stretching of each leg was alternated between right and left until all 3 cycles had been completed.

Following the stretching or rest period, each athlete performed three 40 m sprints. A minimum of 5 minutes of recovery separated each trial. As mentioned earlier, all sprints were initiated from standard starting blocks that each athlete set to their personal preference. The athletes were allowed to perform their usual pre-start ritual, with the exception of any muscle stretching, jumping, or shaking of the limbs. Once the athletes were set, they started at their own volition. The reliability of this protocol in our lab (24), is very high (ICC = 0.999). It is worth noting that in most cases, it would be a solid study design to have a control condition who neither participated in the DW or the SS condition. However, due to the demographics of our subject population, we were unable to gain permission from team coaches to perform maximal effort 40 meter sprints without performing their normal daily warm-up due to concerns about injury of the athletes who were beginning their competition season when this study was performed. Analysis of the results in this study should be observed with that situation taken into consideration.

Statistical Analyses

The 3 times for each stretch condition and distance (0–20 m, 20–40 m, and 0–40 m) were averaged, and the mean value was used in the statistical analyses. A paired *t*-test was used to compare the NS and SS mean times for each of the 3 distances. Since 1 week had elapsed between the first and second testing day, the possibility existed that the differences between treatments might have been influenced by conditions of a specific day. Therefore, additional paired *t*-tests were used to determine whether or not there was a difference between the two different days (i.e., the results of NS and SS were collapsed across days). The level of significance was set at $P \leq .05$, and was adjusted to cover for multiple comparisons using a Bonferroni adjustment (i.e., *P* value divided by number of comparisons). Hence, for significance at the 0.05 level to occur, the F-ratio needed to exceed the required F-ratio for $P < 0.0167$ (i.e., 0.05 divided by 3). Data are reported as mean ± standard deviation. The reliability of the 3 times for each leg (0–20 m and 20–40 m), and the total distance (40 m) for each stretch condition was calculated using an intraclass correlation coefficient. The reliability of the run time for each condition was very high. In each case, the intraclass correlation coefficient (ICC) exceeded 0.98. Intraclass correlation coefficients for the stretch group at 0–20 m were 0.987, 20–40 m were 0.983, and 0–40 were 0.944. For the nonstretch condition ICC were 0.922, 0.944, and 0.999 respectively.

Results

Day Effects

There were no significant differences found between either of the testing sessions.

Stretch Effects

The average 0–20 m, 20–40 m, and 0–40 m sprint times for NS and SS are shown in Figure 1. For the first 20 m, the mean times differed by 0.03s and this difference was not statistically different. During the second 20 m, the mean SS time was significantly ($P < 0.0167$) slower than the mean NS time by 0.08s. The 40 m times were also significantly ($P < 0.0167$) slower for SS as compared to NS. Overall, SS was 0.1 second slower than NS.

In addition to the above analysis on the average 0–20 m, 20–40 m, and 0–40 m sprint times, a post hoc analysis was done on the best time (faster of the 3 times averaged for analysis) for each trial. The same statistical method was used,

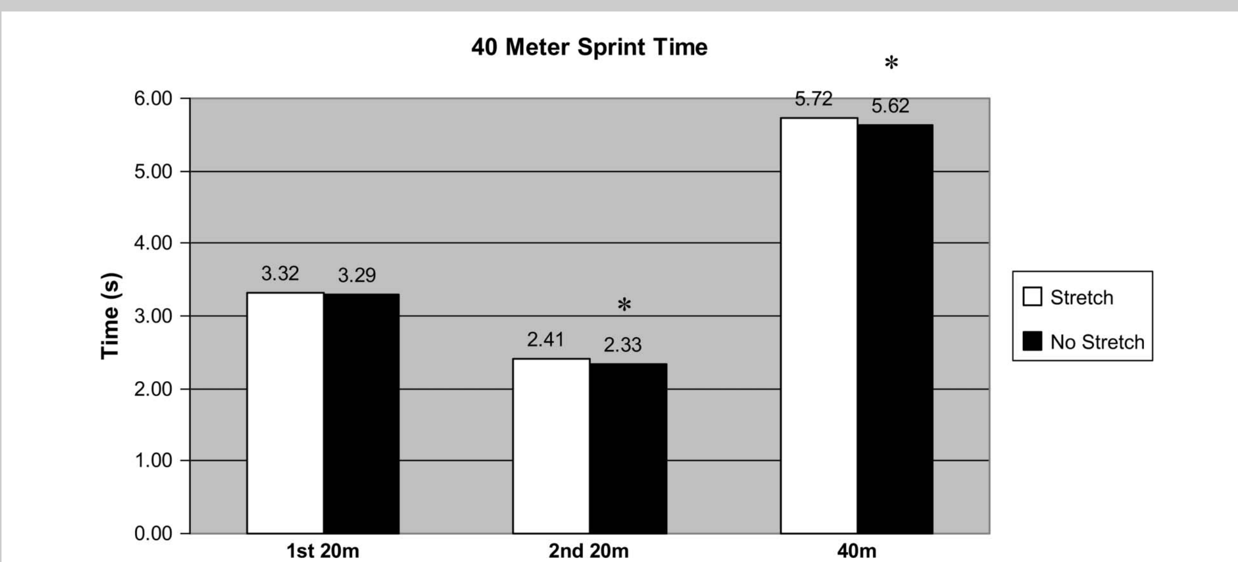

Figure 1. The effect of stretch treatment on sprint time. Values are Mean time for each condition. *Significant between stretch and nonstretch conditions ($P \leq 0.05$).

Table 1. The effect of stretch treatment on sprint time.

Values are Mean ± SD. Variable : Time (seconds)	1st 20 m	2nd 20 m	40 m
Stretch	3.32 ± 0.22	2.41 ± 0.21*	5.72 ± 0.42*
No Stretch	3.28 ± 0.46	2.38 ± 0.35	5.62 ± 0.42

*Significant between stretch and no stretch conditions ($P \leq 0.05$).

and nearly identical statistical results to those mentioned above were obtained.

Originally, data was separated for examination of possible gender effects. However, upon analysis of the data, both males and females experienced a similar deficit in performance. Considering these results, data from both genders were collapsed into one group to allow for greater statistical power. These results on a lack of gender specific response to static stretching as it relates to muscular performance would seem to be consistent with earlier research (18).

Discussion

The major finding of this study was a 3% decrease in sprint performance at 40 m when the subjects participated in the static stretching protocol. This deleterious effect on sprint performance occurred despite having undergone an extensive dynamic warm-up prior to the stretching condition. As mentioned above, previous research has shown that an acute bout of passive muscle stretching can impede maximal force production in both isometric and concentric contractions (3,11). In addition, prior stretching can also compromise the performance of a skill where success is dependent on the rate of force production or power, rather than just the ability to maximize force output (24,40). Our results show that the time of a 40 m sprint was significantly increased when preceded by static stretching. Thus, it appears that pre-performance stretching exercises negatively impact skills that require multiple repetitive high power outputs in addition to those that depend mainly on maximizing a single output of peak force or power.

Stewart et al. (32) demonstrated an increase in EMG activity following the use of a dynamic warm-up protocol. In addition, they found an increase in maximal instantaneous power which suggested that use of this type of warm-up method was beneficial to performance. Dynamic warm-ups have been reported as an effective measure to increase sport specific skills such as sprinting (10), and jumping (8,40). One possible mechanism for this increase in performance with a dynamic warm-up and for observed decreases with static stretching was proposed by Rosenbaum and Hennig (27) who noted an increase in Achilles tendon compliance following a static stretch intervention. Rosenbaum and Hennig (27) noted that the group who participated in a jogging warm-up rather than static stretching, displayed a stiffer tendon which correlated with increased performance in force production.

Another possible mechanism has been proposed by Wilson et al. (39), who suggested that for concentric muscle actions, a stiffer system would improve contractile component force production by allowing more favorable length and velocity conditions. Specifically, they proposed that at a given state of contraction, a stiffer musculotendinous unit should give rise to a greater length and a decreased shortening velocity of the contractile component, thereby placing the contractile component at a more optimal point on both the force/velocity and force/length curve in terms of force production. This is because there is not as much "slack" in a stiffer system that has to be taken up during the initial part of the contraction. Extrapolating to the present study, stretching might have affected sprint performance by preventing the knee and hip extensors from operating over the most favorable parts of their force/length and force/velocity curves.

Another possibility is that the performance may have been hindered during the running portion of the sprint by a decreased ability of the musculotendinous unit to store elastic energy following a stretch-induced increase in musculotendinous compliance. Both muscular and tendinous tissues have the ability to store elastic strain energy after being stretched by an external force. Although disputed by some investigators (5,36), many authors report that the stretch-shortening phenomenon might be partly explained by the release of elastic energy that is stored in the musculotendinous structures during the eccentric phase of stretch shortening-cycle exercises such as running, a mechanism referred to as elastic potentiation (2,13,14,17). The amount of elastic energy that can be stored in the musculotendinous unit is a function of the unit's stiffness and the extension produced by an imposed force (30). Belli and Bosco (4) suggested that an optimum stiffness might exist that maximizes the magnitude of elastic energy return. Furthermore, they demonstrated that the active stiffness of the triceps surae, measured using a vertical oscillation technique with motion restricted to the ankle joint only, was in fact lower than the theoretical optimal stiffness calculated for their participants. Consequently, an acute bout of passive muscle stretching might compromise the effect of a stretch-shorten cycle by decreasing active musculotendinous stiffness, thereby reducing the amount of elastic energy that can be stored and re-utilized. A stretch-induced decrease in musculotendinous stiffness has been demonstrated in some studies (20,27), but not in others (12). In addition, McNair and Stanley (21) found passive stretching to have no effect upon the stiffness of the lower limb muscles during an isometric contraction at 30% maximal effort. However, none of these studies measured stiffness under dynamic conditions of repeated stretch-shortening cycles, and so the impact of passive stretching under actual sprinting remains to be determined. Interestingly, Nelson et al. (23) showed that static stretching did not hinder maximal voluntary isokinetic knee-extension torque production at faster speeds of movement. Since movement speeds investigated in the Nelson et al. (23) study were slower than the limb movement speeds in sprinting, one could have speculated that stretching would have little impact on sprinting. However, more recent data reported by Cramer and colleagues (9) demonstrated a reduction in isokinetic peak torque at both slow and fast movements, thus supporting the idea that pre-event stretching can inhibit high velocity strength performance. It is important to distinguish that while maximal voluntary isokinetic knee-extension torque production does not employ the stretch-shortening cycle, sprinting does.

There are also neurological mechanisms that could account for a stretch-induced decline in the performance. One of these involves the disruption of stretch reflex activity. Bosco et al. (7) have proposed that the eccentric phase of a stretch-shortening movement initiates a myoelectric potentiation (i.e., a stretch reflex which increases muscle activation during the period of concentric work). Rosenbaum and Hennig (27) demonstrated that muscle stretching could diminish the strength of the stretch reflex, elicited by an Achilles tendon tap. Thus, pre-exercise stretching might negatively impact the performance of skills that involve a stretch-shorten cycle by impeding myoelectric potentiation. Another potential neural mechanism is related to the acute response of muscle and/or joint proprioceptors (e.g., Golgi tendon organs) to sustained stretch. Golgi tendon organs respond to tension by initiating a reflex inhibition (autogenic inhibition) of the muscle being stretched and its synergists in both the ipsilateral and contralateral legs (22).

Notwithstanding the statistical significance of this study's findings, the universal applicability of these findings could be questioned in terms of both magnitude and duration of the stretch-induced inhibition. Because the participants performed the sprints within 10 minutes of the last stretch, we cannot state if a similar effect would be evident, 30 minutes later. Moreover, the 40 m sprint was much shorter than the standard competition sprints performed indoors (60 m) and outdoors (100, 200, and 400 m). Hence, it is not known whether the 0.1 second difference seen between the stretched and nonstretched conditions would accumulate, remain static, or decrease over a longer distance. However, Fowles et al. (11) found that a 9% decrement in maximum isometric plantar flexion torque was present 60 minutes following an aggressive 30 minute stretching of the plantarflexors. Thus, it appears that the capacity of pre-event stretching to have a negative impact could endure for a time much longer than that of even the longest sprints. The duration of the stretches used in this study, however, were shorter than those of Fowles et al. (11). Hence, one would presume that the magnitude of any decrease and its duration would be less than that reported by Fowles et al. (11). Clearly, further research is required to establish both the magnitude of prestretching necessary to cause a deleterious effect, and the time-course between the maintenance of the increased range of motion and the resumption of the capacity to generate maximal power.

Practical Applications

Although the mechanisms responsible for the performance decrements cannot be unequivocally established from the present data, the findings from this experiment, nonetheless, have important ramifications. This study shows that passive muscle stretching can negatively impact the performance of a skill that demands repetitive high power outputs even when preceded by a dynamic warm-up protocol. This effect may influence movements performed with either a purely concentric contraction (i.e., explosive take-off out of the starting blocks), a concentric phase followed by repetitive stretch-shortening cycle actions, or both. The performance of other skills, therefore, might be affected if an acute bout of stretching is undertaken immediately prior to engaging in activity (e.g., long jumping, high jumping, pole vaulting). Thus, in addition to establishing the underlying mechanisms, further research should be conducted to determine if this study's findings could be generalized across a variety of skills. Presently, the results only indicate that the knee and hip muscles should not be passively stretched just prior to performing sprints if the intent is to maximize speed. This recommendation opposes the general perception that passive stretching before vigorous exercise is always a prudent practice.

Acknowledgments

The authors would like to thank the LSU Track and Field Team for their assistance in performing this study, our subjects, and the LSU Department of Kinesiology.

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