EFFECTS OF STATIC STRETCHING ON 1-MILE UPHILL RUN PERFORMANCE

RYAN P. LOWERY,[1] JORDAN M. JOY,[1] LEE E. BROWN,[2] EDUARDO OLIVEIRA DE SOUZA,[3] DAVID R. WISTOCKI,[1] GREGORY S. DAVIS,[1] MARSHALL A. NAIMO,[1] GINA A. ZITO,[1] AND JACOB M. WILSON[1]

[1]*Department of Health Sciences and Human Performance, University of Tampa, Tampa, Florida;* [2]*Department of Kinesiology, California State University, Fullerton, California; and* [3]*Laboratory of Neuromuscular Adaptations to Strength Training, School of Physical Education and Sport, University of São Paulo, São Paulo, Brazil*

ABSTRACT

Lowery, RP, Joy, JM, Brown, LE, Oliveira de Souza, E, Wistocki, DR, Davis, GS, Naimo, MA, Zito, GA, and Wilson, JM. Effects of static stretching on 1-mile uphill run performance. *J Strength Cond Res* 28(1): 161–167, 2014—It is previously demonstrated that static stretching was associated with a decrease in running economy and distance run during a 30-minute time trial in trained runners. Recently, the detrimental effects of static stretching on economy were found to be limited to the first few minutes of an endurance bout. However, economy remains to be studied for its direct effects on performance during shorter endurance events. The aim of this study was to investigate the effects of static stretching on 1-mile uphill run performance, electromyography (EMG), ground contact time (GCT), and flexibility. Ten trained male distance runners aged 24 ± 5 years with an average $\dot{V}O_2$max of 64.9 ± 6.5 $mL\cdot kg^{-1}\cdot min^{-1}$ were recruited. Subjects reported to the laboratory on 3 separate days interspersed by 72 hours. On day 1, anthropometrics and $\dot{V}O_2$max were determined on a motor-driven treadmill. On days 2 and 3, subjects performed a 5-minute treadmill warm-up and either performed a series of 6 lower-body stretches for three 30-second repetitions or sat still for 10 minutes. Time to complete a 1-mile run under stretching and nonstretching conditions took place in randomized order. For the performance run, subjects were instructed to run as fast as possible at a set incline of 5% until a distance of 1 mile was completed. Flexibility from the sit and reach test, EMG, GCT, and performance, determined by time to complete the 1-mile run, were recorded after each condition. Time to complete the run was significantly less (6:51 ± 0:28 minutes) in the nonstretching condition as compared with the stretching condition (7:04 ± 0:32 minutes). A significant condition-by-time interaction for muscle activation existed, with no change in the nonstretching condition (pre 91.3 ± 11.6 mV to post 92.2 ± 12.9 mV) but increased in the stretching condition (pre 91.0 ± 11.6 mV to post 105.3 ± 12.9 mV). A significant condition-by-time interaction for GCT was also present, with no changes in the nonstretching condition (pre 211.4 ± 20.8 ms to post 212.5 ± 21.7 ms) but increased in the stretching trial (pre 210.7 ± 19.6 ms to post 237.21 ± 22.4 ms). A significant condition-by-time interaction for flexibility was found, which was increased in the stretching condition (pre 33.1 ± 2 to post 38.8 ± 2) but unchanged in the nonstretching condition (pre 33.5 ± 2 to post 35.2 ± 2). Study findings indicate that static stretching decreases performance in short endurance bouts (~8%) while increasing GCT and muscle activation. Coaches and athletes may be at risk for decreased performance after a static stretching bout. Therefore, static stretching should be avoided before a short endurance bout.

KEY WORDS static stretching, one-mile run, ground contact time, electromyography, performance

INTRODUCTION

Static stretching exercises are a common part of the warm-up routine for athletes and strength practitioners in an attempt to improve performance and reduce the risk of injuries (9). However, previous research has demonstrated that static stretching acutely decreases maximal strength (7,10,11), strength endurance (12), and power (3). Static stretching in endurance events has only recently received attention. Specifically, our laboratory (14) found that static stretching decreased total distance run in a 30-minute time trial in trained collegiate runners (14). Intriguingly, we found that static stretching also decreased running economy. More recently, Wolfe et al. (15) demonstrated that these effects on economy were limited to the first few minutes of an endurance bout. One possible explanation is that static stretching places a portion of the motor units into a fatigue-like state before the endurance exercise begins, resulting in an increased number of motor units recruited to perform the same mechanical work as without stretching (2). Moreover, past research has demonstrated that static stretching may decrease

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Address correspondence to Dr. Jacob M. Wilson, jmwilson@ut.edu.

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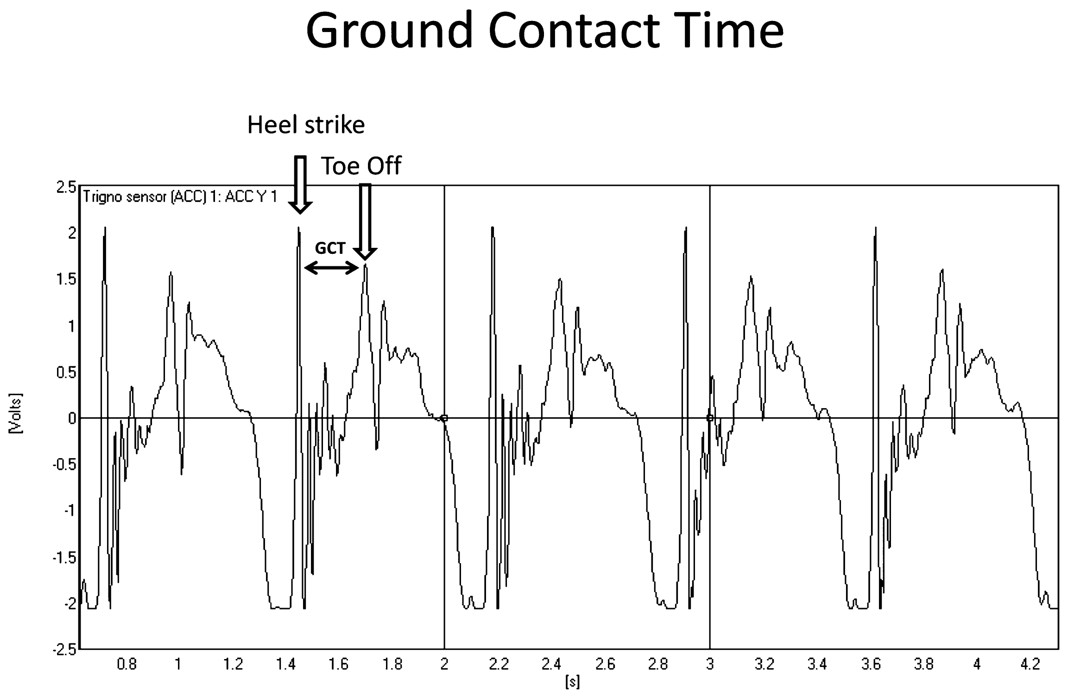


Figure 1. Ground contact time.

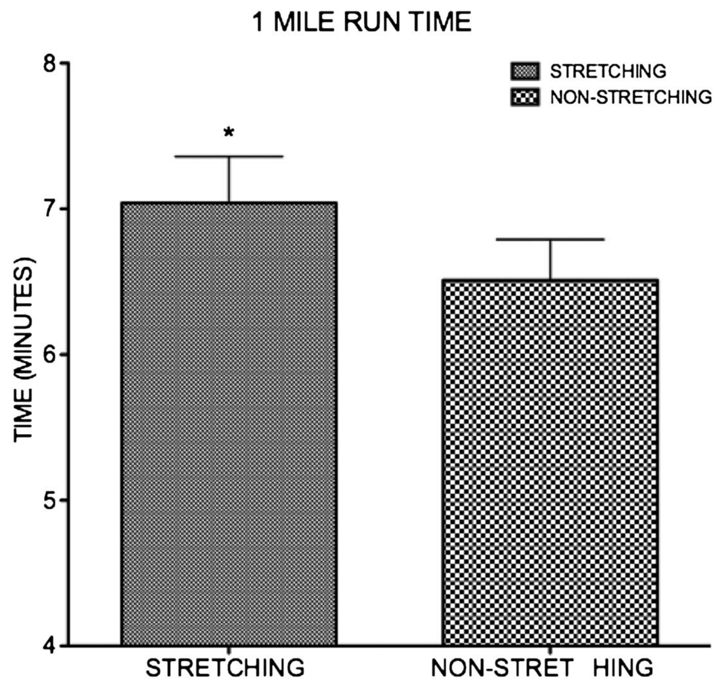


Figure 2. Time to complete the run in the nonstretching condition as compared with the stretching condition.

stiffness of the muscle-tendon unit (14). Theoretically, this may prolong ground contact time (GCT) and decrease running economy. These proposed mechanisms have yet to be investigated in endurance events. Therefore, the purpose of the present study was to investigate the effects of static stretching on running performance, GCT, and muscle activation during a 1-mile uphill run in trained distance athletes. The 1-mile run was selected as it represents a period likely to be affected by the short temporal decrements in economy previously described by Wolfe et al. (15).

METHODS

Experimental Approach to the Problem

Similar to previous research on the topic by Wilson et al. (14), this experiment used a random

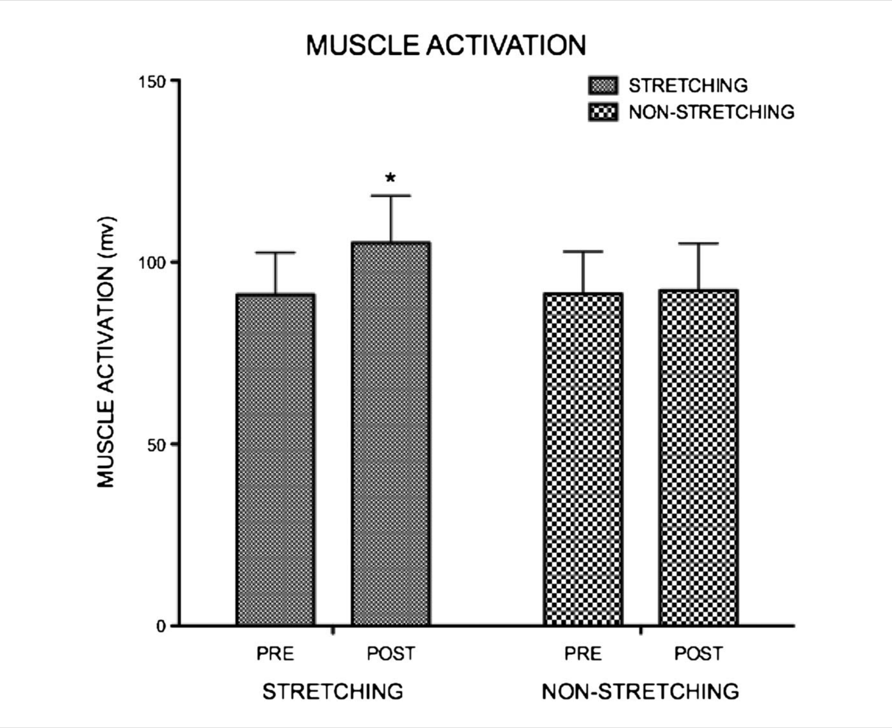


Figure 3. Muscle activation (pre-post) in the nonstretching trial and the stretching trial.

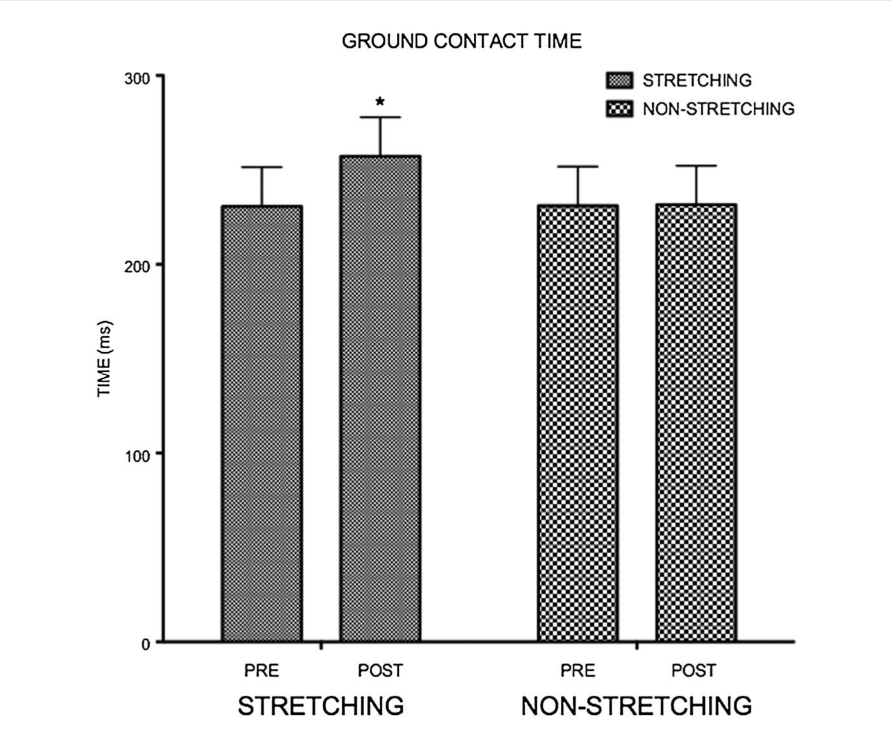


Figure 4. Ground contact time (pre-post) in the nonstretching trial and the stretching trial.

crossover design, in which participants underwent stretching and nonstretching trials before 1-mile run. Participants came to the laboratory on 3 different days. On the first day, baseline $\dot{V}O_2max$ testing was conducted. On days 2 and 3, subjects were randomly assigned to either the stretching or nonstretching condition, with a minimum of 72 hours between visits. Before each laboratory visit, participants were instructed not to engage in any activity requiring significant lower limbs effort (e.g., squatting, leg press, running) for 72 hours before all sessions. Additionally, each participant was required to track his dietary intake for 24 hours before the first trial and repeat the same dietary intake schedule for 24 hours before the second trial. $\dot{V}O_2max$ testing was completed on a motor-driven treadmill (Star Trac, Irvine, CA, USA) using a progressive exercise test to exhaustion protocol as described previously (13). Gas exchange, caloric expenditure, and ventilatory parameters were measured by indirect calorimetry using a metabolic measurement system (Moxus; AEI Technologies, Naperville, IL, USA).

Subjects

Ten male athletes (24 ± 5 years) from a National Collegiate Athletic Association Division II cross-country team with an average $\dot{V}O_2max$ of 64.9 ± 6.5 $mL\cdot kg^{-1}\cdot min^{-1}$ were recruited for the study in the fall. All subjects were thoroughly informed of the purpose, nature, practical details, and possible risks associated with the experiment, as well as the right to terminate participation at will, before they gave their voluntary informed consent to participate. The study was approved by the University's Institutional Review Board.

Condition Protocols

Stretching and nonstretching conditions took place on visits 2 and 3. The order in which each participant completed the trials was randomly determined. During both conditions, electromyography (EMG) sensors were placed on the gastrocnemius of the participant's dominant leg and secured with athletic tape. Sensor locations were outlined with a permanent marker and then shaved. The participant then performed a best-of-three sit-and-reach tests without shoes. As a warm-up, they walked for 4 minutes on the treadmill at a 4.8 $\text{km}\cdot\text{h}^{-1}$ pace with a 5% incline. Afterward, they ran for 1 minute at an 11.3 $\text{km}\cdot\text{h}^{-1}$ pace with a 5% incline. Baseline GCT and muscle activation of the gastrocnemius were recorded during this time. Immediately after warm-up, participants either stretched or rested while sitting for 8 minutes. After the stretch or rest period, they ran again at an 11.3 $\text{km}\cdot\text{h}^{-1}$ pace for 1 minute at a 5% incline while GCT and EMG were recorded. These measurements were used to investigate the isolated effects of stretching on muscle activation and GCT. The treadmill pace was then slowed to a stop before a 1-mile time trial was performed, at a 5% incline. Two minutes of elapsed time occurred between the end of the 1-minute run and the start of the 1-mile run. During the time trial, the participant was told to complete the mile as fast as possible. As such, they could control the speed of the treadmill. However, they could not view the time or speed. After the run, they performed a final sit-and-reach test (Figure 6).

Stretching Protocol

The stretching protocol was derived from Wilson et al. (14). Briefly, the stretches consisted of sit and reach, straight-leg calf stretch, standing quadriceps stretch (per leg), hip flexor lunge (per leg), standing foot-over-opposite heel (per leg), and lying foot-over-opposite knee (per leg) stretches. Each stretch was performed for three 30-second repetitions, with 30-second rest in between each set.

Ground Contact Time

Ground contact time was measured via a uniaxial accelerometer using a method previously described by Chapman et al. (4) Specifically, wireless 5-g accelerometer devices (Trigno Wireless EMG Systems; Delsys, Boston, MA, USA) were attached to the top of the shoe of the dominant leg via plastic ties to the shoelaces. The accelerometers sampled the y-axis (oriented relative to the frontal plane) at a gain of 1,000, sampled at 1,024 Hz, and stored using a 16-bit A/D card. The waveform output was used to identify markers corresponding to the precise times of the initial ground contact and toe off

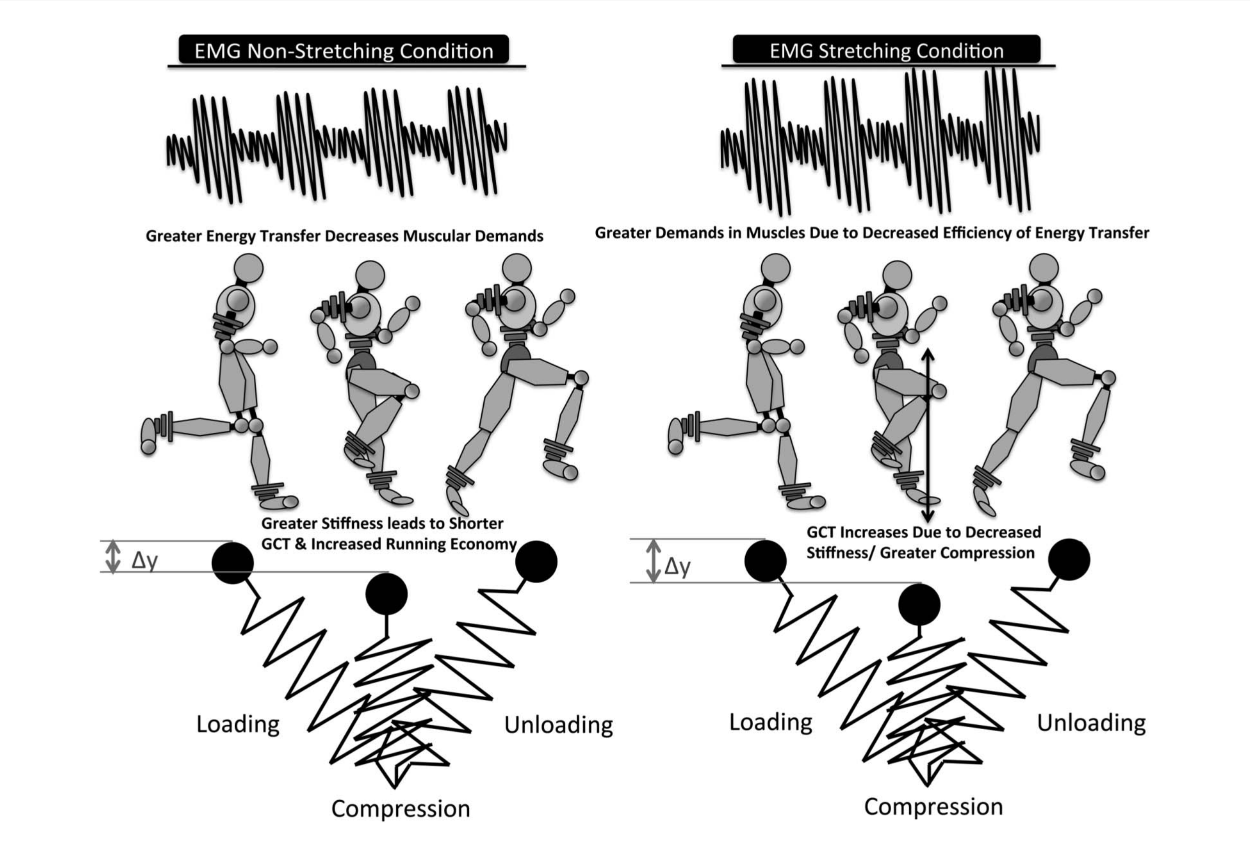


Figure 5. Theoretical model for increased ground contact times and increased muscle activation after stretching vs. nonstretching conditions.

phases (Figure 1). Initial ground contact and toe off phases were defined as the first and second largest acceleration values, respectively. The time interval between ground contact and toe off was defined as GCT. In any case, reliability of ground contact time assessments was 0.97.

Electromyography

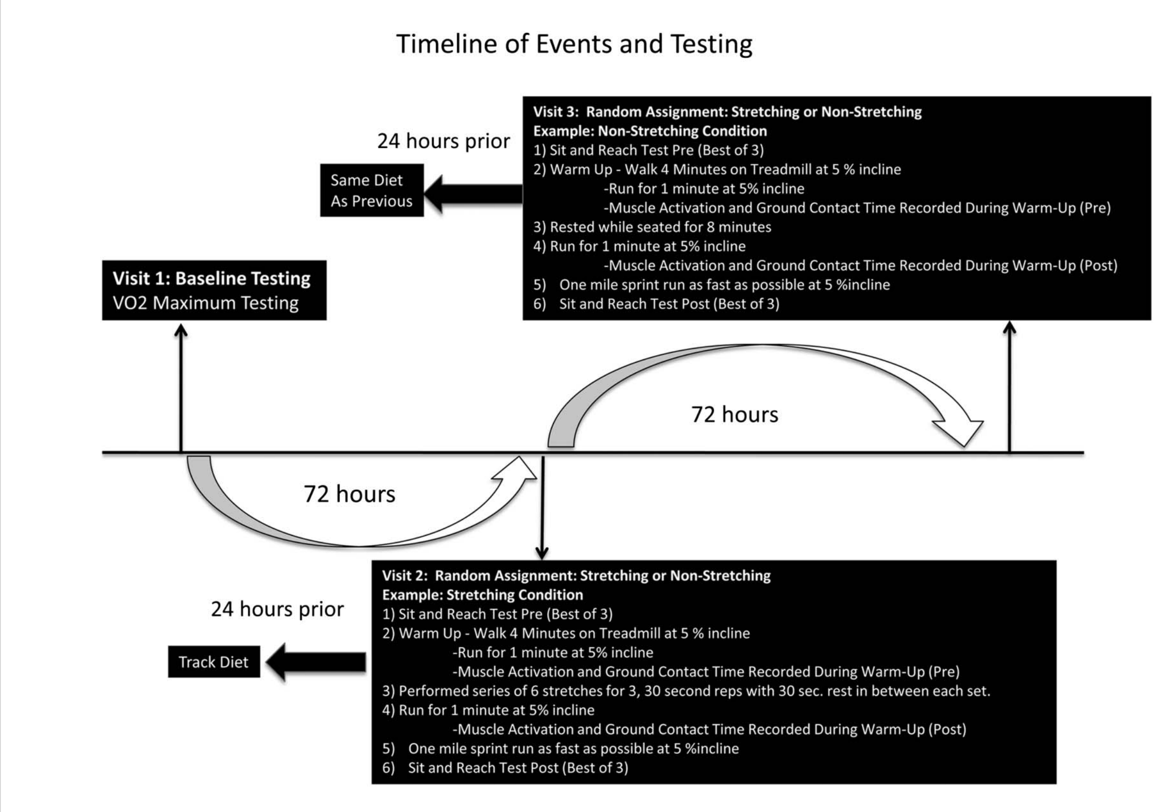
An EMG (Trigno Wireless EMG Systems; Delsys) sensor was applied to the belly of the lateral head of the gastrocnemius of the dominant leg to measure muscle activation during exercise. Before sensor placement, the leg was shaved and sterilized with alcohol to ensure optimal electrical conductance. The sensor was applied using specialized double-side adhesive (Trigno adhesive; Delsys). Surface EMG signals were preamplified (×100), amplified (×2), band-pass filtered (10–1,000 Hz), and sampled at 2,500 Hz with EMG works software (Trigno Wireless EMG Software, Delsys, Version 4.01; Boston, MA, USA). All EMG data are expressed as root mean squared values for the average activation of the gastrocnemius during the prestretch and poststretch or nonstretch 1-minute runs. In any case, reliability of EMG assessments was 0.98.

Statistical Analyses

A paired dependent *t*-test was used to determine differences in 1-mile run performance between conditions. Two repeated-measures analyses of variance (ANOVAs) were used to analyze condition-by-time interactions for GCT and muscle activation. Interactions were followed-up with simple ANOVAs, whereas main effects were followed-up with a Tukey post hoc to locate differences. An a priori alpha level of 0.05 was used for statistical significance. Statistica (StatSoft, Tulsa, OK, USA) was used for all statistical analyses.

RESULTS

Time to complete the run was significantly less (6:51 ± 0:28 minutes) in the nonstretching condition as compared with the stretching condition (7:04 ± 0:32 minutes) (Figure 2). A significant condition-by-time interaction for muscle activation existed, with no change in the nonstretching condition (pre 91.3 ± 11.6 mV to post 92.2 ± 12.9 mV) but increased in the stretching condition (pre 91.0 ± 11.6 mV to post 105.3 ± 12.9 mV). A significant condition-by-time interaction for GCT was also present, with no changes in the nonstretching condition (pre 211.4 ± 20.8 ms to post 212.5 ± 21.7 ms) but increased in the stretching trial (pre 210.7 ± 19.6 ms to post 237.21 ± 22.4 ms) (Figure 4). A significant condition-by-time interaction for flexibility was found, which was increased in the stretching condition (pre 33.1 ± 2 to post 38.8 ± 2) but



Visit 3: Random Assignment: Stretching or Non-Stretching
Example: Non-Stretching Condition
1) Sit and Reach Test Pre (Best of 3)
2) Warm Up - Walk 4 Minutes on Treadmill at 5 % incline
    -Run for 1 minute at 5% incline
    -Muscle Activation and Ground Contact Time Recorded During Warm-Up (Pre)
3) Rested while seated for 8 minutes
4) Run for 1 minute at 5% incline
    -Muscle Activation and Ground Contact Time Recorded During Warm-Up (Post)
5) One mile sprint run as fast as possible at 5 %incline
6) Sit and Reach Test Post (Best of 3)

Visit 2: Random Assignment: Stretching or Non-Stretching
Example: Stretching Condition
1) Sit and Reach Test Pre (Best of 3)
2) Warm Up - Walk 4 Minutes on Treadmill at 5 % incline
    -Run for 1 minute at 5% incline
    -Muscle Activation and Ground Contact Time Recorded During Warm-Up (Pre)
3) Performed series of 6 stretches for 3, 30 second reps with 30 sec. rest in between each set.
4) Run for 1 minute at 5% incline
    -Muscle Activation and Ground Contact Time Recorded During Warm-Up (Post)
5) One mile sprint run as fast as possible at 5 %incline
6) Sit and Reach Test Post (Best of 3)

Figure 6. Timeline of events and testing.

unchanged in the nonstretching condition (pre 33.5 ± 2 to post 35.2 ± 2).

Discussion

The purpose of this study was to investigate the effects of stretching on performance, GCT, and muscle activation during a 1-mile uphill run. The primary findings were that stretching before the endurance bout resulted in decrements in time to complete the run, increased GCT, and increased muscle activation relative to a nonstretching work-matched control condition. Our results indicate that static stretching decreases performance in short endurance bouts (~8%), and this decrease may be mediated by changes in the neuromuscular responses, such as GCT and motor unit fatigue.

Previous research has demonstrated that static stretching leads to decrements in long distance run performance (13). Specifically, Wilson et al. (14) had trained distance runners perform a 30-minute time trial after a static stretching bout. Their results indicated that after the stretching exercises, performance was significantly lower (−3.4%) in the stretching condition. Using a similar population, we found an −8% change in performance after the stretching protocol. Collectively, these findings of current study suggest greater decrements (−8 vs. −3.4%) in performance during shorter distances (1 mile) with greater strength requirements (5% incline) as compared with longer distances (3.73 miles) with lower strength requirements (0% incline).

The greater performance decrements in this study could be explained by the research done by Wolfe et al. (15), which indicated that decrements in running economy were constrained to only the first 5 minutes of an endurance cycling bout. Additionally, Fowles et al. (7) observed that force-generating capacity was decreased for up to 60 minutes after a static stretching bout. Collectively, these aforementioned results suggest that performance deterioration observed in our study is that the uphill running model used demanded higher force generation compared with no incline in previous research.

The mechanisms underlying performance decrements are likely complex in nature. Arampatzis et al. (1) reported a strong positive association between energy cost and GCT at a given velocity. Furthermore, previous research indicated that GCT increased as runners neared fatigue (1). The result is a likely decline in running economy. We previously found that static stretching led to increased energy costs of a run (10). The findings of the current study suggest that decrease in running economy and declines in performance were the result of increases in both GCT and motor unit recruitment. It is possible that decrements in muscle-tendon unit stiffness because of static stretching may require more motor units to be recruited (7). Theoretically, greater muscle activation for a given velocity may increase energy expenditure and thus hasten the onset of fatigue.

Changes in GCT, motor unit recruitment, and efficiency can be further explained using the mass-spring model by Farley and Gonzalez (6). Specifically, the mass spring model is used to predict different mechanisms of running economy and thus may explain why GCT is prolonged after a stretching bout (Figure 5). When human's run, they rely on musculoskeletal springs to store and release elastic energy. The muscles, tendons, and surrounding fascia collectively mimic a spring, in the fact that they store elastic energy when stretched (14). Therefore, changes in running patterns and performance could be due to decreases in the stiffness of the "spring" after a static stretching bout (7). Certainly, the literature demonstrates that there is a strong relationship between stiffness and various measures of performance, including running economy (5). Our findings agree with Heise and Martin (8), who found that less efficient runners use a more compliant leg spring in their running style during ground contact phases. The result is greater GCT and thus a decrease in the efficiency to transfer of previously stored energy. Therefore, in the present study, the acute stretching before the endurance exercise bout resulted in less efficient movement, as indicated through prolonged GCT. As a consequence, it is likely that maintenance of a given velocity required increased recruitment of motor units to maintain the specified pace as evidenced by increased EMG activity in the stretching condition.

Practical Applications

The collective results of our research indicate that static stretching results in performance decrements in short-duration endurance events. Therefore, coaches and athletes should avoid static stretching immediately before engaging in endurance activities. Future research should investigate if rest after a static stretching bout (e.g., 15 minutes) might prevent declines in endurance performance.

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