

THE EFFECTS OF STATIC vs. DYNAMIC STRETCHING ON RUNNING
ECONOMY AND PERFORMANCE

by

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INTRODUCTION

In this age, a hot topic in the sport of track and field is stretching. What kind of stretching should be performed? Are there preferred stretching techniques for different event areas? Should stretching even be done? Countless studies have been conducted to investigate the effects of stretching on various types of physical performance. They have studied effects on flexibility (3), force production (16), isokinetic strength (18), sprinting (8), and agility (23) to name just a few. There are also investigations designed to determine the answers to questions such as the optimal time (3), duration and intensity of stretches (4). Stretching is a key component to training programs, yet only recently have in-depth studies on the effects of a less-obvious response to stretching been conducted. That is, the effects on endurance performance related to oxygen consumption, energy cost, and running economy.

It is a common theory that stretching helps prevent injury. This makes sense if looked at superficially, yet the basic science literature supports the epidemiologic evidence that stretching before exercise does not reduce the risk of injury (19, p. 227). In specialty sports involving continuous movement where stretch-shortening cycles are of low intensity like jogging, swimming, or cycling, strong evidence exists that stretching has no beneficial effect on injury prevention (22, p. 443). This research is enlightening solely because it defies common knowledge. The spread of these findings could affect many training programs. In track and field specifically, warm-ups is thought to be essential. Warm-ups generally include a short aerobic component, drills specific to the event area, and lots of stretching; yet today research has found possible detrimental effects caused by stretching. In sprinting, where forceful contractions are essential, it was

concluded that passive static stretching in a warm-up decreases sprint performance (8, p. 784). Many sprint coaches would agree with this statement. A common phrase in the sprinting community is “a tighter muscle is a stronger muscle.” This is why you rarely see them performing static passive stretching. You do see them perform dynamic stretching however, and this important difference between the two stretching techniques has already yielded many interesting conclusions. Even in distance running, studies suggest that stretching before an endurance event may lower endurance performance and increase the energy cost of running (21, p. 2274). This is vital for distance runners where running economy and energy cost instead of muscle force is essential. Already in two very different athletic arenas, detrimental effects of stretching and/or its type have presented themselves.

Static stretching is defined as the technique used to stretch muscles while they are at rest. It is commonly referred to as the “stretch and hold” technique by many coaches and trainers. Touching your toes for ten seconds is a classic static stretch. Effects on strength, power, flexibility, agility, and balance have all been investigated. The work of Needham et al. (15) arrived at the conclusion that static is most beneficial after a training session rather than before. American Council of Exercise fitness expert Jessica Matthews (MS, E-RYT) stated it clearest: “While static stretching does have its benefits, such as improved posture and flexibility, the best time to perform this type of stretching is at the conclusion of a workout during the cool-down phase, as it is best to stretch muscles when they are properly warmed, and therefore more pliable”. Bandy and Irion (3) agree with the fact that static stretching increases the length of the muscles and therefore their flexibility. However, it was shown that pre-exercise static stretching may temporarily

compromise a muscle's ability to produce strength either isometrically or isokinetically (18, p. 268). So in a sense, this mode of stretching can positively affect flexibility yet negatively affect strength. This leads to the effects on force and power. A statically stretched muscle is more elastic. A stiffer musculotendinous unit would be more effective during the initial transmission of force, thus increasing the rate of force development (16, p. 790). A lengthened muscle due to an acute bout of static stretching could have a less than optimal crossbridge overlap which could diminish muscle force output (4, p. 2641). This concurs with the sprint coaches' theory that "a stiff muscle is a strong muscle." Static stretching would hinder the ability to generate power and force via a reduced force-velocity and length-tension relationship.

Dynamic stretching is defined as actively moving a joint through the range of motion required for a sport in a controlled manner. From a competitive training standpoint, it seems natural to gravitate toward this approach; and the track and field community has. Dynamic stretching is currently replacing static stretching in the modern athletic warm-up (4, p. 2635). The literature tends to indicate that shorter durations of dynamic stretching do not adversely affect performance, and longer durations may actually facilitate performances. Other studies show that at least dynamic stretching does not impair performances. The primary mechanism involved is the positive response to the neuromuscular system provided by longer durations of dynamic stretching. This positive response is the enhancement of neuromuscular function hypothesized to increase force output (7). Because this technique mimics the movements performed in subsequent training or competition and provides similar acute increases in static flexibility as static stretching, dynamic stretching has become preferable. (4, p. 2644-5). Performance

enhancements involving force and isokinetic power were demonstrated with more compared with less than 90 seconds of dynamic stretching (2) Dynamic warm-up activities have been reported to result in improvements in shuttle run time, medicine ball throw distance, and five step jump distance (14), as well as a tendency for increased vertical jump height (6) There have even been studies showing facilitation of performance with shorter durations of dynamic stretching (10). Manoel et al. (13) reported improved knee extensor power with short durations of dynamic stretches as well. Mechanisms by which dynamic stretching improves muscular performance have been suggested to be elevated muscle and body temperature, post-activation potentiation in the stretched muscle caused by voluntary contractions of the antagonist, stimulation of the nervous system, and/or decreased inhibition of antagonist muscles (4, p. 2646). Behm (4) states dynamic stretching increases the rate of cross-bridge attachments allowing a greater number of cross-bridges to form, and resulting in an increase in force production. As a result of these effects, dynamic stretching may enhance force and power development.

Now it is obvious the choice of stretching technique if you were going to pursue strength, high speed, explosive, or reactive activities. This would mean engaging in dynamic stretching before sprint events, jumps, and throwing events, the majority of track and field. One event area remains largely overlooked, however. The distance events in track and field (1500 meters and up) are unique. The basis dictating success in these events depends on running economy and efficiency rather than pure skeletal muscle strength and power. Running economy (RE) is typically defined as the energy demand for a given velocity of submaximal running, and is determined by measuring the steady-state

consumption of oxygen (VO_2) and the respiratory exchange ratio (RER) (17, p. 465). So instead, greater success in these activities comes from cardiovascular and mitochondrial functions where high cardiac output and high VO_2 maxes are favored. It seems like the importance of dynamic stretching in the warm-up may be diminished here. Yet is static stretching even a better option? According to the literature, static stretching has been shown to decrease leg press 1-repetition maximal tests, 20-m sprint performance, vertical jump height, and knee-extensor concentric torque (21, p. 2274). These decrements in performance are attributed to greater stress relaxation of the muscle tissue, which leads to lower muscle-tendon stiffness and strength. Decreasing strength and muscle-tendon stiffness may be deleterious to endurance runners because it has been reported that individuals with high muscle strength and muscle-tendon stiffness are more efficient (higher RE) than individuals with low muscle strength (1). It seems reasonable to suggest that static stretching may increase energy consumption during an endurance event, decreasing the performance of trained athletes. A possible explanation for performance deterioration is that static stretching negatively affects the ability of the muscle tissue to produce force (21, p. 2278). Arampatzis et al. (1) reported greater energy cost at a given velocity with decrements in muscle-tendon stiffness. Thus, it is possible that decrements in muscle-tendon stiffness after static stretching may have induced the number of motor units recruited to perform the same mechanical work. Activation of more motor units in a given condition may increase energy expenditure and provoke earlier fatigue onset (21, p. 2278). Another possible explanation is that the decline in muscle-tendon stiffness may have decreased the stride frequency during the running trials. It has been reported that

endurance athletes have preferred a stride frequency and amplitude in which energy consumption is minimized (11, p. 653).

So what kind of stretching is important prior to a distance event? There is significant debate concerning flexibility and RE. Improved hip flexibility, myofascial balance, and pelvic symmetry are thought to enhance neuromuscular balance and contraction, eliciting a lower VO₂ at submaximal workloads. These findings are compatible with the general belief among runners and coaches that improved flexibility is desirable for increasing RE (17, p. 474). In contrast, elastic energy storage and return could be enhanced by having a tighter musculo-tendinous system. Tightness in the muscles and tendons could increase elastic storage and return of energy and reduce the submaximal VO₂ demand. Inflexibility in the hip and calf regions was associated with better RE by minimizing the need for muscle stabilizing activity and increasing the storage and return of elastic energy (17, p. 474).

The researcher and enthusiast will need to look at and measure how efficiently the runner uses oxygen at a given pace rather than the force output generated by the muscles. A number of factors appear to influence RE in distance runners including metabolic adaptations, the ability of the muscles to store and release elastic energy by increasing the stiffness of the muscles, and less energy wasted on braking forces and excessive vertical oscillation associated with the runner's form (17, p. 466). The literature on stretching and vertical jumps, sprint performance, flexibility and strength greatly outnumbers that done on energy cost and other factors associated with endurance events. The purpose of this study is to determine the effects of static and dynamic stretching on running economy as well as a timed performance distance. The results could yield valuable information to

coaches, trainers, and runners on how to properly warm up before training or competition in order to maximize their performances.

It is hypothesized that dynamic stretching will produce the best results in running economy and a faster time in the designated distance. Although dynamic stretching has been seen to positively impact sprinting and power events, the physiological mechanisms that occur during dynamic stretching also improve movement overall. To discount its advantageous effects in distance running as well might prove ill-advised.

METHODS

Participants

Five NCAA Division I trained cross country runners (3 males and 2 females), ages 18 to 24, were selected as subjects for this study. All have undergone a collegiate training regiment for at least 9 months. They were biomechanically sound to the running motion therefore equipment-based error was diminished. None have undergone an exercise test like this before. All subjects signed a university-approved consent form prior to participation. They were injury free for at least the preceding 90 days.

Apparatus

A metabolic cart (Parvo Medics, Sandy UT) in combination with a treadmill (Trackmaster, City ST) was used to calculate the gas exchanges during the steady state and to set the distance for the performance run. Open space was allowed for subjects to perform the necessary stretching routines. A heart rate monitor (Polar, City ST) was worn by participants for each session.

Procedures

Participants underwent one preliminary laboratory test session, and three experimental trials, all separated by a minimum of 48 hours. The preliminary test session was to determine maximal aerobic capacity (VO₂max). This consisted of a graded exercise test to exhaustion on a treadmill to determine maximal aerobic capacity. The starting speed was individualized based on the participant's running background and capabilities (generally 1 mph slower than their 5-mile run training pace), and the treadmill speed and incline were increased every three minutes until VO₂max was reached. The runner wore a heart rate monitor and breathed into a respiratory gas collection mouthpiece.

The three experimental trials consisted of a control condition with no stretching, a 6-minute static stretching condition (table 1), and a 6-minute dynamic stretching condition (table 2). These were administered in a random order. Illustrations of the different stretching motions can be seen in figures 6-22. For each condition, the intervention was administered prior to completion of a 5-minute steady state run on a treadmill at a pace equivalent to each individual's first mile pace in a 5k race. During the run, oxygen uptake and respiratory exchange ratio (RER) were measured and recorded at 1-minute intervals for the first five minutes to determine running economy. The rating of perceived exertion (RPE-20-pt Borg scale) was recorded as well. The subjects then completed the remaining distance required to finish 5 kilometers with no pause in between. They assumed control of the treadmill's speed from there on with emphasis on a good pace to achieve a fast time. They were blind to the exact speed of the treadmill throughout this performance run. The study was done at the same time of day for each

individual for every session, and no activity was done before-hand for any subject. Time and heart rate at each half-mile were recorded.

Design & Analysis

The independent variables for this study were the mode of stretching (static, dynamic, and a control of no stretching) and time. The latter had multiple levels depending on the number of times a variable was sampled. Dependent variables of oxygen consumption, RPE, RER, heart rate, and performance times were recorded. Comparisons between results from the 3 sessions were statistically analyzed using a repeated measures analysis of variance. Significance will be accepted at the $p < 0.05$ level.

RESULTS

The results of the oxygen uptake analysis are displayed in Figure 1. There were no differences between conditions at any of the time points ($p=0.788$). There was a significant increase in oxygen uptake over the 5-minute period ($p=0.000$).

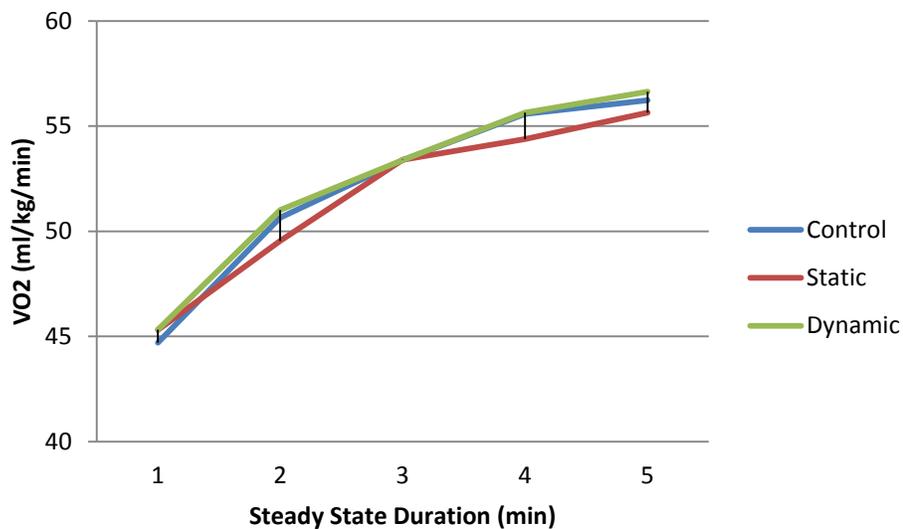


Figure 1 Oxygen uptake during the 5-minute steady state. $p=0.865$

The results of the RER analysis are displayed in Figure 2. There were no differences between conditions at any of the time points ($p=0.570$). There was a significant increase in RER over the 5-minute period ($p=0.000$).

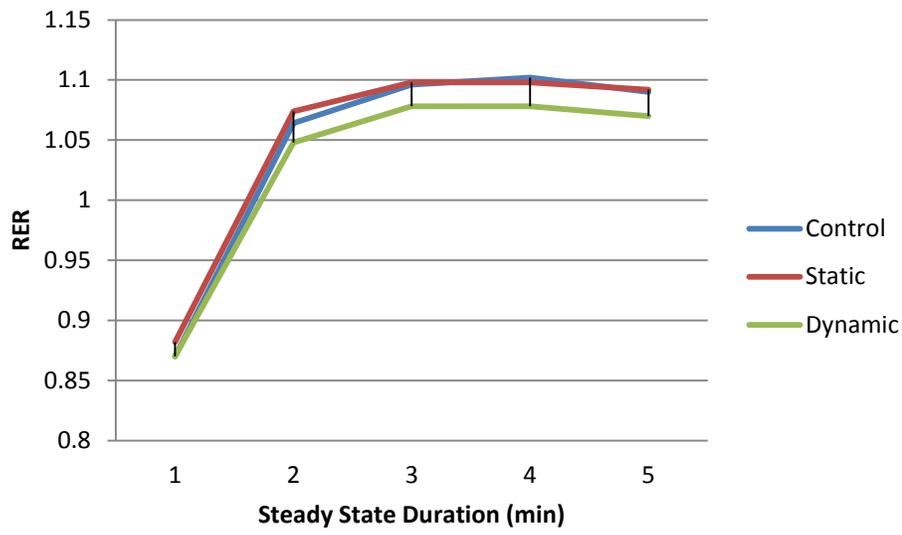


Figure 2 RER during the 5-minute steady state. $p=0.833$

The results of the performance times analysis are displayed in Figure 3. There were no differences between conditions at any of distance points ($p=0.476$). There was a significant increase in time over the 5-kilometer distance ($p=0.000$).

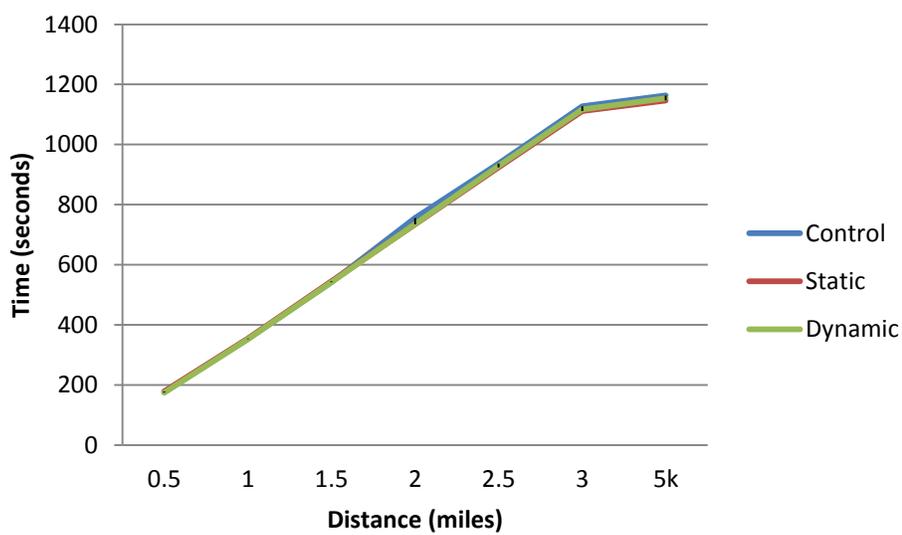


Figure 3 Performance time during the 5-kilometer run. $p=0.479$

The results of the heart rate analysis are displayed in Figure 4. There were no differences between conditions at any of the distance points ($p=0.649$). There was a significant increase in heart rate over the 5-kilometer distance ($p=0.000$).

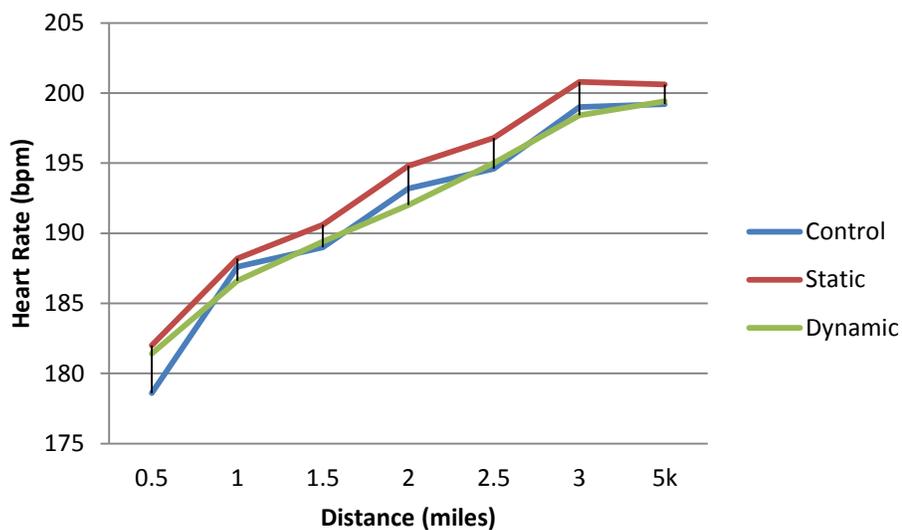


Figure 4 Heart rate during the 5-kilometer run. $p=0.322$

The results of the RPE analysis are displayed in Figure 5. There were no differences between conditions ($p=0.968$).

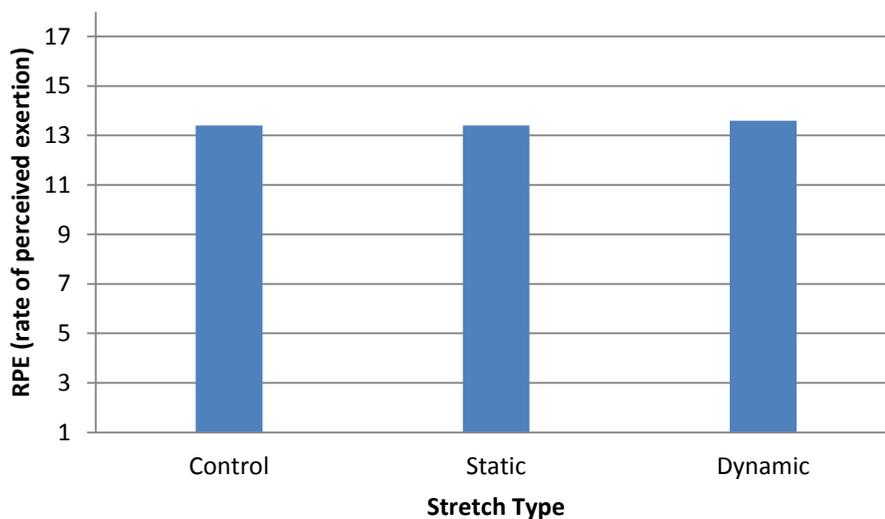


Figure 5 RPE during the 3 conditions. $p=0.968$

DISCUSSION

The purpose of this study was to determine the effects of static and dynamic stretching on running economy and performance. The main findings of this study did not support the hypothesis that dynamic stretching would produce better results in running economy and faster performance times. No significant differences were seen among the three conditions on any variable (VO₂, RER, performance time, HR, and RPE).

One physiological explanation for these results is the duration of stretching. Six minutes of static stretching (20 seconds of holding for each stretch) and six minutes of dynamic stretching were probably not long enough to produce differing effects. The American College of Sports Medicine suggests at least 10 minutes of stretching before and after exercise. Another physiological explanation is that in some subjects, their 5-minute steady states were not at true submaximal levels. This would wash out any effects of the stretching routines as VO₂ and RER would rise to near-maximal levels regardless of the treatment. Since the same near-maximal steady state pace was used for each trial in these subjects, it makes sense that the physiological responses to this same pace were the same each time due to washed out effects.

This study showed results different from the literature that suggested increased running economy from an increase in flexibility. It is possible that both the static and dynamic stretching routines increased subjects' immediate flexibility, but the lack of significant differences found between these experimental trials and the control trial of without stretching refuted the idea that RE increased with flexibility. Neither did this study support the literature that RE decreased with flexibility. Taken collectively, findings suggest that there is an optimal level of flexibility whereby RE can benefit,

although a certain degree of muscle stiffness is also required to maximize elastic energy storage and return in the trunk and legs (17, p. 475). We do not know if the 6-minute stretching routines used in this study were too much or too little in relation to that optimal level of flexibility.

Some practical implications found from this study alone suggest no preference in the modality of stretching before an endurance event. Each mode yielded similar results, so from a coaching standpoint, it is up to personal preferences. Some athletes report “feeling better” from very little stretching which supports previous ideas that muscle stiffness improves running economy. Trehearn et al. (20) found that subjects who exhibited the lowest flexibility were the most economical. Craib et al. (5) found that inflexibility at the hip and calf regions was associated with better RE by minimizing the need for muscle stabilizing activity and increasing the storage and return of elastic energy which has no additional oxygen cost. Jones et al. (12) showed that improved RE may reflect greater stability of the pelvis, a reduced requirement for additional muscular activity at foot strike, and a greater storage and return of elastic energy due to inflexibility of the lower body. Still, other athletes seem to “feel better” from lots of stretching. As far as static or dynamic, there still seems to be a trend toward more dynamic stretching before endurance events as distance coaches are starting to mimic sprint coaches’ dynamic warm-ups. Static stretching is usually performed following the event solely to prevent delayed onset muscle soreness (which is the common thought though not necessarily supported by research).

Further research should include attempting to find the optimal amount of stretching duration prior to an endurance event. Steady state levels should be low enough

so as to not wash out the effects of stretching. Overall, more should be done to discover relationships between stretching and running economy as it greatly lags in quantity behind stretching and flexibility, sprint performance, force production, agility, and muscle power.

The type of stretching is important for events requiring powerful explosive movements in which static stretching beforehand can greatly reduce performances. This might have spilled in to the endurance world which could explain this dynamic-oriented trend. Either way, runners should not abandon stretching as part of their training programs, as a certain amount of flexibility is also required for optimal stride length at high running speeds (17, p. 475).

Limitations

There might have been differences in fitness levels and running form among the 5 participants. Performance times might not reflect the influence of stretching but instead how the subject might feel that day. To avoid this, the same starting speed was used for each trial so as to induce the same amount of exertion each time. Factors such as nutrition and amount of sleep, however, were not controlled.

APPENDIX A

Static Stretching Routine		
Sit-and-reach toe touch	x 20 sec	
Straddled toe touches	x 20 sec	R, L, center
Flaming quad stretch	x 20 sec	R, L
Wall calf stretch	x 20 sec	R, L, both
Butterfly groin stretch	x 20 sec	
Hurdle stretch	x 20 sec	R, L
Covergirl glute stretch	x 20 sec	R, L
Sitting-cross-leg stretch	x 20 sec	R, L

Table 1

Dynamic Stretching Routine		
Arm circles	x 10	forward, backward
Iron crosses	x 10	R, L
Scorpions	x 10	R, L
Scissors	x 10	fwd & bkwd, side-to-side
Donkey kicks	x 10	R, L
Cat and cows	x 10	
Leg swings	x 10	R,L; sideways & in front
Ankle circles	x 10	R, L; clockwise & counter
Calf raises	x 10	

Table 2

APPENDIX B



Figure 6 Sit-and-reach toe touch



Figure 7 Straddled toe touches



Figure 8 Flamingo quad stretch



Figure 9 Wall calf stretch



Figure 10 Butterfly groin stretch



Figure 11 Hurdle stretch



Figure 12 Covergirl glute stretch



Figure 13 Sitting-cross-leg stretch



Figure 14 Arm circles



Figure 15 Iron crosses



Figure 16 Scorpions

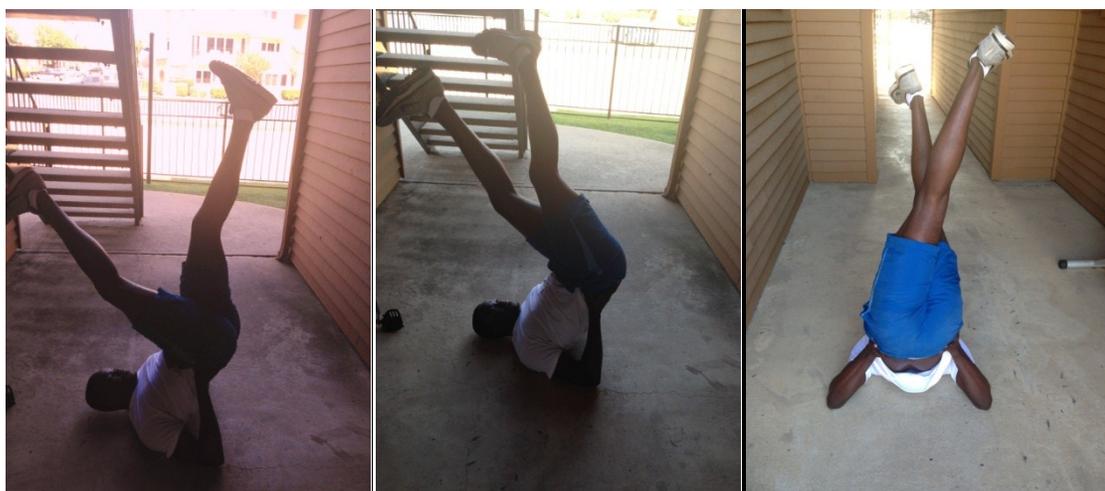


Figure 17 Scissors



Figure 18 Donkey kicks



Figure 19 Cat and cows

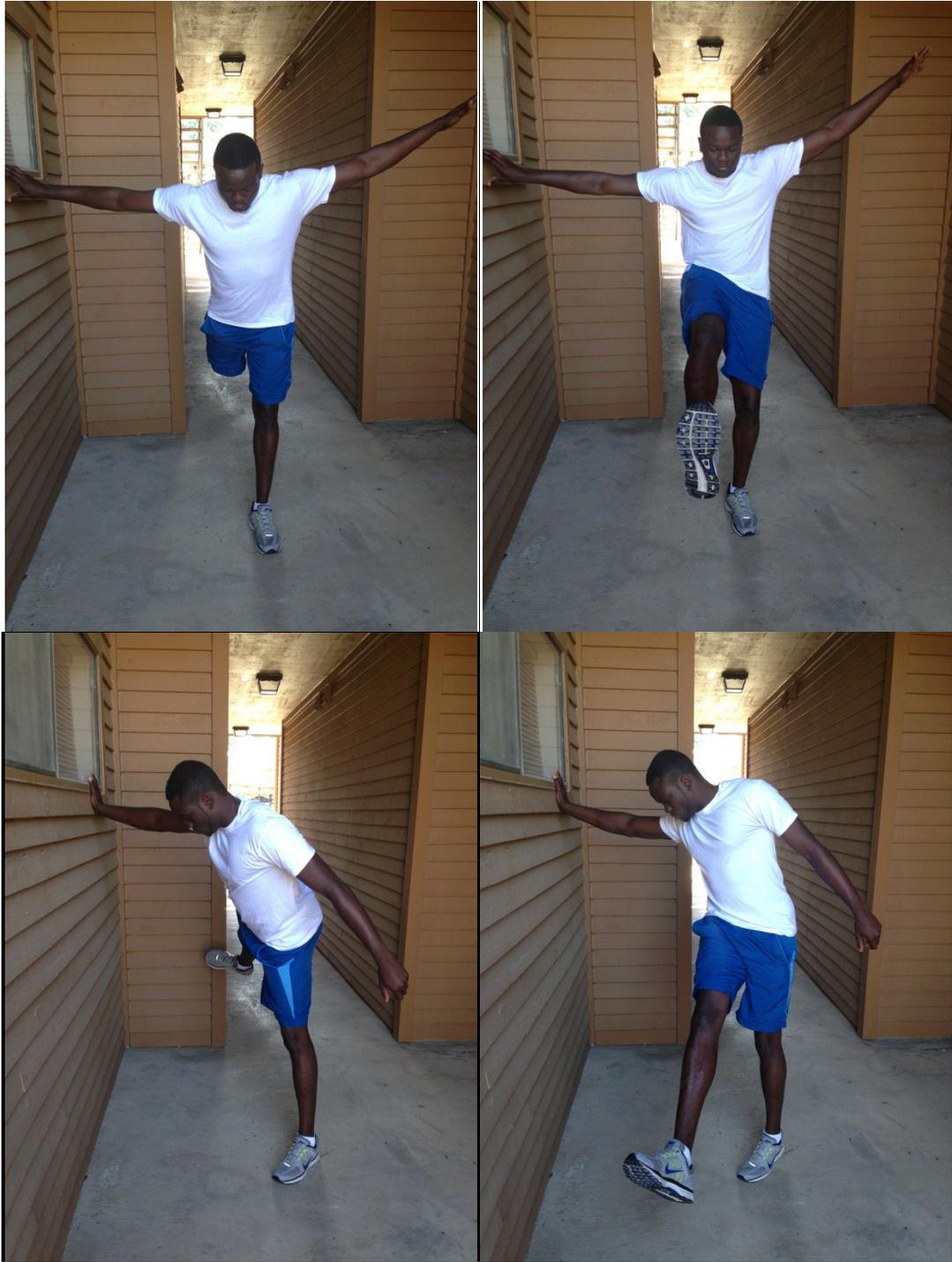


Figure 20 Leg swings



Figure 21 Ankle circles



Figure 22 Calf raises

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ABSTRACT

The purpose of this study was to determine the effects of static and dynamic stretching on running economy and performance. Three male and two female collegiate distance runners aged 19-24 were recruited. Participants reported to the laboratory on 4 separate days. On day 1, VO₂ max was measured. On days 2 through 4, participants performed a 5-kilometer treadmill run randomly under no stretching, static stretching, or dynamic stretching conditions separated by at least 2 days. Static stretching consisted of 6 minutes using 8 reach-and-hold exercises for the major muscle groups, whereas dynamic stretching consisted of 6 minutes using 9 active-stretching exercises for the major muscle groups. The run consisted of a 5-minute steady state followed by the rest of the distance to complete 5 kilometers where participants ran as fast as possible without viewing speed. VO₂ and RER were measured at 1-minute intervals during the steady state, while heart rate and time were measured at 1/2-mile intervals for the entire run. RPE at the end of the steady state as well as final 5-kilometer time were also recorded. There was no significant difference between the three conditions for any variable. This finding suggests little effect of stretch type prior to an endurance event, or that optimal stretching duration should be determined through more research.