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THE EFFECTS OF ACUTE STRETCHING ON RUNNING ECONOMY

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ABSTRACT

Zimmer AM, Burandt AR, Kent CN. The Effects of Acute Stretching on Running Economy, *Journal of Undergraduate Kinesiology Research* 2007;3(1):52-61. Stretching has been used for many years before exercise as a way of preventing injury and improving performance. More recently, several studies have shown that stretching may inhibit power and sprinting sport performances. **Purpose:** This study will investigate whether acute static or dynamic stretching prior to sub-maximal running will have an effect on running economy. **Methods:** Twelve males, age 18-36, participated in a VO₂ max test followed by three stretching interventions (dynamic, static, and no stretching) through performing running economy tests. **Results:** Statistical analysis revealed no significant differences ($p \leq 0.05$) in oxygen cost and heart rate between treatment groups. **Conclusion:** Based on our results, we conclude that pre-performance stretching does not adversely affect running economy in male endurance trained athletes.

Key Words: Endurance, Performance, Warm-Up, Flexibility, Dynamic, Static

INTRODUCTION

Stretching has been used for many years as an essential component in many physical training programs (1). In the past, stretching has been implemented as an important part of physical training programs as a way of increasing sports performance, as well as reducing the risk of injury. Stretching is also very important as a way of improving coordination and proprioception, increasing range of motion, improving circulation, and providing smoother muscle contractions, as well as increasing flexibility (2). Two popular types of stretching are dynamic and static. Dynamic stretching involves movements that imitate specific actions that are used during exercise (2). Static stretching involves slowly stretching a muscle to the end of the range of motion and then holding that position for an extended period of time (3).

Recently, there have been many researchers that have concluded that acute static stretching prior to exercise may actually inhibit power and sprinting sport performances. A study done by Nelson and

colleagues supports the theory that acute static stretching has a negative effect on strength and power performance (4). They specifically found that sprinting times have increased following stretching. The decrease in sprint performance was thought to be attributed to a decrease in muscle/tendon stiffness, and therefore a reduction in the amount of stored elastic energy (2). Throughout McNeal and Sands' review they found very few studies that examined other stretching methods, including dynamic (5). In the studies that did focus on dynamic stretching, they found evidence to suggest that the negative effects of acute static stretching can be improved when followed by a brief bout of dynamic exercise prior to the maximal activity (5). In a study by Fletcher and Anness it was found that sprint times decreased following a bout of active dynamic stretching as well as static dynamic (2). This improvement is thought to be attributed to the rehearsal effects that dynamic stretching provides, in addition to an increase in blood flow and core temperature of the specific muscles involved in sprinting (2). Along these same lines in a 2001 study conducted by Young and Elliot found that drop jump performance decreased following a bout of acute static stretching, attributed to a reduction in muscle/tendon stiffness (6).

Shrier's review of the literature in 2004 supported the conclusion that an acute bout of dynamic stretching decreases the tightness of the muscle/tendon unit (7). This becomes important in power and sprinting performances because stretching lengthens the resting fiber length of the muscle, therefore, taking the muscle longer to contract (7). In a more recent review, done in 2007, the authors also reinforced past research when they examined whether acute or regular stretching affected sport performance (8). The study found the effects of stretching and strength performance both very important, but concluded that stretching should be done after exercise or at a time not related to exercise. Collectively, these studies examined the effects of stretching on strength and power performance, but there is limited research regarding the impact that stretching has on running economy in endurance trained athletes. Only one study could be found regarding the effects of acute stretching on running economy, and the population was unknown (9). The question then becomes what is running economy, and why is it important for endurance trained runners and their performance?

Running Economy is simply the volume of oxygen, relative to body weight (VO_2), that the body requires in order to run at a particular speed (10). In endurance-trained runners, running economy becomes important because it is directly related to the amount of oxygen needed for a given speed. Individuals with a greater running economy are able to maintain higher intensity of exercise for longer periods of time, which is ultimately thought to improve their athletic performance (4). It is apparent from previous research that static stretching inhibits power and sprinting performance. It is unclear, however, whether stretching affects running economy, and ultimately endurance performance. This study will investigate whether acute static or dynamic stretching prior to sub-maximal running will have an effect on running economy, which is shown to be related to performance. It is hypothesized that static stretching will have a negative effect on running economy, whereas dynamic stretching will improve running economy in endurance trained runners.

METHODS


Subjects

Twelve male endurance trained runners were recruited for this study. Individuals ranged from 18 to 36 years old. Each subject was recruited by advertising around the Kinesiology Department and through word of mouth at the University of Wisconsin-Eau Claire. It was required that all of the participants ran a minimum of three hours a week, and had completed a running competition within the past three to six months prior to the start of the study. The subjects' age, height, and weight are

reported in Table 1. The study was approved by the University Human Subjects Institutional Review Board, and each participant was required to give written informed consent prior to participation.

Table 1. Descriptive data of the subjects.

Conditions	N	Minimum	Maximum	Mean \pm SD
Age (years)	12	18.00	36.00	20.75 \pm 4.866
Mass (kg)	12	59.10	82.10	68.95 \pm 6.584
Height (cm)	12	170.18	193.04	181.82 \pm 7.689
Body Fat %	12	3.02	11.18	6.36 \pm 2.96



Instrumentation

For each participant VO_2 was measured using a Medgraphics Cardio₂ Combined VO_2 /ECG Exercise System (manufactured in Palm Springs, CA). The treadmill that corresponded with this metabolic cart is a Woodway (manufactured in Waukesha, WI). To measure the participants' heart rate during testing a T31 Heart Rate Monitor Transmitter, manufactured by Polar Electro Inc. (Woodbury, NY) was used. Lange skinfold calipers (C-130) (manufactured in Cambridge, MD) were used to determine the participants' body fat percentage. The sites that were measured to calculate the men's body fat percentage included: the thigh, abdomen, and chest. We then calculated the participants' body fat percentage using the Jackson and Pollock equation (3).

Calibration

To calibrate the metabolic carts, barometric pressure, room temperature, and room humidity were entered into the computer system. The vacuum pump was then turned on and calibrated with the pneumotach (3-liter syringe). The gas analyzers were calibrated using known and consistent gas concentrations.

Procedures

Pretest Instructions

Before participation subjects were told to refrain from vigorous exercise 24 hours prior to testing, and were asked not to exercise on the day of testing. Subjects were also told to avoid eating a large meal at least five hours before coming in to test. Participants were encouraged to be properly rested, and well hydrated prior to testing. Subjects were also asked to wear the same type of apparel during each testing session.

Testing

In the first session, each subject's body composition was measured, as well as their height and weight. Following this each of the subjects were hooked up to the metabolic cart and its corresponding treadmill. Using the Modified Balke protocol each of the participants VO_2 max was recorded along with their corresponding ventilatory threshold. VO_2 max was measured as the highest amount of oxygen consumed over a 30-second period during the last three minutes of the test. VO_2 max was confirmed with the subjects achieving a rating of 9-10 on the 0-10 RPE scale and a RQ rating of 1.15 or higher (3). Ventilatory threshold was determined as the point in which ventilation increased disproportionately (non-linearly) to exercise intensity. During the subsequent sessions, subjects performed one of three stretching protocols. These protocols were randomized to the participants as demonstrated in *Table 1*. After the subjects performed one of the stretching protocols, described later, they then completed a running economy test. This test involved running at three different submaximal levels on the treadmill for seven minutes. The treadmill speeds used were 6.2 mph, 7.5 mph, and 8.7 mph. These levels were all below ventilatory threshold, which was determined during their VO_2 max test. During each seven minute interval, VO_2 and heart rate were recorded over the last two minutes and interpreted as steady state values.

Table 1. Randomization of stretching protocol.

Group	N	Subjects	Order of Stretching	
One	4	1,4,7,10	NS, S, D	<pre> graph TD A[5 minute Warm-up] --> B[No Stretch (NS)] A --> C[Static Stretching (S)] A --> D[Dynamic Stretching (D)] B --> E[Economy Test] C --> F[Economy Test] D --> G[Economy Test] </pre>
Two	4	2,5,8,11	S, D, NS	
Three	4	3,6,9,12	D, NS, S	

VO_2 Protocol

The VO_2 protocol used in this study was the Modified Balke (see figure 1). With this protocol a two minute walk at 3 mph was used to warm-up subjects. After the two minute warm-up, the speed was increased by 0.5 mph every five seconds, until the subjects reached 7 mph. Following this, every thirty seconds the speed was increased by 0.3 mph, until participants reached their VO_2 max. The time required to complete a standard VO_2 max test was approximately 12 minutes.

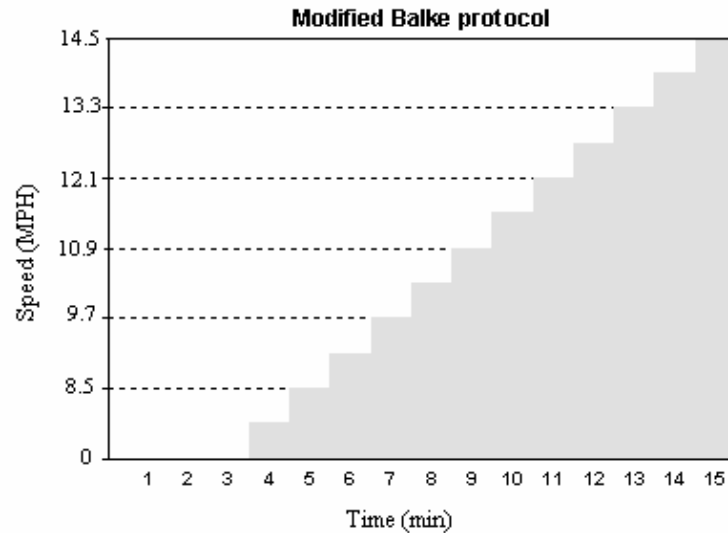
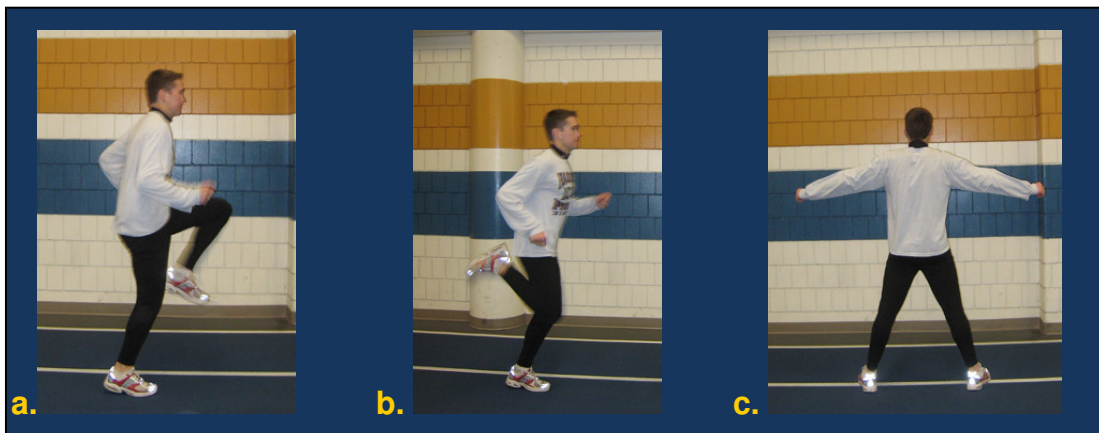


Figure 1. Modified Balke treadmill VO₂max protocol.

Pre-Economy Test Stretching Protocols

In this study, the effects of three different stretching protocols were analyzed. All three protocols included a low intensity aerobic warm up consisting of a five minute walk on the treadmill at three mph. In the first protocol, this warm up was not followed with any types of stretching prior to the economy test. Each economy testing session took approximately 45 minutes.

The second protocol used an acute bout of dynamic stretching following the aerobic warm-up. Each participant was instructed on proper technique for each dynamic stretch to insure consistency between subjects. Each type of dynamic exercise was performed two times over a distance of 50 meters on a mondo track surface in an indoor facility. The dynamic exercises that were performed included high knees, butt kicks, side skips, karaoke step, B-skips, and backwards running (refer to figure 2 for further description). High knees involve a movement similar to running with an exaggeration of pulling the knees toward the chest (figure 2.a). Butt kicks implement pulling the heel toward the hamstrings while performing a running motion (figure 2.b). Side skips involves moving in a lateral direction while alternating bringing the feet together and then moving them apart (figure 2.c). Karaoke step also involves moving in a lateral direction while bringing the trailing knee in front and across the opposite side of the body (figure 2.d). B-skips consist of performing a motion similar to high knees, but when the leg is at chest level the knee is extended and then rapidly snapped down (figure 2.e). Participants were allowed 30 seconds between exercises.



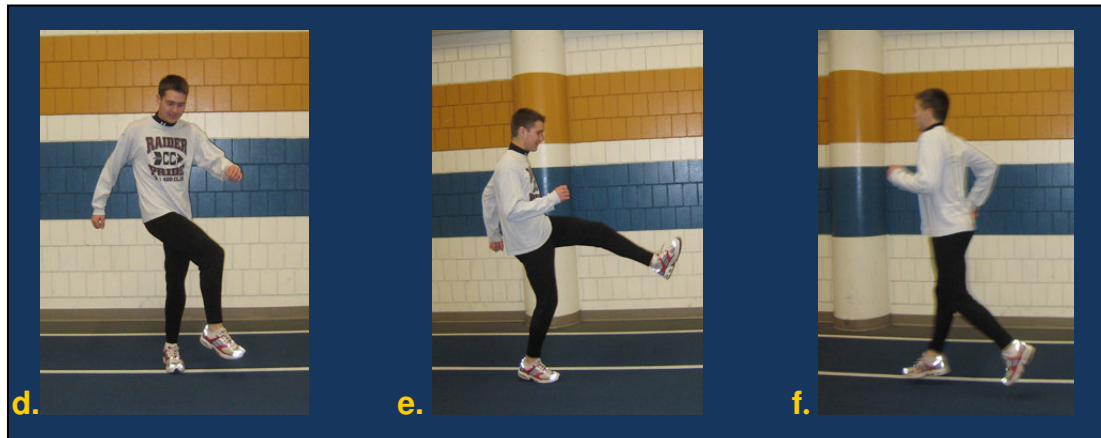


Figure 2. Dynamic Stretching protocol.

The final protocol implemented static stretching prior to economy testing. Participants were instructed on six different stretches targeting the main muscle groups. Each stretch was held for 30 seconds and was performed two times. Subjects cycled through the following stretches in this particular order; hamstring stretch, seated crossover, butterfly stretch, lumbar stretch, quadriceps stretch, and gastroc stretch (refer to figure 3 for further description). Subjects were given 30 seconds of rest between each stretch. Overall, the total time for all of the testing sessions was approximately 2 hours and 45 minutes.



Figure 3. Static Stretching protocol.

Statistical Analyses

All analyses were performed using Statistical Package for the Social Sciences, Version 15.0 (SPSS, Inc, Chicago, IL). Measures of centrality and spread are presented as mean \pm SD. Mean differences in VO_2 and heart rate performance following no stretching, static stretching, and dynamic stretching were assessed with one-way analysis of variance (ANOVA). Tukey's post hoc tests were performed to determine differences between treatment groups. The probability of making a Type I error was set at $p \leq 0.05$ for all statistical analyses.

RESULTS

Statistical analysis revealed no significant differences in oxygen cost between treatment groups for stage 1 [$F(2,33) = 0.005$; $p > 0.05$], stage 2 [$F(2,33) = 0.055$; $p > 0.05$], and stage 3 [$F(2,33) = 0.036$; $p > 0.05$]. Similarly, no significant differences in heart rate response between treatment groups for stage 1 [$F(2,33) = 1.359$; $p > 0.05$], stage 2 [$F(2,33) = 2.249$; $p > 0.05$], and stage 3 [$F(2,33) = 1.589$; $p > 0.05$]. The mean values and standard deviations (SD) for oxygen consumption and heart rate for all three stages are presented in Table 2.

Table 2. Mean testing values.

Conditions	No Stretch	Static	Dynamic
Stage 1 VO_2	39.64 \pm 3.02	39.53 \pm 2.99	39.66 \pm 3.85
Stage 2 VO_2	47.81 \pm 3.14	47.54 \pm 3.51	48.04 \pm 4.39
Stage 3 VO_2	56.39 \pm 3.68	56.26 \pm 4.38	55.91 \pm 5.27
Stage 1 HR	134.17 \pm 7.92	140.10 \pm 11.36	138.83 \pm 8.00
Stage 2 HR	151.15 \pm 6.82	153.89 \pm 6.96	157.21 \pm 7.43
Stage 3 HR	169.04 \pm 5.30	170.52 \pm 7.45	173.65 \pm 6.56

DISCUSSION

The purpose of our study was to determine whether an acute bout of stretching would have an effect on running economy in endurance trained runners. We found no statistically significant difference between various types of pre-exercise stretching and oxygen consumption at the pre-selected running speeds. Our findings failed to accept our hypothesis that static stretching would have a negative effect on running economy, whereas dynamic stretching would improve running economy.

Our research was one of the first studies to examine the effects of acute bouts of stretching on running economy in endurance runners. One other study was found regarding the effects of acute static stretching on running economy. They suggested that static stretching prior to performance would improve running economy. While this study's results were statistically significant, the population was unknown and it was reported that tight hip flexors/extensors prior to the study may have influenced the results (9).

Unlike sprint performance where pre-performance static stretching negatively effects sprint times, our study failed to exhibit similar results. One study regarding sprint performance and stretching showed that sprint times significantly increased after a bout of static stretching (5). The decrease in sprint times was thought to be due to a temporary loss of muscle stiffness following stretching. This decrease in stiffness increases muscle contraction time and results in slower sprint performances (2). This study also found that dynamic exercise prior to performance improved sprint times, because it provides a rehearsal effect that may increase coordination, as well as increasing blood flow and core temperature of the specific muscles involved in sprinting (2).

We suspect that our findings were different from previous sprint and power studies because the pre-selected speeds were sub-maximal, so muscles did not have to contract as quickly as they would during higher intensities. Theoretically, this would result in the recruitment of more Type I slow twitch muscle fibers, rather than a high amount of Type II fast twitch muscle fibers which is required in sprinting. We believe that this gave the muscles more time to react to the changes happening within the unit and possibly allowed for the aerobic capabilities of the Type I fibers to negate the effects of stretching. Perhaps if higher intensities were elicited during the economy testing we would have observed greater recruitment of Type II fibers and a greater reliance on stored elastic energy. Depending on the type of stretching this change could have affected running economy, with static stretching decreasing economy and dynamic improving economy.

In addition, we suspect that if we looked at performance in the form of a post stretching time trial rather than looking solely at the metabolic changes we may have found different results. Furthermore, it can be speculated that the changes that are occurring within the muscle tendon unit are only temporary. Currently, we are unaware of any studies that have looked at how long the effects of stretching on the muscle/tendon unit last. We can speculate that the duration of the economy test may have allowed each subject to recover from the negative or positive effects of stretching, which ultimately could have led to no change in their running economy.

Assumptions

In our study, we assumed that all subjects gave a maximal effort during their VO_2 max test. Results indicated that maximal efforts were obtained based on $RQ \geq 1.15$, $RPE \geq 9$, and a plateau in oxygen consumption with increasing workload. We also assumed that all subjects followed pre-test guidelines given to them prior to testing. Additionally, it was assumed that all instruments used over the course of the study were valid and reliable.

Limitations

There are several factors that may have influenced the results of our study. One of these limitations was that we did not include female subjects in our data collection. Therefore, the results may not be applicable to female runners. However, review of the literature shows that there is no physiological difference in the response to stretching between males and females (1). Another limitation is that we selected our subjects based on convenience, and only included endurance trained runners from the University of Wisconsin – Eau Claire.

Applications

The most important aspect of our study is that we are uniquely contributing to the gap in the research regarding stretching and endurance performance. Our main recommendation based on our finding is that male endurance trained athletes can participate in pre-performance stretching if desired. In addition, according to our research, the type of stretching does not seem to affect performance; therefore, based on our results, static or dynamic stretching can be done prior to endurance running. We feel that coaches and endurance trained athletes will benefit from our findings, because they can

continue to implement their stretching routine of choice without any apparent effects on running economy. Our results are applicable to male endurance trained runners between the ages of 18-36.

Future research

There are many areas that still need to be studied in regards to the effects of stretching on running economy. First, because our study involved a limited number of subjects (n=12) who were selected based on convenience further research needs to be done involving a randomized sample and a larger sample size. Furthermore, future research needs to include females and older individuals as subjects. This research needs to be done in order to determine if females and older adults will demonstrate similar results as the ones previously stated. More research also needs to be completed to evaluate the effects that stretching has on running economy in other sporting situations, as well as involving other stretching methods (such as PNF).

CONCLUSIONS

Based on our results, we conclude that pre-performance stretching does not adversely affect running economy in male endurance trained athletes. It is apparent the certain individuals respond differently to the various types of stretching, but it is unclear why this deviation occurs. To the best of our knowledge, athletes may implement either static or dynamic stretching prior to running without negative effects on their running economy. However, we feel that more studies are needed to clarify our results.

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