

DYNAMIC WARM-UP EFFECT ON 5-KM PERFORMANCE AND RUNNING ECONOMY
IN COLLEGIATE CROSS-COUNTRY RUNNERS

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Keywords: endurance, form drills, muscle stiffness, flexibility, energy cost

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ABSTRACT

The purpose of this study was to investigate the effects of a dynamic warm-up on running economy (RE) and 5-km performance compared to a control protocol in collegiate cross-country runners. Fifteen male cross-country runners underwent both a half-mile warm-up run at 65% VO_{2max} followed by either a dynamic stretching protocol or a control protocol. After the protocols, subjects completed a 5-km performance for evaluation of RE and performance. Sit-and-reach scores were recorded both before and after each protocol. RE was measured as the total calories expended during each 5-km and performance time was recorded. There was no significant interaction for the sit-and-reach. After the dynamic warm-up the sit-and-reach did not significantly increase (29.10 ± 13.66 to 31.23 ± 12.42 cm; $p > 0.05$) and did not significantly increase after the control protocol (29.08 ± 12.7 to 29.00 ± 13.46 cm; $p > 0.05$). Also, values post-dynamic drills were not significantly greater than those for the control protocol ($p > 0.05$). Running economy was not statistically different across conditions (dynamic: 234 ± 26 kcal; control: 239 ± 25 kcal; $p > 0.05$). There was no significant difference found among 5-km performance time (dynamic: 18 minutes, 0 seconds ± 52.52 ; control: 18 minutes, 26 seconds ± 55.00 seconds; $p > 0.05$). These findings suggest that dynamic stretching does not increase hamstring flexibility nor affect RE or performance in NCAA male distance runners.

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Manuscript

Dynamic Warm-Up Effect on 5-km Performance and Running Economy in Collegiate Cross-Country Runners

INTRODUCTION

Endurance running is composed of many various training variables, one of which is the much-debated aspect of the warm-up. Static stretching has been a major part of the warm-up, but a shift to the use of dynamic stretching has become a popular trend, as static stretching may actually hinder performance [1, 2]. An acute bout of static stretching has been shown to cause an increase of slack on the stretched tendons (a decrease in muscle stiffness) which in turn may reduce muscle-force generation and thus may cause a decrease in running economy (RE), defined as the number of calories expended over an exercise bout [2, 3]. Data have suggested that static stretching may relax the muscles, which may explain why there would be a decrease in running performance as a result [1]. Another study demonstrated a significant decrease in distance covered in a 30-minute run as well as an increase in energy expenditure after an acute bout of static stretching as opposed to a control protocol involving only a running warm-up [2].

In contrast, dynamic stretching has been less investigated up to this point [4, 5]. Dynamic stretching has been defined as a series of exercises incorporating sport-specific movement which prepares the athlete's body for activity [6]. In addition, dynamic stretching may provide the athlete with an optimal environment of increased neuromuscular function which then results in a greater force production [6]. While there have been studies conducted on static vs. dynamic

stretching [4], dynamic stretching on flexibility [5], and static stretching on running performance [2], the effect of dynamic warm-up on running performance is unknown.

Dynamic stretching may not cause significant increases in hamstring flexibility when assessed by passive knee extension range of motion [5]. Runners with a lesser sit-and-reach have been shown to have higher RE [7]. A linear relationship may also exist between leg stiffness and RE [3, 8]. We hypothesized that if dynamic stretching prepares the body for activity without decreasing muscle stiffness, then RE would not be affected by the sport specific warm-up and endurance performance would increase. Therefore, the purpose of this study was to investigate the effects of dynamic warm-up on RE and 5-km performance in collegiate cross-country runners.

METHODS

Approach to the Problem

This study had a randomized, crossover design in which the subjects underwent a control and experimental condition. In both conditions, the subjects began by running a half-mile at 65% of their VO_{2max} . In the dynamic condition, the subjects performed dynamic drills before the performance trial, whereas in the control protocol, they sat quietly reading the school newspaper. Sit-and-reach, RE, and performance time were compared across the 2 protocols.

Subjects

Fifteen trained male distance runners (Table 1) were recruited for this study from the cross-country teams of two NCAA DI and DIII Midwest institutions. Criteria for inclusion were a minimum weekly mileage of 45 miles averaged the past 2 years, as well as members of their school's varsity Cross-Country teams. Subjects were excluded if diabetic or considered a smoker. The subjects were instructed to not participate in heavy exercise ($> 65\% VO_{2max}$) 24

hours out from testing as well as maintain a 48 hour dietary log and complete a hydration protocol before each session. The subjects were informed of the experimental risks and read and signed an informed consent before undergoing any testing. The Indiana State University Institutional Review Board approved this investigation for use of human subjects.

48 Hour Dietary Log and Hydration Protocol

Each subject was required to keep a log, provided by the researchers, of all foods and beverages consumed 48 hours prior to the initial session. This log was to be strictly followed before sessions 2 and 3 so as to ensure that there was a consistent dietary pattern for each session. The night before each session, subjects were required to follow a hydration protocol to ensure proper hydration status. Approximately 4 hours before going to bed the subjects were to drink 600ml (20oz) of water, sports drink, or flavored water, avoiding caffeinated beverages and alcohol. Immediately before going to bed they were to drink an additional 600ml (20oz) of water, sports drink, or flavored water, again avoiding caffeinated beverages and alcohol. They were each provided a table to write the scheduled data to help keep track of the hydration commitment.

Sit-And-Reach

Each subject underwent a total of 5 sit-and-reach tests, 1 during the initial session and 2 during each protocol. Using an Acuflex I (Model 67091, Novel Products, Inc., Addison, IL) and following the ACSM protocol for sit-and-reach for trunk flexion testing [9], subjects placed their backs against a straight wall. The legs were placed in front as straight as possible and the test administrator placed her hand on the knees to ensure the legs remained straight through the test's entirety. Placing the right hand on top of the left, the subjects then inhaled and then exhaled while bending forward and pushing the plate as far as possible. This stretch was held for 2

seconds and then the subject returned to the starting position and went through the procedure again. The higher of the 2 scores was recorded and used for data analysis.

Procedures

The subjects reported to the laboratory at the same time of day (± 1 hour) on 3 different occasions, separated by 7 days (± 1 day). On the first visit, age, height, mass, sit-and-reach, body fat percentage, resting heart rate (HR) and blood pressure were obtained. Body fat percentage was measured using the BodPod (Life Measurement, Inc., Concord, California). Resting VO_2 measures were obtained for each subject using a calibrated Medgraphics metabolic cart (Model Ultima CPX, St. Paul, MN). The subject was then asked to undergo a VO_{2max} test using the Costill/Fox protocol [10]. For this protocol, all stages last 2 minutes, and start with a 0% incline. After the first 2 minutes and every 2 minutes thereafter, the treadmill was raised 2%. The speed stayed the same throughout the test at 4.0m/s. The test was considered maximal if 3 of the following 4 criteria were met: 1) plateau in O_2 consumption for an increase in exercise intensity ($<2.0 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ increase), 2) $RER \pm 1.1$, 3) $HR > 85\%$ age-predicted max, and/or 4) $RPE > 18$.

Visits 2 and 3 were randomly determined and consisted of a half-mile warm-up at 65% of their VO_{2max} followed by 1 of the 2 conditions: dynamic stretching or a control protocol (ie. sitting quietly reading the student newspaper). The subjects were then allowed a 2-minute period for pre-race strides simulation. Then the subjects were asked to complete a 5-km run on the treadmill as fast as possible. The subjects were unable to see their current time, distance, or speed, but were verbally given each kilometer split to simulate a cross-country race.

Dynamic Protocol

The dynamic protocol for this study was modified from Zourdos et al. and Wilk et al. [11, 12]. A total of 8 different drills were completed on a clearly marked 15m straight-away and were completed twice at that length. The dynamic drills were performed in the following order: (a) Heel-to-toe Walk: The subject stepped with the right foot placing the heel down first and rolled up onto the toes rising briefly and then repeated with the left foot. (b) Walking 'A' Skip: The subjects stepped on the ball of right foot and lifted left leg, driving the knee upward (parallel to the ground), dorsiflexing the left foot and rising up on the right toes. Then the subject stepped down with the left foot and repeated with the opposite leg. (c) 'A' Skip: This is similar to the "Walking 'A' Skip," but the subjects added a hop after placing the foot down and during the knee drive. The foot was returned to the ground directly under the hips. (d) 'B' Skip: Similar to "A' Skip," but the leg driving the knee then extends outward and then "paws" down to the ground, again with the subject's foot landing underneath the hips. (e) Heel-to-Glute: The subject combined a butt-kick and high-knee drill, pulling the foot up toward the buttocks, but before reaching, pulls the knee upward with the foot dorsiflexed. (f) Side Shuffle: The subject faced the right side and stepped the left foot laterally with a shuffle, then shuffled the right leg to meet them together. The subject then switched legs while still facing the right side on the way back. (g) Carioca: The subjects faced the right side and hop-stepped the left leg to the side, then took the right leg and crossed it behind the body, stepping again to the side with the left leg and then took the right leg and crossed it in front of the body. The drill coming back faced the right side again, but switched the legs. (h) Straight-Leg Run: Subjects kept their knees straight and ran with their legs extended trying to return the feet under the hips. On the non-dynamic days, subjects sat quietly for 10 minutes before the exercise protocol and were given the student newspaper to read.

STATISTICAL ANALYSIS

The baseline characteristics were analyzed using a one-way analysis of variance (ANOVA). A repeated measures ANOVA was used to examine the condition (control protocol versus the dynamic protocol) by time (pre versus post) interaction on the sit-and-reach, RE, and 5-km performance time were examined using a one-way ANOVA across conditions. If an interaction was deemed statistically significant, then main effects were analyzed using paired t-tests. Significance was set *a priori* at $p < 0.05$. Values are presented as mean \pm standard deviation (SD).

RESULTS

Flexibility

There was no significant interaction for the sit-and-reach. After the dynamic warm-up the sit-and-reach did not change (29.10 ± 13.66 to 31.23 ± 12.42 cm; $p > 0.05$) and did not significantly increase after quiet sitting (29.08 ± 12.70 to 29.00 ± 13.46 cm; $p > 0.05$). Also, values post-dynamic drills were not significantly greater than those for the control protocol ($p > 0.05$).

Running Economy (Energy Expenditure)

Running economy was not found to be statistically different across conditions ($p > 0.05$). The dynamic protocol had a mean of 234 ± 26 kcal expended compared to the control mean of 239 ± 25 kcal (Figure 1).

5-km Performance Run

There was no significant difference found among 5-km performance times between conditions ($p > 0.05$) (Figure 2). After the dynamic drills, the mean 5-km time was 18 minutes, 0 seconds \pm 52.52 seconds and after quiet rest was 18 minutes, 26 seconds \pm 55.00 seconds.

DISCUSSION

The purpose of this study was to investigate the effects dynamic stretching may have on 5-km performance time as well as RE in trained male collegiate cross-country runners. The main finding in this study was that there was no significant difference in performance time between the dynamic drills and the control protocols. This is the first study, to our knowledge that suggests that dynamic warm-up does not affect 5-km performance time in male NCAA cross-country runners.

Bishop suggested that adding bursts of specific movement into a warm-up may give additional benefits as long as they are brief in order to avoid fatigue [13]. In a study by Zourdos et al., it was discussed that the dynamic protocol used was too long and may have negatively affected their results [12]. No significant difference in performance was found between the dynamic and control protocols in their study. Hayes and Walker used male middle distance and long distance runners, cross-examining them across 4 protocols [14]. The first protocol of static stretching called for each stretch to be held for 30 seconds and was repeated twice. The second protocol, “progressive static stretch” used the same stretches as the first protocol, but only held the stretch for 10 seconds and then followed this by passively moving the limb and holding that further stretch for 20 seconds and again repeating all stretches twice. The third protocol, “controlled velocity dynamic stretching” used the same stretches as the previous protocols, but were turned into dynamic movements. The fourth protocol was the control. No significant differences were found, but there were a small number of subjects and a non-specific distance to the athletes’ training status was used. These studies share similar findings to the present study, that dynamic drills do not have an effect on endurance running performance.

However, Verrall et al. looked at Australian Rules football players, following them through two competitive seasons while noting their hamstring injuries [15]. After these two seasons, sport-specific drills, along with a stretching protocol and increased interval training programs were then implemented. Continuing these new implementations, the athletes were tracked for another two seasons. The end result was a decrease in hamstring injuries, thus boosting performance since fewer games were missed. However, since dynamic drills were not the only new variable added, it cannot be deduced that these were what helped reduce the hamstring injuries the most. However, it is apparent that they might have played a role. Fletcher et al. used male collegiate semi-pro soccer players, putting them through 3 protocols: no stretch, static passive stretch, and static dynamic stretch [1]. This study did find a significant increase in their countermovement jump test with the static dynamic stretch protocol. Therefore, in this study, dynamic drills did have a performance-enhancing effect. Faigenbaum et al. studied 4 warm-up protocols and their effects on anaerobic performance in high school females [16]. All 3 of the dynamic warm-ups resulted in significantly better vertical and long jumps as compared to the static stretch protocol. Since there was no control group, however, we cannot conclude from this study that doing the dynamic drills is better than doing just the warm-up. It may be suggested from these studies that in sports where anaerobic bursts are prevalent, dynamic warm-up may be a performance-enhancing variable.

Nummela et al. cited that for nearly a century it was believed that endurance performance was limited by a person's VO_2 capabilities [17]. Foster et al. recently stated that there are really 3 variables which dictate running performance: 1) a high VO_{2max} , 2) the ability to maintain a high percentage of that VO_{2max} for a long duration, and 3) RE [18]. Endurance runners with better RE will exhibit less energy use than those with lesser RE when running at the same speed [19, 20].

Astorino followed distance runners through a cross-country season and used 8 minute bouts on the treadmill to track RE [19]. From the beginning of the season to the end, neither RE or VO_{2max} increased. However, the fitness level at the beginning of the study was not reported. Bragado et al. followed distance runners through two competitive seasons. RE, other measured variables, and performance time of a 3,000m run were examined. Over the seasons, performance time actually decreased significantly [21]. It was concluded that RE was perhaps the least important variable for the study, but was probably due to the short race length [22]. From these two studies examining RE, we see no long-term improvement; however there was no alteration in training methods, especially those to focus on enhancing RE. The present study matches these previous findings, in that dynamic drills applied to distance runners do not affect RE.

It has been shown that runners with a better RE tend to exhibit more leg stiffness than another runner of similar VO_{2max} [3]. A study by O'Sullivan et al. compared subjects with previous hamstring injuries to an uninjured control group, all of whom were competitive athletes. Significant increases in hamstring flexibility were seen with both the dynamic and static protocols, but the dynamic protocol had a lesser effect on flexibility than static stretching [5]. In the study by Zourdos et al., a significant increase was seen in sit-and-reach scores with the dynamic protocol[23]. Therefore, the present study contradicts these findings as the sit-and-reach scores post-dynamic drills were nearly identical to those found post-control protocol.

In summary, the present study found that dynamic stretching does not enhance or decrease performance time over 5-km when compared to doing only a running warm-up. However, when comparing a mean of 18 minutes, 0 seconds following the dynamic drills to that of 18 minutes, 26 seconds not doing drills, an athlete is going to look to getting any edge he can. Statistically the data in the present study were not found to be significant, but from an athletic

standpoint it may be looked upon as an advantage. Further investigations are necessary using different distances (both shorter and longer in duration) as well as using different populations (women or non-collegiate athletes).

PRACTICAL APPLICATION

The present study showed that dynamic drills did not have a significant performance-enhancing quality when compared to a non-stretching warm-up. Physiologically speaking, the dynamic protocol exhibited a 28 second decrease in overall 5-km time compared to the control protocol. This may be important to any athlete looking for that extra edge over the competition. Therefore, dynamic warm-up may be used to gain a minimal advantage over the competition based on these data. However, this study is only applicable to the population tested (collegiate, cross-country, male) and conditions specific to this study. When looking at the performance time graph, it is clear that responses were individualized as some subjects saw up to 90 second differences whereas others saw just a few seconds difference in protocol performance. It is always important to keep in mind the individual athlete when prescribing a workout routine.

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Table 1. Subject Characteristics

Age (years)	20 ± 1
Height (m)	176.27 ± 5.96
Mass (kg)	68.93 ± 6.38
Body Fat (%)	7.8 ± 2.32
$\text{VO}_{2\text{max}}$ ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)	58.09 ± 3.90

Data are presented as mean \pm SD

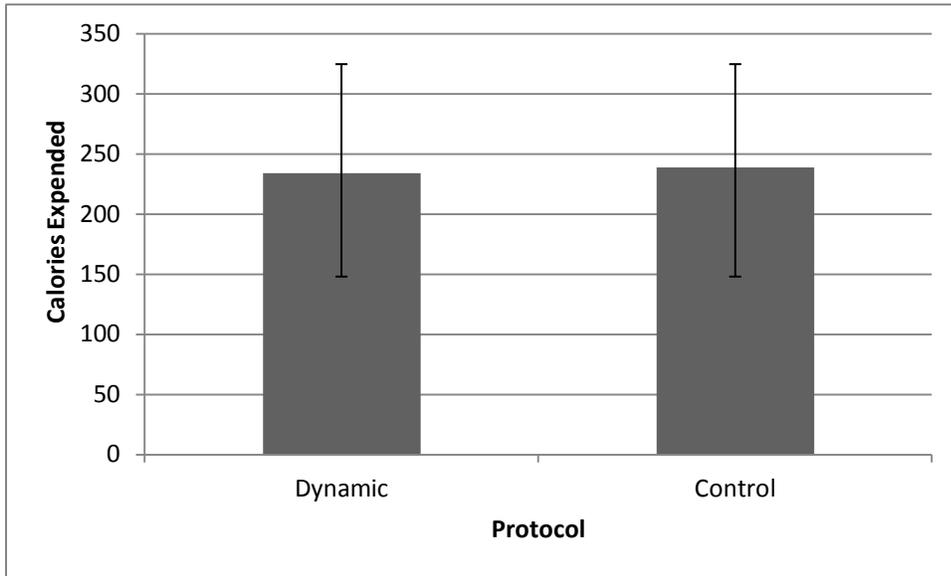


Figure 1. Running Economy (Calories Expended)

Data are mean \pm SD

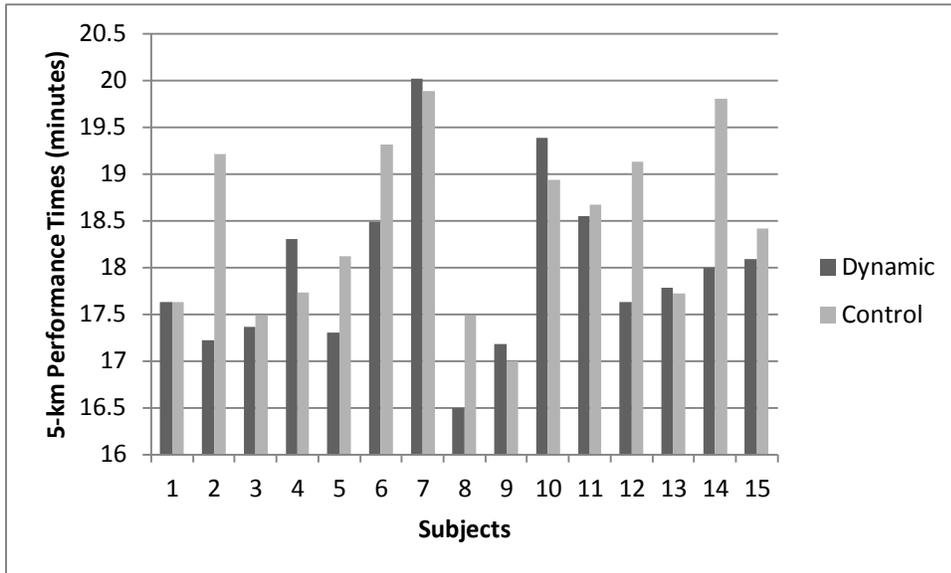


Figure 2. Individual times run in 5-km trial under the dynamic and control protocols.

CHAPTER 1

DEVELOPMENT OF THE STUDY

Introduction

Distance running is at times referred to as an art form. Since the running boom of the 1970s, even the most recreational of runners have tried to sculpt their individual running regimes to achieve maximal fitness gains. Weekly mileage, interval training, and most recently the addition of resistance training are three variables involved in distance running. Another variable is that of the warm-up, as it is a critical factor of performance used both to avoid injuries and prepare the athlete for high performance[1, 2].

The warm-up can be broken down into two options: passive and active [3]. The passive warm-up is used primarily to raise body and muscle temperature via an external source such as a heating pad or a whirl pool [3]. The main benefit of a passive warm-up may be that it does not deplete energy stores [3]. An active warm up consists of actually going through exercise (running, cycling, rowing, etc.). There are two major benefits of an active warm-up over the passive warm-up. The first is to decrease the muscular stiffness created by the bonds between actin and myosin - thus better preparing the athlete for activity with an increase in the speed/force of contraction[3]. The second benefit of the active warm-up is that it allows the athlete to mentally prepare for the activity itself [1, 3]. The benefits of an active warm-up, when conducted at a proper percent of VO_{2max} , outweigh the benefits of the passive warm-up [3].

The active warm-up can be further broken down into general and specific parts. The general warm-up focuses on primarily increasing core and muscle temperature as well as increasing cellular metabolism and range of motion [2] and can be applied to nearly any activity (i.e. a 10 minute jog). The specific part, however, focuses on further preparing athletes for whatever activity they are about to engage in by taking portions of the activity and breaking it down into simple drills [3].

In the past, static stretching was a major part of the warm-up, but a shift to the use of dynamic stretches has become a popular trend, as static stretching may actually hinder performance [4, 5]. An acute bout of static stretching has been shown to cause an increase of slack on the stretched tendons (a decrease in muscle stiffness) which then reduces muscle-force generation and in turn may cause a decrease in running economy (RE) [5, 6]. Fletcher and Monte-Colombo [4] suggested that static stretching may relax the muscles, which may explain why there would be a decrease in running performance as a result⁴. The study conducted by Wilson, Hornbuckle [5] actually showed a significant decrease in distance covered in a 30-minute run as well as an increase in energy expenditure after an acute bout of static stretching as opposed to a control protocol involving only a running warm-up [5].

In contrast, dynamic stretching has been less researched up to this point [8,9]. Shelton and Praveen Kumar [7] described dynamic stretching as a series of exercises incorporating sport-specific movement which prepares the athlete's body for activity [7]. In addition, dynamic stretching may provide the athlete with an optimal environment for "explosive force production by enhancing neuromuscular function" [7]. While there have been studies conducted on static vs. dynamic stretching, dynamic stretching on flexibility, and static stretching on running

performance, the effect of dynamic warm-up on running performance remains to be untested [5,8,9].

Statement of the Problem

Current researchers lack an understanding of dynamic warm-up on running performance [5, 8, 9]. Static stretching has been suggested to decrease performance if part of the regular warm-up for athletes and dynamic drills have slowly been replacing this part of the warm-up [5]. However, whether these drills positively affect endurance running performance remains untested. The present study may help identify the benefits of incorporating a dynamic stretching routine into daily warm-up activity prior to a performance event.

Purpose of the Study

The purpose of this study is to examine the effect dynamic drills may have on 5-km performance and running economy in collegiate cross-country runners.

Limitations

1. This study will only include a small sample, of similar-trained athletes.

Delimitations

1. The study will be conducted on a treadmill, which may decrease the subject's competitive mindset to finish the 5km as fast as possible.
2. Only males will be used.
3. This study will only apply to collegiate athletes.

Hypothesis

It has been suggested that dynamic stretching prepares the body for activity without decreasing muscle stiffness and a stiffer hamstring typically indicates a higher RE, demonstrating a linear relationship between leg stiffness and RE[8, 6, 10]. Therefore it is

hypothesized that RE will not be affected by the sport-specific warm-up and running performance will be superior to the controlled protocol. To demonstrate that a dynamic warm-up will enhance running performance and maintain RE, male collegiate cross-country runners will be asked to perform a 5-km time trial after undergoing randomized cross-over trials of dynamic warm-up and control protocols.

CHAPTER 2

REVIEW OF LITERATURE

Distance runners and their coaches are constantly searching for the next advantage to enhancing performance in competition. Endurance running consists of many different variables, starting with the warm-up. This review of literature describes how dynamic warm-up affects hamstring flexibility, running economy, and performance. Resistance training and how it affects running economy as well as the resulting increased body temperature from warm-up is also included in this review of literature.

Search Strategy

Searches on the topic were completed using the following databases: Academic Search Complete, Academic Search Premier, MEDLINE, and SPORTDiscus. The following key terms were used both individually and in combination to search existing literature: running economy, dynamic drills, dynamic warm-up, dynamic stretching, running drills, hamstring flexibility, sit and reach, resistance training, and endurance running. Exclusion criteria included static stretching.

Hamstring Flexibility

Runners with a better economy tend to exhibit more leg stiffness than another runner of similar VO_{2max} [6]. A positive linear relationship may occur at a constant running speed between leg stiffness and RE [6, 10, 11]. In a study testing the effect of sit-and-reach

flexibility on RE, Trehearn and Buresh [12] highlighted the same theory. They suggested that runners with a lesser sit-and-reach flexibility tended to exhibit better RE at a submaximal speed. This study was not gender-specific in its results, but between the sexes, the women had significantly higher sit-and-reach measurements. This study showed sit-and-reach to be a good predictor of RE in distance runners. Although many other leg flexibility tests exist, as the American College of Sports Medicine (ACSM) states, sit-and-reach is the most used [13].

Saunders, Pyne [14] suggested there is an optimal level of flexibility for each athlete that will help increase RE as needed for the proper stride length at high velocities. Leg stiffness is necessary to store and utilize elastic energy, as well as possibly stabilizing the spinal column, which may reduce energy expenditure by reducing some muscle contractions [10, 14]. So it is a positive attribute to have a stiffer leg during performance; therefore static stretching should not be used in the warm-up. However, flexibility still needs to be maintained and/or increased, as it plays a role in stride length, so static stretching post-exercise is still encouraged [14].

Running Economy

Nummela, Paavolainen [15] cited that for nearly a century, it was believed that endurance performance was limited by a person's VO_2 capabilities. However, it has recently been found that although a high VO_{2max} is desirable in aerobic activity, it is not the only variable in endurance performance success [9, 16]. Foster and Lucia [16] stated that there are 3 variables which dictate running performance: 1) a high VO_{2max} (high cardiac output and high rate of oxygen delivery), 2) the ability to maintain a high percentage of that VO_{2max} for a long duration, and 3) RE. RE has been the least studied out of these variables. Shrier [9] reported that running speed is dependent on: 1) force produced, 2) speed of muscle contraction, and 3) once again RE. Because of RE's prevalence in both performance, and more specifically speed, RE might be the

biggest predictor of aerobic running performance [5, 17], as well as a possible limiting variable [6].

RE can be defined as the energy used at a constant running velocity, with energy typically measured by O₂ consumption [18-20]. This may suggest that RE is the most important variable during endurance running since performance directly correlates to the ability of the athlete to maintain the lowest possible VO₂ at high velocities for as long as possible. Endurance runners with better RE will exhibit less energy use (and consequently, oxygen uptake) than others with lesser RE when running at the same speed [14, 18]. If long-distance runners can improve their RE, even the slightest of an increase, this will typically turn into improved performance for the athlete [18, 20].

It is hypothesized that RE is composed of a person's biomechanics, training history, muscle fiber type (along with distribution), VO_{2max}, substrate utilization, muscle power and flexibility [10]. Lucia, Esteve-Lanao [11] listed possible biomechanical factors for a desirable RE as low body fat percentage, a higher distribution of mass near the hip joint, kinematics (forces causing motion), kinetics (motion), and stored energy. This may explain why there is so much variance in similarly trained runners. RE may also be speed-specific. A long-distance runner will be more economical at long-distance, but less so at a shorter interval and the same would hold true for a middle-distance runner or sprinter. So, in order to get a true RE value for a runner, it is necessary to test them at the distance in which they are trained to race [10, 21].

Both Astorino [17] and Bragada, Santos [22] followed middle-distance/ distance runners throughout a competitive season and tracked performance outcomes such as VO_{2max} and RE. Astorino [17] followed the athletes through a cross-country season and used 8 minute bouts on the treadmill to track RE (defined as the average CO₂ (ml/kg/min) at minutes 6-8). From the

beginning of the season to the end, RE along with $\text{VO}_{2\text{max}}$ did not increase. Bragada, Santos [22] followed runners through two competitive seasons. RE, other measured variables ($\text{VO}_{2\text{max}}$, velocity at $\text{VO}_{2\text{max}}$, and velocity at 4mmol/L blood lactate concentration), and performance time of 3,000m (on an outdoor track) were examined. Over time, performance time actually decreased significantly. It was determined that RE was perhaps the least important variable for this study, but this may have been due to the short race length [22]. From these two studies, we see no long-term improvement in RE over the course of a season in middle-distance/distance runners. However, both studies simply tracked progress; there was no alteration in training methods, especially those to focus on enhancing RE.

Resistance Training

A relatively new addition to endurance running training is that of resistance training (RT). Some studies have alluded to RT improving endurance athletes' performances and possibly enhancing RE [18, 21, 23-25]. The increase in RE may be due to the increase in muscular strength as well as anaerobic power which can help when an athlete encounters a hilly course, a surge by a competitor, or "kicking" at the final stretch of a long-distance race [24]. Jung [18] suggested an increase in muscular strength may result in improved biomechanics, coordination, and order of motor recruitment, all of which directly relate to RE. In a discussion on unilateral RT, Holland [25] discussed finding imbalances through the training and being able to work on balance and coordination while also strengthening, thus the body would then waste less energy. However, with all of this speculation on the positives of RT on endurance training, there has been relatively little research done on the effect of RT in trained long-distance runners as compared to its endurance counter-parts: swimmers and cyclists [10, 24]

Paavolainen, Hakkinen [23] utilized a group of 22 elite male cross-country runners that underwent a 9 week training protocol. Both groups did endurance training as well as circuit training, but the experimental group ($n = 12$) added in a large portion of sport-specific explosive strength training (32% of workout volume) while the control group ($n = 10$) had only a small additive of this training (3%). The sport-specific explosive strength training consisted of sprints, jumping exercises, and leg exercises (leg press, leg extension, leg curl) lifted at 0-40% of their 1-repetition max and performed at high velocities. The control group went through more of the circuit training than the experimental and consisted of core and leg exercises with lots of repetitions at slow velocities and no added weight. Five-km performance was measured at baseline and again at 6 and 9 weeks. The performance time was significantly faster in the experimental group compared to the control. It was suggested that all endurance athletes will eventually reach a VO_{2max} and will not see any further increase. Within this study, the experimental group saw an improved performance time, but no increase in VO_{2max} . Thus, it can be concluded from this that VO_{2max} is not a limiting factor in performance and that strength training may have an additive effect on RE. This would confirm the notion by Saunders, Pyne [14] that RE is a better predictor of performance than VO_{2max} .

Performance Effects

Bishop [26] suggested that adding in bursts of specific movements into the warm-up may give additional benefits as long as they are brief to avoid fatigue. Dynamic warm-up occurs as a series of moving drills, performed in a specific sequence proceeding from low to moderate intensity [27]. Dynamic stretching involves the contraction of the muscles preparing for activity, which may activate the central programming, and result in a decrease in fatigue [9]. While there have been studies that have found no significant difference between the dynamic stretch groups

and a control on dynamic stretching [9,28], other studies have reported significant difference in dynamic warm-up [4, 8, 29, 30]. Therefore, it is clear that the effects of a dynamic warm-up are not fully understood and more data are needed.

Hayes and Walker [28] took male middle distance and distance runners and put all of them through four protocols. The first protocol, “static stretching,” held stretches of the quadriceps, hamstrings, calves, and gluteal muscles for 30 seconds and completed 2 repetitions of each stretch. The second protocol, “progressive static stretching,” consisted of the subject holding the same stretches as the first protocol for 10 seconds and then moved the limb passively and held the stretch for another 20 seconds, all completed twice. The next protocol was “controlled velocity dynamic stretching,” and each stretch was the same as the first protocol, except instead of holding the stretch, it was turned into a dynamic movement. The last protocol was “control.” After each stretching protocol, a 10 minute constant velocity run was performed. There were no significant differences found between protocols. However, the interpretation of the data is limited by a small subject number and the performance variable was not necessarily reliable considering that RE is best measured at the distance the athlete trains for [11,22]. Since both middle distance and distance runners were used, a “meet in the middle” approach was used and neither group was tested at their specialties.

O'Sullivan, Murray [8] conducted a study comparing subjects with previous hamstring injuries to an uninjured control group, all of whom were competitive athletes. Both groups were subjected to both the static and dynamic protocols. Again, no significant difference found between static and dynamic stretching, however they did find that there was a significant difference in increases in hamstring flexibility with dynamic stretching showing the lesser effect. This study was simply a measure of flexibility and not of performance itself.

Verrall, Slavotinek [30] examined Australian Rules football players, following them through two competitive seasons and their hamstring injuries were noted. After these two seasons, a stretching, sport-specific dynamic drills, and increased interval training program was then implemented. The athletes continued this new protocol and were tracked for another two seasons. These seasons witnessed a decrease in hamstring injuries which therefore, resulted in less games missed. Since dynamic stretching was not the only variable implemented, it cannot be concluded that was what helped the hamstring injury the most, so perhaps a longitudinal study with only dynamic stretching added would better show the direct effect the drills would have.

Fletcher and Monte-Colombo [4] used 21 male collegiate semi-pro soccer players. All subjects went through three protocols: 1. No stretch warm-up (WU) completing a 5 minute jog at a self-selected pace 2. Warm-up with static passive stretch (SPS) consisting of a 5 minute jog followed by a series of lower limb static stretches 3. Warm-up with static dynamic stretches (SDS) which called for a 5 minute jog and then a series of lower body dynamic stretches. There was a significant increase found in the countermovement jump test in SDS as well as a significantly higher heart rate and core temperature.

Faigenbaum, McFarland [29] studied 4 warm-up protocols and their effect on anaerobic performance in high school females. All protocols called for a 5 minute jog followed by ten minutes of either static stretching, moderate-intensity to high-intensity dynamic exercise, moderate to high-intensity dynamic exercise with a vest composed of 2% of their body mass, and moderate to high-intensity dynamic exercise with a vest composed of 6% of their body mass. After the warm-up, tests of vertical jump, long jump, seated medicine ball toss, and a 10 yard sprint were performed. All 3 of the dynamic warm-ups resulted in significantly better vertical

and long jumps as compared to the static stretch protocol. The dynamic exercise with weighted vest of 2% body mass showed the best results on all 4 tests.

Increased Temperature

Bishop [3] suggested that the main effects from doing a warm-up are attributed to increases in temperature. In table 1, a list of temperature-related and non-temperature related factors are displayed. As discussed previously, a passive warm-up can increase core and muscle temperature, but does not offer all of the benefits that an active warm-up does. Vaz, Mendes [26] tested the difference in 100m performance time when using an active-specific warm-up as compared to a non-warm-up protocol. There was no significant difference found in 100m performance time between the two protocols, but the active-specific warm-up exhibited a significantly higher increase in core temperature. Leg stiffness is desired for performance, especially in sprint events where muscle contraction rate is key and perhaps the lack of a warm-up helped to maintain that stiffness better. Fletcher and Monte-Colombo [4] also found a significantly higher core temperature in their dynamic warm-up group, however performance positively correlated to this increase, as this group exhibited a significant improvement in the performance variable being examined, a countermovement jump test.

Table 2: Possible effects of warm-up collected from Bishop [3].

Possible Effects of Active Warm-up	
<u>Temperature Related</u>	<u>Non-Temperature Related</u>
<ul style="list-style-type: none"> • Decreased resistance of muscles and joints • Greater release of O₂ from Hb and Mb • Increased speed of metabolic reactions • Increased nerve conduction rate • Increased thermoregulatory strain • Altered force-velocity relationship • Increased aerobic energy provision 	<ul style="list-style-type: none"> • Increased blood flow to muscles • Elevation of baseline O₂ consumption • Postactivation potentiation • Effects of acidaemia • Psychological effects • Increased preparedness

CHAPTER 3

METHODOLOGY

Subject Selection and Exclusion Criteria

Subjects selected for this study were male student-athletes from Indiana State University and Rose-Hulman Institute of Technology (NCAA Division I and Division III levels respectively), participating in the endurance sport of cross-country. Inclusion criteria required each subject to average at least 40 miles per week for the last two years as a varsity cross-country athlete. If subjects had either diabetes mellitus or were a current smoker or quit within the past 6 months they were excluded from participating further in the study.

Pre-Test Procedure

Subjects were required to sign and date an informed consent document (APPENDIX G) as well as a subject questionnaire (APPENDIX F) before taking part in this study. All subjects were required to keep a dietary journal (APPENDIX C) 48 hours prior to the first session and ate similarly for the following sessions to ensure that each visit was consistent as possible. Caffeine and alcohol use 24 hours prior to each session were not allowed nor was any type physical activity (APPENDIX B). Berg [10] suggests that if a subject were to have previously worked out, especially at an intense level, the muscles would be fatigued so additional motor units would have to be recruited and this would then elevate the VO_2 measurement, skewing the results. Subjects wore the same shoes and clothes for all sessions so that there was no discrepancy from

test to test [6, 14]. The sessions were spaced one week apart (6 ± 1 days) and conducted at the same time of day (± 1 hour) to control for circadian variance.

Testing Procedures

To be considered for the study, each subject reported to the Exercise Physiology Laboratory on the campus of Indiana State University for three separate sessions. During the first visit, the subjects read and signed the informed consent and filled out the subject questionnaire. At this time, the subjects were informed on exactly how the testing was to be administered and were able to ask any questions they might have. Once they agreed to participate in the study, baseline data was then collected, including: age, height, weight, body composition, sit-and-reach, resting heart rate (HR), blood pressure (BP), and maximal oxygen consumption (VO_{2max}). Also during this session, the subjects were familiarized with the treadmill (Model Trackmaster TMX425CP, St. Paul, MN) used for testing. Once the subjects were comfortable with running on the calibrated treadmill, they each performed a VO_{2max} test. The subsequent sessions were randomized for the subjects and then completed a crossover design, experiencing both protocols. Water was available ad libitum before and after all testing as well as after the warm-up.

Baseline Data Collection

The subjects were asked their age, best 5,000m time, average weekly training distance, and years trained as a cross-country runner. Height was collected using a stadiometer and weight (kg) was taken from the BodPod (Life Measurement, Inc., Concord, California) measurements, used to find body composition. A sit-and-reach test was administered using the Acuflex I (Model 67091, Novel Products Inc., Addison, IL) following the ACSM protocol for sit-and-reach for trunk flexion testing [13]. The subjects were given 3 trials and the best result was recorded. HR was taken as a resting measure, and then throughout all tests with a Polar HR monitor (Model

RS200SD, Lake Success, NY). Resting blood pressure was taken with an automatic blood pressure monitor (Omron Hem-780, Bannockburn, IL) and VO_{2max} was measured using a calibrated Medgraphics metabolic cart (Model Ultima CPX, St. Paul, MN). The subject sat on a chair for the latter baseline measurements.

Maximal Aerobic Test

After baseline data were collected, the subject was allowed to become familiarized with the treadmill used in this study. The subjects adjusted speed and/or degree of incline until they felt comfortable with the apparatus. The Costill/Fox protocol was used to find the VO_{2max} [31]. All stages lasted 2 minutes, and started with a 0% incline. After the first 2 minutes and every 2 minutes thereafter, the treadmill was raised 2%. The speed stayed the same throughout at 4.0m/s. The test was considered maximal if 3 of the following 4 criteria were met: 1) plateau in O_2 consumption for an increase in exercise intensity ($<2.0\text{ml/kg/min}$ increase), 2) $RER \pm 1.1$, 3) $HR > 85\%$ age-predicted max, and/or 4) $RPE > 18$.

Control Protocol

During the second or third test sessions, the control protocol (CP) was observed. The subjects ran for a half of a mile at 65% of their predetermined VO_{2max} . When the half mile was achieved, the subject then completed the first sit-and-reach test. Then, 10 minutes of quiet time were observed while reading the school newspaper. After this period of time passed, another sit-and-reach test was administered and then the subjects were placed back on the treadmill and allowed 2 minutes for a stride simulation at whatever pace the subjects' desired, as if they were at the starting line of a race. From there, the subject was instructed to complete the 5-km run as fast as possible. The subject was able to increase/decrease speed as necessary, without seeing the

exact rate or distance completed. Subjects were given 1-km splits throughout the test, similar to a true cross-country race.

Dynamic Protocol

The dynamic protocol (DP) was used during the second or third testing session, based on random assignment. The subject was to complete a half mile run on the treadmill at a 65% VO_{2max} . Once completed, the subject performed the first sit-and-reach test. Next, the subjects headed to a clearly marked 15m straightaway. Each drill (Table 3) was completed twice. After the drills were completed, the subject did another sit-and-reach test. The rest of this protocol was the same as the CP protocol, as the subject had a 2 minute window to do as many strides as desired and then the 5-km was attempted as fast as possible.

Table 3. Dynamic Drills & Descriptions (Adapted from Zourdos[32] and Wilk[33])

<u>Drill</u>	<u>Description</u>
Heel-to-toe Walk	<i>Step with the right foot placing the heel down first; roll the foot to the toes and briefly rise up your toes. Repeat with left foot.</i>
Walking 'A' Skip	<i>Step on the ball of right foot and lift left leg, driving the knee upward (parallel to the ground), dorsiflex the left foot and rise up on the right toes. Step down with the left foot and repeat with opposite.</i>
'A' Skip	<i>Same as "Walking 'A' Skip," but add a hop after placing the foot down and during the knee drive. The foot should be returned to the ground directly under the hips.</i>
'B' Skip	<i>Same as "'A' Skip," but the leg driving the knee then extends outward and then "paws" down to the ground, again with the foot landing underneath the hips.</i>
Heel-to-Glute	<i>Combination of butt-kick and high-knee drills. Pull the foot up toward the buttocks, but before it reaches, pull the knee upward with the foot dorsiflexed.</i>
Side Shuffle	<i>Face the right side and step the left foot laterally with a shuffle, then shuffle the right leg to meet them together. Switch legs while still facing the right side on the way back.</i>
Grapevine	<i>Face the right side and hop-step the left leg to the side, then take the right leg and cross it behind the body, step again to the side with the left leg and then take the right leg and cross it in front of the body. Coming back face the right side again, but switch legs.</i>
Straight-Leg Run	<i>Keep the knees straight and run with the legs extended. Try to return the feet under the hips.</i>

Statistics

The baseline characteristics were analyzed using a one-way analysis of variance (ANOVA). A repeated measures ANOVA was used to examine the condition (control protocol

versus the dynamic protocol) by time (pre versus post) interaction on the sit-and-reach, RE, and 5-km performance time were examined using a one-way ANOVA across conditions. If an interaction was deemed statistically significant, then main effects were analyzed using paired t-tests. Significance was set *a priori* at $p < 0.05$. Values are presented as mean \pm standard deviation (SD). All statistical analyses were performed using SPSS Version 18 (SPSS, Inc., Chicago, IL, USA).

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APPENDIX A: BASELINE COLLECTION FORM

Age		Average Weekly Training Distance (miles)	
Years Trained		Height (m)	
Best 5,000m Time		Sit-and-Reach (cm)	
Weight (kg)		Resting BP (mmHg)	
Resting HR (bpm)		Resting VO₂ (ml/kg/min)	
Body Fat %		VO_{2max} (ml/kg/min)	

Maximal Costill-Fox Protocol

Minutes	Speed (m/s)	Incline (%)	HR (bpm)	BP (mmHg)	RPE	RER	VO ₂ (ml/kg/min)	VCO ₂ (L/min)	V _E (L/min)
2	4.0	0							
4	4.0	2							
6	4.0	4							
8	4.0	6							
10	4.0	8							
12	4.0	10							
14	4.0	12							
16	4.0	14							
18	4.0	16							
20	4.0	18							

APPENDIX B: 24 HOUR ACTIVITY LOG

Hours Until Testing	Activity
<i>20-24</i>	
<i>16-20</i>	
<i>12-16</i>	
<i>8-12</i>	
<i>4-8</i>	
<i>0-4</i>	

APPENDIX C: 48 HOUR DIETARY LOG

Hours Until Testing	Food/Beverage Consumed	Hours Until Testing	Food/Beverage Consumed
<i>45-48</i>		<i>21-24</i>	
<i>42-45</i>		<i>18-21</i>	
<i>39-42</i>		<i>15-18</i>	
<i>36-39</i>		<i>12-15</i>	
<i>33-36</i>		<i>9-12</i>	
<i>30-33</i>		<i>6-9</i>	
<i>27-30</i>		<i>3-6</i>	
<i>24-27</i>		<i>0-3</i>	

APPENDIX D: DATA COLLECTION FORM

Control Protocol

Sit-and-Reach #1	
Sit-and-Reach #2	
1km	
2km	
3km	
4km	
5km	

Dynamic Protocol

Sit-and-Reach #1	
Sit-and-Reach #2	
1km	
2km	
3km	
4km	
5km	

APPENDIX E: PRETEST HYDRATION PROTOCOL

The following instructions will be given to subjects regarding their fluid intake prior to arriving at the Exercise Physiology Laboratory for testing:

- The following protocol **MUST** be followed the night before reporting to the Exercise Physiology Lab, located in the Arena Building on the campus of Indiana State University
- Failure to report hydrated will result in **delay** when your next test can begin
- Approximately **4 hours** before going to bed drink *600ml (20oz)* of water, sports drink, or flavored water. Avoid caffeinated beverages and alcohol.
- **Immediately** before going to bed drink an additional *600ml (20oz)* of water, sports drink, or flavored water. Avoid caffeinated beverages and alcohol.
- Below you will find a table for you to write your scheduled data collection days to help you keep track of your commitment.

Schedule

Date	Time Report	Est. Time Completed	Hydration

APPENDIX F: SUBJECT QUESTIONNAIRE

Study Title: <i>Dynamic Warm-Up Effect on 5-km Performance and Running Economy in Collegiate Cross-Country Runners</i>			
Please answer the following questions to the best of your knowledge:			
1.	Are you a male NCAA DI or DIII Cross-Country runner?	Yes	No
2.	Have you averaged at least 40 miles per week for the last two years?	Yes	No
3.	Do you have diabetes mellitus?	Yes	No
4.	Are you currently a smoker or have quit within the last six months?	Yes	No
5.	Are you currently taking any prescription medications that may prevent you from participating in this study or hinder your performance in any way? <i>If YES, please list all prescription medications.</i>	Yes	No
6.	Are you taking any over-the-counter medications or supplements that may prevent you from participating in this study or hinder your performance in any way? <i>If YES, please list below.</i>	Yes	No
7.	Are there any other medical problems (past or present) not already mentioned that we should know about? <i>If YES, please explain below:</i>	Yes	No

APPENDIX G: SUBJECT INFORMED CONSENT

Page 1 of 4

Informed Consent**DYNAMIC WARM-UP EFFECT ON 5-KM PERFORMANCE AND RUNNING ECONOMY IN COLLEGIATE CROSS-COUNTRY RUNNERS**

You are being asked to participate in a graduate research project looking at how dynamic warm-up effects running performance and running economy. You have been chosen because you are an experienced male National Collegiate Athletic Association (NCAA) DI or DIII cross-country runner that has consistently run 40 or more miles per week on average for the past two years. You are asked to participate in 3 separate sessions, taking place over 3 weeks, lasting 1-2 hours per session. Your participation in this study is completely voluntary and you may withdraw at any time. Please read this document and ask any questions to assist you in deciding if you would like to participate.

Purpose

The purpose of this project is to determine the effect that dynamic warm-up may have on both running performance and running economy. Please be aware that you will be excluded from the study if you are a diabetic or consider yourself a smoker. You may also be excluded if you are currently taking any prescription medicine or over-the-counter medicine which may prevent you from participating in this study or hinder your performance. If you experience chest pain or dizziness during physical activity, it will be left to the discretion of Adriane Wunderlich and Dr. Derek Kingsley whether you may participate in this study.

Procedures

All sessions will take place in the Exercise Physiology Laboratory in the Arena building (C-54) on the campus of Indiana State University. Prior to the first session, you will need to keep a 48 hour dietary journal along with a 24 hour activity log. You will be required to refrain from alcohol, caffeine, and exercise 24 hours before testing. A hydration protocol will be provided for you, and you are expected to follow it. This protocol will require you to drink 20ml of water, sports drink, or flavored water 4 hours prior to going to bed and another 20ml consumed right before going to bed the night before the testing session. If this is not properly followed, your testing session will need to be rescheduled. During the first session, you will be asked to complete a participant questionnaire. If you do not meet all inclusion criteria or do meet any exclusion criteria, you will be unable to participate in this study. Upon review of this document by Adriane Wunderlich, the document will be destroyed (shredded) immediately.

You are welcome to ask for any and all of your own data obtained during this study. Baseline data (heart rate, blood pressure, height, weight) will be obtained first. Blood pressure will be measured using an automatic blood pressure cuff in a quiet environment after sitting for a 5 minute period. Heart rate will also be taken at this time using a chest HR monitor. The HR monitor will consist of a rubber analysis piece that fits around the front of the chest sitting on the sternum and an adjustable nylon strap that fits along the back. You will wear this strap throughout the entirety of each testing session. Body composition will be measured using the BodyPod. This machine will calculate displacement of air and determine your body density. For this measurement, you will be required to remove any jewelry and glasses and will need to provide your own form fitting outfit (spandex material preferred). A private bathroom is located nearby for your use. This testing will take approximately 5 minutes and will be completed per manufacturer's specifications and by trained technician (Adriane Wunderlich). During this test, the you will sit still in the apparatus with the door closed for analyzing. Adriane Wunderlich will

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open the door once the first analysis is complete and check on you. Once it is determined you are still comfortable, the door will once again be shut for analysis. If the software says an analysis has been sufficiently reached, you will be free to leave the BodPod, otherwise another analysis may need to be conducted. Once body composition has been assessed, you will perform a maximal oxygen consumption test (VO_{2max}). This will be evaluated on a treadmill with the aid of a metabolic cart for gas analysis which will require you to wear a neoprene mask. You will be allowed to become familiarized with the treadmill used in this study. You may adjust speed and/or degree of incline until you feel comfortable with the apparatus. The Costill/Fox protocol will be used to find the VO_{2max} , which calls for you to run at a speed of 4.0m/s (8.9mph) for the test's entirety. All stages last 2 minutes, and will start with a 0% incline. After the first 2 minutes and every 2 minutes thereafter, the treadmill incline will be increased by 2%. You may end the test at any time by hitting the button and stopping the treadmill and also through the use of the Rating of Perceived Exertion scale (i.e. how hard you feel you are working on a 6-20 scale with 20 being maximal). This test should take approximately 30 minutes. At the end of the first session, you will blindly draw one of two colors out of a drawer with each color corresponding to one of the two protocols. The color drawn will be the first protocol you will undergo during the second session. The color not drawn will be conducted during the third and final session.

For sessions 2 and 3, you will need to follow the exact same diet and activity log you carried out the 48 hours prior to the first session as well as the 24 hour activity log and hydration protocol. If these are not properly followed, another session time will be scheduled. You will then be asked to warm-up on the treadmill for a ½ mile at 65% of your VO_{2max} , which will require you to again wear a neoprene mask attached to a metabolic cart. Once completed, you will remove the mask and undergo a sit-and-reach test, reaching across a sit-and-reach box as far as possible. Based on your randomization, you will either perform a dynamic protocol or the control protocol. For the dynamic protocol, you will complete a series of dynamic drills, taking 10 minutes. For the control protocol, you will use this 10 minute period to sit quietly while reading the newspaper. After this time has passed, another sit-and-reach test will be administered. You will then be placed back on the treadmill for a 2-minute period in which you will be able to simulate pre-race stride-outs (running at a self-determined pace, preparing the body for faster running). Then, you will complete 5-km on the treadmill as fast as you possibly can. You will be given your splits at each kilometer and have the ability to adjust speed throughout. However, you will not be able to view the exact time, distance, or speed at which you are running in order to limit their influence on your performance.

Potential Risks and Discomforts

The possible risks are minimal for this study. Since you are a current NCAA athlete, you have previously undergone a pre-participation physical exam, administered by both an experienced athletic trainer as well as a physician. This greatly helps reduce the possibility of any cardiac complications that may arise in a normal population (i.e. alterations in heart rhythm, drops in systolic BP). The use of a treadmill does pose the risk of falling off, but you may stop the testing at any time to prevent this from occurring by hitting the automatic stop button on the treadmill. You may also grab onto the sidebars on the treadmill if you feel yourself losing your balance. If you do fall off the treadmill, Adriane Wunderlich will follow the standard guidelines set forth by the American Red Cross for assessing the degree of injury after ensuring that the treadmill has been turned off. The risk of claustrophobia may arise any time you are wearing the oxygen consumption mask as well as during the BodPod testing, as you will be placed in a tight space. In addition, an allergic reaction to neoprene may also be a risk if you are sensitive. In the

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case of claustrophobia or allergic reaction to the neoprene mask, you may remove it and use the hypoallergenic foam rubber mask instead. There is a button inside the BodPod that automatically stops the test so you may exit when pressed.

Potential Benefits

The possible benefits of your participation in this research project include learning about your activity levels, training status and how dynamic stretching affects your running performance and economy. You will also be given a number of appealing tests (such as body composition and $\text{VO}_{2\text{max}}$) free of charge and the results will be given to you, if you wish. Please let Adriane Wunderlich know at this time if you wish to obtain your data at the end of all testing. This study could yield valuable information for those individuals who actively participate in the sport here at ISU, as well as Rose-Hulman, and at other DI and DIII universities. Furthermore, these data may assist not only you, but also the distance running coaches at DI and DIII universities as they relate to warm-up for the athletes.

Payment for Participation

As per the National Collegiate Athletic Association (NCAA) rules, no compensation for participation shall be awarded.

Confidentiality

Any information collected for this study identifying you will remain confidential. Your participant questionnaire will be destroyed once it is determined you have met inclusion criteria and do not meet any exclusion criteria. The informed consent will be kept in a locked cabinet in a secure room after the investigators Adriane Wunderlich and Dr. Derek Kingsley have reviewed it. This will be kept for 7 years and at this time will be destroyed. The only document that will have your name on it is the informed consent. On all other documents you will be referred to as a number, chosen using a random number generator, which you will be given and need to keep for the following sessions. All collected test data will be stored separate from the previous documents for three years after completion and will be destroyed at that time. Investigators Adriane Wunderlich and Dr. Derek Kingsley will be the only people to have access to these records. The results in this study will be published in summary format so that your own statistics will be unidentifiable.

Medical Attention

In the event that medical attention is required past that which can be provided by the investigators in the Exercise Physiology Laboratory, **the cost of additional medical treatment will be your responsibility**. Financial compensation will not be available from Indiana State University or the investigators.

Contact

If you have questions regarding your rights as a participant in this study, or if you feel you have been placed at risk, you have the right to contact the Institutional Review Board at Indiana State University at (812) 237-8217 or irb@indstate.edu. You may also reach the primary investigator, Adriane Wunderlich, at (812) 230-7531 or awunderlich@svcamores.indstate.edu. Dr. Derek Kingsley is the Faculty Sponsor for this study and may be contacted at (812) 237-2594 or Derek.kingslev@indstate.edu.

Voluntary Research and Withdrawal

Your participation in this study is completely voluntary. Refusal to participate will result in no penalties or loss of benefits. You retain the right to discontinue participation at any time without penalty or loss of benefits. If you withdrawal from the study, your data will be removed from the data sheet, but your records will be kept until they and be destroyed with others.

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I understand the procedures described above. I have been given my own copy of this informed consent to keep for my own records. My questions have been answered to my satisfaction, and I agree to participate in this study.

Printed Name of Subject

Signature of Subject

Date

APPENDIX H: FUTURE RECOMMENDATIONS

In future studies researching the effect of dynamic drills, a broader population is necessary to fully understand the variable. This study focused on collegiate-aged males but it would benefit the sport to expand the population to females and both younger and older populations. It would be interesting to see if there would be any different effect with completing the 5-km on a treadmill versus a track or even a cross-country course.

More drills may be added and/or replaced, as very generic drills were used. It would also be interesting to see the difference dynamic drills may cause when implemented at the beginning of a season and completed regularly throughout the season. This may create an improvement in running economy, as is partially the purpose of doing dynamic drills, and perhaps this would affect overall performance.