THE EFFECTS OF STATIC STRETCHING ON ENDURANCE CYCLING PERFORMANCE

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THE EFFECTS OF STATIC STRETCHING ON ENDURANCE CYCLING PERFORMANCE

A Thesis

by

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Abstract

of

THE EFFECTS OF STATIC STRETCHING ON ENDURANCE CYCLING PERFORMANCE

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Introduction

It is commonplace for athletes and coaches to use stretching as a part of pre-activity warm-up. Most individuals use static stretching based on prior experience and the ease of performing the task, and some even believe that it will improve performance and reduce injury. Findings from different studies are somewhat conflicted regarding static stretching and its usefulness in the warm-up. Many groups have found that a static stretch warm-up will hinder performance, while other research has indicated no positive or negative effect. Most of the research to-date has been performed on strength and speed focused activities, with minimal attention paid to endurance activities.

Methods

Participants included competitive men and women cyclists of not pre-set age range (average age= 32 ± 7 years). Testing consisted of four sessions; with the first including a graded exercise test and baseline lower body ROM (range of motion) measurements. This session determined VO_2 max, maximal power, time trial resistance, and aided to acclimatize the subjects with the testing site and equipment. On the first day of testing subjects were assigned to one of three groups in a Latin squares fashion. The three groups consisted of a Stretch (S), Active Warm-Up (W), or a No Stretch (NS) group, and subjects were given a minimum of 48-hours to rest between testing days

as the effects of stretching can last 24 hours. The static stretch protocol consisted of five positions that target the primary cycling muscles in the lower limbs: quadriceps, hamstring, plantar flexors, hip extensors and hip flexors. The warm-up protocol consisted of no stretching, but rather subjects pedaled on a stationary cycle for 15 minutes at 20, 35, and 50% of their max wattage, as determined from the baseline GXT. Each stage is five minutes in length and transfers to the next stage without stopping. Subjects participating in the no stretch treatment sat quietly in the riding position, refraining from excessive movements, for 15 minutes. Following each protocol subjects had two minutes to prepare and mount the testing cycle to perform the 576kJ TT. All variables were measured and recorded in the same way for each trial.

Results

No significant differences was found in time to completion (S= 41.34 min ± 7.166, WU = 41.31 ± 7.61, NS = 40.92 ± 7.18, p= 0.993) for the three trials. Power output every 28.8 kJ was not significantly different between treatments (p=0.88) but showed a trend over time (p=0.07). HR showed a trend (p=0.09) between trials while RPE was not significantly different between trials (p= 0.43), however, both increased significantly over time (p=0.00). VO_2 was also not significantly different between trials (p=0.981) or over time (p=0.61).

Conclusions

The results of this study suggest that static stretching as a part of the pre-exercise routine is neither beneficial nor detrimental to the subsequent endurance performance.

________________________, Committee Chair
Dr. Daryl Parker

____
Date

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Dr. Parker – I'm glad that two totally kick back people could actually create (flexible) deadlines and get this thing done. When I doubted myself you were there to tell me what I needed to hear and I am grateful to have had the *years* of enjoyment in your lab and office. I am lucky to have you as, well, you….the man of many job titles, but always there for me. I cannot thank you enough.

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Chapter 1

INTRODUCTION

It is commonplace for athletes and coaches to use stretching as a part of pre-activity warm-up. Long seen as a means of maintaining range of motion (ACSM, 2009), improving performance and preventing injury, stretching has been suggested as a necessary activity with minimal scientific backing to support its use. Not taken into consideration are the form of stretching and their individual effects on sport and performance. Different types of stretching include static stretching, proprioceptive neuromuscular facilitation (PNF), and ballistic or dynamic stretching. These styles can either benefit the athlete or diminish the intended sport outcome, reinforcing the need for evidence as to the appropriate timing and type of stretching activity.

Most individuals use static stretching based on prior experience and the ease of performing the task, and some even believe that it will improve performance (Nelson, A.G. & Kokkonen, J., 2001). Findings from different studies are somewhat conflicted regarding static stretching and its usefulness in the warm-up. Many groups have found that a static stretch warm-up will hinder performance (Fowles, J. R., Sale, D. G., & MacDougall, J. D., 2000; Black, J. D. & Stevens, E. D., 2001; Nelson, A. G., Guillory, I. K., Cornwell, C., & Kokkonen, J., 2001), while, other research has indicated no positive or negative effect (Unick, J., Kieffer, H. S., Cheesman, W., & Feeney, A., 2005; Alpkaya U, Koceja D., 2007). Much of the research to-date has been performed on strength and speed focused activities, all of which are brief in duration, with minimal attention paid to endurance activities.

The topic of stretching, particularly static stretching, which comes into controversy, is its potential to decrease performance. These decrements have been seen in vertical jump (Power, K., Behm, D., Cahill, F., Carroll, M., & Young, W., 2004), maximal force production (Nelson, A. G., Kokkonen, J., & Arnall, D. A., 2005; Egan, A. & Cramer, J., 2006), and sprinting when paired with a dynamic warm-up (Winchester, J. B., Nelson, A. G., Landin, D., Young, M. A., Schexnayder, I. C., 2008; Kistler, B.M., Walsh, M.S., Horn, T.S & Cox, R.H., 2010). While cycling is scarcely represented in current scientific findings regarding stretching, the little that is available indicates negative effects. Recreationally active male cyclists experienced a significant decrease in peak power and mean power output during a Wingate cycle test following static stretching (Ramierz, E. B., Williford, H. N., & Olson, M. S., 2007). Another group of cyclists performed four 10-second power tests and showed no significant differences in power after 20 minutes post stretch, but significant decreases at 40 and 60 minutes post-static stretch (O’Connor, D.M., Crowe, M.J. & Spinks, W.L., 2006). Several mechanisms have been identified as possible causes of decrements in athletic performance including a depression of muscle activation (Kokkonen, J., Nelson, A., Cornwell, A., 1998), increases in tendon slack resulting in an increased time for muscle contraction (Rosenbaum, D., & Henning, E. M., 1995), and a decrease in active stiffness resulting in disruption of the stretch reflex activity (Cornwell, A., Nelson, A. G., &

Sidaway, B., 2002). A decrease in active stiffness may be of benefit to those who wish to increase range of motion; however, individuals who require optimal performance will find that active stiffness is what keeps movement quick and power at optimal performance levels.

It is true that most cyclists do not stretch prior to training or competition (D. Parker, personal communication, March 2012). Similar to many other sports it is difficult to implement a change in training strategy, however, new information can sway those who direct the future decisions and trends that trickle down to the athletes. Given the uniqueness of this current line of research it is warranted that new findings deserve a second look from coaches and riders in their application to current training sessions.

Statement of Purpose

The purpose of this study is to determine the effect of pre-exercise stretching on cycling time trial performance when compared to an active warm-up and no warm-up.

Significance

This research can lead to a greater understanding of the contributions from nerve, tendon, and active muscle stiffness on endurance cycling conditions following static stretching. By assessing this study's results comparisons can be made between cycling and other sports, revealing physiological similarities and differences in power production and stretch reflex responses in endurance situations. Further significance may be derived in the application of knowledge gained in rehabilitation and cardiac settings. Insight to the response of the body post-stretch, in terms of endurance, would improve future recommendations for those desiring a flexibility program in conjunction with a training program.

Limitations

1. Prior/concurrent exposure to flexibility training will not be assessed.

Delimitations

1. All subjects will be trained cyclists acclimated to time trial testing.
2. Subjects will limit exercise the day before testing to prevent fatigue/soreness.
3. Environmental conditions will be controlled.

Assumptions

1. Subjects will adhere to exercise testing procedures and provide honest measurements of stretching and fatigue.
2. A 576 kJ TT is equivalent to a 20 km outdoors TT.
3. All subjects will be healthy.

Definitions

- Active stiffness – a state where the body utilizes its limited range of motion (due to muscular and connective tissue tension) to aid in generating power (Wilson, J. M. & Flanagan, E. P., 2008).
- Endurance exercise – activities involving large muscle masses, performed over long periods of time (Brown, S. P., Miller, W. C. & Eason, J. M., 2006).

- Muscle activation – once the muscle's sensory organs have detected a stimulus, membrane permeability increases and sodium (Na^+) diffuses into nerve fiber causing depolarization and allowing the muscle to perform a specific action (Alter, 1996).
- Static stretching – slow, sustained muscle lengthening to increase range of motion (Heyward, V. H., 2006). Example: Lying in a supine position and flexing the hip joint with the knee in full extension.
- Stretch reflex – after a muscle has been stretched, the lengthening of the muscle fibers and muscle spindles activate secondary nerve endings. When the stretch is great enough, the tension created will cause enough depolarization to set off a chain of reactions resulting in a reflex contraction (Alter, 1996). This reflex is routed through the spinal cord instead of the brain and will last for the duration of the stretch (Robergs, R. A. & Keteyian, S. J., 2003).
- Tendon slack – an occurrence where the muscle is stretched to the point of the unit taking longer than usual to contract and/or less force being transmitted to the muscle (Alter M. J., 1996).
- Time trial – a racing term used to describe a cycling event where a given distance is covered in the shortest time possible (USA Cycling, 2004).
- Viscoelastic properties – tension within the muscle-tendon unit caused by the elastic and viscous deformation of the unit when force is applied during stretching (Heyward, V. H., 2006).

- VO_2 max – a measurement of maximal oxygen consumption during exercise, meeting two out of three criteria: an RER ≥ 1.1, an RPE greater than 17, and an increase in oxygen consumption of less than 2 ml/kg/min (ACSM, 2009).
- Warm-up – the process of preparing the body for physical activity, resulting in increased body temperature, heart rate, muscle viscosity, metabolic rate and oxygen-hemoglobin disassociation (Shellock, F.G. & Prentice, W.E., 1986; ACSM, 2009).

Hypotheses

1. Static stretching prior to a 576kJ time trial will have no effect on cyclist's time to completion when compared to active warm-up and no warm-up.
2. Static stretching prior to a 576kJ time trial will have no effect on heart rate over the course of the testing when compared to active warm-up and no warm-up.
3. Static stretching prior to a 576kJ time trial will have no effect on RPE over the course of the testing when compared to active warm-up and no warm-up.
4. Static stretching prior to a 576kJ time trial will have no effect on VO_2 max over the course of the testing when compared to active warm-up and no warm-up.

Chapter 2

REVIEW OF LITERATURE

This chapter will discuss current research on the topic of stretching and its physiological effects on sports performance. Subject matter to be addressed will include the basic physiology of a warm-up and stretching and their effects regarding mechanical and neuromuscular factors. Specifically, pre-exercise stretching and its effects on cycling and related variables will also be addressed.

Physiology of Warm-up and Stretching

The warm-up has long been a part of preparing an individual before activity (Nelson, A. et al. 2001). Prior beliefs indicated that stretching before a sport or exercise will help to decrease injury, but research cannot confirm the prophylaxis of injury, regardless of the activities nature (Bracko, M. R., 2002; MacAuley, D. & Best, T. M., 2002). Proper warm-up, however, is essential to a few key components before starting an event, namely physiological processes in the body that are temperature-dependent (Shellock, F.G. & Prentice, W.E., 1985). Light physical activity (jogging, cycling, brisk walking) can trigger responses such as increased body temperature, which will produce an increase in the dissociation of oxygen from hemoglobin and myoglobin. By increasing the dissociation of these two molecules, oxygen transfer in the lungs and muscles can occur with greater ease, reducing time in exchange. An active warm up also causes increases in blood flow to muscle tissue, increasing oxygen delivery and metabolite removal. This response will help buffer the acid-base changes that occur during intense exercise (Robergs, R. A. & Keteyian, S. J., 2003). Finally, the muscles will experience a reduction in viscosity. Viscosity is the friction between fibers within the muscle, and by decreasing this factor the muscle tissue can glide with increased ease over other tissue. Under such conditions the muscle undergoes specific changes to its structure allowing for greater range of motion as well (ACSM, 2009).

There are many propositions regarding the possible neuromuscular factors affecting physical performance. Starting at one of the smallest points possible, the Golgi tendon organs (GTO) are the mechanoreceptors in human muscle tissue that are contract sensitive. Located in muscle-tendon junctions, they are hypersensitive to changes in tension of the muscle fibers on which they are attached. Referred to as "stretch receptors," the GTO play a vital role in the stretch reflex mechanism (Alter, M., 1996). This response occurs after a muscle has been stretched, either by contraction or passive stretching (Singh, I., 2006), lengthening the muscle fibers and muscle spindles and activating secondary nerve endings. When the stretch is great enough, the tension created increases depolarization and begins a chain of reactions resulting in a reflex contraction. The GTO reaction can be divided into two categories, dynamic and static. The dynamic response occurs when tension increases suddenly (example: moving a limb into a stretch position) but quickly moves into the stretch response as muscle tension is held (example: holding the stretch) (Guyton, A., & Hall, J. 1996).

With stretching, chronic stretching in particular, these receptors become accustomed to a longer length and therefore require a greater stimulus or subsequent loading to the GTO will result in a weaker signal transmitted to the muscle. This phenomenon is also referred to as a depression in muscle activation (Kokkonen, J. et al.1998), leaving the "newer" elongated state to require more time to reach a fully contracted position than its previous length, causing movements to take more time (Rosenbaum, D., & Henning, E. M., 1995). The slower reaction time may only be a fraction of a second but in highly competitive sporting situations that is all it takes to finish in first or set new records. In chronic conditions this lengthening will actually increase the number of sarcomeres present in the muscle, as well as increases in muscle fiber girth (Hutton, R. S., 1993). This type of muscle deformation hints that all changes occurring post stretch may not be exclusively nervous system related. Many have theorized nervous system participation as a possible regulator of stretch effects on muscle and performance; however, current physical limitations on assessing nerve interactions in such situations leave researchers to only postulate the connections.

With an increase in flexibility from a bout of stretching there is a decrease in active stiffness. It has been found that just 10 minutes of static stretching will decrease viscosity and increase elasticity (Kubo, K., Kanehisa, H., Kawakami, Y., & Fukunaga, T., 2001), however these effects may only be seen acutely. While this mechanism will allow for fibers to slide with less resistance, the compliance of the muscle tissue will also increase, leaving it difficult to create cross bridges and thereby diminishing the muscles ability to produce a greater force (Rubini, E.C., Costa, A.L.L. & Gomes, P.S.C., 2007) and disrupting the stretch reflex mechanism (Cornwell, A. et al. 2002).

Effects of Stretching on Muscle Performance

Cycling. Of the few stretching trials performed on cyclists available, variables measured lack support from each other. It is possible that there is so little literature due to the nature of the sport and its tendency within the sport to resist change. Typically, competitive cyclists do not engage in stretching so the purpose of examining its effects on performance may be lost or dismissed by many in the field.

The rationale of the many different warm-up styles currently in use is to elicit a change in both temperature and non-temperature related effects, however, cycling is unique in terms of the body's movement. The cyclists' actions are highly repetitive but the bicycle itself limits ROM, and it is suggested that these unique situations may result in stretching having little effect on performance. Prior studies have observed the effects of stretching on time to perceived exertion and leg power. While highly variable in nature, with many facets effecting results, time to perceived exertion still reveals a valuable concept in terms of stretching and cycling. Subjects tested three protocols in random order (active, passive and no warm-up) at the same time of day, a week apart. RPE determined warm up intensity (RPE < 11) as well as test termination (RPE 15). ANOVA results showed the passive stretch warm up to yield a greater exercise time than the active or control; however, improvements in time could be linked with subject's familiarization with the testing procedure. The hypothesis behind the active warm up's inability to outperform the passive warm up is potentially linked to the warm up being too demanding, thus leaving the subjects fatigued early. A quantitative evaluation of performance was not fully measured in this particular study, prompting further research to take that into consideration (Ng, G.Y.F., Cheng, C.Y.Y., Fung, W.M.L., Ngai, N.T.W., Wong, E.C.Y., Yeung, A.W.F., 2007). Although testing a much shorter bout of exercise, one group found similar results to those of Ng et al. College students experienced an increase in work done (J/kg) at 5 and 20 minutes post-stretch (O'Connor, D.M. et al. 2006), however, these findings were thought to be optimal for short-term performance (< 10 s) in activities where elastic energy is not playing a large role.

To contrast these results are those concerning power output during a Wingate cycle test. Ten recreationally active male cyclists were tested for peak and mean anaerobic power output in two trials following a randomized warm-up, consisting of a static stretching warm-up protocol, and one without a stretching protocol. The stretching protocol contained stretches targeting the lower extremities, with each position held for 30 seconds, 4 times each. An ANOVA data analysis showed significant differences mean and peak power output for the stretch versus conventional warm-up. The stretching group tested peak power output of 753 (± 167) watts, and a mean power output of 549 (± 108) watts, compared to the conventional warm-up (PP = 889 ± 258 watts), MP = 584 (± 116 watts) (Ramierz, E. B. et al. 2007). Based on these results, it appears the decrements in power post-static stretch may also apply on a bicycle. This area would benefit from future research comparing stretching types and their effects on cycle performance.

More recently, research has started observing longer cycling bouts after stretching. After 30 minutes of static stretching one group observed decreases in economy while subjects pedaled at 85% max wattage (Esposito, F. & Limonta, E., 2011). Similar to these findings, increases in VO_2 while pedaling at 65% of $VO_{2\ max}$ were also measured, however, these findings were only statistically significant in the first 5 minutes of the 30 minute bout. In addition, challenging the findings of Ng, et al (2007), RPE measurements revealed no statistical significance after static stretching (Wolfe, A. E., Brown, L. E., Coburn, J. W., Kersey, R. D. & Bottaro, M., 2011).

Force production and torque. To account for the decreases in performance related to stretching there have been two proposed theories; mechanical factors and neuromuscular factors. Many researchers have mentioned these ideas; however, the data is limited regarding the topic due to the difficulty of measuring such variables. One proposition notes that if the central nervous system (CNS) mediated such effects then the un-stretched limb would experience similar results to that of the stretched limb. In an attempt to test this theory in conjunction with testing the effects of static stretching on eccentric torque production in women, one group proposed a three part study to test for velocity specific effects seen during maximal voluntary eccentric isokinetic leg extensions, compare stretched and un-stretched limbs, and examine the neural and mechanical outcomes using EMG and MMG. Twenty-one recreationally active subjects were given a 5-minute warm-up before testing peak torque (PT) for extension of the dominant and non-dominant legs, pre- and post- static stretching. Stretching consisted of four holds on the dominant leg (as per Nelson, A. G. et al. 2001), one unassisted and three assisted. MMG and EMG were calculated for ROM not including the acceleration and deceleration phases of movement. This information was then compiled and put into a four way repeat measures ANOVA to analyze PT and joint angle at PT, mean power output, and EMG and MMG amplitude. Data analysis revealed a decrease in PT in the stretched limb, though not velocity specific and EMG amplitude also displayed a decrease in amplitude. Evident decreases in PT and EMG in the non-stretched leg could indicate that the inhibitory mechanism could be CNS driven. Further research is necessary to hone in on technique to prove these proposed theories (Cramer, J.T., Housh, T.J., Weir, J.P., Johnson, G.O., Coburn, J.W., & Beck, T.W., 2005).

Regardless of information to the contrary, stretching is still commonly used as a technique for improving ROM and hopefully reducing injuries. It is noted that stretching is also used prior to strengthening exercises, however some research has shown this to not be necessary, and may actually be counterproductive. Marek, et al, (2005) aimed to examine the short-term effects of static and proprioceptive neuromuscular facilitation stretching on peak torque, mean power, active ROM, passive ROM, EMG amplitude, and mechanomyographic (MMG) amplitude of the vastus lateralis and rectus femoris muscles during voluntary maximal concentric isokinetic leg extensions at 60 and 300 degrees per second. The subject pool consisted of nineteen recreationally active subjects, who were given a five minute warm-up at 50 watts (W) on a stationary cycle ergometer. Before and after the static or PNF stretching protocols, maximal concentric isokinetic PT for extension of the dominant leg (based on kicking preference) was measured at randomly ordered velocities (60 and 300 degrees per second). Three or four submaximal warm-up trials preceded three maximal muscle actions at both velocities. Power, electrical signals, and ROM were measured and analyzed using two three-way ANOVA's. Significant effects were seen for time and velocity with power output, both showing a decrease after stretching. Active and passive ROM both increased from pre to post in response to the treatments, and the EMG recording was shown to decrease from pre to post testing, in response to both types of stretching. Excluding leg extensions while weight training, the action of being strapped to a chair and having a single leg isolated for an activity is not one seen in sports, or recreational activities for that matter. There is the possibility that in an effort to determine specific muscles effected after treatment that results may not carry over to sport. Actual movements involve a total body effort (legs, core musculature) and these decreases in performance may have only a miniscule effect once the whole body is working together.

With much of the research available regarding stretching performance conflicted it is important to be able to reproduce results. While the primary objective of one such study was to determine how stretching effects muscle strength endurance, previous research in the area has been criticized for poor reliability; therefore the purpose of one such trial also included the repeatability of measured results (Nelson, A. G. et al., 2005). The study design was comprised of two different experiments, the first measuring the influence of stretching on maximal lifts at 60 and 40% of 1RM. The second using the same test at 50% of 1RM, utilizing multiple sessions for test-retest purposes. An ANOVA was run to compare the results of the tests and revealed significant decreases in the average number of lifts demonstrated in both tests, with experiment two showing a 28% mean decrease in number of lifts. Supporting these findings are those of Winchester, et al (2008), who found significant decreases in knee flexion strength after 30 seconds of hamstring stretching among college students. While mechanisms of causation were not the purpose of this research, muscle stiffness, decreased blood flow with resulting increased metabolites, and calcium (Ca++) kinetics are all offered as possibilities. It is even suggested that fatigue, as seen by the decrease in excitatory input, may also be to blame. Given the results of the data analysis, it is suggested to refrain from stretching prior to lifting to maximize results and progress.

Although many studies have shown otherwise, not all research testing power production and torque has yielded detrimental results from the application of static stretching. Eleven NCAA Division I women's basketball players were instructed to perform four static stretching exercises, preceded and followed by isokinetic testing, measuring maximal voluntary concentric isokinetic peak torque (PT) and mean torque (MT) on their dominant leg at randomly ordered velocities of 60 and 300 degrees per second. An ANOVA was run for pre- vs. post-five, 15, 30 and 45 seconds. The calculations indicate stretching did not affect isokinetic peak torque or mean power at either speed, at any interval, consistent with similar studies. Possible mechanisms include stiffness and neural factors affecting muscle activation (Egan, A. & Cramer, J., 2006). It is worth noting the theory hypothesized by the authors suggests muscluotendinous training adaptations associated with resistance and flexibility training, as well as the cardiovascular conditioning that comes with the sport of basketball may be responsible for the lack of negative effects from stretching.

Endurance. When looking at the effects of flexibility and running, there is a negative relation to range of motion and running economy (RE). It is suggested that inflexibility in certain areas of the musculoskeletal system may enhance running economy in sub-elite male distance runners by increasing storage and return of elastic energy and minimizing the need for muscle-stabilizing activity (Craib, M.W., Mitchell, V.A., Fields, K.B., Cooper, T.R., Hopewell, R. & Morgan, D.W., 1996). This was determined after testing 19 well-trained male sub-elite distance runners. Subjects flexibility was assessed for the areas of the lower body directly involved in running; trunk, lower back, hips, buttocks, hamstrings, quadriceps, and calves. After two ten minute running economy assessments, totals were averaged and the analysis revealed a significant and positive correlation between standing external hip rotation and dorsiflexion flexibility with submaximal VO2. These results indicate the less flexible athletes are more economical when running, and that increased speeds will make this variation more dramatic. Supporting this statement is Jones (2002), who came to a similar conclusion when looking at international-standard male distance runners. Subjects performed a sit and reach test after a warm-up, followed by a graded exercise test to determine VO2 max and RE. Researchers found that those runners with poor flexibility had greater RE. The potential reason suggested for this finding is the tighter muscles having a greater storage of elastic energy, providing a greater return from muscles and tendons and increasing economy.

Summary

While there are still gaps in the research in this area there do appear to be some agreements amongst researchers. These trends point to a more sport specific warm up, such as a dynamic warm-up mimicking sport related movements to aid in performance. Though many have found the effects of static stretching to be negative, there is a chance that this could be from speed or temperature dependent variables, not to mention the tested range of motion.

One downfall of stretching research has been the reliability and repeatability. Nelson, et al. (2005) composed an experiment to observe if previously published findings on lifting power and stretching could be applied to endurance lifting. The results of the two-part experiment revealed significantly fewer lift attempts at 40 and 60 percent of body weight (an average of 9.8 and 24.4 percent fewer repetitions). Reliability for test-retest was high, with an interclass coefficient for the stretching program at R = 0.970. The flexibility portion of testing consisted of the sit-and-reach stretch under four conditions (self, self-assisted, assisted, and self-assisted again) for three bouts of 30 seconds with a 15 second recovery. A three way repeated-measures ANOVA revealed that significant increases in sit-and-reach performances were due to participation in the leg stretching.

There are other factors that may have influence on stretching results as well; the possible connection between testing speed and ROM of an activity as to whether or not stretching will affect the performance outcome being one such scenario. While cycling is not a slow sport, there is very little stretching of the muscles or joints while on a bike. It is possible that the decreases seen in elastic energy may not apply to this activity (O'connor,et al. 2006), as elastic energy is not an issue while on a bicycle. This points to a need for research in this area.

Chapter 3

METHODOLOGY

Trained male and female cyclists participated in this study. All subject baseline measurements were gathered before beginning testing in one of three randomly selected groups. These groups followed a specific protocol prior to exercise, consisting of a stretch, no stretch, and active warm-up. After the pre-cycling treatment, subjects immediately completed 576 kJ on a stationary bicycle. Groups systematically completed all pre-exercise protocols using the Latin-square system.

Subjects

Participants were men and women from a variety of competitive cycling age classes (see descriptive data in Table 1), and were free from physical limitations (those with an acceptable amount of risk factors as determined by the ACSM). Human subject approval and written informed consent was obtained prior to participation. Requirements for participation included a minimum of five hours of training per week, over the course of ≥ one year.

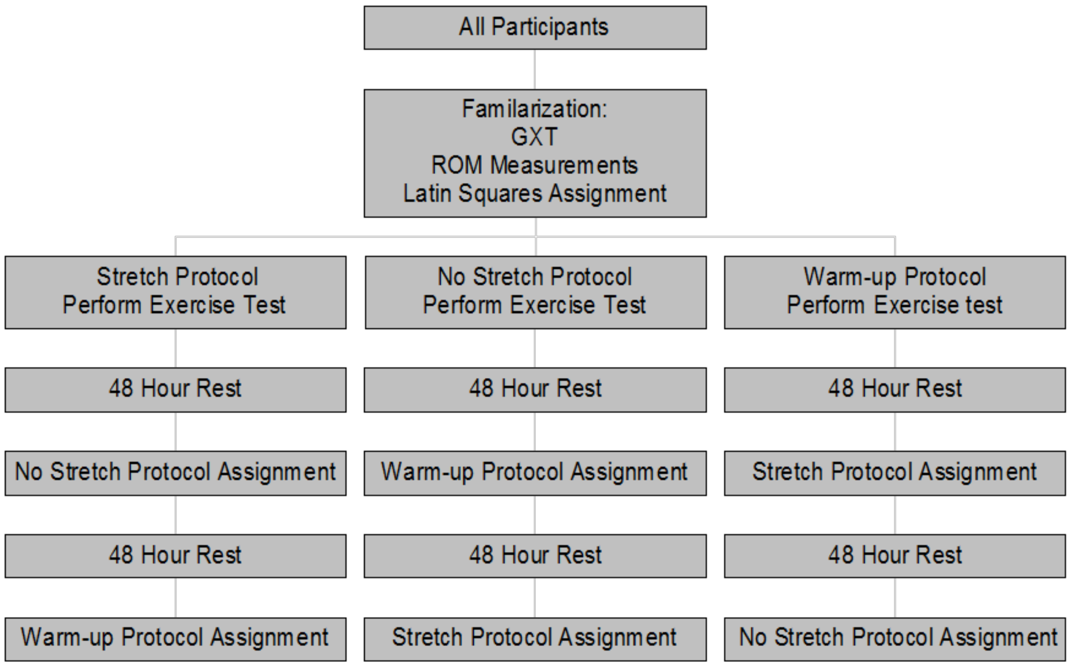
Table 1:
Subject Characteristics

Age (years)	32 ± 7
Height (cm)	174.8 ± 8.7
Weight (kg)	69.7 ± 9.6
VO_2max (mL/kg/min)	61.3 ± 7.3
BMI	22.7 ± 1.6

Experimental Design

Testing consisted of four sessions (Chart 1). The first session included a graded exercise test (GXT) and baseline lower body ROM measurements. This session determined VO_2 max, maximal power, time trial intensity, and acclimatized the subjects with the testing site and equipment. On the first day of testing subjects were assigned to one of three groups in a Latin squares fashion (see example in Chart 1). The three groups consisted of a Stretch (S), Active Warm-Up (W), or a No Stretch (NS) group. There was a minimum of 48-hours rest between testing days as the effects of stretching can last 24 hours (de Weijer, V.C., Gorniak, G & Shamus, E., 2003).

Figure 3.1. **Flow chart of subject participation through study.**



Procedures

Thorough instructions were given to all participants by the same tester to ensure consistency. Testing occurred at the same time of day to prevent diurnal variations, with subject's limiting exercise the day prior to prevent soreness during testing and to allow proper rest before an all-out cycling bout. A 24-hour activity recall was collected upon arrival at each testing to confirm subject's adherence to protocol. Participants performed all riding on an electronically braked stationary bicycle (Lode Excalibur). Variables measured were observed for the duration of the test and recorded at every 28.8 kJ completed and upon completion of the time trial. These measurements included: Heart Rate, RPE, and wattage (W) at each 28.8kJ. Oxygen consumption (VO_2 (ml/kg/min)) was measured during every 144kJ of the time trial. Heart rate was tracked using a Polar heart rate monitor. The Borg RPE scale was explained and utilized in all visits to determine perceived exertion. Expired air was collected and measured using a Parvo Medics TrueOne 2400 metabolic cart (Sandy, Utah USA). During time trial performance the only indicator of time was the acknowledgement of each 28.8 kJ completed as to promote an all-out effort and avoid intentional pacing. RPM and running time were kept hidden from subjects in order to base personal performance on physical ability post-warm-up protocol.

Graded exercise test (GXT). Subjects had the cycle set to their personal measurements before starting, including attachment of personal pedals. Using a one-minute stage protocol, resistance increased by 35 W for males and 25 W for females in each stage. Gas analysis was collected for the entire time of the procedure, with the completion of the test ending at VO_2 max (previously defined as an RER ≥ 1.1, an RPE greater than 17, and an increase in oxygen consumption of less than 2 ml/kg/min).

Range of motion. Once the subject had recovered from the GXT measurements for the five positions used in the stretch protocol were collected (Quadriceps, Hamstrings, Hip Flexors, Hip Extensors, and Plantar flexors). ROM was determined using a Leighton Flexometer, with reliability of hip flexion at 0.978 for the right leg and 0.995 for the left leg (Leighton, J. R., 1942). The Flexometer was centrally located on the thigh, approximately equidistant to the hip and knee, for the measurements of hip and thigh ROM. For the plantar flexors the Flexometer was centrally located on the lower leg, approximately equidistant to the knee and ankle. Once all baseline measurements were collected subjects were informed of testing order.

Time trial warm-up.

Stretch protocol (S). The static stretch protocol used was a modified version of that utilized by Yamaguchi & Ishii (2005), consisting of five positions that target the primary cycling muscles in the lower limbs: quadriceps, hamstrings, plantar flexors, hip extensors and hip flexors. Stretching positions were demonstrated and thoroughly explained before the subject was aided in attempting each position. Target areas of where to feel the stretch and proper form were emphasized. All stretching was done individually, or with the assistance of the instructor, to ensure the stretching elicited a change in flexibility.

Quadriceps. Starting in a prone position and with a fully flexed knee the subject and/or instructor brought the heel to the gluteus. If required, the knee was also lifted to ensure maximal stretch.

Hamstring. While lying supine, the subject flexed the hip while keeping the knee extended and both hips on the stretching surface. The instructor, if necessary, applied added pressure.

Plantar flexors. In a standing position with their feet approximately shoulder width apart, the subject dorsiflexed the ankle joint, letting the knee fall directly over the toes while keeping the heel on the ground.

Hip extensors. The subject flexed both the joints of the hip and knee while laying supine, keeping their hips on the stretching surface.

Hip flexors. In a prone position the instructor lifted the subject's leg with a slight bend in the knee. Using one hand for support of the stretching leg, the other hand applied pressure on the gluteus to keep the focus of the stretch on the hip.

These stretches were all demonstrated and explained by the same individual to prevent confusion and to ensure all groups received the same instruction. In the interest of time the plantar flexor and quadriceps stretches were performed on both legs at the same time, while the other three positions were done one leg at a time. Positions were held in 25-second intervals, with five seconds of rest/re-position time allowed between stretches (two minutes per stretch, five stretching positions), for a total time of 16 minutes and 40 seconds. An instructor stretched participants and held the positions to the point just past discomfort, minimizing variations and ensuring all subjects reached an adequate point in their stretches. To provide evidence as to the effectiveness of the stretching being provided the dominant leg hamstring ROM was also measured using the Flexometer pre- and post-stretch. Following the stretching subjects had two minutes to prepare and mount the testing cycle to perform the 576kJ TT. All variables were measured and recorded in the same way for each trial. Heart rate, RPE, and W measured and recorded every 28.8kJ and immediately upon completion of the 576 kJ. Expired air was collected every 144 kJ.

Warm-up protocol (W). The warm-up protocol consisted of no stretching, but rather performing an active warm-up. Subjects pedaled on a stationary cycle for 15 minutes (the approximate time equivalent of the stretching protocol) at 20, 35, and 50% of their max wattage, as determined from the baseline maximal exercise test. Each stage was five minutes in length and transferred to the next stage without stopping. After the warm-up pedaling was completed and the two-minute break given, subjects began their time trial, with HR, RPE, and W measured and recorded every 28.8kJ and immediately upon completion of the 576 kJ. Expired air was collected every 144 kJ.

Non-stretch protocol (NS). Subjects performing this protocol were instructed to sit quietly in the riding position, refraining from excessive movements, for a period of time matching that of the stretching and warm-up protocols (15 minutes). Once this time was up, subjects were given two minutes to prepare and mount the testing cycle and commence cycling. Heart rate, RPE, and W measured and recorded every 28.8kJ and immediately upon completion of the 576 kJ. Expired air was collected every 144 kJ.

Data Analysis

Variables analyzed were HR, RPE, VO_2, power, and time to completion. A two-way ANOVA with repeated measures was used to compare treatments for each individual, as well as assess changes in the variables in work completed over time. An alpha level of 0.05 was used to establish significance in the data. A Tukey post-hoc test was utilized to reveal relationships on any significant results.

Chapter 4

RESULTS

The current investigation examined the effects of a static stretching warm-up when compared to an active warm-up and no warm-up on a 576 kJ cycling time trial performance. Nine trained subjects (n= 1 female, 8 male) volunteered and completed the pre-cycling treatments in Latin squares format over the course of 10 days (Chart 1). All procedures were performed at California State University Sacramento, in the Human Performance Research Laboratory.

Heart Rate

Heart rate was collected every 28.8 kJ. A two factor ANOVA with replication revealed no significant main effect for treatment ($p = 0.174$). However, there was a significant main effect for work completed over time ($p = 0.000$). Further analysis reveals that, while not significant, there was a trend for the main effect over the first five data collection points ($p = 0.09$). Data for VO2 changes can be seen in Figure 4.1.

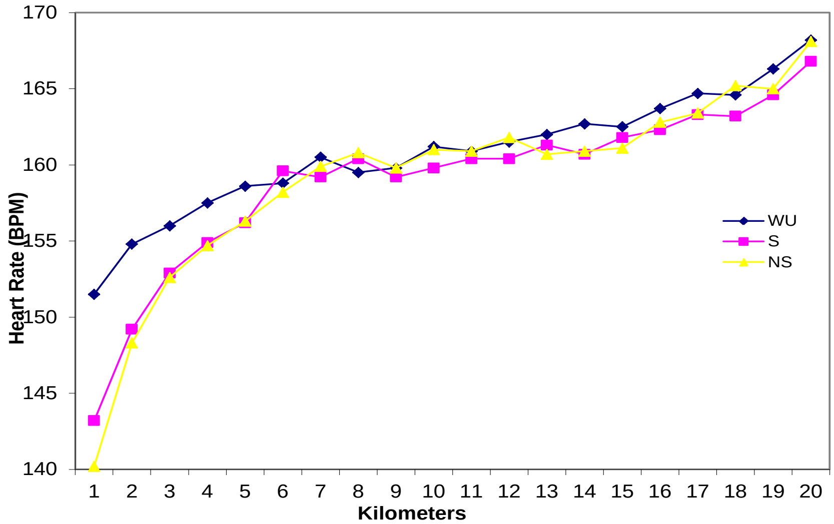


Figure 4.1. Heart rate averages by testing condition. There was not a significant interaction between groups (p= 0.00).

RPE

Rate of Perceived Exertion was collected every 28.8 kJ. The ANOVA revealed no significant main effect for treatment (p= 0.19). However, there was a significant main effect for work completed over time (p= 0.000). Tukey's post hoc revealed a significant increase in RPE from 28.8kJ (14.037 ± 2.53) to 86.4 kJ (15.778 ± 1.76) (p=0.000), followed by a significant and gradual increase in RPE for the remainder of the data collections (p=0.000). There was a significant interaction between treatment and work completed over time (p= 0.000). Data for VO2 changes can be seen in Figure 4.2.

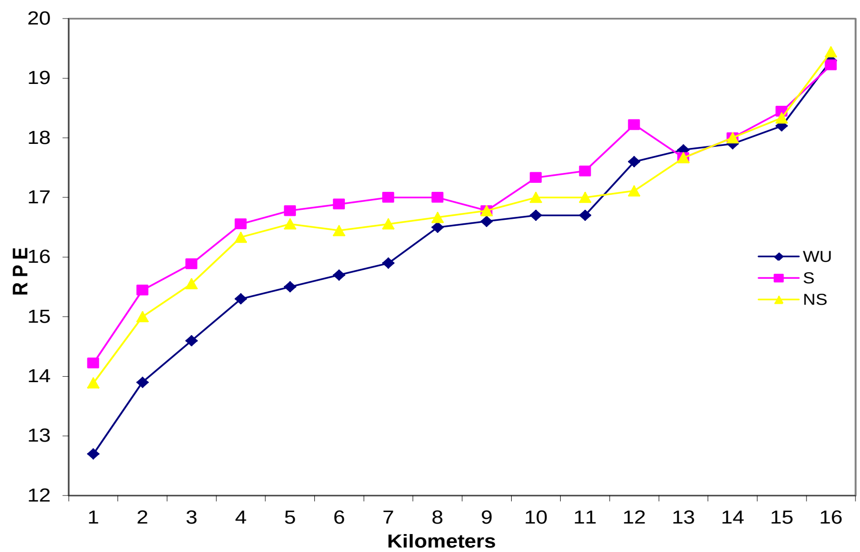


Figure 4.2. RPE averages across conditions. Data reveals no significant difference between treatments (p=0.43).

Power

Power output (W) was measured every 28.8 kJ. The ANOVA revealed no significant main effect for treatment (p= 0.76). However, there was a significant main effect for work completed over time (p= 0.003). Tukey's post hoc revealed a significant decrease in W from 28.8kJ (276.89 ± 51.25 W) to 144 kJ (250.26 ± 51.90) ($p=0.005$). There continues to be a significantly depressed power output across the trial up to the collection point at 547.2 kJ (251.15 kJ ± 47.12) ($p= 0.008$). Data for the final collection at 576 kJ reveals a significant increase in W (277.07 kJ ± 63.19) ($p= 0.007$). There was a significant interaction between treatment and work completed over time ($p= 0.000$). Data for VO2 changes can be seen in Figure 4.3.

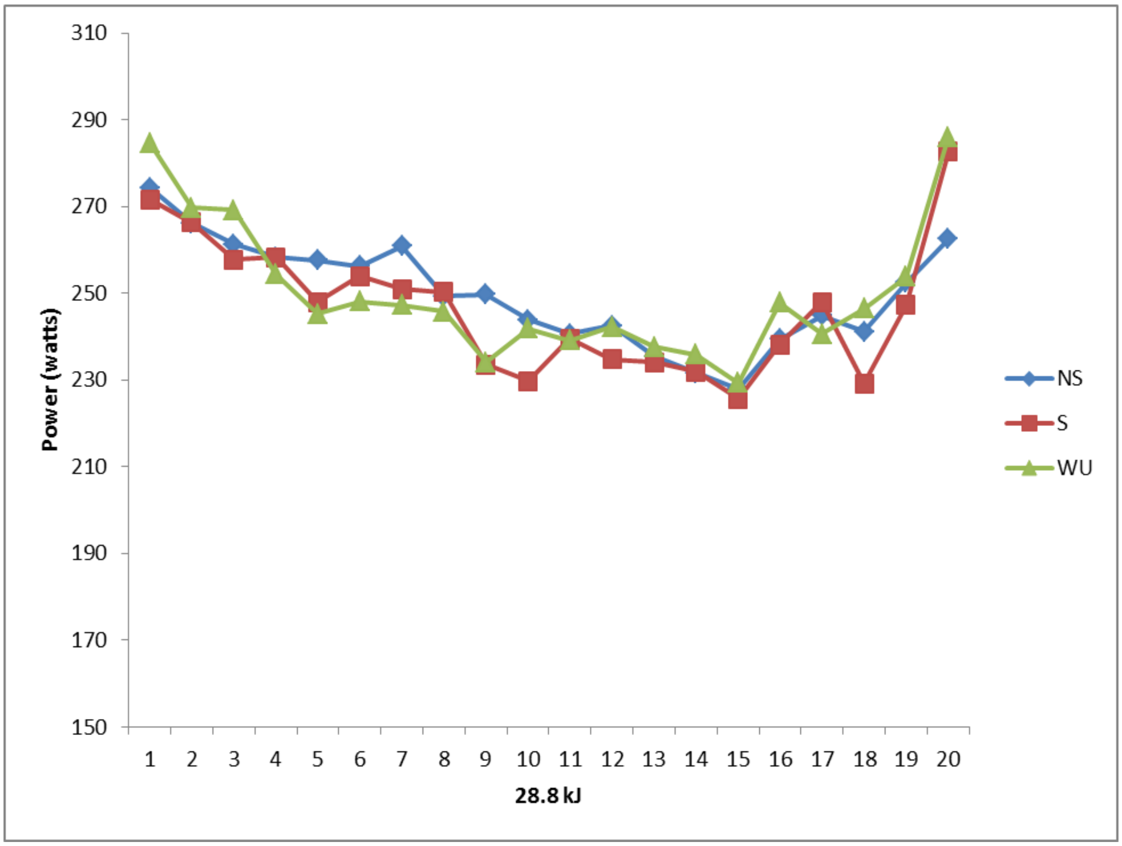


Figure 4.3. Power output over time. Significant decreases were observed from the first to the fifth data point ($p=0.005$). Collection at the final data point revealed a significant increase in power ($p=0.007$).

VO_2

Expired gas was collected and analyzed every 144 kJ. The ANOVA revealed no significant main effect for treatment ($p>0.05$). However, there was a significant main effect for work completed over time ($p= 0.000$). Tukey's post hoc revealed a significant decrease in VO2 from 144kJ (3.79±0.51 L/min) to 432 kJ (3.64±0.54 L/min) ($p=0.02$), followed by an increase in VO2 at 576 kJ (3.85±0.53 L/min) ($p=0.001$).There was a significant decrease in VO2 from the first to the third data collection ($p= 0.021$), and a significant increase in VO2 from the third to the fourth data collection ($p= 0.00$). There was not a significant interaction between treatment and work completed over time ($p= 0.12$). Data for VO2 changes can be seen in Figure 4.4.

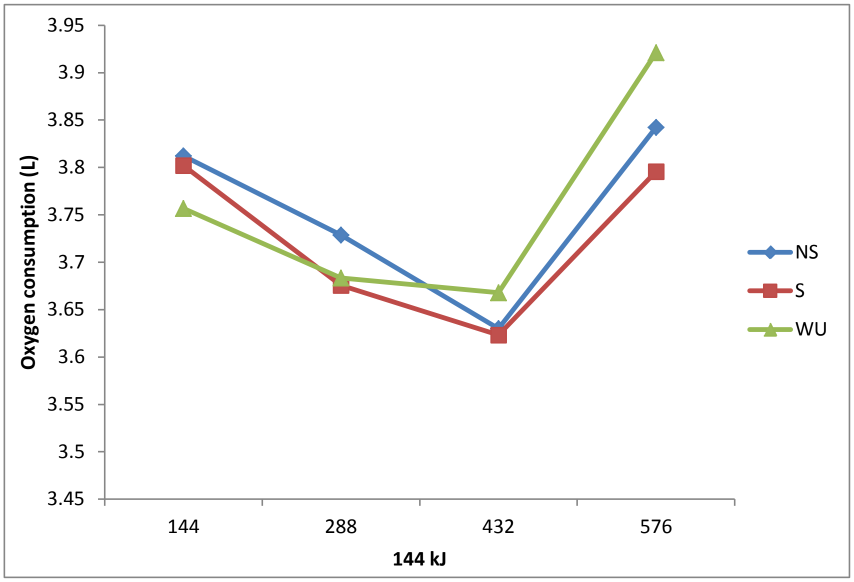


Figure 4.4. Gas analysis averages. While not statistically significant over time there was a significant increase in VO_2 from the third to the fourth collection.

Time to Completion

No significant differences were found in time to completion for the three trials (S= 39.44 min ± 7.18, WU = 39.57 ± 7.61, NS = 39.89 ± 7.66, p= 0.993). Individual times per trial can be found in Table 2. The ANOVA revealed no significant main effect for treatment (p= 0.99). There was not a significant interaction between treatments (p= 1.00). Table 2 displays a comparison of individual subjects time to completion. Data for time to completion can also be seen in Figure 4.5.

Table 2. Comparison of Subject Time to Completion.

Subject	Stretch	No Stretch	Warm-up	Individual Average	Individual SD
1	34.93	33.73	33.3	33.99	0.84
2	48.43	46.33	47.33	47.36	1.05
3	45.73	45.78	46.65	46.05	0.52
4	35.03	34.98	35.01	35.01	0.03
5	51.25	50.4	51	50.88	0.44
6	42.8	43.01	43.56	43.12	0.39
7	31.26	32.23	32.33	31.94	0.59
8	33	31.1	31.12	31.74	1.09
9	36.55	37.38	35.81	36.58	0.79
Group Averages	39.44	39.89	39.57	-	-
Group SD	7.18	7.66	7.62	-	-

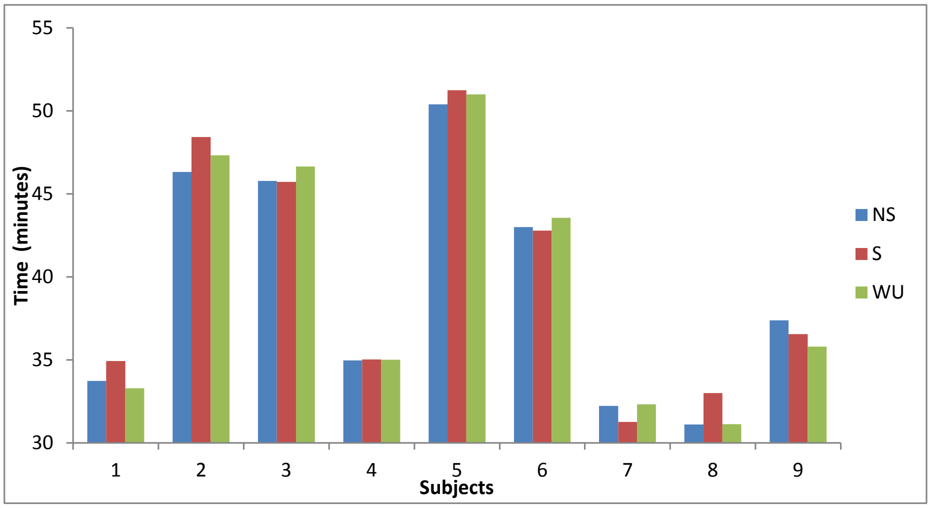


Figure 4.5. Visual comparison of each subject and their time to completion per treatment.

Chapter 5

DISCUSSION

The aim of this study was to examine the effects of static stretching on cycling time trial performance in comparison to an active warm-up and no warm-up at all. After collecting baseline data, nine healthy and experienced subjects (n= 8males, 1 female) completed the three different pre-cycling treatments in a Latin squares format. Data collected per trial included HR, RPE, W, VO_2, and time to completion. Subjects were given 48 hours of rest between trials, for a total time commitment of 10 days to complete the study.

As was hypothesized, the static stretching protocol had no significant effect on time to completion ($p = 0.993$) or any other variable measured. This is the first study to observe the effect of stretching on time to completion of any endurance event. With little to compare in this aspect, Ng, et al (2007) noted that passive stretching and heating prior to a bout of cycling significantly increased time to fatigue. This was attributed to the dilation of blood vessels, speeding up metabolite removal and thereby increasing exercise time. While this is a possibility, an active warm-up can also illicit these physiological changes. Upon observing the trends in all data collected it appears that physiological responses may be delayed post-stretch. These effects can be observed in the initial drop of power output and VO_2, and the apparent lag in HR and RPE. By mere observation, all variables appear to drift to along a similar path regardless of pre-time trial treatment. Statistically, there is no significant difference in pre-time trial treatment.

Heart rate response in performance post-stretch has also received little attention from the current research available. An active warm-up is associated with an increase in heart rate (amongst other variables previously noted) and the gap observed at the beginning of the trials from warm-up compared to stretch and no stretch is to be expected (Figure 4.1). The initial separation could be the body catching up to the performance demands, hence the statistical equalization later in the time trial. Opposite to HR, RPE displayed an initial depression with the warm-up treatment when compared to stretch and no stretch protocols (Figure 4.2). Although not statistically significant between trials, RPE achieves a perceived equalization almost half way through data collection. Supporting this data is the secondary findings from Wolfe, et al. (2011), who also found RPE measurements to lack a statistically significant difference after static stretching prior to 30 minutes of cycling. Both variables increased significantly over time (p= 0.00, p= 0.00), which is to be expected in an all-out exercise bout performed at maximal effort.

Following the trend observed for HR and RPE, power output was not statistically different across trials; however there were significant changes within the trial over time (Figure 4.3). There is a significant decrease in power output over the first five data points (p= 0.005) and then a significant increase from the 19^{th} to the 20^{th} data collection (0.008). After a post exercise discussion, most cyclists admitted to attempting a power output unrealistically high for the demands of the trial, potentially leading to the decreases observed in the beginning of each time trial. Another possible explanation is the body’s need to increase physiological responses to keep up with the demands of exercise. Subjects may have perceived an adequate starting pace, but the body was incapable of maintaining and the cyclist must decrease power to compensate for the lower starting level of heart rate, blood pressure, body temperature, metabolite removal and the improved processes that follow these initial changes. In the last 28.8 kJ of each trial subjects were made aware of being close to completion and this anticipation may account for the significant increase at the end of each trial.

In comparison, O'Connor, et al. (2006) found 15 minutes of static stretching would significantly increase power when compared to five minutes of sub-maximal cycling (50 W for females, 75 W for males). The authors cite a potential difference in muscle temperature as possible reason for the obtained results; this supports the previously stated theory that body temperatures (and its subsequent effects on physiological processes) can play into power output. To account for the differing results of O'Connor and this study the previous utilized a five minute warm-up protocol compared to the 15 minutes used in this research. Five minutes may not match the temperature achieved in 15 minutes of stretching, and certainly would not achieve the levels attained in the 15 minutes of cycling performed in this study. It is possible that O'Connor may have achieved similar results to this project if warm-ups were similar.

Lastly, in continued support of the prior theory that static stretching merely results in delayed physiological responses, VO_2 across treatments were not statistically different but an initial significant drop within trials was observed. This differs from that of recent findings, where subjects displayed decreases in economy when pedaling at 65% of VO_2

$_{max}$ (Wolfe, A. E., et al. 2011) and pedaling at 85% of max wattage (Esposito, F. & Limonta, E., 2011) showed no change in VO_2. This variable has primarily been investigated by observing the correlation between ROM and economy. Multiple investigations (Jones, A. M., 2002; Craib, M. W., et al 1996; Wilson, J. M. & Flanagan, E. P., 2008) support the findings that there is an inverse relationship between economy and flexibility. It could then be hypothesized that pre-exercise stretching would cause a shift in oxygen consumption and that does not appear to occur in this study. Limited ROM and use of elastic energies has been suggested as one major factor differentiating cycling from other activities and it could be the link as to why cycling has not seen the same detrimental effects that running has.

Conclusion

The results of this research fall in line with the investigations claiming static stretching will have no effect on performance. However, there are still many who feel that stretching prior to activity will diminish outcomes. Given the conflict, it will be a long time before there is enough scientific evidence to create a pre-exercise stretching program specific to any one discipline. This debate can only be quelled when future research is not only repeatable, but also realistic. As is the case in numerous studies (Rubini, E. C. et al. 2007) stretching times were far too great to reasonably be used in an athletic or rehabilitative setting. Real world implications are also an issue; where this investigation utilized common stretching positions that were easy to apply, some research has developed complex contraptions (Godges, J. J., MacRae, H., Langdon, C., Tinberg,

C. & MacRae, P., 1989; de Weijer, V.C., Gorniak, G & Shamus, E., 2003), used multiple investigators to assist (Godges, J. J., MacRae, H., Langdon, C., Tinberg, C. & MacRae, P., 1989), and relied upon specific angular measurement (Decoster, L. C., Scanlon, R. L., Horn, K. D. & Cleland, J., 2004) to attain full ROM.

Future warm-up protocols will need to address the specific needs of an activity and take into consideration the elastic energy demands. It is possible that the results observed in this study were due not to the decreased amount of tension, but to the lag in physiological responses in the beginning stages of exercise. To address this, future research would benefit from observing a stretch/warm-up combined protocol, which would cover any potential gaps this current design has left out.

What this project lacks are the participants to provide greater statistical strength. More athletes would solidify results and also allow for a comparison in flexibility to performance. While running performance can be linked to ROM, this analysis could show that cycling is not effected by such variables and therefore athletes need not be concerned with enhanced flexibility.

Lastly, it is not uncommon for some cyclists to perform an active warm-up lasting 60 minutes or greater, at resistances exceeding that experienced in this laboratory. By allowing a participant to pursue a pre-testing warm-up mimicking that which they are familiar may reveal a different outcome in testing situations. Experienced athletes are in tune with their bodies and have established pre-exercise routines that are both mentally and physically comfortable. Employing such a tactic would be far more in tune with what to expect in training situations.

APPENDIX A

Informed Consent

Informed Consent
Effect of Stretching and Flexibility on Performance

Purpose of Study

In recent years the importance of pre-exercise stretching has been questioned. Previous research examining weight lifting and sprinting has found that pre-exercise stretching has decreased performance. However, very little data has examined endurance performance. This study will examine the effects of pre-exercise stretching on an endurance cycling performance. This investigation is being conducted by Daryl Parker, PhD in the department of Kinesiology at CSUS, and is the lead investigator. Dr. Parker will be assisted in the laboratory by graduate students completing their education at CSUS. Any questions regarding the study can be directed to Dr. Parker, (916) 278-6902 or parkerd@csus.edu.

Testing Procedures

Body composition and Flexibility Assessment will be assessed prior to any exercise tests. Your body fat % will be assessed via the skinfold technique. This technique requires a light pinching of the skin while the thickness of the skin is measured with a caliper. Flexibility will be assessed after a short warm-up. Flexibility will be measured with a seat and reach test that requires that you make an effort to touch your toes while the forward distance is recorded. Hip and knee flexibility will also be assessed with an inclinometer while you flex the knee and hip.

Maximal stress testing will be completed on an electronically braked bicycle. The testing procedure will begin at 70 Watts (50Watts for females). Every minute thereafter the load will increase 35 Watts (25 Watts for females) and will be terminated when 70 rpm can no longer be maintained. During the testing procedure you will have to breathe through a two-way valve while wearing a headgear and nose clip. During the test heart rate will be monitored continuously. Heart rate will be monitored with a heart rate monitor strapped around your torso.

Wingate Cycle Testing will be carried out 30 minutes after the maximal stress test. Following a 10 minute warm-up you will spin the bike ergometer up to highest rpm you can achieve. The workload will then be added to the bike and you will attempt to maintain the highest rpm possible for 30 seconds. Following the 30 seconds the load will be removed from the bike ergometer and you will cycle at a slow rpm until recovered.

Cycle Time Trials will be performed on separate days and under three different warm-up conditions. The three warm-ups will consist of a passive warm-up, a 10 minute active warm-up, or 10 minutes of stretching. Following the warm-up period a time trial will be complete in which you will complete 576kJ of work (~20Km) as fast as possible.

*Total time commitment for the study is approximately six hours.

Risks and Discomforts

Vigorous exercise, such as graded exercise testing and time trialing, involves a certain amount of risk. The associated death rate with vigorous exercise is very low in low risk individuals. During the testing procedures you will experience increased blood pressure, rapid breathing, increased heart rate, increased exertion, sweating, muscular discomfort, and fatigue. Also during this procedure it is possible that you will experience an alteration in heart rhythm, and in rare cases a heart attack or stroke. However, risks of these events taking place will be minimized by pre-health screening and monitoring during the tests.

In the event of an emergency, we will activate the emergency medical response process for the university. Any medical treatment or response that incurs a charge will be the responsibility of the research participant and not the university. The investigators of this study are trained in CPR and basic first aid.

Responsibilities of the Participant

Knowledge of your current health status and any abnormalities associated with it could profoundly affect the outcomes of your test, as well as your safety during the testing procedure. It is your responsibility to disseminate accurate and complete information regarding your health and condition prior to undergoing the test procedures. During the procedure it is your responsibility to provide the technicians with accurate information regarding how you feel during the test. It is also your responsibility to report any chest pain, tightness, or other abnormal discomfort during the testing procedures.

Benefits of the Testing Procedure

The exercise test may provide you with information regarding your current state of health and physical fitness. These tests can be used as a baseline beginning assessment to determine changes in physical state over time as well as various states of conditioning. Further, depending on the testing procedure this information may be beneficial in developing an exercise program for the enhancement of your current physical fitness.

Use of Medical Records

The data collected during this study will be treated as confidential. No one may view your results without your expressed written consent. This data will be coded with a random ID number and used for statistical analysis with your right to privacy maintained.

Consent to Participate

This testing procedure is voluntary and you are free to withdraw from the procedure at any time. Please feel free to ask questions regarding the procedure at any time. This may include clarification on the consent form, instructions on the procedure, or any part of the testing process that you are not comfortable with. You may also feel free to contact Daryl Parker PhD, the primary investigator, at any time regarding questions that you have 916-278-6902 or parkerd@csus.edu.

I have read this consent form, and understand the procedure, risks involved and my responsibilities during the testing process. Knowing the risks involved and having had my questions answered to my satisfaction I hereby consent to participate in this study.

___________	________________________________
Date	Print Name
	________________________________
	Signature
___________	________________________________
Date	Print Name of Witness
	________________________________
	Signature of Witness

APPENDIX B

Subject Medical History and Questionnaire

Health History Questionnaire

Name ______________________________________Date ________ Ph# ____________

Age ______ Height _______ Weight _______ Gender ________BMI __________

Waist girth ___________ cm

Ethnicity (only required for body composition tests) _____________________________

Pre-Exercise Blood Pressure _________________

1) Do you smoke? Y N

Have you ever smoked? Y N If yes how long since you quit? ____________________

2) Have you ever had your blood cholesterol measured? If yes what were the results?

Total cholesterol _____________

HDL ______________________

LDL ______________________

3) Do you have diabetes or any signs of diabetes such as frequent urination or extreme thirst? Y N

4) Do you have any chronic disease conditions or had any previous surgeries? Y N If yes please list ____

5) Are you currently taking any medications? If so please list ________________________

6) Do you have any physical limitations? (i.e. ankle, knee, back, or other injury that may limit your performance on an exercise test) If so please list ________________________________

7) Do you exercise regularly? Y N

If so what do you do for physical activity? _______________________________

How many times/week do you exercise? ________________________________

How long is each exercise session? ___________
Estimate your intensity _________

8) Family History

Have any of your immediate relatives (parents, siblings, or offspring) experienced a cardiovascular complication (heart attack, chest pain, etc.) or sudden death?
Y N

If yes, what was their relation and at what age did the incident occur?

____

9) Have you ever experienced any of the following:

Pain in the neck, chest, or jaw	Y	N
Shortness of breath w/mild exertion	Y	N
Dizziness or passing out	Y	N
Rapid breathing at night	Y	N
Swollen Ankles	Y	N
Abnormal heart beat	Y	N
Calf pain with exercise	Y	N
Known heart murmur	Y	N
Unusual fatigue or shortness of breath	Y	N

For lab personnel to fill out

Number of risk factors _____

Number of signs/symptoms _____

<u>Risk Stratification (circle one)</u>

Low Medium High

APPENDIX C

Baseline Testing Data Collection

Stretching Study

Name/#________________________________DOB/age___________Gender_____________

Height ________________________ Weight ________________________ Experience ________________

Resting HR ____________________________ Resting BP ____________________________

Baseline		
Control		
TT Time to completion =	VO2 =	
Comments:		
Warm-up		
TT Time to completion =	VO2 =	
Comments:		
Stretch		
TT Time to completion =	VO2 =	
Stretches	Before (degrees)	After (degrees)
Hamstrings		
Quadriceps		
Hip Flexors		
Hip Extensors		
Plantar Flexors		
Comments:		

APPENDIX D

Time Trial Data Collection

Non-stretch Protocol **Order #_____**

1. 60 minutes prior to test time warm up the cart.
2. Calibrate prior to the subjects arrival.
3. Set the Lode to the proper vertical and horizontal seat and handlebar settings.
4. Have clients dress before rest period. Subjects performing this protocol shall sit quietly, refraining from excessive movements, for a period of time of 15 minutes. Gather activity recall and weight.
5. Once this time is up, subjects immediately mount the testing cycle and complete their time trial.
6. Record using a new TT data sheet.

Number_______________________ Date_______________ Weight_________________

24 hour activity recall:

	Time Trial Max Values
Time to completion	
VO2 (ml/kg/min)	
Heart Rate	
RPE	

Warm-up Protocol **Order #**

1. 60 minutes prior to test time warm up the cart.
2. Calibrate prior to the subjects arrival.
3. Set the Lode to the proper vertical and horizontal seat and handlebar settings.
4. Have clients dress before warm-up period. Subjects performing this protocol shall refrain from pre-exercise movements and or stretching. Gather activity recall and weight.
5. Participants shall begin pedaling for a period of time of 15 minutes total – 5 minutes each 20/35/50 % of max wattage.
6. Once this time is up, subjects are allowed 2 minutes to make adjustments.
7. Complete time trial.
8. Record using a new TT data sheet.

Number____________________Date________________Weight____________________________

24 hour activity recall:	Warm Up settings: 20% = 35% = 50% =

	Values at Max
Time to completion	
VO2 (ml/kg/min)	
Heart Rate	
RPE	

Stretch Protocol **Order #**

1. 60 minutes prior to test time warm up the cart.
2. Calibrate prior to the subjects arrival.
3. Set the Lode to the proper vertical and horizontal seat and handlebar settings.
4. Have clients dress before stretching. Subjects will perform the self-administered and assisted stretching protocol while being observed and corrected for form and technique. Record on the **Stretching Data Sheet**. Gather activity recall and weight.
5. Participants shall mount the bicycle and begin their TT with no warm-up within two minutes.
6. Record using a new TT data sheet.

Number____________________ Date_________________ Weight____________________________

24 hour activity recall:

	Values at Max
Time to completion	
VO2 (ml/kg/min)	
Heart Rate	
RPE	

Stretching Data

Stretches	Before (degrees)	After (degrees)
Hamstrings		
Quadriceps		
Hip Flexors		
Hip Extensors		
Plantar Flexors		
Comments:		

Hamstring
While laying supine, the instructor flexes the hip while keeping the knee extended.

Quadriceps
The subject lies in a prone position, and with a fully flexed knee the subject pulls the heel to the glute and lifts the knee to ensure maximal stretch.

Hip Flexors
In a prone position, the subject’s leg will be lifted with a slightly bent leg to keep the stretch focused on the hip joint.

Hip Extensors
The subject will flex the joint of the hip and knee while the laying supine.

Plantar Flexors
While standing the subject will bend their knees, gently supporting themselves on the stretching table. Subjects heels will remain on the ground.

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