STATIC STRETCHING DOES NOT AFFECT MEASURES OF POWER AND FATIGUE DURING VIGOROUS CYCLING AMONG WOMEN

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Static stretching has been linked to lesser performance in many sport activities. The purpose of this study was to determine the impact of static stretching upon power and fatigue performance measures during vigorous cycling. In this study, vigorous cycling was assessed using the Wingate Anaerobic Test (WAnT). Using a counterbalanced design, twenty nine female participants completed standardized static stretching and non-stretching protocols prior to completing the WAnT. No statistically-significant differences ($p \leq 0.05$) were found between conditions for measures of peak power (PP), low power (LP) or fatigue index (FI). These findings suggest that static stretching had no statistically-significant effect on these performance measures commonly assessed during the WAnT.

KEY WORDS: coordination, power-cadence relationship, critical power

INTRODUCTION: Poor gross motor coordination patterns (GMCP) are linked to musculoskeletal injury (Jacobs et al., 2008). While altered kinematics are typically displayed and connective tissues within the musculoskeletal system often withstand abnormal loads during poor GMCP, the relationships between poor GMCP and musculoskeletal injuries are not fully understood (Hewett, Ford, Hoogenboom, & Myer, 2010). Greater understanding of the relationships between poor GMCP and musculoskeletal injury is vital to improving sporting performance and lessening injury due to repetitive activity (Hewett et al., 2010). In this context, it is widely acknowledged that fatigue can negatively influence GMCP. As fatigue levels rise, GMCP measures may lessen (Dingwell, Joubert, Diefenthaeler, & Trinity, 2008). Thus a combination of poor GMCP and fatigue may put one at increased risk for injury as well as undermine performance (Hewett et al., 2010).

Static stretching (STST) is often used to warm-up prior to sport and fitness activities, as well as within rehabilitation programs (Brody & Hall, 2011). The popularity of STST is linked to its relative safety as a form of exercise, and while some advocate it as a means of reducing injury the evidence to support this notion is disputable (Shrier, 2004). Similarly, a number of studies have linked STST to decreased performance measures. A common theme in such studies is the completion of a STST protocol immediately prior to high intensity, short duration muscular force production. Authors have noted STST produced decreased measures for one repetition maximum (1-RM) leg press, knee-extensor concentric torque, 20-m sprint performance, and jumping performance (Young & Elliott, 2001).

Cycling is a continuous motor task well suited for laboratory studies and may be used to assess GMCP. A common cycling test is the Wingate Anaerobic Test (WAnT). This test is widely used in laboratory settings, as it measures power output during a maximal 30 second cycling bout (Rana, 2006). The WAnT is used to assess anaerobic power and can assess a person's ability to produce maximal power while using both ATP-PCr and anaerobic glycolysis energy systems (Powers & Howley, 2006). While countless studies have used the WAnT (Rana, 2006), little research exists on the biomechanics or GMCP exhibited during this test. Similarly, no studies have addressed the impact of STST on WAnT performance. A deeper understanding between GMCP measures, STST, and fatigue characteristics during the WAnT may lead to a better understanding among sport scientists of how to increase performance and reduce injury during vigorous cycling.

The purpose of this study was to assess the impact of STST on measures of power and fatigue while completing a maximal bout of anaerobic cycling.

METHODS: Twenty nine (n= 29) women (21.29±2.62 yr, 168.13±6.32 cm, 62.52 ±7.93 kg) participated in this study. Inclusion criteria included women between the ages of 18 and 30 who were apparently healthy and physically active (30 min/day, 3 days/week for at least 3 months). Individuals with lower extremity pathology or who regularly cycle were excluded. The study received approval from the Institutional Review Board (IRB) prior to its start.

Each participant visited the laboratory on two occasions. At the beginning and end of each testing session, her heart rate, blood pressure, and respiratory rate were taken and recorded. Using a counterbalanced design, participants completed a STST protocol or non-stretching (NS) protocol. The STST protocol used in this investigation was based on methodology used in previous studies on static stretching. The STST protocol consisted of four, 30-second repetitions each of 5 stretching exercises, which were performed with an average total stretching time of 20 minutes, and included stretches for the hip extensors, hip flexors, knee flexors, and knee extensors (Nelson, Kokkonen, & Arnall, 2005). The static stretches for these muscle groups were performed separately on each leg. In the no-stretch condition, participants sat quietly for 20 minutes (Nelson et al., 2005). Then, following a standardized 10 minute warm-up and short rest period, participants completed the WAnT, riding at maximal intensity for 30 seconds.

Cycling conditions for the WAnT occurred on an electronically-braked ergometer (Racermate, Seattle, Washington, USA) and were controlled and continually measured by computer. The following variables were assessed continuously during each trial: speed, watts, cadence, and measures of cycling efficiency (SpinScan^{TM}, and average torque angle (ATA) throughout the 360^{o} of pedal travel). Measures of peak power (PP), mean power (MP), minimum or low power (LP), and fatigue index (FI) were calculated using 5 second time intervals. Fatigue index was calculated using the following equation:

FI: [(Peak Power Output – Min Power Output)/Peak Power Output)] x 100

Paired t-tests and correlational analyses were completed using SPSS 21 (IBM SPSS, Armonk, NY, USA). Statistical significance was set at the $p \leq 0.05$ level.

RESULTS: Non-significant differences were found between conditions (static stretching versus control) for measures of PP, MP, LP and FI. Each of these dependent variables was also significantly correlated between the two conditions. These findings are depicted in Table 1.

Table 1. Comparison of power measures by condition.

Condition (n=29)	Stretch Mean±SD	No Stretch Mean±SD	F score	P value	Correlation	P value
Peak Power (PP)	396.17±51.24	404.95±53.32	-1.124	0.271	.688	0.000
Mean Power (PP)	305.02±34.28	310.48±36.35	-1.298	0.205	.802	0.000
Low Power (LP)	233.85±37.10	237.12±37.10	-.793	0.435	.808	0.000
Fatigue Index (FI)	40.37±10.15	40.89±7.87	-3.28	0.745	.593	0.001

DISCUSSION: These findings suggest that the power and fatigue measures collected during this short-term physical activity were not significantly influenced by STST. However, the power measures in this analysis were negatively affected across the board in the STST condition, so they likely have clinical meaningfulness. Previous authors have linked lesser force production following STST to stress relaxation of the muscle tissue, which leads to lower muscle-tendon stiffness and strength (Kubo, Kanehisa, & Fukunaga, 2001) or peripheral nervous system inhibition that results in lesser muscle activation (Cramer et al., 2005). Each of these factors are important considerations in sport biomechanics, as it stands to reason either is capable of altering performance during high-intensity, short-duration activities such as the WAnT. While the present findings were non-significant between the stretching conditions, a cycling coach or sport scientist might still reasonably give pause before instructing their athletes or participants to engage in STST prior to maximal cycling due to the consistently lesser values for PP, MP, LP, and FI following the STST protocol used in this study. Similarly, while measures of fatigue over a 30 second period represent a longer time frame than the following studies, the present findings partially support previous reports that STST produced decreased measures for one repetition maximum (1-RM) leg press, knee-extensor concentric torque, 20-m sprint performance, and jumping performance (Young & Elliott, 2001). In short, the present findings partially support previous reports that STST negatively affects many measures of short duration, high intensity physical activity. But subtle differences between this and previous studies – such as test duration, type of muscular action (e.g. concentric, eccentric, reliance upon the stretch-shortening cycle, etc.), and so on – may account for some of the difference in response seen in the present findings.

These results are consistent with previous studies that investigated the influence of STST upon longer duration cycling. Similar to the present study, Wolfe et al. found no differences in VO2 measures between STST and NS conditions during the final 25 minutes of a submaximal cycling protocol (Wolfe, Brown, Coburn, Kersey, & Bottaro, 2011). But they did find an effect of STST on cycling economy, reporting a decrease in cycling economy measures during the first 5 minutes of a submaximal VO_2 test that followed a STST regimen. These authors speculated that this lesser economy could be attributed to alterations in muscle mechanics, neural factors, or a combination of the two. They further speculated that STST may place motor units in a fatigued state. By fatiguing motor units, there may be a decreased number of available motor units recruited to produce force or the recruited motor units may simply produce less force. Nonetheless, while the differences were statistically non-significant, the fatigue measures used in this study did appear to be negatively influenced by STST, which is likely clinically meaningful. Additional study is needed to better understand how STST may negative affect this form of high force production, anaerobic activity in ways which differ from high force production, anaerobic activities such as sprinting, weight lifting, and vertical jumping.

The present findings also partially support a study by Fowles et al., which showed that STST can decrease force production and muscle tendon stiffness for up to one hour (Fowles, Sale, & MacDougall, 2000). It is possible that the 10 minute warm up ride completed between the STST and NS conditions attenuated in some way the potential impact of STST on fatigue measures. Future study might include repeating this same study, differing only in the removal of the 10 minute warm up ride; doing so might provide additional insights into ways that STST does, or does not, impact measures of fatigue. Similarly, future study might assess the impact of STST on WAnT performance on experienced cyclists, as they may respond to this condition differently than did the novice cyclists who completed this study.

The strength of this study was its focus on the impact of STST upon fatigue characteristics during the WAnT, a topic unaddressed to date in the sport science literature. Such research is vital to understanding the impact of STST during anaerobic activity. This type of research can, for example, help coaches better train athletes so as to improve athletic performance and decrease odds of injury, or help physical therapists to better understand the cause of injury due to repetitive motion, which is an important consideration when constructing any rehabilitation program. While these results did not fully support our original hypothesis, it does shed some light upon the impact of STST upon the GMCP that have been linked to musculoskeletal injury in the scientific literature (Jacobs et al., 2008).

CONCLUSION: Authors have linked both GMCP and fatigue to musculoskeletal injuries, and STST to decreased performance measures. As such, this study has scientific value as the first known investigation on the effect of STST on fatigue characteristics during vigorous cycling. The participants demonstrated no significant differences in fatigue measures, but they clearly showed decreased power measures following STST. Thus, the present study did partially support the many previous papers detailing STST prompting decreased measures for many sport activities fueled by anaerobic metabolism. These findings may help sport scientists better understand the impact of stretching methodologies in improving performance and injury.

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