EFFECTS OF STATIC STRETCHING, PNF STRETCHING, AND DYNAMIC WARM-UP ON MAXIMUM POWER OUTPUT AND FATIGUE

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The purpose of this study was to determine the effects of static stretching, PNF stretching, and dynamic warm-up on maximum power output and fatigue. Ten participants were recruited to perform a vertical jump test at 3 minutes and 20 minutes post-treatment for all treatments until voluntary fatigue. Participants performed a standard protocol including one of the stretching/warm-up treatments followed by two repeated, counter-movement, vertical jump tests. Results of the study showed no statistically significant differences in maximum power output although the dynamic warm-up group resulted in a 10% and 9% higher average output compared to the control group. Results also showed no statistically significant differences in percent decline in power output as well as time to voluntary fatigue, although there was up to a 6 s difference between treatments and the control group. Although this study concluded with no statistical significance, an argument could be made for applicable significance.

KEY WORDS: PNF, static stretching, dynamic warm-up, power output, fatigue.

INTRODUCTION: Pre-physical activity stretching and/or warm-ups are used in almost every activity or sporting event. Many recent studies have claimed that stretches such as static and proprioceptive neuromuscular facilitation (PNF) stretching are hindering, rather than aiding, to maximum power output (Behm et al., 2006; Cramer et al., 2005, Marek et al., 2005). Dynamic warm-up does not appear to increase range of motion (ROM) as much as a stretching exercises, however, beneficial effects of performing an active warm-up prior to supramaximal exertion have been previously shown (Bergh & Ekblom, 1979; O'Brien et al.,1997). Two primary hypotheses have been developed to explain the stretching-induced strength deficit: (1) mechanical factors, such as alterations in the viscoelastic properties of the muscle that may affect the length/tension relationship, and (2) neural factors, such as decreased motor unit activation, firing frequency, and/or altered reflex sensitivity (Cramer et al., 2005; Marek et al., 2005). Since the tendon has viscoelastic properties, it is able to change in length without immediately 'springing' back to its original length. The compliance of the tendon has been viewed as both positive and negative in that a more compliant tendon may aid in reducing injuries, where as a less compliant tendon may aid in increase performance (Åstrand et al., 2003). To maximize performance as well as ensure maximal possible safety of those involved, stretching procedures should be studied to identify the appropriate techniques to prepare properly an individual for physical exertion. Therefore, the purpose of this study was to determine the effects of static stretching, PNF stretching, and dynamic warm-up on maximum power output and fatigue. The following research hypotheses were tested: (1) there will be a difference in power output following the static stretching, PNF stretching, and dynamic warm-up treatments when compared to the no treatment condition, (2) there will be a difference in fatigue following the static stretching, PNF stretching, and dynamic warm-up treatments when compared to the no treatment condition, (3) there will be a difference in power output and fatigue when comparing values of the three-minute post-treatment tests to the 20-minute post-treatment tests.

METHODS: Ten participants, five males and five females, with average age of 19.8 yrs (±1.8), were recruited to participate in this study. Participants had an average mass of 75.6 kg (±15.5 kg). Each participant completed a control trial (no stretching) as well as each treatment in random order, each on a separate day. Treatments consisted of a pre-testing protocol utilizing static stretching, PNF stretching, dynamic warm-up, or no treatment (control). The order of each session was as follows: (1) Perform a warm-up on a stationary bicycle for three minutes instructed as a "slow, easy peddle," (2) perform one of the treatment protocols or no treatment (control), followed by a three-minute rest, (3) perform a repeated, counter-movement, vertical jump test until voluntary fatigue, (4) sit quietly until 20 minutes post-treatment, and (5) repeat vertical jump test. Duration of the treatment protocol lasted approximately three minutes. During the control trial, participants sat quietly in place of the stretching or dynamic warm-up exercise.

Protocols: The static and PNF stretching protocols being used have been established as an appropriate amount of stretch time to increase ROM (Bandy et al., 1997; Shrier & Gossal, 2000). Both the static and PNF stretching routines were designed to stretch the knee flexors, hip extensors, knee extensors, hip flexors, and plantar flexors. During the static and PNF stretching protocols, each muscle group was stretched with the participant in either the supine or prone position. For the static stretch protocol, each stretch was performed twice and held for 30 s with a 10 s rest between stretches.

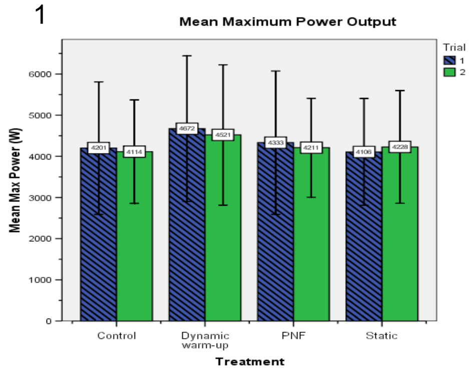
In the PNF stretching protocol, a contract-relax method was used. Participants were stretched by the researcher for 15 s, followed by a concentric contraction of the stretched muscle against the resistance of the researcher for 6 s, followed by a second passive stretch of the participant by the researcher.

The dynamic warm-up protocol used was established by the literature to effectively increase muscle temperature (Bergh & Ekblom, 1979; Sargeant, 1987; Stewart et al., 2003). Drills performed were in the following order: high knee drill (slow jog), gluteus kicks (slow jog), stationary body squats (x10), high knee lunge (walking), carioka (slow jog), forward and lateral leg swings (x10 each).Each warm-up drill was performed twice for approximately 10 s, with a 10 s rest between sets.

Data Analysis: Maximum power output and time to voluntary fatigue were recorded during the vertical jump performance using a customized portable force plate (AMTI Inc., Boston, MA) amplified at 200 Hz. Percent decline in power output was also used to measure fatigue and was calculated by determining their change in power output, from their max power output to minimum power output. All values recorded for both the three-minute and 20-minute post-treatment performance tests were compared between each treatment using a repeated mesures ANOVA test followed by a Tukey post hoc test. SPSS Version 14.0 statistical software was used to analyze data. An alpha level of ≤0.05 was accepted as significant.

RESULTS: The following figures (1-3) show means and standard deviation bars of all four treatments as well as trial 1 versus trial 2 for maximum power output (Fig. 1), percent decline of maximum power output (Fig. 2), and time to voluntary fatigue (Fig. 3). There were no statistical differences between any of the treatments in trial 1 nor in trial 2 for maximum power output, percent decline of power output, and time to voluntary fatigue.

1



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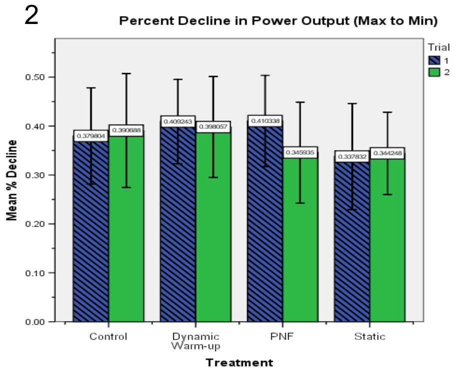

Fig. 1: Average maximum power output for all four treatments in trial 1 and trial 2.

Fig. 2: Average percent decline of power output for all four treatments in trial 1 and trial 2.

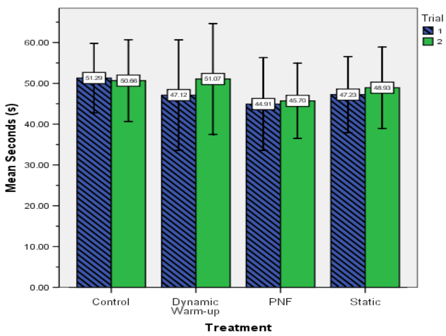

Fig. 3: Average time to voluntary fatigue for all four treatments in trial 1 and trial 2.

Data analysis of the results also showed no statistically significant differences between trial 1 and trial 2 for each treatment. Therefore, all three hypotheses were rejected.

DISCUSSION: Results of this study indicate that different stretching and warm-up techniques had no statistically significant influence on power output nor fatigue, three or 20 minutes post-treatment. This study did not concur with many previous studies that reported statistically significant changes due to stretching and warm-up protocols. Some results, however, were similar to previous studies in a practical sense. Bergh and Ekbolm (1979) showed a correlation between an increase in muscle temperature and an increase in vertical jump and peak power output. In this study, the dynamic warm-up treatment, which has been shown to increase muscle temperature, had an average max power output of 4672 W three minutes post-treatment. After 20-minutes post-treatment, which would most likely result in a muscle temperature cool-down, max power output dropped to 4520.9 W. The control group had an average maximum power of 4201 W (10% lower than the dynamic warm-up condition) in trial 1 and an average maximum power output of 4113 W (9% lower than the dynamic warm-up condition) in trial 2. According to the equation of Sayers et al. (1999) for estimating peak power, an increase of 470 W of power output, similar to the difference between the dynamic warm-up and control group in trial 1, would increase a 90 kg person’s vertical jump from 76 cm to approximately 84 cm, a dramatic increase in performance for an athlete.

In this study, all treatments in trial 1 produced quicker times to fatigue when compared to the control group by at least 4 s. Specifically, the PNF treatment was 6.38 s shorter in duration when compared to the control group in trial 1. In trial 2, the PNF group was 4.96 s quicker to fatigue than the control group. Although not statistically significant in this study, in any given anaerobic physical activity, 4-6 s is a long period of time. Therefore, this data set may indicate PNF stretching has a detrimental effect on performance and this effect may last up to 20 minutes post-stretch. Just as well, the static stretching treatment resulted in a time to fatigue of 4.06 s shorter than the control group in trial 1. This may indicate that static stretching may also have a detrimental effect on performance immediately following stretching. Also noteworthy was the difference from trial 1 to trial 2 in time to fatigue for the dynamic warm-up treatment. The quicker time to fatigue in trial 1 (by 4 s) may indicate that a higher muscle temperature, and ultimatley a dynamic warm-up, may be related to a quicker time to fatigue.

The PNF condition showed the highest percent decline of power output in trial 1 at 41%. Interestingly, the PNF treatment also showed the largest change from trial 1 to trial 2, resulting in a 34.5% decline in trial 2. Percent decline in the control group remained relatively unchanged. This may indicate that PNF stretching had an effect on performance at three minutes post-stretch. The static treatment showed the lowest percent decline in power output in both trials (~34% for trial 1 and trial 2). Overall, although not statistically significant, an argument could be made that all treatments had an influence on fatigue, particularly in trial 1, and that the PNF stretching treatment may have had a larger impact on fatigue than static stretching or dynamic warm-up.

CONCLUSION: Results of this study may have applicable relevance to practitioners including athletes and coaches. The data set, although not statistically significant,indicates that performing a dynamic warm-up prior to an activity may allow for a greater maximum power output performance during that activity compared to performing a stretching routine or no routine at all prior to an activity. However, the data set also indicates a dynamic warm-up, PNF, and static stretching may all lead to a quicker time to fatigue when compared to the control group. The dynamic warm-up treatment also showed the greatest difference in time to fatigue when comparing trial 1 to trial 2. This may indicate that allowing a rest period (20 minutes or greater) would certainly be beneficial for time to fatigue, but it may have a detrimental effect on power output. Based on trends of this study data, recommendations could be made for performing a dynamic warm-up prior to any activity reliant on maximum power output, and stretching routines be reserved for post-activity. Future research may benefit from having a set amount of time each individual will test for and then measuring percent decline of power output that occurred in that set amount of time. To receive a more accurate measure of stretching, future research may need to measure angles of joints when stretching participants so as to limit some of the variability in relying on the participants feeling of “slight discomfort.” Increasing the number of participants would also give rise to data with more statistical power.

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