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EFFECT OF 30 S OF STATIC ACTIVE STRETCHING ON ANAEROBIC POWER USING THE WINGATE TEST

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Abstract

Stretching is performed with or without assistance when individuals warm up prior to physical activity. This study aimed to evaluate the effects of 30 s of static active stretching on anaerobic power using the Wingate test (WT). Ten healthy men performed the WT under two different conditions: after performing 30 s of active static stretching (SS-condition) or after sitting in a chair (CON-condition). During the SS-condition, participants performed three stretching exercises for the hamstrings and quadriceps. Participants stretched the targeted muscle slowly until it reached its most comfortable position and maintained the position for 30 s. The WT was performed using an electromagnetic bicycle ergometer. Participants were instructed to pedal as fast as possible against a load corresponding to 7.5% of their body mass. Although peak performance (peak power and peak revolutions per minute) during the WT did not differ significantly between the CON- and SS-conditions, the mean power in the SS-condition (579.2 ± 15.8 W) was significantly greater than that in the CON-condition (560.3 ± 17.8 W). These results suggest that although 30 s of active static stretching has no effect on peak performance, it increases mean power during WT. Further, heart rate in pre-WT was significantly higher in the SS-condition (96 ± 5 bpm) than in the CON-condition (63 ± 2 bpm). Therefore, increased HR by active static stretching might elicit an aerobic warm-up effect.

Keywords: Warming up, peak power, mean power, cycle ergometer

Introduction

Warming up prior to physical activity is an important factor in enhancing performance and decreasing the incidence of injury (Herbert & Gabriel, 2002; Safran, Seaber, & Garrett, 1989). Because stretching is believed to be an important component of warming up, researchers have attempted to evaluate the effects of various stretching techniques such as static, ballistic, proprioceptive neuromuscular facilitation, and dynamic stretching on sports performance (Avela, Kyrolainen, & Komi, 1999; Behm, Button, & Butt, 2001; Fowles, Sale, & MacDougall, 2000; Franco, Signorelli, Trajano, Costa, & de Oliveira, 2012; Kay & Blazevich, 2012; Ogura, Miyahara, Naito, Katamoto, & Aoki, 2007; Taylor, Dalton, Seaber, & Garrett, 1990; Yamaguchi & Ishii, 2005; Yamaguchi, Ishii, Yamanaka, & Yasuda, 2007). Pre-exercise stretching increases muscle strength and power (Franco et al., 2012; Yamaguchi & Ishii, 2005; Yamaguchi et al., 2007). However, the positive effects of stretching on muscle performance vary by stretch type. Prolonged static stretching interferes with the neural input to the stretched muscle group (Avela et al., 1999; Behm et al., 2001; Fowles et al., 2000; Taylor et al., 1990). Therefore, some researchers have reported that muscle strength and power production in the stretched muscle group are acutely decreased by static stretching (Avela et al., 1999; Behm et al., 2001; Cornwell, Nelson, and Sidaway, 2002; Fowles et al., 2000; Kokkonen, Nelson, & Cornwell, 1998; Ogura et al., 2007). For instance, Behm et al. (2001) reported a significant decrease in maximal voluntary isometric knee extension force after passive static stretching of the quadriceps. Cornwell et al. (2002) also reported a significant decrease in the countermovement jump height after the passive static stretching of the triceps surae. These findings suggest that static stretching is not a suitable component of pre-exercise warm-up to increase muscle performance (i.e., strength and power).

However, the effects of static stretching on muscle performance depend on the stretch duration (Kay & Blazevich, 2012; Ogura et al., 2007). Ogura et al. (2007) reported that although 60 s of static stretching significantly decreased muscle strength, 30 s of stretching did not affect muscular performance. Similar effects were reported in a systematic review (Kay & Blazevich, 2012); although shorter stretch durations (<45 s) can be used in pre-exercise routines without the risk of significant decreases in strength-, power-, or speed-dependent tasks, longer stretch durations (>60 s) are more likely to slightly or moderately reduce performance. Furthermore, Bandy and Irion (1994) observed that the effects of a shorter duration of static stretching (30 s) on flexibility do not differ from those of a longer duration of stretching (60 s). Therefore, these findings suggest that a 30-s period of pre-exercise static stretching is optimal.

Although shorter stretch durations can be used in pre-exercise routines without the risk of significant decreases in muscle strength and power (Kay & Blazevich, 2012; Ogura et al., 2007), anaerobic performance is also important factor that contribute to sports performance. The Wingate test (WT) is commonly used to evaluate anaerobic performance (Green, 1995; Vandewalle, Peres, & Monod, 1987). Franco et al. (2012) reported the effects of several kinds of stretching using the WT and observed that 30 s of static stretching with assistance from the examiner did not have significant effects on mean power (MP) and peak power (PP) output compared with a non-stretching trial. Therefore, a shorter duration of assisted static stretching may have no effects on muscle strength and power production (Kay & Blazevich, 2012; Ogura et al., 2007) or on anaerobic performance (Franco et al., 2012). However, stretching as a pre-exercise warm-up can be performed with (passive stretching) or without (active stretching) assistance from a coach, trainer, or other athlete. Thus, the purpose of this study was to evaluate the effects of 30 s of active static stretching on anaerobic power using the WT.

Methods

Participants

Data were obtained from 10 healthy men (mean age, 19 ± 1 years) with no current or medical history of neural, muscular, or skeletal disorders. The participants were informed of the study's purpose before study entry, and each provided informed consent. Further, this study adhered to the Declaration of Helsinki's ethical principles for medical research involving human subjects.

Measurement of anaerobic power

Anaerobic power was measured using a traditional WT for 30 s. The WT was performed on a bicycle ergometer (Powermax-VII; Combi, Japan) with toe clips to prevent foot slippage. The WT was performed in the seated position, and the participants were instructed to pedal as fast as possible against a load corresponding to 7.5% of their body mass (Inbar, Bar-Or, & Skinner, 1986). Body mass and body composition were measured using the Direct Segmental Multi-frequency Bioelectrical Impedance Analysis method with a body composition analyzer (InBody 720; Biospace, Korea).

The power output data were collected on a computer linked to the ergometer at 10 Hz. PP, MP, and peak revolutions per minute (peak RPM) during the WT were calculated from the data and displayed on an LCD screen on the computer. The PP and MP data normalized to the respective participant's body mass to reduce inter-subject variability. One week before the experiment, the participants practiced the WT with their own warm-up routine to become familiar with the WT procedure. After the practice session, the participants performed two WT trials (active static stretching [SS] condition and no stretching exercise [CON] condition) with a rest period of 1 week between the trials. The order of conditions was randomized across the participants.

Stretching exercise

During the SS condition, the participants performed three stretching exercises for the hamstrings and quadriceps. Each targeted muscle was stretched slowly until the most comfortable position was reached. This position was maintained for 30 s for each stretching exercise with a rest period of 30 s between stretches. The stretches included:

1) Hamstring stretch (including the lower back): The participants sat on a flat surface with their legs together and extended in front of them. The participants bent forward at the waist and slowly flexed the torso toward their feet and touched their toes, if they could. When the most comfortable position was reached, they held the position for 30 s while breathing naturally. During the stretching exercise, the participants were encouraged to maintain a straight back.

2) Quadriceps stretch: The participants laid on their side with their legs stacked on top of each other and propped their head up with one hand. The upper leg (knee) was flexed to hold the foot and the participants pulled the upper foot backward toward the buttocks. When the most comfortable position was reached, they held the position for 30 s while breathing normally. During the stretching exercise, the participants were encouraged to maintain a firm and flat abdomen.

Protocol

For the CON condition, participants were given 3 min to adjust their seat position and familiarize themselves with the cycle ergometer without a load. After this period, the participants sat on the chair for 8 min. The participants then rode the cycle ergometer and performed the WT. Thereafter, the participants sat on the chair again for 3 min.

For the SS condition, participants were given 3 min to adjust their seat position and familiarize themselves with the cycle ergometer without a load. After this period, they sat on a chair for 5 min and were randomly assigned to perform three stretching exercises for the hamstrings and quadriceps (right and left). These exercises take a total of 8 min, the same duration as the CON condition. Then participants then rode the cycle ergometer and performed the WT. Thereafter, the participants sat on the chair again for 3 min.

Throughout the experiment, the participants' heart rate (HR) was measured via a HR monitoring system (RS800CX; Polar Electro Oy, Kempele, Finland). The electrodes were affixed to the chest (just below the pectoralis major) using the chest strap.

Statistical analyses

The CON and SS conditions for the PP, MP, and peak RPM were compared using the paired t-test and effect size (r). Comparisons between the CON and SS conditions with regard to changes in HR were made using two-factor analysis of variance (ANOVA). If a significant interaction between stretching conditions and time course change was observed, Scheffe's test was used to identify differences between the stretching conditions. These analyses were performed using JSTAT software (version 12.5, Japan). Significance was identified at values of $P < 0.05$. The data are presented as mean ± standard error of the mean unless stated otherwise.

Results

The mean participant measurements were 173.8 ± 1.6 cm in height, 64.9 ± 1.5 kg in body mass, and 57.5 ± 1.3 kg in lean body mass.

In the CON condition in which the participants performed the WT without stretching, the values were PP of 731.3 ± 27.2 W and peak RPM of 154.1 ± 4.7 rpm. Although the SS condition participants performed the WT with active static stretching for 30 s, the PP was 744.1 ± 20.0 W and peak RPM was 157.5 ± 3.8 rpm. These results are not significantly different between the CON and SS conditions and did present a medium-sized effect ($r = 0.31$–0.40) (Table 1). These results indicate that peak performance during the WT was not affected by active static stretching for 30 s. Although peak performance during the WT was not significantly different between the CON and SS conditions, the MP in the SS condition (579.2 ± 17.4 W) was significantly higher than that in the CON condition (560.3 ± 19.6 W). Further, it presented a large sized effect ($r = 0.65$) (Table 1).

With regard to the change in HR during the WT (Figure 1), ANOVA revealed significant effects on the stretching condition (CON or SS condition), time course of change, and interaction between them. This result indicated the following: 1) static stretching increased HR; 2) the WT increased HR; and 3) the effect of static stretching on HR was greater during the WT. Further, multiple analysis observed that pre-WT HR was significantly higher in the SS condition (96 ± 6 bpm) than in the CON condition (63 ± 2 bpm).

Table 1: Peak power, peak revolutions per minute (RPM), and mean power of participants.

Variables	CON-condition	SS-condition	Probability	Effect size
Peak power (W)	731.33 ± 24.75	744.12 ± 18.21	$P = 0.30$	$r = 0.33$
Peak power / Body weight	11.27 ± 0.31	11.48 ± 0.24	$P = 0.27$	$r = 0.35$
Peak RPM (rpm)	154.10 ± 4.26	157.50 ± 3.47	$P = 0.18$	$r = 0.42$
Mean power (W)	560.30 ± 17.84	579.20 ± 15.79	$P = 0.02$	$r = 0.67$
Mean power / Body weight	8.64 ± 0.23	8.93 ± 0.21	$P = 0.02$	$r = 0.66$

CON-condition; no-stretching condition
SS-condition; active static stretching condition

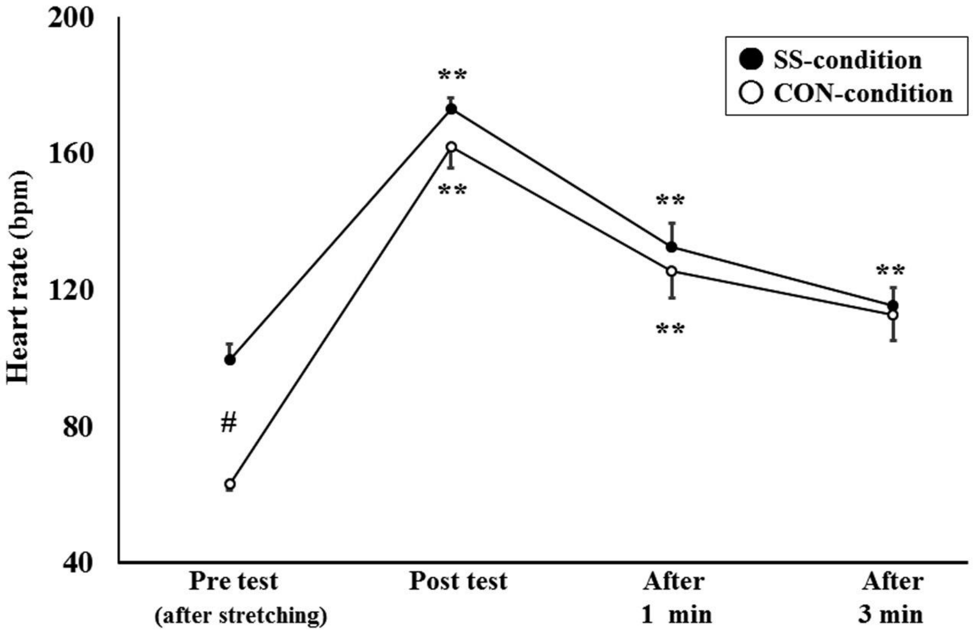

Figure 1: Changes in Heart rate before and after Wingate test

CON-condition; no-stretching condition
SS-condition; active static stretching condition

Significant effect: Condition ($P < 0.01$), Time ($P < 0.01$), Interaction ($P = 0.02$)
; SS vs. CON ($P < 0.05$, Scheffe's method)
** ; vs. Pre WT ($P < 0.01$, Scheffe's method)

Discussion

The main findings of the present study are as follows: (1) peak performance during the WT was not affected by active static stretching for 30 s; (2) average power during the WT was significantly increased; and (3) pre-exercise HR was also significantly increased by active static stretching for 30 s.

Peak performance (i.e., PP and peak RPM), the PP ("explosive power") during the WT, was not affected by SS for 30 s. Several studies have demonstrated that a relatively longer duration of static stretching (>45 s) temporarily altered the musculotendinous unit (decreased muscle stiffness or increased fascicle length)

(Fowles et al., 2000, Magnusson, Simonsen, Aagaard, & Kjaer, 1996; McHugh, Magnusson, Gleim, & Nicholas, 1992). McHugh et al. (1992) reported a significant decrease in stretch resistance (tensile force) at the maximum tolerated range of motion during static stretching for 45 s. Therefore, a longer duration of static stretching acutely impairs muscle performance and neural input (Avela et al., 1999; Behm et al., 2001; Fowles et al., 2000; Taylor et al., 1990). However, recent studies indicated that these effects depend on the stretching duration. Ogura et al. (2007) reported that, although 60 s of static stretching significantly decreased muscle strength, 30 s of stretching did not affect muscle performance. Yamaguchi and Ishii (2005) also reported no significant difference in leg extension power after non-stretching compared with that after passive static stretching for 30 s in the lower limb muscles. Thus, the effects of different stretching durations on muscle performance were revealed, and a systematic review indicated that shorter stretch durations could be used in pre-exercise routines without the risk of significant decreases in muscle performance (Kay & Blazevich, 2012). Furthermore, Franco et al. (2012) reported that 30 s of static stretching with assistance did not have a significant effect on PP output compared with the non-stretching trial. Thus, this previous study and the present study suggest that 30 s of static stretching does not exert negative effects on maximal power.

According to the WT index, although PP and peak RPM indicated the component of explosive power, MP indicated a relative power decline compared with PP. The relative importance of the anaerobic energy process during cycling exercise is reported to be approximately 60% for 30 s; thus, the importance of the aerobic energy process is approximately 40% (Medbo & Tabata, 1989). This report suggested that the WT may depend not only on explosive power but also on aerobic ability. A previous study reported that power output did not change significantly in PP or MP through static stretching with assistance (Franco et al., 2012). In this study, although the effect of active static stretching on peak performance during the WT did not differ significantly between the CON and SS conditions, the MP was significantly increased through active static stretching. These results contradicted those of the present study and previous reports (Franco et al., 2012) suggesting that the contradictions may be attributable to the different stretching types.

With regard to the difference between passive and active static stretching, Nelson and Kokkonen (2013) investigated the effect of passive static stretching on the metabolic response. They reported that HR after passive stretching increased by approximately 1.2 times (quiet sitting, 70 ± 11 bpm versus passive static stretching, 84 ± 11 bpm); thus, they suggested that the magnitude of the increases was not adequate to elicit an aerobic warm-up effect. However, physiological responses during exercise differ between active and passive stretching (Nobrega, Williamson, Friedman, Araujo, & Mitchell, 1994). In this study, the HR after active stretching (96 ± 6 bpm) increased by approximately 1.5 times (CON condition, 63 ± 2 bpm). Thus, the change in HR in this study (active stretching) was greater than that in the previous study (passive stretching). Therefore, an increase in MP after active static stretching may be affected by a greater increase in pre-exercise HR compared with that after passive stretching. Kaur, Kumar, and Sandhu (2008) reported that after pre-exercise active static stretching for 20 s, there was 18.7% increase in running time to exhaustion (18.3 to 21.6 min) and a 40.7% decrease in blood lactate accumulation (9.8–5.8 mmol/L) during treadmill running at an intensity of 65–75% of HR reserve compared with that after the CON condition. These results suggest that although active static stretching for 30 s does not affect peak performance during the WT, it may prevent a power decline compared with peak performance by eliciting an aerobic warm-up effect.

The present study and a previous study suggested that 30 s of static stretching is not adequate to exert the negative effects on explosive power during the WT in passive (Franco et al., 2012) and active stretching. However, the power decline compared with PP during the WT was significantly smaller after active static stretching than with no stretching (i.e., MP was increased by SS). Stretching is performed not only with assistance from a coach, trainer, or another athlete but also without assistance during the actual warm-up prior to physical activity, especially in individual competitions. Several researchers observed that the effects of a shorter duration of static stretching on flexibility do not differ from those of a longer duration of stretching (Bandy & Irion, 1994). Therefore, this study suggested that active static stretching is more effective according to the WT, a common test for evaluating the dynamic muscle task. However, several studies reported that dynamic stretching is more effective for increasing muscle power on the WT (Franco et al., 2012). Therefore, further studies should reveal the difference in the effects between active static stretching and dynamic stretching on the WT. In conclusion, although active static stretching for 30 s does not affect peak performance, it increased MP during the WT. This finding suggests that 30 s of active static stretching increases the MP during WT by eliciting an aerobic warm-up effect.

Conclusion

The purpose of this study was to evaluate the effects of 30 s of active static stretching on anaerobic power using the WT. The main findings of the present study are as follows: (1) peak performance during the WT was not affected by active static stretching for 30 s; (2) average power during the WT was significantly increased; and (3) pre-exercise HR was also significantly increased by active static stretching for 30 s. These results suggest that although 30 s of active static stretching has no effect on peak performance, it increases mean power during WT by eliciting an aerobic warm-up effect.

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