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ONSET AND OFFSET OF RECTUS FEMORIS ACTIVATION DURING DOUBLE POLING ERGOMETRY IN TWO POSITIONS: STANDING VS. SITTING

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The purpose of the current study was to assess the onset and offset of Rectus Femoris (RF) activation during two different positions of Double Pole Ergometry (DP_{erg}). Ten collegiate Nordic skiers randomly performed two peak oxygen consumption tests using the DP technique, standing and sitting. Electromyography (EMG) data were collected and the onset and offset of activation were determined using a combination of EMG and video data at three intensities: Low, Mid, and High. A Two-Way Repeated Measures ANOVA revealed RF onset and offset values for standing and sitting tests to be different. Post hoc comparisons revealed differences between Low and High intensities in onset and offset of muscle activation. These variations indicate that seated DP_{erg} is not an ideal replacement for standing DP_{erg} and athletes should use seated DP_{erg} mindfully.

KEYWORDS: cross-country skiing, double pole ergometry

INTRODUCTION: Techniques in cross-country skiing have been studied to improve performance. Double Poling (DP) is a technique used by cross-country skiers to propel themselves forward via bilateral pole pushes. In cross-country sprint races, the DP technique is used at the end of the sprint, often the most determinant portion of the track (Zory et al., 2009). Becoming a main technique in cross-country ski racing, DP has developed substantially in the last 15 years (Holmberg et al., 2005; Rusko et al., 2002). In addition, anecdotal suggestions have indicated that seated Double Pole Ergometry DP_{erg}, a technique used by Paralympic athletes, may be an appropriate surrogate for Nordic skiing when a skier has a lower extremity injury (Vasa, 2011).
Many studies have investigated DP both physiologically and biomechanically. Researchers have found regular stand-up skiing to require high levels of upper body strength (Mahood et al., 2001). Cross-country skiers use their upper body to create the increased pole force necessary for high speeds (Lindinger et al., 2009). However, other studies have discovered that upper body musculature is not solely responsible for propulsion in DP. Holmberg and colleagues (2005) found high levels of activity in the lower extremity during DP as well.
Although researchers have investigated lower extremity muscle activity during stand-up cross-country skiing, very few have studied muscle activity in a seated position. Therefore, the purpose of this study was to assess RF activation during DP_{erg} in stand up ergometry (SU) and seated ergometry (SE) in order to determine if flexion at the hip joint during DP_{erg} influences the onset and offset of RF muscle activation at 3 levels of intensity. While an analysis of co-activation may give additional information on total muscle activity, this study sought to examine muscle activity of the prime movers of the trunk during the force development phase of the double poling movement.

METHODS: Ten collegiate Nordic skiers (Mean ± SD Age = 21.2 ± 2.9 years; Height = 159.2 ± 7.8 cm; Weight = 63.1 ± 6.4 kg) were asked to participate in this study. Subjects signed an informed consent form and completed a Physical Activity Readiness-Questionnaire prior to participating. Approval by the Institutional Review Board was also obtained prior to the beginning of the study.
At least 24 hours apart, participants randomly performed two peak oxygen consumption tests using the double pole technique with one test in the standing position and one test in the sitting position. A modified VASA Ergometer (Essex Junction, Vermont, USA) with adjustable cross-bar, to which the pull cords for poling were mounted, was used for the current study. The bottom of this cross bar was set to a height 15% higher than each skier's individual classic pole height for standing Nordic skiing.

A standard set of adjustable poles was used to measure the seated height of the adjustable cross bar for the seated test. The top of the pole was adjusted to equal the height of the skier's eyebrow when seated on the sit-ski. The adjustable cross bar was then set to a value 50% higher than the determined pole height. Three adjustable straps approximately 10 cm distal to the greater trochanter, 10 cm proximal to the knee joint, and a heel cup with strap across the ventral side of the foot were placed on the sit-ski limiting mobility of the lower extremity. Angles of pull at the start of pull for SU and SE were 45.9 and 45.5 degrees respectively.

Warm-up prior to each maximal test consisted of 5 minutes low-intensity exercise on the VASA Ergometer. After the warm-up, the test began at a cadence of 40 strokes per minute increasing 5 strokes per minute each succeeding minute. Feedback for stroke rate was provided via an auditory metronome and visual feedback from the VASA Ergometer. Inability of the participant to maintain the cadence or volitional fatigue resulted in termination of the test.

Video data of the exercises were obtained at 60 Hz from the saggital view using 1 cm reflective markers placed on the acromion process, greater trochanter, and a point horizontal from the greater trochanter not on the human body. Trunk angles were defined as the angle determined by these three markers and expressed relative to horizontal. Markers were then digitized and absolute trunk angles were calculated using Motus 8.5 (Peak Performance Technologies, Englewood, CO).

EMG data were also collected at 1000 Hz from the RF of the participant's dominant leg, determined as the leg the participant kicked a ball with, during both the standing and sitting tests. Data were processed using AcqKnowledge 3.9.1.6 software. The electrodes were connected to a Biopac Systems, Inc. MP 150 (Goleta, CA). The skin was prepped using rubbing alcohol and an abrasion pad of coarse material to abrade the skin. A small drop of Signa Gel (electrode gel Parker Laboratories, Inc.; Fairfield, NJ) was applied to the Noraxon Dual Electrode (product #272 Noraxon USA; Scottsdale, AZ) before it was placed on the muscle belly of the RF. A ground electrode was then placed near the iliac crest on the same side as the dominant leg. Raw EMG data were filtered with a 10 to 500 Hz band pass filter and integrated over 100 samples via root mean square with the baseline removed. Data were normalized by cadence timing as the same increments of time were used in each trial for each subject.

To determine the onset and offset of muscle activity the threshold was defined as the level +2SD above the mean base signal at rest. In order to synchronize trunk angles and EMG data, a light signal was used to initialize EMG data which also showed in the video data in order to be able to combine both sets of data. Data were then combined into a single file and splined to create a file of equal length at 1000 Hz. Levels of intensity (low, mid, & high) were determined to be stages of each test with at least 2 stages between each level.

Statistical comparisons were made using SPSS (v.18) via Two-Way Repeated Measures ANOVA (position X stage) for the angle at which both onset and offset of the muscle activity occurred. Significance was set at $\alpha = 0.05$ and follow-up pair-wise comparisons were performed with Bonferroni's correction.

RESULTS: Results of the Two-Way Repeated Measures ANOVA revealed a main effect of trunk angle for both position and intensity and an interaction for the onset data ($p<0.05$). Post hoc comparisons for the onset of muscle activity relative to trunk angle revealed that Low intensity was significantly different from Mid and High intensities. Mid and High intensities were not different, ($p>0.05$) (see Figure 1).

Results of the Two-Way Repeated Measures ANOVA for the offset of muscle activation revealed a main effect for both position and intensity ($p<0.05$). There was no significant interaction ($p>0.05$). Post hoc comparisons indicated that trunk angle of the EMG offset differed only between Low and High intensities. In addition, muscle activity during standing DP_{erg} ceased at a lower trunk angle than for seated DP_{erg} ($p<0.05$).

DISCUSSION: Results indicate a significant difference in the trunk angle at the onset and offset of RF muscle activation during seated and stand-up skiing at 3 levels of intensity. Further investigation of these results found that within SE, there were no differences in the onset or offset of RF muscle activation. However, results of SU indicated that the trunk angle at onset and offset was greater for the High intensity relative to Mid and Low, with a significant interaction in the onset of muscle activation. These results indicate a significant difference in trunk angle for the onset and offset of RF muscle activation during Low intensity and maximal intensity work during a DP_{erg} exercise.

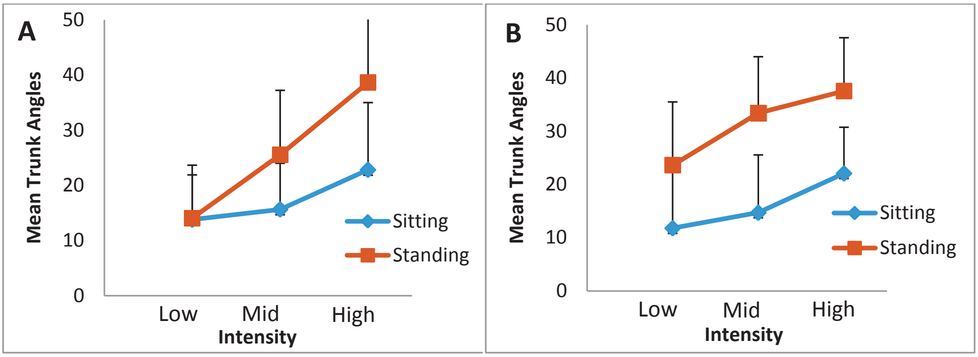

Figure 1: Trunk Angle vs. Intensity for Onset (A) and Offset (B) of RF Activation.

Previous studies by Holmberg and colleagues (2005) found high levels of muscle activity in the hip flexors, including the RF, during a DP cycle. This cycle was performed on a treadmill using roller skis rather than on snow or using an ergometer. When rating muscles in order of importance to the DP cycle, the RF was rated first followed by the abdominal muscles. Holmberg and colleagues (2005) also assessed joint angles in their study finding distinct flexion-extension patterns in the hip, knee, and ankle joints giving further evidence of the importance of the RF to the DP technique. In addition, their results showed angle minima to occur very close to the time of peak pole force during the cycle (Holmberg et al., 2005).

Another study by Holmberg and colleagues (2006) employed maximal and peak oxygen uptake tests studying effects of knee joint mobility at a sub maximal level. Participants in their study performed two tests, with the knee joints immoveable or freely moveable. Results indicated increased pole force and maximal DP velocity to be 9.4% higher during the tests when the knee joints were freely moveable than during the tests with knee joints immoveable. Thus, their study indicated the importance of joint mobility during the DP cycle at a sub maximal level of intensity. These studies however, failed to assess the onset and offset of lower extremity activity during increasing levels of intensity.

Similar to the study by Holmberg and colleagues (2006) the current study allowed little movement of the knee joint in the seated position. This limit of mobility in the seated position may account for the significant difference of muscle activation between the standing and seated positions. It may also account for the lack of difference between the 3 intensities in the seated position.

Results of the current study indicate that while the trunk angle at onset of muscle activity did not differ between conditions; trunk angle offset during the seated condition was much less at low intensities. This would suggest a lower duration of muscle activity, which is in agreement with Holmberg et al. (2005).

Tervo and colleagues (2010) also found differences in EMG activity in the lower extremity between SE and SU, while Jensen and colleagues (2011) found differences in range of motion in the upper extremity during DP_{erg} in these two positions. The current study supports their findings that seated DP_{erg} is not an ideal replacement for standing DP_{erg}.

However, although studies have shown research with ergometers to be highly comparable to research with participants on snow (Holmberg et al., 2008), results of the current study may very well be different between seated and standing positions on snow and further research would be needed in order to validate the current findings.

CONCLUSION: Variations in the trunk angle onset and offset of Rectus Femoris activity between SE and SU indicate that the two types of DP_{erg} are not ideally interchangeable. While the onset of RF activity was similar at low intensity between the two conditions, seated RF activity began at a lesser angle with increasing DP intensity. The trunk angle at which offset of RF activity occurred only varied between high and low intensities. These differences in RF muscle activation suggest that using SE as a substitute for injured standing skiers may not be ideal.

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