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ELECTROMYOGRAPHICAL ANALYSIS OF DOUBLE POLE ERGOMETRY: STANDING VS. SITTING.

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This study assessed the difference in stand-up athlete's muscle activity of the rectus femoris in standing and sitting using a double pole ergometer. Five subjects participated in two technique specific peak VO_2 tests, and a percentage of the maximum scores were used to determine stages for analysis of the electromyography data that was collected. An ANOVA revealed a significant difference in electromyographical activity between ski position and stage using a pre-determined alpha level of $p<0.05$. Separate paired T-tests were used to determine that there was no statistical difference in muscle activity between the two stages in sitting ($t=1.464$, $p=0.217$). However, there was a statistical difference between stages in the standing position ($t= -5.023$, $p=0.007$).

KEYWORDS: cross country skiing, disabled sports, biomechanics, Nordic skiing.

INTRODUCTION: Nordic skiing may date back to 5,000 BC according to cave drawings found in Norway (Clifford, 1992). Initially skis were used as a tool to assist in moving across the snow for practical purposes such as military pursuits (Holmberg, 2003) and hunting (Seiler, 1996). Nordic skiing competition evidence dates back as early as 1520 in Norway (Holmberg, 2003). In 1924 Nordic skiing was included in the Winter Olympic games (Clifford, 1992), and in 1976 was added to the Paralympic Winter games (Nordic Skiing).

One event in Paralympic Nordic Skiing is sit-skiing where the athlete sits on a frame mounted to cross-country skis and employs shortened ski poles and the double pole technique for propulsion over the snow. Double poling is defined when the upper body provides most of the propulsion via bilateral pole pushes (Holmberg, 2003), and is a common technique for both stand-up and sit-skiing.

The double pole technique has greatly developed over the past fifteen years (Lindinger et al., 2009). A number of research articles have been published related to performance and evaluation of the physiological and biomechanical aspects of double poling in the standing position. This previous research has found that double poling requires high levels of upper body fitness, and ski specific upper body fitness has been found to be an important predictor of Nordic ski performance (Mahood et al., 2001). Only one study has investigated double poling in the standing position versus the sit-ski position employed by Paralympic skiers (Tervo & Jensen, 2009). Results revealed that stand-up skiers, using a sit-ski obtained peak velocity at the same point during the poling cycle as a sit-ski athlete. This suggests that it may be possible to use experienced stand-up skiers as subjects for biomechanical sit-ski research, but additional research is needed.

In 2005, Holmberg et al. studied muscle involvement of stand-up skiers using electromyography and found that the rectus femoris (RF) is involved in stand-up double poling. When considering the use of stand-up skiers in sit-ski research, it would be important to know if the RF is activated during sit-ski double poling in this group. Since some sit-ski athletes with paraplegia may have no function of the RF, the use of athletes with intact RF function in sit-ski research could complicate interpretation of results. The current study constitutes foundational research to help determine if stand-up athletes could be used for research of sit-skiing.

METHODS: Five Nordic ski collegiate athletes participated in this double pole study which used two positions: standing and sitting. The mean (± SD) age was 19.8 ± 2.12, height was 174 ± 7.77 cm, and weight was 68 ± 5.8 kg. The current research study was approved through NMU's IRB (#HS09-307). The subjects signed an informed consent and completed a PAR-Q questionnaire (Physical Activity Readiness Questionnaire, Public Health Agency of Canada, 2002) before participating in the study.

Subjects performed two maximal oxygen consumption tests using the double pole technique on a modified VASA Ergometer (Essex Junction, Vermont, USA). A standard VASA Ergometer was mounted at the base of a parallel vertical railing system. The pull cords for poling were directed through pulleys which were mounted to an adjustable cross-bar attached to the railing system, which allowed for height adjustment. In order to keep the double pole as similar to skiing as possible the VASA Ergometer was adjusted according to each skier's classic pole height. The position of the skier's stance on the floor was set at 73 cm horizontal distance from the toes to the VASA for the standing test. The rear edge of the sit-ski seat was positioned 162 cm from the VASA for the sit-ski test (Figure 1). Each subject brought in a pair of their classic poles, and the pull height was set by using the bottom of the cross-bar adjustment at 15% higher than the classic pole height for standing. An adjustable set of poles was used to determine the seated height by using the top of the pole set at the level of their eyebrow when seated in the sit-ski. This height was then measured and the pull height was set at 50% higher than the pole height. The discrepancy of the percentages is due to the fact that static nylon extenders (68 cm) were added to the VASA for the seated test so that the length of the cords were long enough to complete a pole cycle.

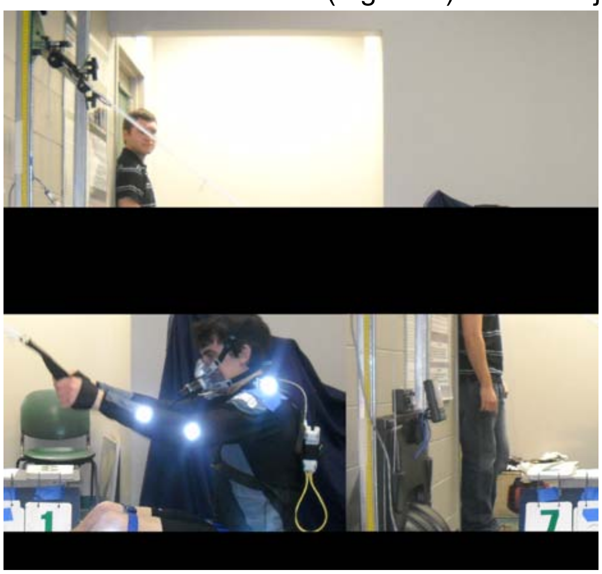

Figure 1. A photo of the VASA Ergometer set-up with a sit-skier.

One maximal test was performed in a standing position to simulate on-snow cross-country skiing. A second maximal test was performed in a seated position on a modified sit-ski to simulate sit-skiing. Both tests were performed at least 24 hours apart. To randomize the order of testing, a counterbalancing method was used. The subject's weight was taken using a Tanita Digital Scale BWB-800A Class III (Tanita Corp., Japan), and a Seca wall stadiometer was used to obtain height to the nearest 0.5 centimeter. The subject was fit with a portable breath-by-breath expired air analysis system to measure maximal oxygen uptake (Oxycon Mobile; CareFusion, CA). The Oxycon Mobile instrumentation weighed approximately 950 grams and was carried via an adjustable vest harness sized to each subject. The instrument flow sensor was calibrated according to manufacturer's auto-cal procedure and the oxygen and carbon dioxide sensors were calibrated with known calibration gases prior to each test. Data for the oxygen uptake were averaged and stored using 60 second averages.

Electromyography data were also collected from the RF of the dominant leg during both maximal tests. A rough abrasion pad was used to abrade the skin, and rubbing alcohol was applied to a 4x4 gauze pad and rubbed over the muscle belly of the rectus femoris in order to take skin oils off of the skin to lessen the impedance seen in the muscle activity. A small drop of Signa Gel (electrode gel Parker Laboratories, Inc.; Fairfield, NJ) was applied to the Norax Dual Electrode (product #272 Noraxon USA; Scottsdale, AZ) before it was placed on the preparation site of the rectus femoris. A ground electrode was placed near the iliac crest on the same side. The electrodes were connected to the Biopac Systems, Inc. MP 150 (Goleta, CA). Data were processed using AcqKnowledge 3.9.1.6 software, with a gain of 1000, sample rate of 1000, high and low pass filters set at (10Hz) and (500Hz) respectively, and were rectified using root mean square and averaged over 100 ms.

A continuous graded exercise test on the VASA Ergometer was used. The VASA Ergometer uses "an 'aqua-flow' flywheel resistance" system with an adjustable damper, and a digital feedback screen which shows cadence, and total time of work-out (Training for Nordic Skiing). A damper setting of 3 was used for all tests and subjects. The protocol included a warm-up and accommodation period of 5 minutes before the test to raise the subject's VO_2 up to 60-70% of predicted maximum (Howley, 1995). The protocol started with a cadence of 40 strokes per minute which was controlled via an auditory metronome and visual feedback from the VASA Ergometer monitor. The stroke cadence was increased by five strokes per minute each 60 seconds of the test. The test was terminated when the subject chose to terminate due to exhaustion. The data were used in reference to technique specific VO_2 peak.

The oxygen consumption data were averaged and used in order to collect information to determine the subject's VO_2 at 80%, and 100% of their maximum oxygen uptake. The recorded peak VO_2 score that was closest to the 80% and 100% increments were used to determine the stages of the test.

This stage was documented, and the corresponding EMG data were analyzed using a 2x2 Repeated Measures ANOVA (Position x Stage). A paired T-test was used to assess the differences in technique specific peak VO_2 between sitting and standing positions. All statistical procedures were carried out using SPSS 17.0 (SPSS Inc., Illinois, USA). The predetermined alpha level was set at $p \leq 0.05$.

RESULTS: Results of the ANOVA revealed a significant interaction between position and stage ($F=65.86$, $p=0.001$). A follow-up paired T-test showed that the difference between seated 80% (70.5 ± 53.1 mV) versus seated 100% (65.4 ± 52.6 mV) was not significant ($t=1.464$, $p=0.217$). The difference between standing at 80% (30.8 ± 21.9 mV) versus standing at 100% (56.3 ± 27.6 mV) was statistically different ($t=-5.023$, $p=0.007$). A paired T-test demonstrated that peak VO_2 for standing (52.06 ± 3.65 ml/kg/min) was significantly higher than for sitting (38.88 ± 3.53 ml/kg/min), where $t=11.16$ and $p<0.001$.

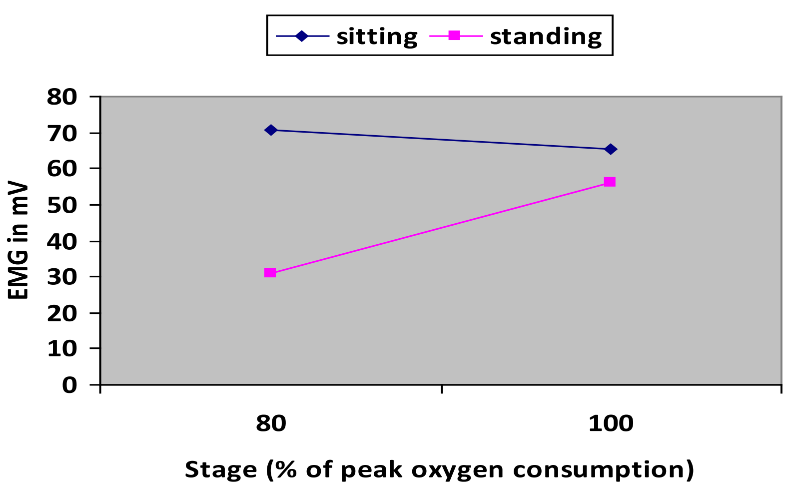

Figure 2. Muscle activity of the rectus femoris response for two stages of a VO_2 max test while standing and sitting

DISCUSSION: The results of this study demonstrate that the RF activity is greater in sitting versus standing. The sit-ski position produced a notable RF activation at both work rates. Thus, RF appears to be highly activated in sit-skiing, or at least more-so than in stand-up skiing. This would indicate a potentially serious limitation to using stand-up skiers for sit-ski research. Since the RF is used to extend the knee and flex the hip, and the seated position naturally places the RF in a shortened position. The shortened position is less optimal for force generation than a more lengthened position (Marginson & Eston, 2001). Theoretically, the length-tension relationship may help to explain why more motor units are recruited for sitting than standing. The RF activation of 80% of max during sit-skiing was similar to that at 100% of max for stand-up double poling, thus we can assume that the RF would be notably activated, if possible, during most competitive sit-skiing intensities. The lack of this activation in skiers with paraplegia would likely require a change in the nature of double poling performance relative to able-bodied skiers. The authors suggest that more research be performed in order to increase the understanding of the biomechanics of sit-ski double pole ergometry.

CONCLUSION: These data suggest it may not be possible to use stand-up athletes for biomechanical sit-ski research, because the stand-up athletes will activate musculature that the sit-ski athletes with paraplegia are unable to activate.

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