DIRECTIONAL COMPRESSION AND MUSCLE ACTIVITY IN A RETIRED WORLD CUP ALPINE SKIER

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The purpose of this study was to identify the effects of directional compression tights on muscle fatigue in alpine skiing as characterized by EMG. A retired world cup skier skied two different full days, one with directional compression tights and one without. In the morning and afternoon a single run of controlled turns was made while EMG, plantar pressure, and accelerometer data were collected. Plantar pressure data was used to divide EMG results into individual turns. Mean amplitude for vastus lateralis, adductor longus, rectus femoris, gluteus medius, and gluteus maximus was assessed by mean RMS amplitude of EMG. For a significance level of 0.01, no significant difference in turn times was determined. No significant differences were seen between morning and afternoon runs. A decreased mean RMS for the compression conditions was observed for rectus femoris ($p < 0.001$) and vastus lateralis ($p = 0.005$).

KEY WORDS: directional compression, alpine skiing, muscle activity, sport performance.

INTRODUCTION: The effects of compression garments on sports performance has been a growing field of interest in recent years. Recent research has reported compression garments may influence muscle strength, and factors associated with muscular fatigue such as motor unit recruitment patterns or muscle pH (Fu et al., 2013, Zhang et al., 2016). Compression garments have also been shown to increase efficiency, resulting in lower muscle electromyographic (EMG) activity even while force production is held constant (Wang et al., 2016).

A sub-category of compression garments, directional compression garments, utilizes specific construction techniques in an effort to exert a perpendicular force on the underlying tissues to create an increased pressure gradient within the tissue (Fu et al., 2013). Directional compression may be especially beneficial for improving fatigue resistance during activities such as alpine skiing which are characterized by repeated eccentric and isometric contractions (Berg & Eiken, 1999; Berg, Eiken, Tesch, 1995) over a long period of time. Two recent studies reported that in competitive alpine skiers, directional compression results in reduced muscle activation, kinematic changes at the hip and knee, and increased fatigue resistance (Decker et al., 2016, Simons et al., 2016). The competitive skiers in these studies utilize a carving technique where the quadriceps are active throughout the entire turn, though in different amounts on the inside and outside legs (Kroll, Wakeling, Seifert, & Mueller, 2010; Mueller & Schwameder, 2003). Previous research on this technique has suggested that more fast twitch muscle fibers are recruited on the inside leg during turns and that this difference between legs may be a substantial contributing factor to fatigue throughout a day of skiing (Kroll et al., 2010). However, it is not known whether the beneficial effects of directional compression are limited to competitive skiers, or if similar changes in muscle activation would be observed in non-competitive skiers who are technically proficient in using a carving technique.

Therefore, the purpose of this study was to examine changes in muscle EMG patterns throughout a day of skiing for a recreation skier technically proficient in using the carving technique when skiing with and without lower body directional compression clothing. We hypothesized in the compression condition, vastus lateralis, adductor longus, rectus femoris, gluteus medius, and gluteus maximus will have lower EMG intensities (RMS) later in the day as compared to the beginning.

METHODS: The participant for this case study was a retired alpine ski racer who competed on the World Cup circuit from 1979-1990, earning top 20 results at the 1985 World

Championships and multiple North American Cup titles. The 54-year-old female has continued with the sport, coaching 20 plus years as a junior ski coach and skiing recreationally. The unique background of the subject provides an excellent technical proficiency in the carving technique, yet her current participation in the sport is as a recreational skier. As previous studies utilized competitive skiers (Simons et al. 2016), this study sought observe recreational skiers, while still ensuring strong a carving technique.

The participant skied two different days, two weeks apart, the first with directional compression tights (Opedix Kinetic Health Gear, Denver, CO, USA) and the second without. Snow and weather conditions were similar between testing days. Bipolar Ag/AgCl surface EMG electrodes (Trigno, Delsys Inc, MA, USA) were placed on the right leg over the mid belly of the vastus lateralis, adductor longus, rectus femoris, gluteus medius, and gluteus maximus muscles. Prior to placing electrodes skin at the placement site was gently abraded and cleaned with rubbing alcohol. Raw EMG signals were amplified at the source and recorded at 1500 Hz (Tringo Personal Activity Monitor, Delsys INC, MA, USA). A gyroscope (Motion Sensor, Electronic Realization, Bozeman, MT, USA) mounted to the back of the boot was used to track ski edge angle at 100 Hz.

The participant completed two measurement runs on each assessment day, one first thing in the morning and one in the afternoon. A course of 12 turns around brush gates, set with 10 m between gates was used for the measurements. Between measurement runs the participant was instructed to ski their choice of runs through the ski area. On the second testing day, the exact sequence of ski area runs was replicated.

Gyroscope data were used to determine turn times by finding the midpoints between maximum and minimum edge angles. For each turn, average root mean squared (RMS) amplitudes from the EMG were found by filtering with a band-pass and then using a 125 ms window with a 62.5 ms overlap. A 2x2 (time of day x condition) repeated measures ANOVA was used to compare morning and afternoon turn times and RMS for the compression and non-compression conditions (significance level of 0.01). Average maximum edge angle for each condition was also determined from gyroscope data.

RESULTS: No significant difference in turn times was found for either compression or time of day conditions. Rectus femoris demonstrated a main effect of condition ($F = 72.633$, $p < 0.0001$) with mean RMS values being lower in the compression condition than the non-compression condition (Table 1). Gluteus medius also demonstrated a main effect of

Table 1
Mean RMS values throughout the turn for each time of day and compression condition.

Time	Factor	Mean RMS for Compression	Mean RMS for No Compression
AM	Turn Time	1.2033 ± 0.1627 s	1.2500 ± 0.1384 s
	Vastus Lateralis	0.0272 ± 0.0052 V	0.0271 ± 0.0053 V
	Adductor Longus	0.0206 ± 0.0066 V	0.0204 ± 0.0043 V
	Rectus Femorus*	0.0204 ± 0.0028 V	0.0287 ± 0.0050 V
	Gluteus Maximus	0.0062 ± 0.0020 V	0.0094 ± 0.0094 V
	Gluteus Medius*	0.0284 ± 0.0095 V	0.0444 ± 0.0110 V
PM	Turn Time	1.2200 ± 0.2231 V	1.2200 ± 0.2231 V
	Vastus Lateralis	0.0248 ± 0.0040 V	0.0227 ± 0.0023 V
	Adductor Longus	0.0159 ± 0.0079 V	0.0181 ± 0.0030 V
	Rectus Femorus*	0.0165 ± 0.0038 V	0.0267 ± 0.0033 V
	Gluteus Maximus	0.0057 ± 0.0014 V	0.0054 ± 0.0008 V
	Gluteus Medius*	0.0268 ± 0.0104 V	0.358 ± 0.0063 V

* Significant difference observed at $p < 0.01$

condition (F = 23.582, $p < 0.005$) with mean RMS values being lower in the compression condition than the non-compression condition (Table 1). For all other muscles there were no effects of condition, time of day, or time of day by condition interactions.
A ski peak edge angle difference of 4.6% was also observed between the compression (61°) and non-compression (64°) conditions, although these results were not statistically analyzed.

DISCUSSION: A decrease in muscle activation for skiers in compression garments was previously observed by Decker et al. (2016) and Simons et al. (2016). Our findings are consistent with these results for rectus femoris and gluteus medius. Gluteus medius activity is part of the steering phase of the carving technique and a lower mean RMS value in this muscle may be directly related to the decrease in edge angle. It is interesting that in the compression condition we observed a very strong decrease in mean RMS for only the rectus femoris muscle and not for vastus lateralis. Previous studies have shown a decrease mean frequency in vastus lateralis and vastus medialis as associated with skiing fatigue (Kröll et al., 2011; Kröll, Seifert, Scheiber, Schwameder, & Müller, 2005). Thus, we would expect to see some change in vastus lateralis activity with fatigue.
A decrease in mean RMS under a compression condition is not unique to directional compression garments. In 2016, Wang et al. reported a decrease in EMG amplitude under a compression condition for isokinetic measurements of quadriceps muscles under various movement speeds. However, as the purpose of directional compression is to target specific muscles, directional compression in the garment used appears to target rectus femoris and gluteus medius, which are applicable to to skiing, although other muscles like vastus lateralis may be important as well. The effects of decreased mean RMS on fatigue throughout the day must be considered, but the results of this case study provide no differences from morning to afternoon.

CONCLUSION: A retired world cup skier, highly efficient in the carving technique as a recreational skier, was observed for two full days of skiing. When wearing directional compression, a decrease in mean RMS activity in rectus femoris and gluteus medius was observed. Average peak edge angle also decreased by 4.6% in the compression condition, although this value was not tested for statistical significance. No differences in turn duration or in time of day were observed. Further investigations are necessary to determine the effects that decreased muscle activity due to directional compression garments may have on skier fatigue.

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