Opedix Ski Science

Influence of the Opedix tights on alpine skiing biomechanics

This first page is a summary of the research performed on the Opedix Knee-Tec tights during alpine skiing. The following pages provide the scientific abstracts which provide specifics supporting the various findings.

Biomechanics Findings

The purpose of this study was to measure alpine ski turning technique during slalom race simulations and compare ski turning technique while wearing the Opedix Knee Tec tights (OPX) or a standard compression garment (CMP). A three-dimensional inertial based method utilizing inertial measurement units (IMUs), a global positioning system (GPS) and a pair of foot pressure insoles was implemented to capture the slalom performance of 9 highly skilled athletes (4 men, 5 women) on a course with 13 m linear gate distances offset by 3 m. The skier's movements, ski loading characteristics, ski orientation, speed and the electromyographic (EMG) activation of select knee muscles of the right downhill leg were measured during the performance of 9 consecutive left turns while skiing with OPX and CMP tights. The performance order of the two conditions was balanced across participants.

Skier's Movements. Minimum, maximum and average sagittal plane hip, knee and ankle motions were measured and compared between OPX and CMP conditions. The minimum ankle position was 7% less flexed at the initiation of the turn for the OPX condition. No statistical differences were found between conditions for the knee variables. The maximum and average hip angles were 5% and 3% more flexed forward during the OPX condition.

Ski Loading. Maximum ground reaction force, and minimum, maximum and average anterior/posterior and medial/lateral force application points were compared between OPX and CMP conditions. The peak ground reaction force was 9% lower (≈27 lbs of force) during the OPX condition. The maximum and average anterior-posterior force application point was 2% and 3% more anterior (≈3 and 4 mm forward, respectively) for the OPX condition. The minimum medial-lateral force application point, occurring at the initiation of the turn was 9% more medial (≈2 mm towards the inside edge) for the OPX condition.

Ski Orientation. The minimum, maximum and average edge angle was measured and compared between OPX and COM conditions. The edge angle at the initiation of the turn was 13% greater (≈10 deg) for the OPX condition.

Knee Muscle Function. The peak knee extensor torque and the average EMG activation of two quadriceps muscles (rectus femoris, RF; vastus lateralis, VL) and a hamstring muscle (biceps femoris; BF) were compared between OPX and CMP conditions. The peak knee torque was 16% lower for the OPX condition. The RF and VL EMG activations were each 17% lower and BF was 4% higher during the OPX condition.

Performance. Average right turn speed and turn duration were compared between OPX and CMP conditions. Although these variables were statistically equal, average turn speed was .3 mph slower (OPX 20.7 mph; CMP 21.0 mph) but average turn duration took .044 s less time for the OPX condition (OPX 8.314 s; CMP 8.358 s).

Biomechanics Summary

A different ski turning technique was demonstrated with the OPX tights. Greater hip flexion at the initiation of the turn moved the force application point forward and towards the inside edge of the ski resulting in a greater edge angle (ie., carving). Greater carving at initiation reduced the ground reaction force during the steering phase of the turn and when combined with greater hip flexion reduced the muscular effort from the quadriceps muscles to steer the skis. This modified ski turning technique with the OPX tights ultimately resulted in a reduced amount of time to complete the turn presumably due to a shorter turn length. Collectively, these results may have implications for alpine skiing safety, performance and training.

Leg compression tights and turning direction influence alpine skiing mechanics and dynamic balance

Decker MJ, Simons CJ, Seifert JG, Shelburne KB, Sterett WI, Davidson BS. Leg compression tights and turning direction influence alpine skiing mechanics and dynamic balance. Med Sci Sports Exerc. 2016;48(5S):284-5.

Leg compression tights have been found to influence the neuromuscular and clinical aspects of professional alpine skiers but the mechanisms that underlie these benefits are unclear.

PURPOSE: To determine the influence of leg compression tights on alpine skiing mechanics and dynamic balance.

METHODS: Foot pressure insoles captured the ground reaction force (GRF) and the trajectory of the COP during slalom race simulations from 9 collegiate alpine ski racers. Peak GRF, maximum anterior-posterior (AP), minimum medial-lateral (ML) COP, COP area and COP velocity were measured from the downhill leg during 18 turns (9 right; 9 left) while wearing either directional compression (DCP) or standard compression (SCP) tights. The order of DCP and SCP conditions was balanced. A 3-way mixed factor, repeated measures ANOVA contrasted the effects of turn direction and compression product across the 18 turns. RESULTS: Peak GRF was 9% lower during the DCP condition (DCP, 1175.5 ± 36.7 N; SCP, 1295.5 ± 24.3 N; $p<.001$) and 6% lower for the right leg (right, 1200.2 ± 32.2 N; left, 1270.8 ± 26.7 N; $p=.005$). The maximum AP COP was 2% more anterior during the DCP condition (DCP, 173.1 ± 1.3 mm; SCP, 170.4 ± 1.4 mm; $p=.008$) and 3% more anterior for the left leg (right, 169.0 ± 1.4 mm; left, 174.4 ± 1.6 mm; $p=.001$). The minimum ML COP was 3% more medial during the DCP condition (DCP, 32.3 ± .5 mm; SCP, 33.4 ± .5 mm; $p=.025$) and 3% more medial for the left leg (right, 33.4 ± .5 mm; left, 32.3 ± .4 mm; $p=.011$). The COP area was 12% greater for the left leg (right, .43 ± .01 mm2; left, .48 ± .01 mm2, $p<.001$). The COP velocity was 14% lower during the DCP condition (DCP, 365.2 ± 17.3 mm/s; SCP, 422.2 ± 30.1 mm/s; $p=.024$) and 9% higher for the left leg (right, 377.0 ± 22.6 mm/s; left, 410.4 ± 23.4 mm/s; $p=.025$). CONCLUSION: Alpine skiing mechanics and dynamic balance were improved with DCP tights but differences between the right and left legs persisted.

Leg Compression Tights and Turning Direction Influence Alpine Skiing Mechanics and Dynamic Balance

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University of Denver[1], Montana State University[2], Vail-Summit Orthopaedics Foundation[3]

Abstract

PURPOSE: To determine the influence of leg compression tights on alpine skiing mechanics and dynamic balance.

METHODS: Foot pressure insoles captured the ground reaction force (GRF) and the trajectory of the COP during slalom race simulations from 9 collegiate alpine ski racers. Peak GRF, maximum anterior-posterior (AP), minimum medial-lateral (ML) COP, COP area and COP velocity were measured from the downhill leg during 18 turns (9 right; 9 left) while wearing either directional compression (DCP) or standard compression (SCP) tights. The order of DCP and SCP conditions was balanced. A 3-way mixed factor, repeated measures ANOVA contrasted the effects of turn direction and compression product across the 18 turns.

RESULTS: Peak GRF was 9% lower during the DCP condition (DCP, 1175.5 ± 36.7 N; SCP, 1295.5 ± 24.3 N; p<.001) and 6% lower for the right leg (right, 1200.2 ± 32.2 N; left, 1270.8 ± 26.7 N; p=.005). The maximum AP COP was 2% more anterior during the DCP condition (DCP, 173.1 ± 1.3 mm; SCP, 170.4 ± 1.4 mm; p=.008) and 3% more anterior for the left leg (right, 169.0 ± 1.4 mm; left, 174.4 ± 1.6 mm; p=.001). The minimum ML COP was 3% more medial during the DCP condition (DCP, 32.3 ± .5 mm; SCP, 33.4 ± .5 mm; p=.025) and 3% more medial for the left leg (right, 33.4 ± .5 mm; left, 32.3 ± .4 mm; p=.011). The COP area was 12% greater for the left leg (right, .43 ± .01 mm^2; left, .48 ± .01 mm^2, p<.001). The COP velocity was 14% lower during the DCP condition (DCP, 365.2 ± 17.3 mm/s; SCP, 422.2 ± 30.1 mm/s; p=.024) and 9% higher for the left leg (right, 377.0 ± 22.6 mm/s; left, 410.4 ± 23.4 mm/s; p=.025).

CONCLUSION: Alpine skiing mechanics and dynamic balance were improved with DCP tights but differences between the right and left legs persisted.

Introduction

- During alpine skiing, the determination of the center of pressure and the magnitude of the ground reaction force acting on the ski provides useful information regarding the motion and balance of a skier [1]
- Leg dominance is a risk factor for knee injury [2]
- Standard and directional compression tights have been suggested to influence alpine ski performance [3,4] but it is currently unclear whether they have different effects on the motion and balance of an alpine skier.

Methods

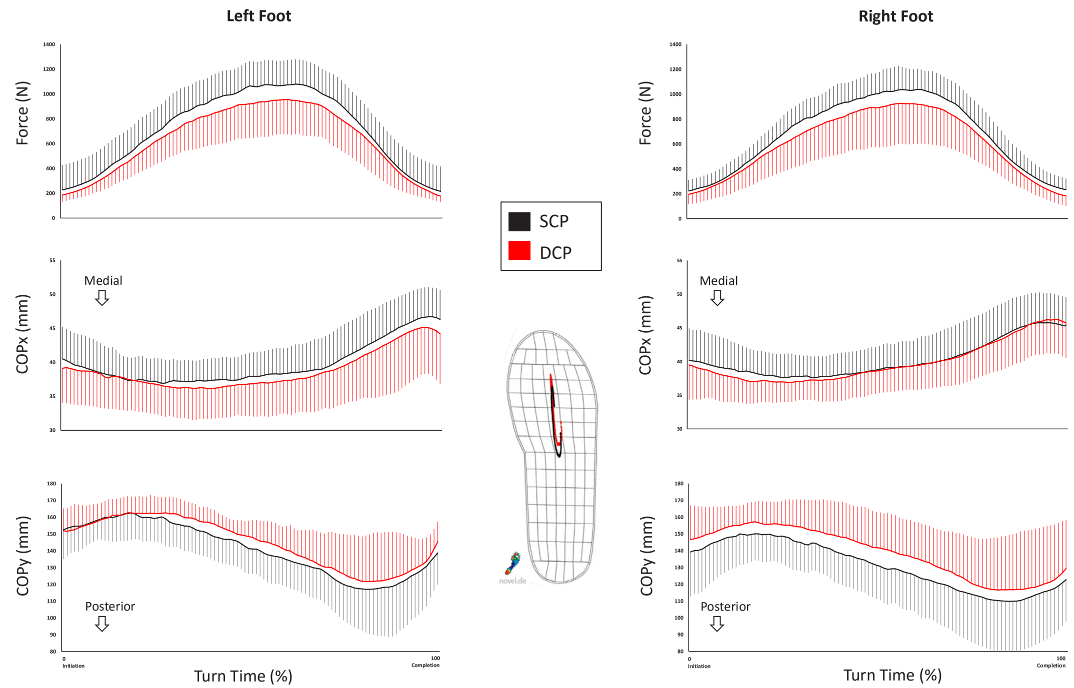
- 9 right leg dominant participants (5 males, 4 females; 21.8 ± 2.7y)
- FIS slalom ranking 24.0 ± 16.3 (range: 10-58)
- 12 m gates with 3 m offset (20 deg pitch)
- 2 runs; 18 consecutive turns (9 right, 9 left) for two conditions: standard compression tights (SCP, top right), directional compression tights (DCP, bottom right)
- Normal force and center of pressure (COP) measured with pressure insoles (Novel)
- Dynamic balance computed as the COP velocity and area
- 3-way mixed factor, repeated measures ANOVA (leg, compression product, turn)

Standard Compression (SCP)

Directional Compression (DCP)

Results

Figure 1. Mean (SD) curves for normal force (Force; top), medial-lateral center of pressure (COPx; middle) and anterior-posterior center of pressure (COPy; bottom) for the downhill leg during 18 consecutive (9 right, 9 left) alpine ski turns.



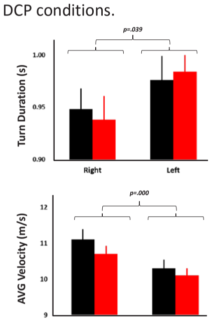


Figure 2. Mean (SD) turn duration and velocity for right and left legs during SCP and DCP conditions.

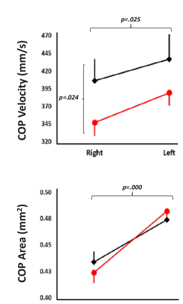


Figure 3. Mean (SD) COP velocity and area for right and left legs during SCP and DCP conditions.

Summary and Conclusion

- Compared to the SCP tights condition, skiing with the DCP tights influenced ski turning technique and demonstrated a shift in the center of pressure forward and towards the inside edge of the downhill ski.
- This ski turning technique required smaller peak forces and improved dynamic stability while preserving performance.
- Although differences between dominant and non-dominant legs persisted, skiing with DCP tights may enhance ski turning technique and reduce the risk of injury.

References

[1] Nakazato et al., *Journal of Sports Science and Medicine*, 10: 754-762, 2011.
[2] Ruedl et al., *American Journal of Sports Medicine*, 40(6): 1269-1273, 2012.
[3] Sperlich et al., *BMC Sports Science, Medicine, and Rehabilitation*, 5(18), 2013.
[4] Decker MJ., *Proceedings of the 3rd Annual Rocky Mountain American Society of Biomechanics*, 2013.

Leg Compression Tights Reduce Muscle Activation by Altering Ski Turning Technique

Simons CJ, Seifert JG, Decker MJ, Shelburne KB, Sterett WI, Davidson BS. Leg Compression Tights Reduce Muscle Activation by Altering Ski Turning Technique. Med Sci Sports Exerc. 2016 May;48(5S):285.

PURPOSE: To determine the influence of leg compression tights on the kinematic and neuromuscular performance of alpine ski turns.

METHODS: Wireless inertial measurement units (IMUs) and surface electromyography (EMG) electrodes captured bi-lateral segmental orientations and uni-lateral vastus lateralis (VL), rectus femoris (RF), biceps femoris (BF) and gluteus medius (GM) muscle activations during slalom race simulations from 9 collegiate alpine ski racers. Average ankle, knee and hip positions and turn durations were calculated from the downhill leg during 18 turns (9 right; 9 left) while wearing either directional compression (DCP) or standard compression (SCP) tights. Average VL, RF, BF and GM EMG amplitudes from the right leg were measured during 9 turns. The order of DCP and SCP conditions was balanced. A 3-way mixed factor, repeated measures ANOVA contrasted the effects of turn direction and compression product across the 18 turns whereas one-way repeated measures ANOVA contrasted EMG amplitudes. RESULTS: Average turn duration was 4% longer for the left leg (right, .943 ± .020; left, .980 ± .021 s; $p=.039$). Average knee position was 3% more flexed during the DCP condition (DCP, 117.1 ± 1.4 deg; SCP, 120.8 ± 1.3 deg; $p=.010$) and the right leg was 4% more flexed (right, 116.5 ± 1.5 deg; left, 121.3 ± 1.1 deg; $p=.020$). Average hip position was 5% more flexed during the DCP condition (DCP, 145.4 ± 1.5 deg; SCP, 153.5 ± 1.2 deg; $p<.001$) and the right leg was 3% more flexed (right, 147.6 ± 1.3 deg; left, 151.3 ± 1.2 deg; $p=.012$). Average GM, RF and VL activations were 26%, 17% and 17% lower for the DCP condition, respectively (GM: DCP, 2.7 ± 1.9 mV; SCP, 3.7 ± 2.6 mV; $p<.001$; RF: DCP, 3.0 ± 2.0 mV; SCP, 3.6 ± 2.7 mV; $p=.020$; VL: DCP, 2.4 ± 1.5 mV; SCP, 2.9 ± 2.1 mV; $p=.020$). CONCLUSION: The DCP tights demonstrated an alpine skiing turn technique with greater hip and knee flexion positions and reduced VL, RF and GM muscle activations, hence identify the mechanism of reduced fatigue rates for these muscles.

International Congress on Science and Skiing

Decker MJ, Simons CJ, Seifert JG, Shelburne KB, Sterett WI, Davidson BS. Redistribution of Lower Extremity Joint Moments during Alpine Skiing. Conference Proceedings of the 7th International Congress on Science and Skiing, St. Christolph, Austria, 2016

INTRODUCTION: The sagittal plane knee joint moment is a surrogate measure of knee loading. Changes in the magnitude of this moment with a specific intervention are often attributed to alterations in the magnitude of the ground reaction force (GRF) or the length of the lever arm between the GRF and knee joint center. The product of these two variables comprise the simplified lever-arm method of computing knee joint moments. This method becomes functionally meaningful to alpine skiing research when calculations are made with respect to the load bearing axis (LBA) of the lower limbs. Coordinated hip, knee, and ankle motions during a ski turn influence the orientation of the LBA consequently altering the distribution of lower extremity joint moments. The purpose of this study was to apply the lever-arm method of measuring joint moments to determine the effects of a wearable, knee loading intervention device during alpine skiing.

METHODS: Three male and 3 female ski racers (FIS Slalom ranking: 23.5 ± 17.8) performed 4 to 6 trials of simulated slalom racing on a water-injected course with a mean slope inclination of 20°. The gates were 12 m apart down the fall line and offset 3 m. The racers were instrumented with foot pressure insoles, 13 wireless inertial measurement units and a global positioning sensor. The data were combined with anthropometric models to measure the kinematics and kinetics of the racer's dominant leg during 9 consecutive double turns. Each participant performed with their own equipment while either wearing a knee loading intervention device consisting of directional compression (DCP) tights (Opedix LLC, USA) or standard compression (SCP) tights (2XU, USA). Average turn velocity and select kinematic and kinetic variables were contrasted between conditions with repeated measures ANOVA.

RESULTS and DISCUSSION: Average turning velocity was not different between compression conditions ($p>.05$). Maximum GRF, average knee joint moment arm length, peak knee joint moment and extensor angular impulse was 6%, 2%, 6% and 14% lower for the DCP condition (all $p<.05$), whereas the average AP FAP was 3% greater ($p<.05$). Reduced knee joint moments but similar average turning velocities during the DCP condition indicate that the intervention device induced a shift in function between muscle groups and reduced the demand on the knee extensors.

CONCLUSION: A simple intervention device was found to exploit the flexibility inherent in the human neuromuscular system to redistribute lower extremity joint moments and reduce knee joint loading during alpine skiing.

KNEE SYMPTOMS AND FUNCTION IN PROFESSIONAL SKIERS: CAN KNEE SUPPORT HELP?

Decker, MJ. Knee Symptoms and function in professional skiers: Can knee support help? Conference Proceedings of the Rocky Mountain American Society of Biomechanics Annual Meeting, Estes Park, CO, 2013.

INTRODUCTION:

The population of professional ski instructors and patrollers ski on average 110 days per season and are at a considerable risk for knee injury [5]. Educational seminars on ski equipment, fall training programs, higher standards of slope preparation and skier codes of responsibility are the major programs that ski resorts make use of to reduce the chance of a skiing injury yet traumatic knee injuries are at a higher rate now than 20 years ago [1]. Further, a previous knee injury is a major risk factor for an additional injury and the eventual development of knee osteoarthritis (OA) [1,2]. External knee support devices have been shown to reduce the risk of secondary injury during skiing [3] but it is currently unknown if a knee support device can improve the symptoms and function in professional skiers with a history of knee injury. The purpose of this study was to compare self- reported measures of knee symptoms and function between professional skiers with a history of knee injury and those with no history (control); and whether skiing with a knee support device can influence these measures.

METHODS:

Self-reported measures of knee symptoms and function were collected weekly over three consecutive weeks of skiing from 88 (53 men; 35 women) professional ski instructors or patrollers from eight ski resorts (Aspen, Beaver Creek Breckenridge, Heavenly, Keystone, Northstar, Vail, Taos). Upon the participant's written informed consent, the International Knee Documentation Committee (IKDC) and knee injury history questionnaires were completed to classify the skier's knee impairment and study group inclusion. The Western Ontario McMasters (WOMAC) questionnaire measuring knee function and four, 15 point Visual Analogue Scales (VAS) measuring muscular fatigue and recovery, knee pain and stiffness were completed at the end of each week. Measurements during weeks 1 and 3 (pre, post) were considered as the baseline values of knee function and symptoms while skiing. During week 2 (OPX), the ski professionals performed all skiing while wearing knee support tights under their ski pants. These tights were constructed of 2 types of overlapping fabrics with different elastomeric properties that are specifically located in the garment to provide multidirectional knee support (Opedix LLC, Scottsdale, AZ). Two-way, mixed factor repeated measures ANOVA and Bonferroni post-hoc tests were performed over 3 weeks of skiing for the professional skiers with and without a history of knee injury on the following variables: Total WOMAC score, VAS fatigue during skiing, VAS fatigue recovery after skiing, VAS pain during skiing, VAS stiffness during skiing, and total skiing time. An unpaired t-test was used to determine whether the knee impairment score measured with the IKDC was different between groups. All statistical testing employed an alpha level of .05.

RESULTS and DISCUSSION:

Fifty nine (25 men, 35 women) of the professional skiers (67%) reported a history of knee injury. No statistical differences were found for total time skiing between groups or weeks (all $p>.05$). Compared to the control group, knee impairment measured with IKDC was 11% greater ($p=.001$) and knee function measured with the total WOMAC score was 17% lower for the knee injury group ($p=.02$). Group means for the dependent variables collapsed across groups for each week of skiing are presented in Figure 1. These data demonstrated quadratic trends (all $p<.05$) and were on average 25% lower (improved) while skiing with knee support during week 2 compared to the baseline condition at week 1 (pre vs OPX, all except VAS stiffness, $p<.05$). All variables returned to baseline while skiing without knee support during week 3 (pre vs post, all $p>.05$).

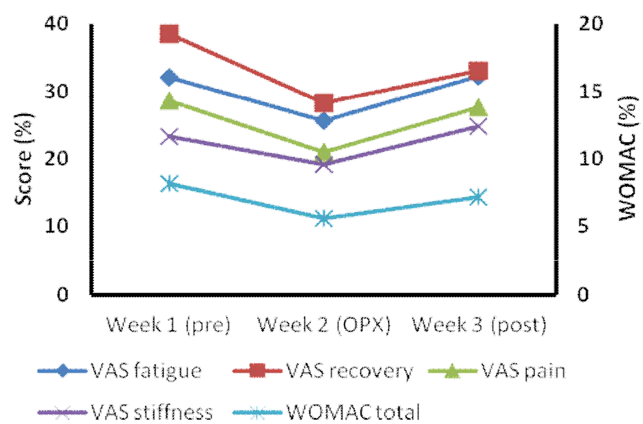


Figure 1: Dependent variables collapsed across groups measured over three consecutive weeks of skiing. Knee support was worn during week 2. Lower scores indicate

CONCLUSION:

Compared to controls, skiers with a history of knee injury demonstrated greater knee impairment and less knee function but no differences in knee symptoms or fatigue during skiing. Wearing knee support constructed of a combination of fabrics during skiing reduced self-reported measures of muscular fatigue and knee pain and enhanced muscular fatigue recovery and knee function.

REFERENCES

1. Pećina. Croatian Medical Journal, 43, 257-260, 2002.
2. Ratzlaff et al. Arthritis Research & Therapy, 12, 1-8, 2010.
3. Sterret et al, et al. American Journal of Sports Medicine, 34,1581-1585, 2006.
4. Viola et al. American Journal of Sports Medicine, 27, 792-795, 1999.