



## **The Effects of Anatomic Enhancing Base Layer Garments on Knee Performance and Injury Reduction Among Professional Ski Instructors.**

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**(pre-publication only)**

### **Introduction**

There are nearly 30 million individuals engaged in downhill skiing in the United States every year. Injury rates currently range between 3.7 and 9.1 injuries per 1000 skier days, and there has been a well-documented increase in the number of trauma cases and fatalities associated with this sport (Langran & Selvaraj, 2002; Rossi et al., 2003). Significant technological improvements in bindings and boots over the past decade have surpassed advances in knee support and traumatic knee injuries are at a higher rate now than 20 years ago (Pecina 2002). The need for new injury prevention technology is compounded by the fact that the majority of traumatic lower extremity injuries are due to muscular fatigue and performance errors rather than equipment issues (Girardi et al., 2010).

The human musculoskeletal system strives for Balance. Normal equilibrium is defined as the ability to maintain the center of body mass over its core support with dynamic postural stabilization. This involves both motor control and sensory processes (neuromuscular activity). During skiing, posture is critical for optimal performance and energy optimization. If one body segment or link in the body's kinetic chain is out of sync, movement efficiency and coordination is reduced thereby commencing early fatigue and the probability for injury. Fatigue reduces muscular function and reflex reaction time, which can render the knee joints, the hips, and the upper body more susceptible to damaging stresses. Hence technology that would influence dynamic posture and muscle fatigue may be an effective approach to ski injury prevention.

A previous pilot study with Vail Resorts investigated the effects of the knee support tights on ski professionals over 3 consecutive weeks and found a dramatic increase in knee function and a decrease in knee fatigue, pain and stiffness. The aim of this new study was:

- 1) To further investigate the initial study results with a much larger group of ski professionals

2) To create a study sub-group that would be tested with a lower and upper extremity anatomic garment; an Evidence Based Posture Shirt to determine if a measurable improvement in dynamic posture, functional enhancement and fatigue reduction would occur between the two groups.

## **Methods**

Three standardized questionnaires (International Knee Documentation Committee (IKDC), Western Ontario McMasters (WOMAC), Visual Analogue Score (VAS)) were electronically administered via email over three consecutive weeks of skiing (week 1, 2 and 3) while wearing or not wearing the knee support tights and Posture Shirt.

## **SUMMARY OF RESULTS**

- 1) Majority of the Participants were Skiers that Taught Skiing Professionally**
- 2) The Participants had Knees that were on Average below Normal Functioning**
- 3) 20% of the Participants had Knee Arthritis**
- 4) Knee Pain, Stiffness and Fatigue were improved when skiing with the Anatomic Enhanced Garments. No upper body pathology was reported or observed**
- 5) Improvements in Knee Pain, Stiffness and Fatigue were greater when skiing with both the Knee Support Tights and Posture Shirt**
- 6) Knee Pain, Stiffness and Fatigue had Dramatic Long Term Improvements for the Participants with Knee Arthritis**
- 7) Standard Compression Garments were showed little or no measurable effect during skiing**
- 8) Knee injuries were Reduced by 43% at Vail Resorts for the 2010-2011 Season and may Translate into a Savings of Greater than \$1.48 million**

## PURPOSE

The primary goals of this study were to 1) investigate the short and long term effects performance and fatigue in two groups of ski professionals, one using Knee Support Tights only, and one with both ski tights and an anatomical Posture Shirt;

and 2) determine if the performance and injury benefits of ski tights is augmented when adding a Posture Shirt upper extremity garment.

Figure 1.  
*Aligned Short  
Sleeve Posture  
Shirts and Knee  
Support  
Tights*



## INVESTIGATIVE TOOLS

Health and Safety directors from 6 mountains, Vail, Beaver Creek, Breckenridge, Keystone, Northstar provided 300 volunteers to study Knee function and fatigue in 300 professional ski instructors for 3 consecutive weeks while they performed their on-mountain skiing activities with and without Knee Support Tights and Aligned Posture Shirt®. Three standardized questionnaires (International Knee Documentation Committee (IKDC), Western Ontario McMasters (WOMAC), Visual Analogue Score (VAS)) were electronically administered via email over three consecutive weeks of skiing (week 1, 2 and 3) and at the end of the season while wearing or not wearing the Knee Support Tights and Posture Shirt.

**IKDC.** The IKDC is a knee specific, self-evaluation questionnaire consisting of 18 questions with scores ranging from 0 (poor function) to 100 (excellent function). This validated form (Higgins et al., 2007) was used to describe the general knee status of the participants prior to testing.

**WOMAC.** The WOMAC is a self-evaluation questionnaire used to measure dysfunction and pain of the lower extremities by assessing 17 functional activities, five pain related activities and two stiffness categories (Bellamy et al., 1988). Scores range from 0 (poor function) to 100 (excellent function). The WOMAC has been shown to be a robust measurement tool for assessing therapeutic interventions that are intended to enhance knee function; hence this questionnaire was administered for the first 3 consecutive weeks of testing and at the end of the season.

**VAS.** In addition, the participants were assessed for fatigue, pain and stiffness with a 15 cm visual analogue scale (VAS). Electronically, this scale consisted of 15 circles where the participant selected a circle that best answered the personal sensations experienced during a particular time period. At the very left side of the line was the lowest value (most positive response; score of 0), at the very right the highest (most negative response, score of 15). The value is expressed as a percentage by dividing the score by 15 and then multiplying by 100. The

VAS provided a quantitative metric of muscle fatigue during and after skiing; as well as knee pain and stiffness induced from a normal week skiing. This questionnaire was also administered for the first 3 consecutive weeks of testing and at the end of the season.

## **RESULTS and DISCUSSION**

### ***Majority of the Participants were Skiers that Taught Skiing Professionally***

There were 210 (age,  $40.6 \pm 12.6$  y;  $68.6 \pm 4.0$  in;  $165.3 \pm 30.7$  lbs) professional ski instructors that contributed to the results of this study (143 men; 67 women). Of the 90 that did not participate, 7 reported fit issues and the remainder did not respond to the online testing procedures. The majority of the participants were from ski school (ski school, 83%; ski patrol, 11%; other, 6%) and performed skiing as their primary mode of employment (skiing, 80%; snowboarding, 17%; telemarking, 3%).

### ***The Participants had Knees that Were on Average below Normal Functioning***

The participants had a mean IKDC score of 85.5 (range, 51.7 to 100.0). An IKDC score between 87 and 91 is indicative of normal functioning knees (Higgins et al., 2007) and signifies that the participants in this study did not, on average, have normal knees. In fact, 81 of the 210 participants demonstrated IKDC scores below 87 (range, 51.7.0 to 86.2) indicating that 38.6% of the ski professionals had knees that were below normal functioning.

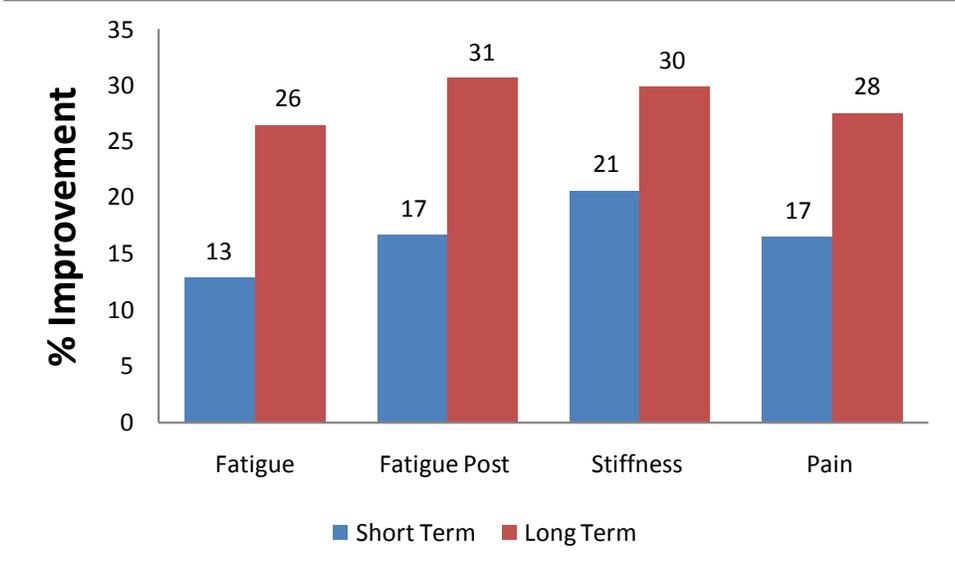
### ***20% of the Participants had Arthritis***

A total WOMAC score between 60 and 82 signifies knee degeneration (Bellamy et al., 1988). The average total scores during each testing interval of the study were greater than 90 indicating that the participants did not, on average, have significant knee degeneration. However, 20% of the participants scored 82 or below indicating that a moderate proportion of the group had knee degeneration and echoes the IKDC scores above.

### ***Knee Pain, Stiffness and Fatigue were Improved when Skiing with the Anatomic Enhancing Garments***

The primary goal of this study was to determine the effects of the Knee Support Tights and Posture Shirt on fatigue, knee pain and stiffness during skiing. We measured the baseline values of fatigue, knee stiffness and pain when skiing without the anatomic enhancing garments; and determined how these variables changed in the short term and long term while skiing with the anatomic enhancing garments (Figure 2). Compared to the baseline values, all knee performance variables continuously improved, some as high as 31% by the end of the testing period.

Figure 2.



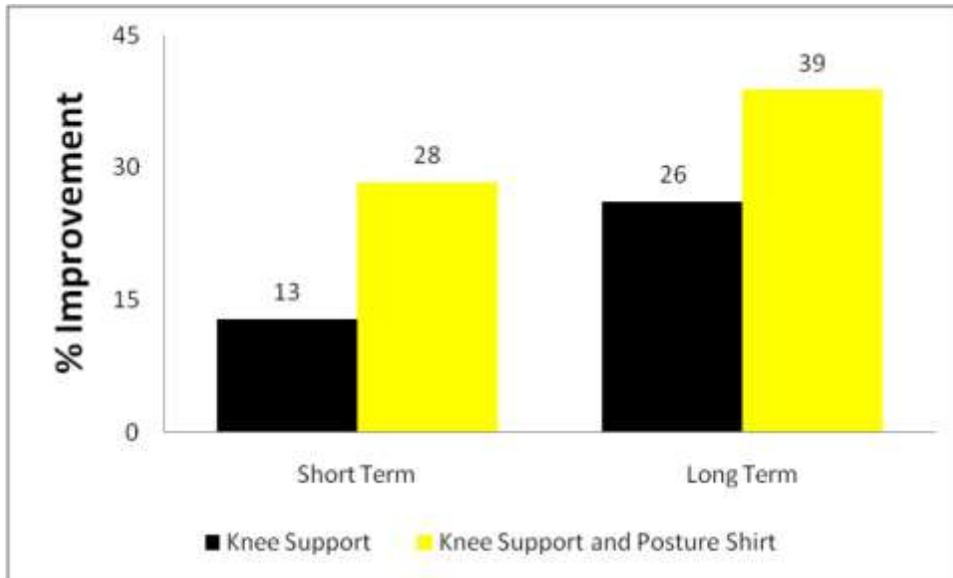
**Improvements in Knee Pain, Stiffness and Fatigue were Greater when Skiing with both the Knee Support Tights and Posture Shirt**

The secondary goal of this study was to determine whether the performance benefits of skiing with the Knee Support Tights on fatigue, knee pain and stiffness during skiing were augmented with an upper extremity garment; the Posture Shirt. We measured the average baseline values for these knee performance variables when skiing without an anatomical garment and determined how the variables changed during the short term and long term when either skiing with the Knee Support Tights or the Knee Support Tights and Posture Shirt (Table 1). Compared to the baseline values, all knee performance variables continuously improved throughout the testing period for each subgroup; but skiing with the Knee Support Tights and Posture Shirt more than doubled the average improvements in knee performance compared to skiing with the Knee Support Tights alone (Figure 3).

Table1. Short term and long term improvements (%) in fatigue, knee stiffness and pain when skiing with the Posture Shirt and/or Knee Support Tights.

	Knee Support		Knee Support and Posture Shirt	
	Short Term	Long Term	Short Term	Long Term
Fatigue	7	24	31	38
Fatigue-post	16	26	21	48
Stiffness	17	28	33	37
Pain	12	26	29	33

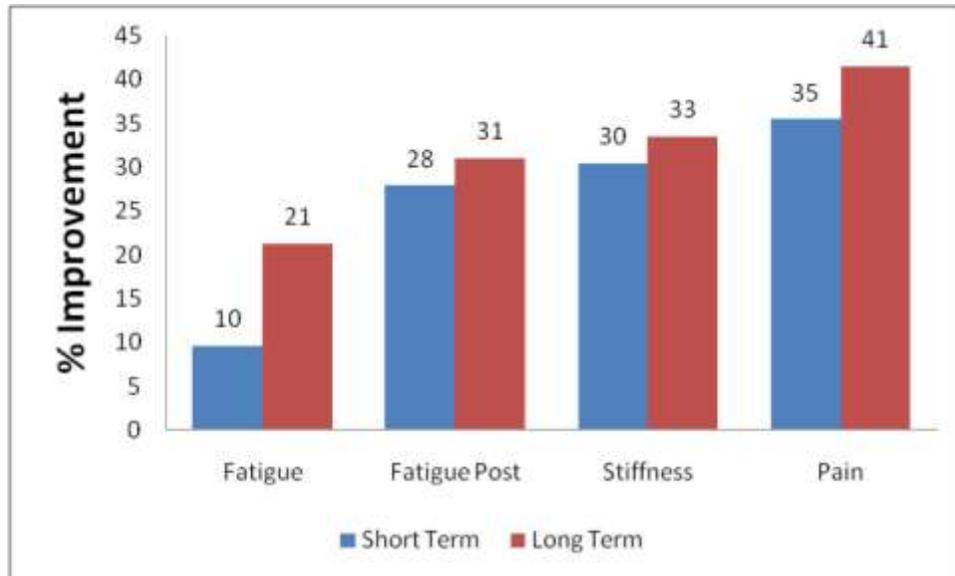
Figure 3.



***Knee Pain, Stiffness and Fatigue had Dramatic Long Term Improvements for the Participants with Knee Arthritis***

The skiing population is ageing and an important question was to determine how the anatomic enhancing garments fared in skiers with knee arthritis. The current study found 20% of the participants to demonstrate WOMAC scores indicative of knee arthritis. For this subgroup, we measured the baseline values of fatigue, knee stiffness and pain when skiing without the anatomic enhancing garments; and determined how these variables changed in the short term and long term while skiing with the anatomic enhancing garments (Figure 3). Improvements for this population of skiers were dramatic, particularly for knee stiffness and pain, and only 2% of the participants were measured to have knee arthritis at the end of the testing period. This is an interesting statistic, but does not mean that the anatomic enhancing garments cured the arthritic ailment. Rather, the decreased function and pain that stems from stiff arthritic knees were considerably improved while skiing with the reduction in fatigue brought on by the anatomic enhancing garments and they were no longer categorized as skiers with knee arthritis.

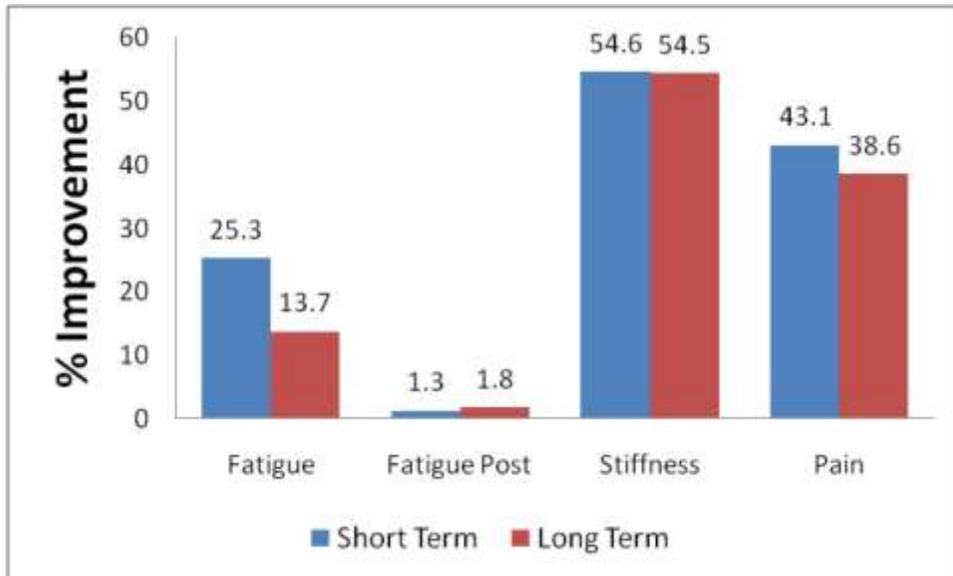
Figure 4.



***Standard Compression Garments were Inferior to the Anatomic Enhancing Garments during Skiing***

An important question was whether the positive effects of the Knee Support Tights and Posture Shirt during skiing was simply due to a placebo effect or the form fit analogous to a popular standard compression garment. Only 10% of the participants reported to regularly wear compression tights while skiing. For this subgroup, we measured the baseline values of fatigue, knee stiffness and pain when skiing with compression garments; and determined how these variables changed in the short term and long term while skiing with the anatomic enhancing garments (Figure 4). Although muscular recovery after skiing was comparable between garments, the anatomic enhancing garments were far superior during skiing performance. These results indicate that the form fit of the anatomic enhancing garments acts similar to a compression garment to help microvascular blood flow and muscular recovery after skiing but the addition of targeted touch and tension technology primarily accounted for positive performance benefits and injury reduction during skiing.

Figure 5.



***Knee Injuries Were Reduced by 43% at Vail Resorts for the 2010-2011 Season and may Translate into a Savings of Greater than \$1.48 million***

Compared to the 2009-2010 ski season, total body injuries were reduced by %10 in the 2010-2011 ski season. Further, injuries to the legs, and particularly the knees were reduced by 28% and 43%, respectively. In the current study, only 7% of the participants reported that they were injured and missed 1 or more days of work over the course of this study. Only 2 individuals reported a knee injury of which upon direct personal communication both were determined to be caused while walking with their skis (ie, not skiing). The other reported injuries were primarily caused by an impact with another skier resulting in either a head, neck or torso injury. Hence, none of the injuries were caused by the anatomic enhancing garments. Additionally, no injuries were reported or observed to the upper extremity. Rather, it is likely that these garments contributed to the reduction in the total injuries for Vail Resorts. If indeed this was accurate than the anatomic enhancing garments would have saved the employees of Vail Resorts 37 knee injuries. Assuming the scenario that the 37 prevented knee injuries were all ACLs (anterior cruciate ligaments), then Vail Resorts would have saved \$1.48 million (average cost of surgery and rehabilitation  $\approx$  \$40,000) not accounting for the costs of missed time and the new employee training.

**CONCLUSION**

In conclusion, skiing with the Knee Support Tights and the Aligned Posture Shirt garments dramatically enhanced knee function, pain and stiffness during skiing. Reduction in quadriceps fatigue (“quad-burn”) was a consistent comment among test subjects. The knee performance effects were immediate and continuously improved throughout the last two months of the ski season. Concurrently, knee and upper extremity injuries requiring medical attention and lost time

from work were reduced compared to the previous season at Vail Resorts. Collectively, these data are interpreted to indicate that dynamic posture awareness through conscious and/or sub-conscious bio-feedback, provided neuromuscular support by Anatomic Enhancing Garments. The combined use of a lower extremity tights and upper extremity Posture Shirt promoted good posture and joint alignment, in particular by lending balance to knee joint stress. These effects surpassed the effects of compression garments alone and therefore suggest that the specific touch and tension technology was primarily responsible for enhanced joint and skeletal alignment, efficient muscular coordination, and body awareness. Skiing with the Knee Support Tights and Posture Shirt could provide a remedy to ski injury prevention, skier fatigue, and a means to promote longevity in skiing populations with knee arthritis or other joint pathologies who may otherwise not consider a ski vacation.

## **References**

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