Does Ski Width Influence Muscle Action in an Elite Skier? A Case Study

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ABSTRACT

Zorko et al. reported significant differences between wide and narrow ski widths on knee joint kinematics. Those authors reported skiers on WS had more knee extension and less internal knee joint rotation than when on narrow skis. The purpose of this case study was to investigate the differences in muscle activity, ski, and skier actions in an elite skier when skiing slalom skis (SL) and WS. An Olympic Giant Slalom gold medalist, who is also an elite level ski instructor and national demonstration team member, completed a run on SL skis (66 mm underfoot) and a run on wide skis (WS; 95 mm underfoot). Each run was divided into standardized turns with 13 gates and a free ski sections. EMG was assessed from the gluteus medius (GMED) and maximus (GMAX), rectus femoris (RF), vastus medialis (VM), tibialis anterior (TA), and peroneus longus (PL). A 9 channel motion sensor was used to define turns and ski edge angles. Results: Turn time was 35% slower and ski edge angle 15% less for WS than SL during free skiing. In the course, turn time was 31% slower and edge angle 12% less with WS compared to SL. RMS values for GMED, RF, VM, and TA were less (about 24%) in the WS trial than SL during the free skiing section. Only the GMED RMS data was less for WS than SL when skiing in the course. The GMAX and PL RMS values were greater for WS than SL in the free skiing and course (GMAX: by 131% and 116%; PL: by 23% and 27%). Average knee extension was greater for WS than SL during free skiing (136^o vs. 118^o), but similar in the course (116^o vs. 113^o). Conclusions: Skiing WS substantially changes skier movements, muscle activity, and ski actions compared to SL. The greater GMAX values during free skiing and the whisker course with WS may be indicative of greater effort to maintain pelvic stability, increase hip extension, or of greater lateral femoral rotation compared to SL. The increased lever arm of the WS may also explain the greater PL activity through eversion when edging.

INTRODUCTION

Alpine skiing is a complex activity where internal and external factors act on the skier and influence skiing performance. Internal factors include muscle activity and psychological aspects whereas external factors include turn characteristics, snow conditions and slope of the run (Seifert et al., 2009). Muscular responses are not only dictated by these factors, but by equipment as well. Wide skis, for example, were originally designed for off-piste powder skiing. However, wide skis are gaining in popularity and are now found routinely on groomed runs. In fact, wide ski sales made up over 60% of new ski sales in western United States during the 2015-16 ski season (SIA, 2016). However, there is not a standard industry definition of what width constitutes a wide ski.

It stands to reason that a wide ski could substantially change skiing technique as well as how these skis respond on the snow compared to a narrow-waist ski. A wide ski can add upwards of 20-60 mm of underfoot width compared to a narrow ski. While the potential for skiing powder may be enhanced, the extra width also adds a longer lever arm in which the skier has to produce force to overcome when skiing on a groomed run. The additional width results in increasing knee and hip torque unless there is a change in technique (Figure 1). The wider ski changes the point of ground reaction force application. Zorko et al., (2015) reported on knee kinematics comparing skis of different widths on a groomed run. They found less knee flexion and greater relative femoral rotation with wide skis compared to narrow skis.

How wide skis (WS) affect muscle activity, however, is not known. The purpose of this case study was to compare the differences in muscle activity, ski and skier actions in an elite level skier when skiing narrow (SL) and wide (WS) width skis.

METHODS

This study was approved the Institutional Review Board from Montana State University. The subject provided signed informed consent prior to participation. The subject was a 53 y old female. She is an Olympic gold medalist in Giant Slalom, National Alpine Skiing Champion, a two-time PSIA National Demonstration Team member, and an elite level ski instructor.

The testing protocol consisted of one run on narrow skis (66 mm underfoot width) and one run on wide skis (95 mm underfoot width). Two skiing segments within each run were used for data collection. The first segment consisted of 13 whisker gates set at 15 m diagonal distance with 4 m offset. Distance between gates was chosen to be halfway between the ski company's reported radii of the skis. Following completion of the whisker course, the subject conducted a free skiing segment of self-selected turns. Both skiing segments were conducted on a groomed run with an average pitch of 22^{o} pitch. The run was groomed the night before testing.

Muscle activity was assessed with a Delsys Trigno wireless electromyography system (EMG; Boston, MA). All measurements were taken from muscles of the right leg. Muscles that were assessed included: *gluteus maximus, gluteus medius, rectus femoris, vastus medialis, peroneus longus, and tibialis anterior*. EMG sensors were fixed to the skin surface according to Rainoldi et al. (2004). The root mean square analysis was used to assess the EMG data. A time window of 0.125 s with 0.0625 s overlap were used in the computation.

A Biometrics goniometer (Newport, UK) was used to assess knee kinematics. The goniometer was placed on lateral aspect of the right leg. Full extension was measured at 180^{o}. The goniometer was interfaced with the Trigno EMG system. Sampling frequency was 1950 Hz/channel for the EMG and goniometer.

A 9-channel motion sensor (Electronic Realization, Bozeman, MT) was used to define turns and ski edge angle. The start and end of each turn was defined when the right ski was flat (0^{o}) during the edge change phase. The motion sensor was attached to the right ski behind the heel binding. Sampling frequency was 100 Hz.

The first two turns of both skiing segments were not used in the analysis to allow the skier to reach a consistent velocity. Data from next five right foot turns were averaged with the average value being reported. Data are presented as mean $\pm$ SD.

RESULTS

Table 1 contains turn times, ski edge angle, and % of turn where peak edge angle occurred. Turn times were 31% and 35% slower for WS than SL in the whisker course and during free skiing. Peak ski edge angles were 12% and 15% less for WS than SL during skiing through the whisker course and free skiing, respectively. Percent of turn where peak edge angle occurred was 24% earlier in the whisker course for WS, but was similar between skis in free skiing segment.

Average knee angle was similar between skis in the whisker course (WS: 116 ±7^{o} vs. SL: 113 ±5^{o}). However, the average knee angle was 15% greater for WS (136 ±8^{o}) than SL (118 ±7^{o}) during free skiing.

While skiing through the whisker course, skiing WS resulted in greater RMS values than SL for the *gluteus maximus*, *rectus femoris*, and *vastus medialis* by 116%, 46%, and 3%, respectively. The RMS value for the *gluteus medius* was 17% greater for the SL than WS (Table 2).

For the free skiing segment, *gluteus maximus* activity was 132% greater for WS than SL (Table 2). However, *gluteus medius*, *rectus femoris*, and *vastus medialis* activities were greater for SL than WS by 35%, 23%, and 25%, respectively.

Table 3 contains EMG activity for muscles of the lower leg. Skiing through the whisker course resulted in greater RMS values for WS than SL for *peroneus longus* (26%) and *tibialis anterior* (6%). Skiing WS also elicited greater *peroneus longus* activity (23%) than SL during free skiing. However, *tibialis anterior* activity was 14% greater for SL than WS during free skiing.

DISCUSSION

The current subject was chosen as she is an elite level ski instructor and an elite level racer. It was assumed, therefore, that she could make consistent turns with limited variability based on her experience and skills regardless of ski type. The findings of this study were that skiing WS resulted in greater muscle activity, slower turn times, and less peak edge angle than when skiing SL.

It is not surprising that turns times were substantially slower with WS than SL by 31% and 35% in the whisker course and free skiing, respectively. Based on muscle activity patterns, more muscular work had to be completed to execute the turns, presumably due to the additional force needed to overcome the longer lever arm with the increased ski width.

Skiing WS also resulted in greater knee extension by 15%. This finding supports that reported by Zorko et al. (2015) of 14% greater extension with WS. Greater knee extension would imply a more upright stance. A more upright stance is used to reduce knee loading (Zatsiorsky, 2002). This increase in knee torque may be further magnified by the wider skis due to the additional moment arm from the ski edge to the edge of the binding plate. Another potential problem with greater knee extension is that now the muscle is taken out of it optimal range of force production according to the length-tension relationship. As the leg extends, there is less actin-myosin overlap to generate force to stabilize the knee.

Another interesting finding was that the *gluteus maximus* exhibited 116% and 132% more activity with WS compared to SL during standardized turns and free skiing segments. There are a number of possible explanations for this increased activity. The greater activity of the *gluteus maximus* may indicate greater effort to stabilize the femur. Zorko et al., (2015) reported that the application point of the ground reaction force moves medially across the knee as ski width increases. As force moves across the knee, the femur has to be stabilized to avoid a loss of balance or body position. Another possible explanation of greater activity is that there may have been greater hip extension since knee extension was greater. This would serve to aid in an erect posture, body position, and balance over the skis. The increased *gluteus maximus* activity may have also been related to increased relative external femoral rotation with WS compared to SL. Given that the *gluteus maximus* is a powerful external rotator, this explanation is plausible as Zorko et al., (2015) reported greater external femoral rotation with WS than with a narrow ski. Finally, the *gluteus maximus* may be activated in order to stabilize the pelvis. From observation, skiers often will tilt and rotate their pelvis in a turn to facilitate steering when skiing on WS.

The increase in activity of *gluteus medius* during free skiing indicates that there was greater femoral internal rotation force with the SL skis. This finding would support Zorko et al.'s results of greater internal rotation with narrow skis. Additionally, the RMS signals from the *rectus femoris* and *vastus medialis* were greater for SL than WS during free skiing. Although ground reaction force was not measured in the present study, this increased muscle activity could be due to greater ground reaction force generation due to higher speeds or a shorter turning radius. This is plausible as edge angle was substantially greater for SL than WS.

The greater EMG activity measured in *peroneus longus* would indicate greater effort to evert the foot for edging. In order to optimize foot eversion, the foot must be allowed to dorsiflex. Both of these actions require the contraction of *peroneus longus* and *tibialis anterior*. Interestingly, the greater *tibialis anterior* activity with the SL skis during free skiing could be due to the action of stabilizing the ankle joint during the turn. With greater edge angle and lower *peroneus longus* activity in free skiing with SL, it stands to reason that the *tibialis anterior* was used primarily as an ankle stabilizer.

In conclusion, skiing WS on a groomed run generally led to greater muscle activity and knee extension, slower turn times, and lower ski edge angle than when on SL. Future work should attempt to utilize motion sensors along with EMG to elucidate the simultaneous actions of the knee and hip and investigate the influence of ski width in less skilled skiers.

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Figure 1. Ground reaction force with different ski widths.

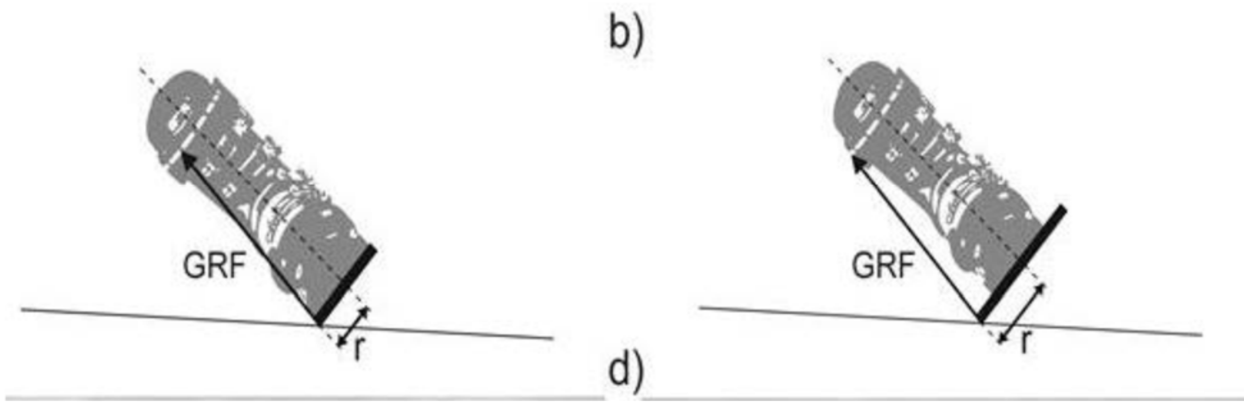

Table 1. Turn characteristics for wide and narrow skis during skiing.

	Turn Time (s)	Ski Edge Angle (°)	% Turn for Peak Edge Angle
WS course	1.68 (0.24)	46 (2)	37 (3)
SL course	1.28 (0.12)	52 (2)	49 (2)
WS free	1.72 (0.22)	54 (3)	53 (4)
SL free	1.27 (0.14)	64 (2)	51 (3)

WS: wide skis, SL: narrow skis; Course: standardized turns, Free: free skiing

Table 2. Muscle EMG activity of hip and thigh muscles (RMS: µHz).

	Gluteus Maximus	*Gluteus Medius*	*Rectus Femoris*	*Vastus Medialis*
WS course	9.5 (4.4)	20.1 (14.7)	22.1 (10.6)	38.7 (15.4)
SL course	4.4 (0.8)	24.3 (6.3)	15.2 (10.4)	37.5 (9.1)
WS free	10.9 (3.3)	23.1 (6.6)	24.6 (6.8)	34.8 (8.9)
SL free	4.7 (1.5)	35.8 (6.3)	31.9 (5.4)	46.4 (15.6)

WS: wide skis, SL: narrow skis; Course: standardized turns, Free: free skiing

Table 3. Muscle EMG activity of the lower leg (RMS: µHz).

	Peroneus Longus	*Tibialis Anterior*
WS course	24.2 (6.5)	35.7 (9.9)
SL course	19.1 (1.5)	33.8 (10.1)
WS free	24.5 (5.1)	37.5 (5.4)
SL free	20.0 (6.2)	43.7 (5.9)

WS: wide skis, SL: narrow skis; Course: standardized turns, Free: free skiing