Torsion loads on a ski-touring boot sole during uphill climbing and downhill skiing

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Introduction: Ski-touring is a well settled winter activity in mountain regions. Differently to alpine skiing, the high ground is reached by climbing the mountain using sealskins under the skis and special boots and bindings. This difference introduces higher concerns on the weight of the equipment rather than other skiing disciplines. Nevertheless, to allow a safe and enjoyable skiing the structural properties of the boot must be guaranteed. Past studies aimed to determine loads and stiffness of alpine and cross-country skiboots using in field or laboratory approaches [1,2,3]. The present study aims to provide an estimation of the torsion loads acting on the ski-touring boot sole during walking and skiing phases. Such measure is helpful towards the design of more performant ski-touring boots.

Methods: A ski-touring boot (left side, size: 26.5 MP) was prepared with strain gauge bridges and calibrated using a servohydraulic machine (Fig 1a). First, the outer rubber sole was cut to reach the plastics of the boot shell. Then, two full Wheatstone bridge were placed on the sole in middle length of the boot to measure torsion and flexion loads.

To calibrate the boot sole close to in-field testing conditions, a silicone dummy foot was fitted inside the boot. Then, the skiboot was mounted on ski-touring bindings surrogates attached to a servohydraulic torsion machine. The torsion channel was calibrated by applying a quasi-static ramp between -5/+5°, reading the applied torque and bridge output synchronously to obtain the bridge sensitivity.

The in-field test took place in Val di Zoldo (BL, Italy), outside temperature was 10 °C, on a slope covered by spring snow. The instrumented boot was connected to a SoMat eDAQ lite data acquisition system (HBM) powered with a 12 V battery, instrumentation was fitted in a small backpack (total weight: 3 kg). Data were acquired at a 500 Hz sampling rate.

Tests were performed by an amateur skier (height: 175 cm, weight: 70 kg, age: 25 yr) who climbed and skied an off-piste route graded BS in Blachère scale. The participant performed a 400 m gain uphill climbing which was divided into straight climb, and left/right side traverses. During the descent the participant was asked to perform narrow and wide slaloms at its own typical speed. Overall length of the test was 45 minutes.

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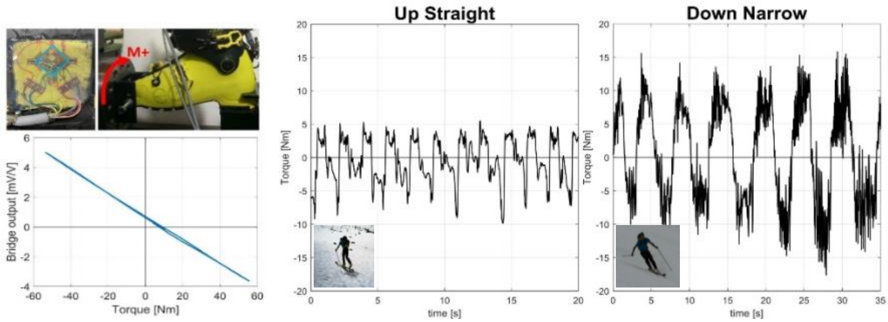
Peak and valleys of data were computed and averaged for each phase to obtain the range of the load. The mean of the signal during each phase was also computed. Internal rotating torques applied to the boot front are positive.



(a) (b)

Fig. 1: (a) boot preparation and torsional calibration, (b) in-field tests. Internal rotations correspond to positive torque.

Results and discussion: Calibration trials gave a bridge sensitivity of -12.59 Nm/(mV/V) with an applied torque ranging from -50 to +50 Nm. In field test data (Fig 1b, Table 1) evidenced highest torque ranges during skiing phase; torque mean values showed opposite sign in the two sides of uphill climbing. In both phases the range was well below the torque reached during the calibration trials.
This suggests that ski-touring boot torsion loads should be based on maximal values collected during skiing trials. The analysis and implementation of further measurement channels such as the sole flexion and the ski/walk links will be performed to improve the understanding of climbing and skiing loads. More tests are being conducted to account for subject variability and snow/terrain conditions.

Table 1: Torque Loads [Nm] recorded during each phase.

	Up Straight	Up Right	Up Left	Down Wide	Down Narrow
Peak	4.72	7.09	3.98	14.72	9.02
Valley	-7.59	-4.96	-7.96	-13.66	-16.56
Range	12.31	12.05	11.94	28.38	25.58
Mean	-0.40	1.86	-0.96	0.525	-1.31

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