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Historical Trends in Alpine Ski Design: How Skis Have Evolved Over the Past Century †

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Abstract: Alpine skis have changed dramatically in the last century. Long and straight wood skis have evolved into shorter lengths and now contain a plethora of modern materials. Shaped skis have become the norm. Today's skis also offer a variety of waist widths and shapes to cater to specific uses. By studying how skis have evolved, it is possible to gain insight into how the design of alpine skis has progressed. To do so, the mechanical properties of 1016 skis, from the 1920s to 2019, were measured with a machine developed at the University of Sherbrooke. The resulting data are used to calculate various geometric, stiffness and performance parameters. The evolution of these parameters over the years is analyzed. This analysis provides a better understanding of the evolution of ski design and shows when the introduction of new materials and shaping concepts has changed the way skis are designed.

Keywords: alpine skis; camber; mechanical properties; stiffness; sidecut; rocker; shaped skis

1. Introduction

Alpine skis have changed dramatically in the last century, both in their shapes and in the methods and materials used in their construction. From the straight, cambered skis of a century ago that were turned mainly by skidding, modern shaped skis have evolved into a wide variety of application-specific skis, designed to float in powder or carve a high-angle turn on hard snow. Historically constructed from wood, today's skis are made of glass and carbon fibers, epoxy resin, metal, polyethylene bases, rubber, polymer foams and a host of other materials [1]. By examining how the mechanical properties of skis have changed over time, it is possible to gain insight into ski design trends.

To do so, the mechanical properties (shapes and stiffnesses) of 1016 skis were measured using a machine developed at the University of Sherbrooke and analyzed in their historical context.

Section 2 presents the data collection and analysis process. In Section 3, the resulting data is presented and analyzed. This analysis clearly shows when paradigm shifts in design, such as new materials and changes in shaping philosophy, have occurred over the past century.

2. Materials and Methods

The mechanical properties of the skis included in this study were measured using a measurement machine developed at the University of Sherbrooke [2] and now commercialized by Sooth Ski (https://soothski.com/). This machine is capable of simultaneously measuring the sidecut profile and the base height profile, as well the bending (EI) and torsional (GJ) stiffness distributions along the length of the ski. Using this machine, measurements were conducted on 1016 skis from inventory at various retailers in Quebec (*Ski Michel*, *Oberson*, *Ski Town Brossard*, *Ski-Vélo Vincent*

Renaud and *Atmosphère Sherbrooke*), as well as from the Vermont Ski and Snowboard Museum collection, the Blister Gear Review test fleet and Greg Rich's personal collection. Only adult skis were used in this study; skis intended for youth were not included in the measurement set.

Using custom MATLAB code, geometric and stiffness parameters were automatically extracted from the measurement profiles obtained with the machine. Waist width was taken as the minimum width of the ski, excluding the tips and tails. The average sidecut radius was calculated using a least-squares fit on the half-width profile of the ski, also excluding the tip and tail (the radius calculation laid out in FIS regulations and ISO6829 was not used, since it requires actual ski length, which was not recorded). Maximum camber was defined as the maximum base height between the front and rear contact points, while tip and tail length were defined as the length between the front and rear contact points and the end of the ski, respectively. In the case of fully reverse-cambered skis, maximum camber is defined as the maximum distance between the base profile and a line drawn between the widest tip and tail points, while tip and tail length are undefined. Effective edge length, which is used to estimate directional stability, was approximated as the distance between the widest points of the tip and tail. Ski lengths and model years were recorded from the manufacturer's published data. In certain cases where published data were unavailable, length was directly measured with a tape measure (±1cm) and model years were established to the best of our ability with a web search. The mechanical properties were then used to evaluate directional stability based on the second moment of the pressure distribution along the length of the ski [3], using the estimation equation proposed by Truong and Lussier Desbiens [4].

3. Results and Discussion

3.1. Model Year Distribution

The model year of the skis measured varied from approximately the 1920s to 2019. Figure 1 shows the measurement set's model year distribution. The relatively small number of pre-2010 skis is explained by the difficulty in finding and obtaining older, but still functional, skis.

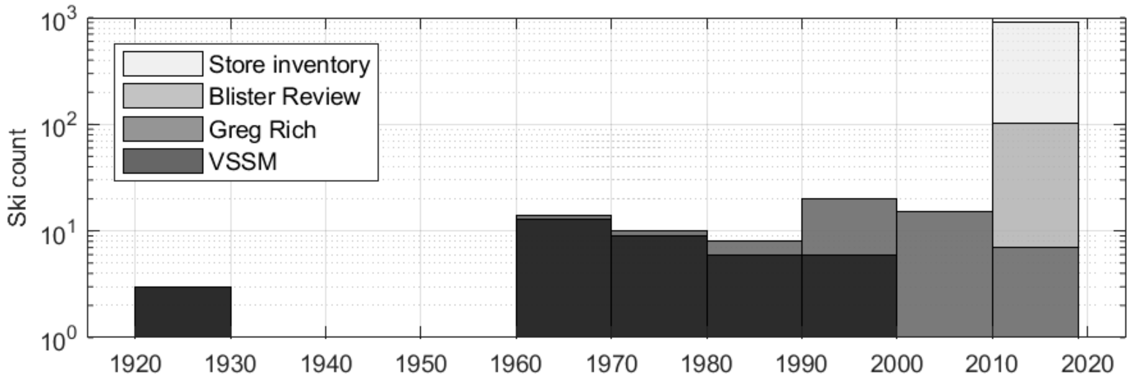

Figure 1. Model year distribution of measured skis, classified by source.

3.2. The Evolution of Ski Shapes

3.2.1. Shaped Skis

Figure 2 shows the evolution of ski length throughout the last century. In this figure, we can see a general shortening and a diversification in the overall length of skis starting in the 1990s, transitioning from over-200-cm to sub-200-cm length skis. Figure 3 shows the sidecut radius as a function of model year. The Elan SCX (1994), one of the first commercial shaped skis [5], clearly marks the start of a transition to deeper sidecut skis. Whereas older skis have a sidecut radius generally over 30 m, and sometimes up to 100 m, subsequent skis rarely present a sidecut radius over 40 m, and more generally in the 10–20 m range. One explanation for the almost simultaneous appearance of smaller sidecut radii and shorter lengths is that the wider tips and tails created by a deep sidecut generate an unacceptably large swing weight in longer lengths, hence the need for shorter skis [5].

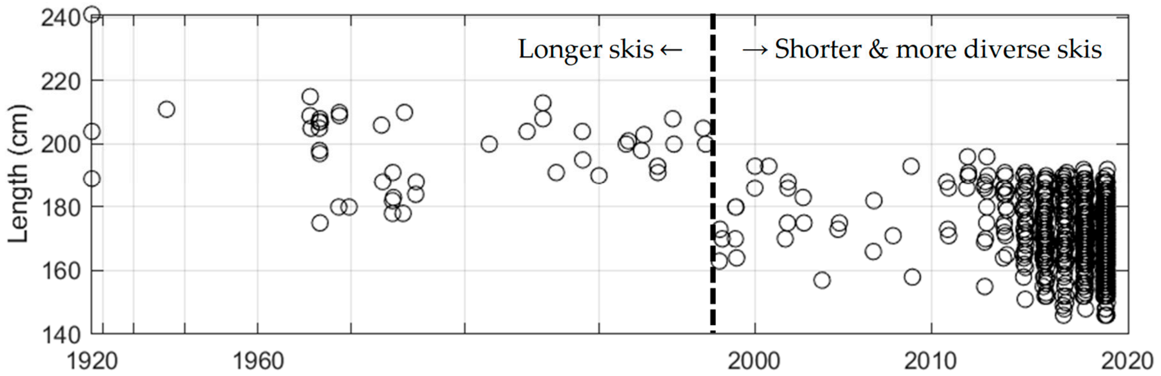

Figure 2. Ski length vs. model year.

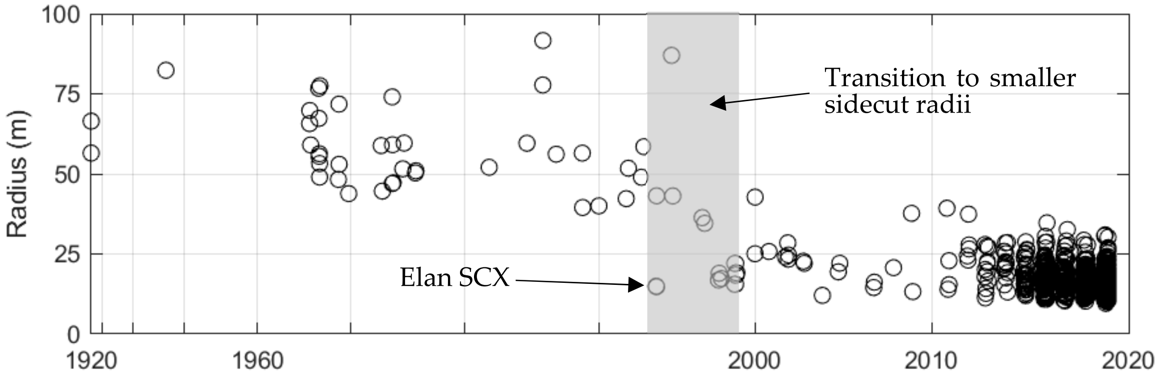

Figure 3. Sidecut radius vs. model year.

3.2.2. Diversification—The Appearance of Fat Skis, Rocker and Early Rise

Figures 4–6 show, respectively, how camber, waist width and tip and tail lengths have evolved. These three figures show that little change has occurred between the 1920s and the 2000s. Starting in the early 2010s, it is possible to see the generalized appearance of three characteristics intended to make powder skiing easier: wider waists (and therefore more surface area), reverse-cambered skis (also known as full rocker), and early rise tips and tails (sometimes called semi-rocker or just rocker).

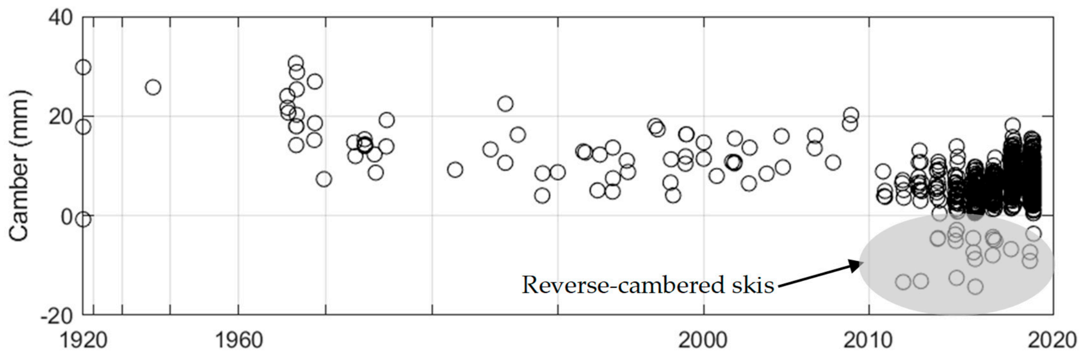

Figure 4. Maximum camber vs. model year. Negative camber represents fully-rockered (or reverse-cambered) skis.

Pretty much all skis measured up until 2010 show a traditionally cambered shape, a waist width of 60–80 mm, flat tails (little to no tail length), and an upturned tip measuring, at most, 200 mm in length. After about 2010, however, Figures 4–6 show an explosion in the variety of ski shapes, with waist widths ranging from 60 to 140 mm, fully reverse-cambered skis in some cases (negative camber values in Figure 4), and very large early rise tips and tails in other cases, with tip lengths up to 700 mm. It is interesting to note, however, that one early ski, dating from the 1920s, already presented a fully reverse-cambered and reverse-sidecut shape (camber and tip and tail length are undefined for this shape and thus this ski does not appear in Figures 4–6). It is also worth noting that at least two skis, known to the authors but which could not be obtained for measurements, predate the suggested year, 2010, for the start of the mass appearance of powder skis: the Atomic Powder Magic (1988) and the Volant Spatula (2001) [6].

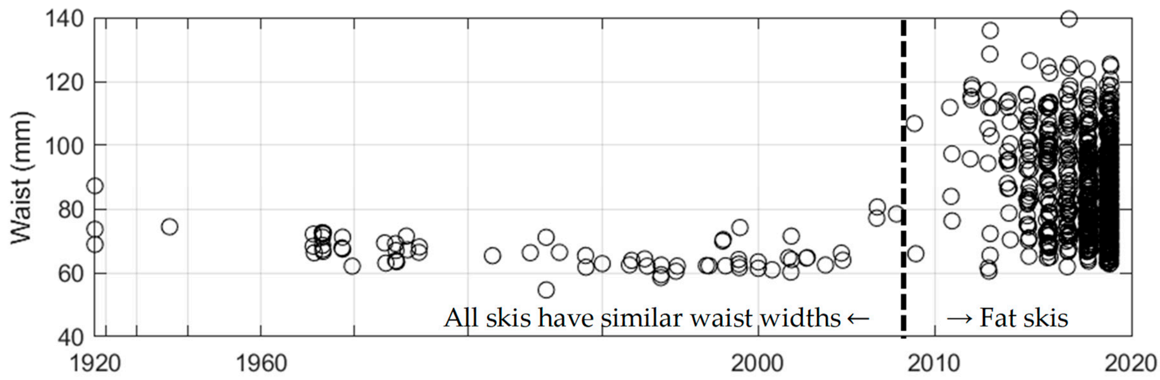

Figure 5. Waist width vs. model year.

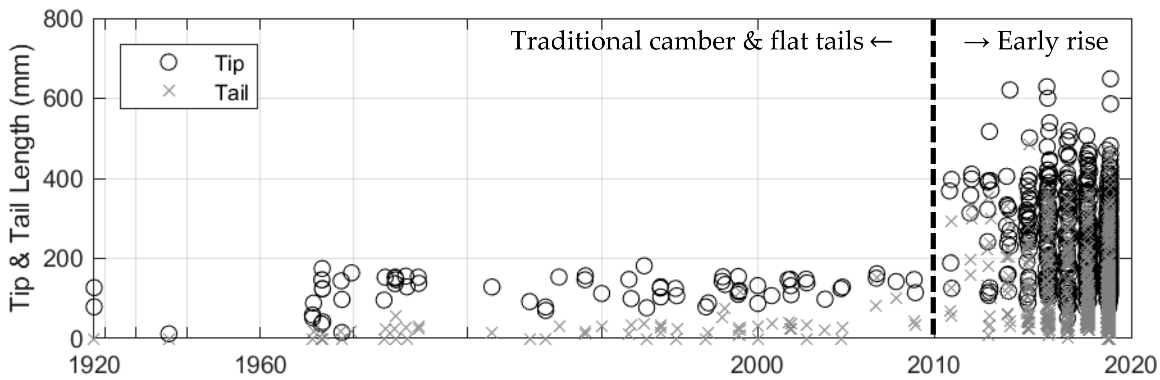

Figure 6. Tip and tail lengths vs. model year.

3.3. Bending and Torsional Stiffnesses

Figure 7 shows the change in bending and torsional stiffnesses (average measures over the whole ski length) over the years. Two areas of interest are very old, wood skis (1920s–1940s), who exhibit very high bending stiffnesses but low torsional stiffnesses, and the first metal skis, by Head, in the 1950s (the skis obtained for measurement were from the 1960s), who were very stiff in both bending and torsion. The increased torsional stiffness due to the metal construction reportedly made them extremely easy to turn [7]. It is also interesting to note that, on average, bending stiffness has decreased between earlier, long, straight skis and more modern, shorter, shaped skis. Meanwhile, torsional stiffness has stayed relatively constant (except for the Head metal skis).

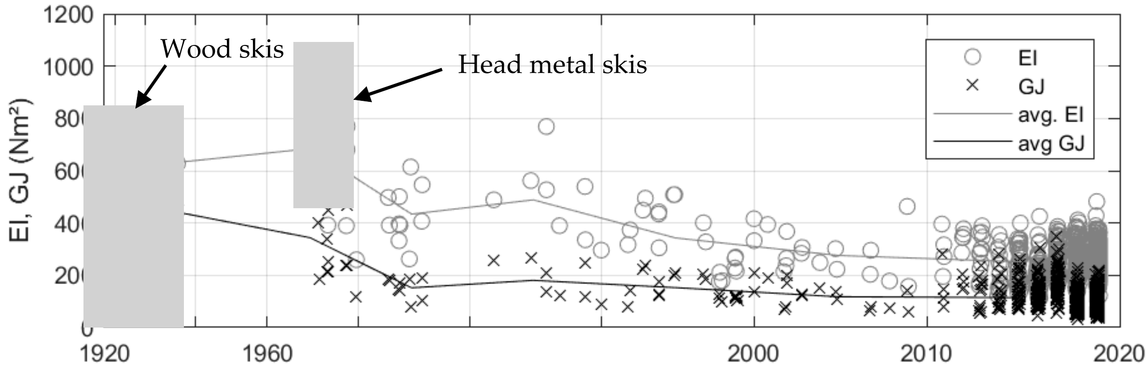

Figure 7. Length-averaged bending and torsional stiffnesses vs. model year. The solid lines, 'avg. EI' and 'avg. GJ' are the mean values averaged over each whole decade.

3.4. Mass

Figure 8 shows ski mass vs. model year. It is interesting to note that, except for recent specialty skis (race skis with binding plates, touring and ultralight skis), mass hasn't significantly changed in the last century, even though shapes and construction methods have evolved. One possible explanation for such little change in the mass of skis is the previously mentioned problem of high swing weight and low maneuverability for heavier skis. On the opposite end of the spectrum, it is widely agreed that too-light skis suffer from detrimental vibrations at higher speeds on harder snow [8].

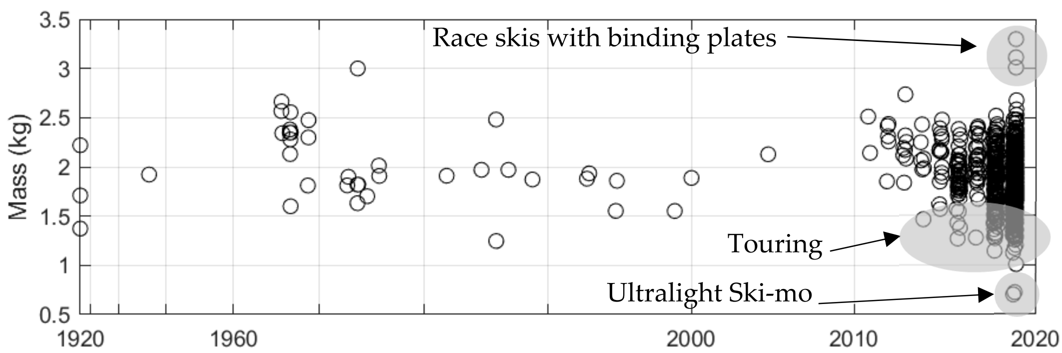

Figure 8. Ski mass vs. model year.

3.5. Directional Stability

The pressure distribution along a ski's edge is a significant factor in ski performance [9-11]. As such, directional stability on hard-snow surfaces, based on the second moment of linear pressure distribution [3], was estimated [4] from the mechanical properties (L_{SC} , the effective edge length; R_{SC} , the sidecut radius; $camber_{Max.}$, the maximum camber; and $\overline{EI}$, the average bending stiffness):

$$Stability \approx F_0 L_{SC}^2 = \frac{48\overline{EI}}{L_{SC}}\left(camber_{Max.} + R_{SC}\tan(\varphi)\left[1-\sqrt{1-\left(\frac{L_{SC}}{2R_{SC}}\right)^2}\right]\right) \tag{1}$$

Figure 9 shows this estimated stability vs. model year for a lateral lean angle (φ) of 45° (the results remain similar for other edge angles). Except for the first Head metal skis, directional stability has not significantly changed over the years. This can be explained by the fact that as ski sidecuts have grown deeper to facilitate carving turns, lengths, stiffnesses and cambers have gotten smaller; these changes tend to cancel each other out. This may suggest a certain desirable level of stability over which skis become too hard to maneuver, and under which skis are too squirrelly. One notable observation from Figure 9 is the presence of a large number of skis with very low stability (<50 Nm²) from 2010 onwards. These are heavily or fully rockered skis are intended for powder skiing, not for hard snow carving. This does not mean that these skis perform poorly for their intended use, rather that they are not designed for the conditions for which the directional stability metric is calculated.

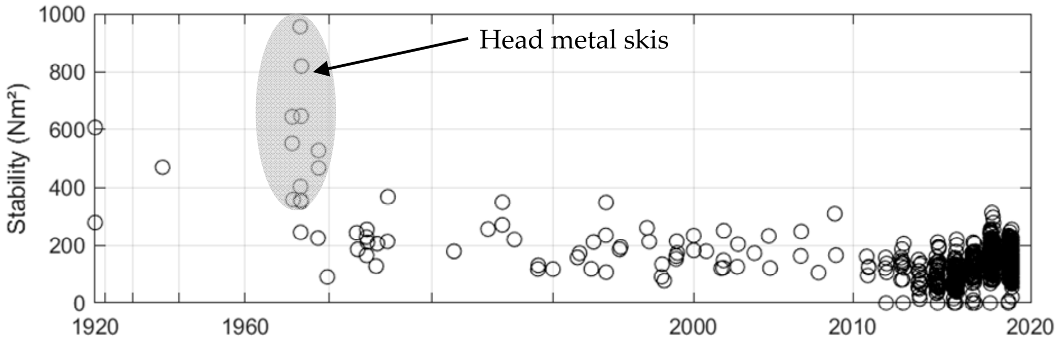

Figure 9. Directional stability estimated at a lateral lean angle of 45°.

4. Conclusions

Alpine skis have evolved considerably in the last century. The analysis of how ski shapes and stiffnesses have evolved clearly shows when paradigm shifts in ski design occurred. Between the 1920s and the 1990s, ski shape changed little; the typical ski was a long, narrow, straight ski. However, ski construction evolved from wood to include, in the 1950s, metal skis which were much stiffer in torsion. Eventually, composite materials were also added to skis. In the 1990s, advances in ski shaping led to the rise of shorter, shaped, deep sidecut skis. In the 2000s and 2010s, the appearance of rocker, reverse camber and wider widths led to a large diversification of ski shapes. The study of the evolution of bending and torsional stiffnesses shows that skis have tended to be softer in bending as they grew shorter, with a more pronounced sidecut. This might be explained by examining the directional stability resulting from the interaction of these parameters, which has remained relatively constant. This might suggest that this level of stability is desirable and that deviating significantly from this may yield too little stability or too little maneuverability. Interestingly, torsional stiffness has remained relatively unchanged. The mass of skis has also changed very little during the past century, which might suggest that heavier or lighter skis would suffer from performance issues. Further research is warranted to better understand the reasons behind the negligible variation in mass and stability, even while shapes, stiffnesses and materials have evolved so much.

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References

1. Howe, J. *Skiing Mechanics*, 1st ed.; Poudre Press: Laporte, CO, USA, 1963.
2. Truong, J.; Brousseau, C.; Desbiens, A.L. A Method for Measuring the Bending and Torsional Stiffness Distributions of Alpine Skis. *Procedia Eng.* **2016**, *147*, 394–400.
3. De Cecco, M.; Angrilli, F. Testing ski stability. *Meas. Sci. Technol.* **1999**, *10*, N38.
4. Truong, J.; Desbiens, A.L. Evaluating the Directional Stability of Alpine Skis through the Simulation of Ski Deformation during a Steady-State Turn. *Multidiscip. Digit. Publ. Inst. Proc.* **2018**, *2*, 315.
5. Masia, S. *Evolution of Ski Shape|International Skiing History Association*. Available online: https://skiinghistory.org/history/evolution-ski-shape (accessed on 8 October 2019).

6. REI. *An Abbreviated History of Modern Ski Technology|REI Co-op Journal*. Available online: https://www.rei.com/blog/snowsports/an-abbreviated-history-of-modern-ski-technology (accessed on 8 October 2019).
7. Leuthner, S. *A Bad Skier's Revenge|Airport Journals*. Available online: http://airportjournals.com/a-bad-skiers-revenge/ (accessed on 8 October 2019).
8. Foss, G.C.; Glenne, B. Reducing on-snow vibrations of skis and snowboards. *Sound Vib.* **2007**, *41*, 22–27.
9. De Gobbi M.; Petrone N. Structural behaviour of slalom skis in bending and torsion. In Proceedings of the 7th International Conference on the Engineering of Sport, Biarritz, France, 2–6 June 2008.
10. Petrone, N. The use of an Edge Load Profile static bench for the qualification of alpine skis. *Procedia Eng.* **2012**, *34*, 385–390.
11. Scott N.; Yoneyama T.; Kagawa H.; Osada K. Measurement of Ski snow-pressure profile. *Sports Eng.* **2007**, *10*, 145–156.