INTERNATIONAL SOCIETY FOR SKIING SAFETY

Possible interventions of the ski and ski boot to reduce knee injuries in recreational alpine skiing

Frank I. Michel[1], Stefan Lehner[2], Veit Senner[2]

[1]bfu – Swiss Council for Accident Prevention, Sports Research, Berne, Switzerland
[2]Department of Sport Equipment and Materials, Technische Universität München, Munich, Germany

Introduction and Aim

Although the total incidence of alpine skiing injuries has shown a steady downward trend since the late 1970s it is noticeable that knee injuries did not follow this positive trend. Among the level III injuries, only severe knee sprains declined since the 1990, which is generally attributed to the shortening of the ski length that accompanied the introduction of the shaped skis.

Anterior collateral ligament sprains represent the highest injury rate among skiers. The proportion of knee injuries remains very high compared to the total incidence of injuries and continues to be the central topic for prevention in alpine skiing. Hence, the goal of the literature review was to elaborate and discuss how modifications of the ski and boot might alleviate the risk of knee injuries.

Method – Literature Source

The present poster is based on a comprehensive research report on behalf of the bfu – Swiss Council for Accident Prevention which also covers ski bindings [1, 2].
The comprehensive analyse of the current situation regarding knee injuries in relation to ski equipment was carried out in which, alongside scientific papers and "grey literature", consideration was also given to patents and international standards as well. The PubMed literature search using the MeSH terms ''Skiing AND knee AND injury AND (binding OR boot OR ski)'' was performed to obtain relevant articles published in this field (n=142). Moreover, in search for additional information, all reference lists of the papers retrieved were checked manually

Results

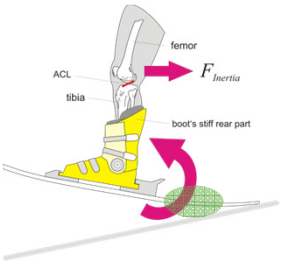
There are few sports where there is such close and complex interaction between the design of the equipment, ambient conditions and the execution of the sports movement as in alpine skiing. Today's variety of ski categories and models, which makes it difficult even for experts to gain an overview, (not least influenced by clever marketing) is a consequence of this fact. From the safety aspect, this product variety should therefore tend to be evaluated more critically because it has become more difficult for skiers to find the ski and boot material that suits their personal skiing technique, their skiing style and their preferred terrain. The most important physical properties of the individual components of ski, boot and binding can be described by a number of key characteristics.

The ski properties include its (partial) bending and torsional stiffness, its contact length and its impact-absorbing properties. The functionally most important ski boot properties are the basic forward lean angle and the stiffness of its upper. The most critical issue, however, is the suitability of the product for the individual. Skiers, who prefer higher speeds and larger radii, will feel more comfortable and safer with a system that absorbs impacts to a greater degree. Those who like shorter and faster turns will experience the more agile and lively handling of a ski that absorbs impact to a lesser degree as being pleasant and safe.
The technical possibilities for optimising the ski and the ski boot to reduce knee injuries in alpine skiing are listed in tables below (**Tab. 1 and 2**).

Ski and binding interface (Tab. 1: Possible interventions for the ski and binding interface to reduce knee-joint injuries in recreational alpine skiing)

Design parameter(s)	Possible intervention	Influence on knee joint injuries	Comments (e.g. opposite effects)
Sidecut radius (geometry)	Reduction in sidecut radius (less aggressive)	Only proven for certain target groups	– Less edge grip – Less directional quality – Less control on hard or icy piste – More effort may be needed to initiate a turn
Length of skis	Shorten the skis	Yes	– Influence on stability at higher speeds (intervention only valid for specific target groups; dependent on ability level)
Flexural rigidity in the rear part of skis	Predetermined breaking point behind the binding **(Fig. 1)**	Yes	– Currently no technical implementation so far (but the possibility exists)
Height of the ski in the area of the binding	Lower height	Yes, less effect due to the increase in lever arm for lateral forces	– Boot-out (sudden loss of edge grip due to contact with the ski boot at extreme edge angles)
State of preparation of base and edges	Regular inspection and maintenance	Yes, indirectly due to the increase in skiing safety	– Cost (ongoing costs)
Ski edge profile	– Product adjusted to the skills, individual style and (physical) capabilities as well as current slope and snow conditions – Precondition: better sales advice (ideally with a practical test with instructions) as well as ski comparison tests carried out according to scientific criteria	Yes, indirectly due to the increase in skiing safety	– Effort, perhaps further ski models necessary (ski rental)

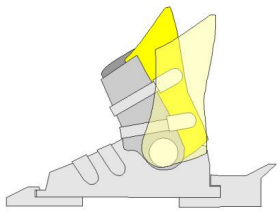
Fig. 1: Schematic drawing of a possible injury mechanism (BIAD – Boot Induced anterior drawer) and an intervention possibility – a predetermined breaking point behind the binding (potential location coloured in green) – to reduce the risk of an ACL-rupture. The idea is to eliminate the lever effect during landing after a jump.



Ski boot (Tab. 2: Possible interventions for the ski boot to reduce knee-joint injuries in recreational alpine skiing)

Design parameter(s)	Possible intervention	Influence on knee joint injuries	Comments (e.g. opposite effects)
Height of upper	Reduce	No	– The reduction in the height of the upper should go far enough to allow plantar flexion in the ankle – Ankle injury protection is thus forfeited – Reduction in skiing quality/performance
Inner shoe	Optimisation of fitting and comfort properties	Unclarified	– Positive influence on sensorimotor system
Canting (position/ alignment of the boot/upper in the frontal plane)	Better adjustment to individual leg axis position that in turn influences (optimising) knee-joint kinematics	Yes, indirectly due to improvement in ski safety and reduction in constraining forces	– Standard equipment on high-price ski boot models – Correct setting (requires experience/skill, possibly tools for setting) – Increase in adjustment possibility (angle amplitude) – Cost
Position of the boot in the transversal plane	Exorotated foot position (with respect to the longitudinal axis of the foot)	Unclarified	– Only limited movement amplitude possible so far (<10°) – No physiological neutral-0 position defined so far – Constraining forces may occur at larger angle settings
Flexible construction in the sagittal plane	Re-launch of «soft boots» (increase in dorsal flexion in the ankle)	Conceivable, direct influence, by better trained regulation of movement	– Corresponding products have already been on the market – but with low functionality (poor skiing characteristics) – Only meaningful if the ankle protection function is retained (finding the best compromise between ankle protection and flexibility of the boot upper)
	Flexible rear spoiler (in the posterior direction) **(Fig. 2)**	Yes	– Corresponding product (Lange company) has already been on the market (re-launch)

Fig. 2: Schematic drawing of a flexible rear spoiler: This approach is characterized by a targeted yield towards the posterior due to a degree of freedom in the upper of the ski boot. The potential benefits of such a flexible boot to reduce shear forces in the knee have been described by various authors. However, at present there does not appear to be any empirical evidence that the flexible spoiler actually has any benefit.



Conclusion

In terms of the possible realization of interventions an interaction between trade and industry, academic fields (engineering, biomechanics, material sciences, medicine, sports science) and public institutions (e. g. public health sector, standard committees) as well as media and sports organisations at national and international levels is necessary.

Additionally, more research is needed for the future development and implementation of intervention strategies to prevent knee injuries in alpine skiing including the analysis and detailed description of relevant injury mechanisms. The next step will be an evaluation of the suggested intervention possibilities by an international expert panel.

References

[1]Senner, V., Michel, F.I., Lehner, S., Brügger, O. (2013). Technical possibilities for optimising the ski-binding-boot functional unit to reduce knee injuries in alpine skiing. *Sports Engineering, 16* (4), 211-228.
[2]Senner, V., Lehner, S., Nusser, M., Michel, F.I. (2014). *Skiausrüstung und Knieverletzungen beim alpinen Skifahren im Freizeitsport – Eine Expertise zum gegenwärtigen Stand der Technik und deren Entwicklungspotenzial.* Bern: Beratungsstelle für Unfallverhütung, bfu-Report 69.

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