University of Ljubljana
Faculty of Sport

JOINT WORLD CONFERENCE

25th International Congress on Snowsports Trauma and Safety
50th Year Anniversary

38th Congress of the International Society for Snowsports Medicine
70th Year Anniversary

BOOK OF ABSTRACTS

MARCH 10-16, 2024
KRANJSKA GORA, SLOVENIA

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SUNDAY (10. 3. 2024)

15:00 Registration

17:30 Welcome coffee

18:00 Plenary session (45 min): Veit Senner (Session chair: Matej Supej)

19:00 Opening ceremony

THE SKI BINDING BETWEEN ANACHRONISM AND ARTIFICIAL INTELLIGENCE

NEVER CHANGE A RUNNING SYSTEM?

Prof. dr. Veit Senner

Technical University of Munich, Germany

There are some similarities between automobile drive engineering and ski bindings. Only one decade ago, no one would have believed that the traditional combustion engine might ever be replaced by an electrical drive train. Meanwhile we have gone through a paradigm change, several of us happily driving battery cars. The concepts of today's ski bindings have already been lasting for decades. And they are fulfilling the task they have been designed for, quite well. Which task? Prevent from overloads to the lower leg bones – epidemiology from many countries agree on rather low incident rates of tibia fractures. But if we look at unchanged high knee injury rates worldwide – around 30% of all injuries concern the knee - we have to state a severe lack with respect to injury prevention. This rises the question: Do we have to cope with this fact or is there a need for a concept change in binding technology – just like it is ongoing in the automobile sector?

This plenary talk will try to wrap-up the current research efforts in this field and to provide the understanding of the challenging boundary conditions given by the existing international standards, law court decisions and the difficult economic situation the manufacturers have to deal with. It will also dare to take a look into the future of ski binding development, which – like in almost all technology fields - will have to be open to digitization and the use of artificial intelligence.

Are the current ski bindings becoming a thing of the past? Not yet, but the engineers are working on it…

MONDAY (11. 3. 2024)

10:15 PERSONAL AND SKI RESORT PROTECTIVE EQUIPMENT (Session chair: Pierre-Jean Arnoux):

- I. Scher, L. Stepan, D. McFarland, N. Yang: CHAIRLIFT RESTRAINT BAR EFFECTIVENESS: MODELING RIDER KINEMATICS
- A. Kestly, L. Stepan, I. Scher, M. Petrozzi: OPERATIONAL CONSIDERATIONS OF SKI AREA PADDING AND MARKING AT US SKI AREAS
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12:00 Lunch

13:30 BIOMECHANICS 1 (Session chair: Veit Senner):

- J. G. Seifert, H. Mueller, D. Graham, R. W. Kipp, M. Decker: EMG AND KINEMATIC RESPONSES TO SKI WIDTH IN A FEMALE SKIER: A SINGLE SUBJECT DESIGN
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SNOW RACE SAFETY AND PERFORMANCE (Session chair: Veit Senner):

- G. C. Cuniberti, L. Bortolan, B. Todesco, T. Forrer: REPEATED PRACTICE RUNS DO NOT INDUCE FATIGUE IN RECREATIONAL SKIERS IF THEY ALLOW FOR SUFFICIENT RECOVERY TIME
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15:00 Coffee break

15:30 FIS INJURY PREVENTION MISSION (Session chair: Matthias Gilgien):

- **Keynote (45 min): J. Spörri, M. Gilgien: INJURY PREVENTION IN ALPINE SKI RACING: WHERE DO WE COME FROM AND HOW COULD WE GO ON?**
- M. Lasshofer, G. Mitterbauer: IMPLEMENTATION APPROACHES OF PREVENTATIVE STRATEGIES IN FIS SPORTS: PERSPECTIVES OF THE FIS ATHLETE HEALTH UNIT

16:30/17:00 FIS Round table

Chairlift Restraint Bar Effectiveness: Modeling Rider Kinematics

Irving Scher, PhD, PE[1,2]*, Lenka Stepan, PhD[1], Daniel McFarland, PhD[1] & Nicholas Yang, PhD[1]

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[2] *Mechanical Engineering Department, University of Washington, Seattle, WA, USA*

Keywords: Chairlift, ski lift, restraint bar, safety bar, human body modelling

INTRODUCTION. Chairlifts are aerial lifts at ski areas that transport riders up the mountain on cable-supported carriers often high above the ground. Though many chairlifts in the United States (US) are equipped with restraint bars and ANSI B77.1-2022 [1] requires that all new or relocated chairlifts in the US have restraint bars, there are many chairlifts that do not have restraint bars. Also, restraint bar use is not mandated and many riders do not use them, even when they are available [2]. To our knowledge, there are no epidemiologic studies focused on the effectiveness of restraint bars to keep riders from becoming unseated and to lower injury incidence and severity. The absence of data has sparked debate in the United States (US) about whether restraint bars would help prevent riders from becoming unseated or injured. To assess the effectiveness of restraint bars in preventing falls and injuries in specific accidents, a procedure was developed to create a computer model to examine fall-and-injury producing scenarios. The procedure was tested by modeling a high-profile fatality accident (that occurred in Colorado in 2016) in which a swinging carrier contacted a lift tower and three riders fell 10 meters to the snow.

METHODS. Using a high-resolution laser scanner, a detachable quad (4-person) chairlift was digitally measured, including the towers, haul rope, and chairs. Using the scanned data and the material properties of each component, finite element models of a lift tower and carrier were created. Three riders (two skiers and one snowboarder) and their equipment were modelled using height and weight scaled, facet human body models (HBMs) in MADYMO; see Figure 1. Initial conditions for the model included ranges for haul rope speed, carrier angular velocity, rider positions, and restraint bar use. Forward integration of the equations of motion was performed for each model scenario. For simulations in which the HBMs became unseated, the final resting locations were compared to those reported in the accident investigation. The head kinematics, head injury criterion, chest compression, and viscous criterion for all tests were compared to the injury assessment reference values (IARVs) [3] to assess injury risk.

RESULTS. For the 2016 accident, 48 simulations were performed, 30 with the restraint bar raised (not used) and 18 with the restraint bar lowered (used). When the restraint bar was raised (not used), the model predicted that the HBMs would become unseated and come to rest near the locations measured by the ski patrol. In all scenarios with the restraint bar lowered (used), the HBMs did not become unseated during the accident sequence and the head and chest injury criterion were all below IARVs.

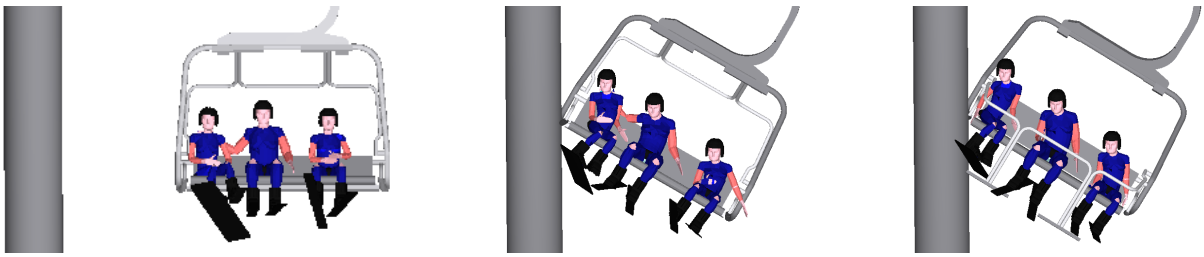

Figure 1. Initial configuration of HMBs on the chairlift model (*left*). The carrier swung sideways and contacted a lift tower, caused relative motion between the HBMs and carrier, either with the restraint bar raised (*center*) or lowered (*right*).

CONCLUSIONS. The modelling method can be used to assess chairlift fall accident scenarios and restraint bar effectiveness, for both research purposes and the analysis of specific accidents. In the 2016 accident, had the riders used the restraint bar, it is unlikely that they would have become unseated or sustained severe injuries. While many chairlifts are equipped with restraint bars in the US, they can only be effective in preventing riders from becoming unseated if they are used (that is, lowered by riders).

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Operational Considerations of Ski Area Padding and Marking at US Ski Areas

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Keywords: Ski area padding, ski area operations, collision avoidance, skier responsibility

INTRODUCTION. In the United States (US), ski area padding is often used to mark man-made objects. There has been an international effort to study Collisions With Fixed Objects (CWFO) and the ability of ski area padding to mitigate injuries. In the US and France, ASTM and AFNOR have been examining proposals for standards related to ski area topics, such as padding properties, maintenance, and installation [1]. The significant differences in the management practices and the use of padding between regions (such as the US and France) make a uniform international standard difficult, and maybe unlikely. Though engineering studies have shown that no padding can prevent all injuries and fatalities for all impact configurations or skier speeds [2], the goal of these standards would be to improve safety for recreational snow sports participants. Factors beyond the injury mitigation capabilities of padding need to be considered to reduce the risk of a CWFO and associated injuries [1], with a primary factor being padding's value as a warning device. Other factors include the responsibility to ski and ride under control, industry safety educational efforts, and the operational effort and cost of padding and marking thousands of man-made objects. This study aims to identify: (1) *operational hurdles* to newly proposed padding standards and (2) the widespread use of *safety educational programs* aimed at snowsports participants at US ski areas.

METHODS. In the first part of the study, risk and ski patrol managers at the US ski resorts were interviewed to identify guidelines used to mark and pad man-made objects at their ski areas, the number and types of padded objects, personnel responsible for padding, and challenges to achieving proposed installation and maintenance procedures related to ski area padding. For the second portion of the study, educational campaigns to enhance skier awareness and safety were evaluated for their content regarding skier collisions and their implementation throughout the US.

RESULTS. Based on interviews with risk and ski patrol managers at US ski areas, ski areas rely on individual ski area knowledge and expertise, prevailing generally accepted industry practices, and state statutes (when they exist) to guide marking and padding man-made objects. The surveys revealed that the most significant operational hurdles to a uniform padding standard are: (1) regional/geographic differences; (2) the number of pads; (3) personnel requirements; and, (4) financial resources. All respondents were aware of industry wide educational campaigns, specifically NSAA's Your Responsibility Code and Ride Another Day, and supported their use at their individual ski areas.

DISCUSSION. Regional and individual ski area padding differences exist because of weather patterns, infrastructure, skier/rider demographics and skiable terrain. Some general commonalities include padding or marking on-piste man-made objects; for example, padding lift towers and marking snowmaking equipment with bamboo or padding. Because many areas may have hundreds or thousands of padded objects, ensuring that all pads are free from damage (created by weather related wear and tear, grooming machines, or other means) is not currently feasible during the ski season. Keeping padding at the snow surface also poses significant operational challenges. For example, at many ski areas in the mountain and western US, a meter or more of snowfall during a storm cycle is common and may bury many hundreds of pads. Because ski patrollers (often responsible for padding maintenance) are also tasked with other safety activities, such as avalanche mitigation prior to opening the ski area for patrons and emergency medical response, it is not possible to dig out or adjust all of the padding.

Over the last 40 years, the US ski industry has developed and delivered multiple skier/rider safety education campaigns and initiatives to raise patron awareness of the inherent risks of skiing including collision with fixed objects. Tools such as an updated NSAA's Your Responsibility Code and Ride Another Day and most importantly individual resort efforts help educate children and adults how to safety navigate ski areas.

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COLLISONS WITH OBSTACLES ON SKI SLOPES: EXPERIMENTAL EVALUATION OF COMPLEMENTARY SOLUTIONS TO PADDING

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Keywords: Padding; Protection; Safety; Injury Risk; Collision; Ski

INTRODUCTION. Previous studies investigated the capacities of padding placed on obstacles to reduce injury risks during collisions with such obstacles (CWO) (Dorsemaine et al., 2023; Scher et al., 2021). However, for high-speed areas combined with accident-prone slopes, padding could bring insufficient protection. Thus, the objective of this study is to design a dedicated experimental setup to perform full-scale impact tests and to provide an evaluation of impact energy mitigation sustained by the user by coupling two devices in front of an obstacle.

METHODS. CWOs were reconstructed by propelling at 30 km/h an instrumented 50th Hybrid III dummy laid on a wooden platform. The platform was then mechanically stopped, inducing the projection of the dummy towards the obstacle. Five obstacle protections (combining pads and/or net) were investigated for two dummy positions (axial or slanted CWO), resulting in 10 CWOs (Figure). Head linear accelerations, head angular velocities and thoracic accelerations were recorded at 10 kHz and filtered at 1650 Hz or 300 Hz and the tests were filmed at 1000 Hz. Maximal linear and rotational head accelerations, HIC_{15} and 3ms thoracic accelerations were used to investigate injury risks (respective thresholds: 180 g, 6383 rad/s², 700 and 60 g).

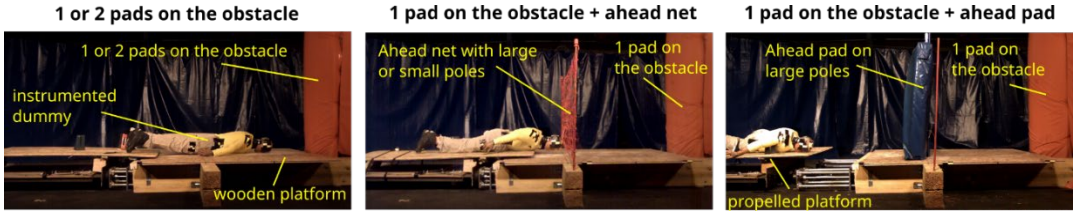

Figure. *Experimental set up and protection device used*

RESULTS. The axial CWO with only 1 pad on the obstacle was characterized by a head-first impact and injury criteria above all thresholds. The addition of a second pad on the obstacle or a change in the orientation of the dummy (slanted CWO) reduced these metrics under thresholds. The addition of an ahead pad seemed very promising by either slowing down the dummy or retaining it and avoiding the collision with the obstacle. The use of the ahead net also slowed down the dummy, changed its kinematics though the dummy was frequently partially retained (net removal from the poles or pole failure). All injury criteria were under thresholds except for one CWO with a net where the thoracic 3ms acceleration was close to the 60 g threshold.

DISCUSSION AND CONCLUSIONS. This study extended the experimental studies on padding previously mentioned by reconstructing full CWOs. The different complementary obstacle protections investigated showed good capacities to reduce head and thoracic injury risks for obstacle at high risk of impact. This study gives practical information for ski areas by offering different complementary protections regarding the slope configuration: narrow slopes (use of 2 pads on the obstacle), single skier flow (use of an ahead pad) or multiple skier flows (use of one or multiple ahead nets).

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EVALUATION OF SKI HELMET: A NOVEL TEST BENCH TO REPRODUCE A HEAD IMPACT ON SNOW

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Keywords: Helmet, ski, traumatic brain injuries, snow, standard test

INTRODUCTION. The majority of traumatic brain injury in skiing occur during a head impact against the snow. Helmets are not currently evaluated for such impacts in the standard tests. In a recent study, drop tests were conducted using an instrumented head-form directly on groomed ski slopes, both with and without a helmet, at three speeds (5.3 m/s, 6.1 m/s, 7.5 m/s)[1]. The study revealed that the impact experienced during a head-to-snow impact differed significantly from the impacts tested in standard evaluations. It also demonstrated that a ski helmet's performance in high-energy impacts of standard tests does not necessarily translate to reduced head acceleration during head-to-snow impacts. Therefore, to assess and improve helmet protection during head impacts on snow, it is crucial to evaluate them under similar impact conditions. The objective of this study is to develop a laboratory test bench that reproduces the same impact signature (time of impact, maximal head acceleration, energy absorbed) as a head impact on hard snow for evaluating ski helmets.

METHODS. Our approach was to use polymeric foam in a traditional helmet drop test to replicate the deformation and energy absorption seen in very hard snow on ski slopes in a previous study [1]. We selected the foam and determined the pad dimensions through numerical methods, simulating the head-form impact on the foam padd using finite element modeling. The pad thickness (ranging from 10 to 50 mm) and the foam type (selected from previously tested materials) were adjusted to minimize the difference between head acceleration on the pad and on the snow. The chosen foam pad was then used in an experimental drop test compliant with EN-1077, featuring a Nocsae head-form (see Figure 1.1). We conducted impacts both without a helmet (n=4) and with a helmet (n=2) at three speeds (5.3 m/s, 6.1 m/s, 7.5 m/s), and compared the resulting head accelerations to those on snow.

RESULTS. The foam pad selected to mimic the very hard snow was a 40 mm pad made of polyethylene foam (PE, 160 kg/m3). The head acceleration resulting from impacts on these pads was highly repeatable. The peak head acceleration obtained in the lab fell within the range of peak accelerations obtained on the ski slope on very hard snow for both helmeted and non-helmeted impacts (see Figure 1.2). However, the duration of the impact was slightly longer on the foam pad compared to that on the very hard snow.

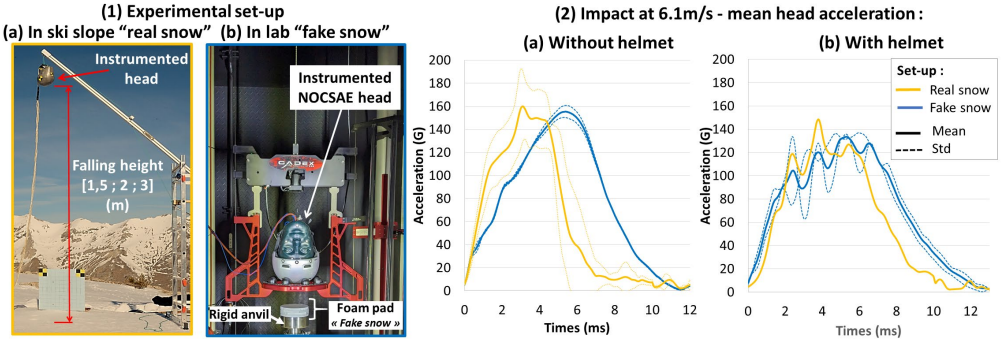

Figure 1. *Experimental set-up and comparison between head acceleration with and without helmet on "real snow" in the ski slope [1] and on "fake snow" in the lab for impacts at 6.1m/s.*

DISCUSSION AND CONCLUSIONS. Results suggest that the proposed setup produces similar head acceleration compared to impacts on very hard snow for both helmeted and non-helmeted trials at 5.3 m/s, 6.1 m/s, and 7.5 m/s while producing repeatable results in a controlled environment. This is a promising step in developing a tool to assess ski helmet effectiveness in reducing head acceleration on snow impact.

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THE INFLUENCE OF PROTECTIVE HEADGEAR ON THE PERIPHERAL VISION REACTION TIME

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Keywords: recreational skiing, head injuries, safety equipment, visual stimulus

INTRODUCTION. Due to the specific and dynamic conditions in which alpine skiing is performed, it demands a rapid and constant processing of visual information. Based on a visual feedback, skiers must make quick judgements and adapt their actions, such as speed, direction, or body position. Wearing protective headgear can significantly diminish the risk of serious head traumas but at the same time it can potentially decrease visual abilities causing a delay in perception of visual stimulus. Currently there is a gap in the available knowledge regarding the number of injuries that occur because of the inability to react to peripheral visual stimuli during skiing when using various forms of protective headgear. A comprehensive investigation of protective headgear use in skiing and its influence on skiers' visuomotor abilities is necessary to optimize their performance and enhance their safety. Therefore, the aim of this study was to examine the effects of wearing various combinations of protective headgear on the timing of visual stimuli perception and adequate response when simulating on-the-slope situations.

METHODS. The sample consisted of 22 recreational level skiers, regular ski helmet users. Testing protocol was carried out directly on the ski slope. Reaction time on perceived visual stimuli was observed in a way that a skier was approaching behind a participant's back randomly from the left and the right side. Response time upon five peripheral visual stimuli was measured with photocells (Witty timing system). Overall, five combinations of wearing protective headgear were tested (1 – ski cap, 2 –ski cap and sunglasses, 3 – ski cap and goggles, 4 – helmet and sunglasses, 5 – helmet and goggles). Repeated-measures ANOVA was used to determine differences between each tested combination of wearing a protective headgear.

RESULTS. The response time of the participants was the slowest when wearing a combination of ski helmet and goggles with an average response time of 0.50 seconds for both sides. In comparison, this response time is significantly slower ($p < 0.01$) than the baseline result (ski cap), which had an average response time of 0.29 seconds for both sides. Moreover, the combination including ski cap and ski goggles also proved to be a combination in which significantly slower response times were obtained in comparison to the control measurement ($p < 0.01$).

DISCUSSION AND CONCLUSIONS.
Protective role of the ski helmet and goggles is inevitable, but it may be impaired by changes in skiers' behaviour, i.e., more risk-taking related to a false sense of increased safety. In this research, ski goggles proved to be a greater limiting factor compared to the ski helmet itself. In the design and construction of the goggles, it is necessary to pay attention to reducing the thickness of the frame to reduce the distance between the eye and the lens, which consequently reduces interference in the peripheral parts of the visual field. Although wearing a helmet and goggles is generally recommended for safety reasons, skiers should also be aware of the potential impact on the reaction time and visual field and must adjust their technique and equipment accordingly to ensure better visibility and safety on the slopes.

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A servo controlled multiaxial test bench for knee injuries mechanism and protective devices dynamic simulations

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Keywords: knee injury, leg surrogate, instrumented knee, dynamic simulations

INTRODUCTION. It is well known that knee shows the highest injury incidence both in competitive and recreational modern alpine skiing. Efforts from research and industry are focused on the identification of protective strategies involving intervention at the bindings [1] or other protective devices such as passive knee braces [2] or active airbag systems. The present work describes the concept and functioning of a servo controlled multiaxial test bench designed for reproducing knee injuries dynamic mechanism and measuring the effectiveness of protection devices by real time risky fall/overload simulations.

METHODS. Analysing World Cup knee accidents [3] allowed estimating knee Flex/Ext, Ab/Adduction and I/E rotation critical angle/speed values. These three rotational knee DOFs were included in the bench design, to produce cyclic/dynamic imposed movements of knee flexion (1), ab/adduction (2) and rotation (3). A flexion-extension servomotor (0/150°, max 1000°/s) can produce a dynamic swinging of the frame supporting the proximal thigh of a leg surrogate, connected to a multiaxial 6-axis load cell. A second servomotor can move a carriage on vertical linear bearings causing max +/- 40° knee ab/adduction; a third motor installed in the carriage can apply +/- 50° of int/ext rotation to the distal prosthetic tibia. (Figure 1.a). The leg surrogate (3D printed surfaces covered with silicon layers to mimic soft tissues) includes two types of knee surrogates: a 3 DOF instrumented cardan joint and a biofidelic knee with 4 sensorized main ligaments, tibial plateau and Quadriceps tendon (Figure 1.b). Static tibial axial and shear loading, as well quadriceps contraction can be applied (Figure 1.c). Complex risky fall kinematics can be reproduced playing back angular range and speed estimated from available literature.

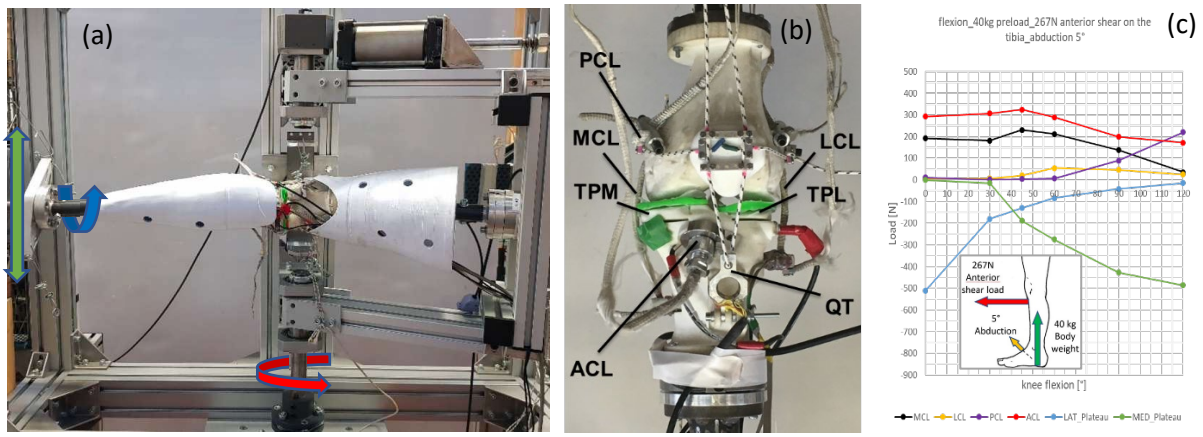

Figure 1. *(a) Test bench view, with 1-flexion (red), 2-ab/ad (green) and 3-rotation (blue) actuators; (b) biofidelic knee surrogate with sensorized channels; (c) example of internal structure loading at increasing knee flexion.*

RESULTS. The bench has been successfully used with mechanical and air kneebraces to estimate their stiffness and hysteresis values after cyclic tests: a significant effect of air pressure on stiffness was found. Flexion and abduction speed can reach 800°/sec: loads on MCL, LCL, ACL, PCL and tibial plateau agree with literature data.

DISCUSSION AND CONCLUSIONS. Differently from static other complex benches including all muscles [4], the bench can be used to simulate high speed kinematic actions on the surrogate leg: calculation of the intervention time under controlled input conditions is possible.

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EMG AND KINEMATIC RESPONSES TO SKI WIDTH IN A FEMALE SKIER: A SINGLE SUBJECT DESIGN

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Keywords: EMG, ski width, kinematics, knee stress

INTRODUCTION. Ski width is an extrinsic factor that can alter ski technique and lead to increased knee joint stress during skiing (Zorko et al., 2015). Seifert et al. (2019) observed contrasting EMG responses between wide skis (WS) and narrow skis (NS) while skiing on groomed and powder snow. Elite level skiers demonstrated greater knee extension and less internal knee rotation on WS than NS (Zorko et al., 2015). Those authors also noted that the knee joint is susceptible to increased stress as underfoot ski width increases. This problem may be exacerbated in women due to anatomical and neuromuscular differences compared to men. However, those previous reports were completed using fewer than 14 turns. The purpose of this study was to track EMG and kinematic responses between skis of different underfoot widths over repeated runs in an expert level female skier.

METHODS. One expert level female skier completed four runs with each of her skis (WS: 98 mm underfoot width; NS: 67 mm underfoot width) in a counterbalanced design. Each run consisted of 14 measurement turns/run in standardized courses based on the turning radius of the ski. Snow surface was groomed the night before testing and the courses were slipped after each run to minimize rut development. Surface EMG assessed activity of semitendinosus (ST), gluteus medius (GM), rectus femoris (RF), vastus lateralis (VL), peroneus longus (PL), and tibialis anterior (TA). Percent of maximal EMG (EMGmax%) was calculated by dividing the mean EMG signal by maximal amplitude. EMG data were time normalized for analysis between skis. XSens Motion Tracking System was used to track body segments.

RESULTS. EMGmax% increased from run 1 to run 4 for ST and GM by 41% and 52% while on WS. ST and GM activity decreased by 12% and increased by 8% over the four runs for NS. All other muscles had marginal changes over the four runs. Time normalized EMG activities for ST and GM were 8x and 3x greater in WS than NS. However, EMG activities for VL, RF, TA, PL were 1.5-2x greater for NS than WS. There was 11% less internal knee rotation with WS than NS. Knee and hip extensions were 10% and 3% greater with WS than NS. Hip rotation was 15% greater with NS than WS. Hip abduction was 13% greater with WS than NS.

DISCUSSION AND CONCLUSIONS. The largest EMG difference between skis was noted for the ST where skiing WS resulted in substantially greater activity than NS. To accomplish the prescribed turns, the skier had to redirect the skis out of the fall-line. In opposing the gravitational fall-line force, the internal rotational properties of the ST were challenged to redirect and hold the WS in the turn. This same challenge may also explain the increased hip abduction suggesting greater hip angulation as the skier attempts to keep the WS on the needed edge angle to accomplish the prescribed turn. The 68% increase in GM activity of the WS over the NS may also have aided in ski redirection through increased internal femoral rotation and hip abduction. Lastly, greater knee and hip extension led to a more upright stance in WS. This may have exacerbated the need for the ST's internal rotation due to a less than optimal rotation advantage according to the knee's Screw Home Mechanism. In conclusion, the EMG and kinematic differences between skis, as well as the substantial longitudinal changes, may lead to increased joint and muscular stresses during prolonged skiing on groomed runs for WS compared to NS.

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PREDICTING VERTEBRAL LOADING AND TRUNK IMPACT CONDITIONS IN MOUNTAIN BIKING "OVER-THE-BARS" FALLS

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Keywords: multibody model, mountain biking, spinal fracture, injury risk, video analysis

INTRODUCTION. Mountain biking (MTB) has become an increasingly popular sport and more and more ski resorts are turning into bike parks during the summer season. During MTB practice, spine and thorax are at risk with 20% of severe injuries (Injury Severity Score > 12) implicating trunk area [1]. To prevent these injuries, riders use back protectors. However, there is no standard evaluation of these protections specific to MTB, and there is very little data available on the impact condition of the back (impact speed, force involved, risk of injury) during an MTB crash. The aim of the present work is to investigate impact conditions leading to spinal injuries during an "Over-the-bars" (OTB) scenario, identified as the main situation leading to spinal injuries [2], to better design back protectors (area, structure, force absorption threshold).

METHODS. A video of an OTB accident after jumping from a height has been analyzed (Source : Pinkbike) using Kinovea and reconstructed in multi-body (MB) simulation with Madymo to validate a mountain bike and cyclist MB coupling. Then, the model has been used to investigate the influence of initial speed and slope angle changes (4 speeds and 3 slope angles) on impact conditions like head and trunk speed and force of impact. Additionally, the force and torque on each vertebra were recorded to predict the risk of injury.

RESULTS. In all scenarios, a head-first impact is observed with head-to-ground impact velocities ranging from 2 to 13 m/s, so higher values than the initial cyclist speed because of the momentum created by the OTB mechanism. An increase of the initial velocity reduces cervical spine loading (vertebral forces and moments) but increases lower spine loading. A landing slope angle increase influences in the same way vertebral forces and torques. In most simulations, spine injury thresholds are exceeded for cervical and lumbar forces and moments.

a) *b)*

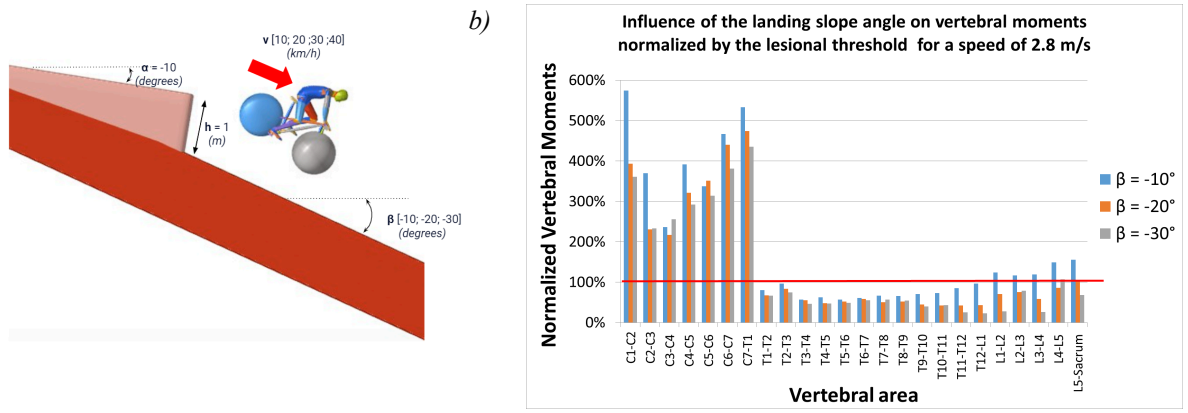

Figure *a) Parametric MB study b) Evaluation of spinal risk injury : example with vertebral moments analysis*

DISCUSSION AND CONCLUSIONS. Velocity and slope angles variation change fall kinematics by influencing fall length and bike angle of impact. Thus, a head-first impact leads to cervical spine loading while a face and trunk impact to lumbar spine loading [3]. However, for this OTB with a fall from a height, risks of spine injury are observed for all cyclist speeds and slope angles, which highlights a real need to rethink back protectors to limit extension of the spine during head-first impact. Further investigation of OTB mechanisms with smaller height drops, ground hardness and friction coefficients must be considered.

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ACL load at binding release in simulated backward twisting falls

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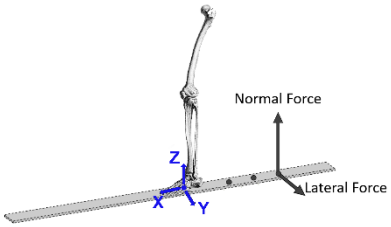
Keywords: alpine skiing, backward twisting falls, ACL load, lateral heel release binding

INTRODUCTION. Lateral heel release bindings were developed to reduce the ACL load in backward twisting falls. First results showed lower ACL loads for a lateral heel vs a toe release binding at release setting z6 [1]. In this study, we investigated the ACL load at binding release as a function of release setting and gradient for the lateral force increase for bindings with and without heel release.

METHODS. The release forces for a toe and a lateral heel release binding (PRX/12 and Protector PR 11 GW, Head Sport GmbH, Schwechat, AT) were measured for release settings z6, z12, and z15. For the simulation, we used the leg model of [1], which includes the validated FE knee model of Harris et al. [2]. Backward twisting falls were imitated by applying a linearly increasing lateral force and a constant normal force (1 BW), both 25 cm behind the leg. Slow to fast falls were modeled by varying the lateral force gradients, *k* from 2.0 to 10.0 kN/s which resulted in release times from 250 to 50 ms for the toe release binding at z6. These impacts imitate slower falls as reported in [3] for a competing skier (60 ms). Muscle forces from a validated simulation of a carved turn [4] were applied. We simulated the ACL load at release for each case. According to [5], the ultimate ACL load is 1503±83 N for 40-50 years old men. Thus, with the 3σ-rule an ACL load below 1254 N is considered save and risky, respectively.

RESULTS. Higher ACL loads at binding release were calculated for the toe release binding, higher z-numbers, and slower falls, i.e. smaller gradients, *k* (Table in Figure 1). The green color denotes save falls and the red color risky falls for 40-50 years old men.



	k	10 kN/s	5 kN/s	3.3 kN/s	2.5 kN/s	2 kN/s
T	z6	16	399	1162	1457	1669
	z12	672	1901	2408	2586	2419
	z15	1423	2054	2741	2586	2419
H	z6	6	6	11	49	212
	z12	10	241	510	1338	1333
	z15	29	655	1530	1705	1983

The figure shows the leg model and the table the ACL loads in N for the toe and the lateral heel release binding, T and H, for the release settings z6, z12, and z15, and for different gradients of the lateral force increase, k. Smaller gradients denote slower falls.

DISCUSSION AND CONCLUSIONS. The lateral heel release binding showed considerably lower ACL loads at release for the three release settings and for the different lateral forces applied. The knee model of [2] implements a 50 years old male. We speculate, that the reduction of the ACL load applies to males and females of any age. For other age groups and females, the material parameters of the ligaments should be adapted.

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REPEATED PRACTICE RUNS DO NOT INDUCE FATIGUE IN RECREATIONAL SKIERS IF THEY ALLOW FOR SUFFICIENT RECOVERY TIME

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Keywords: alpine ski, fatigue

INTRODUCTION. Literature has well established that physical activity positively affects health at any age, and in particular, activities conducted in a natural environment positively influence physical and mental health (Calogiuri et al., 2015). Alpine skiing falls within this category of activities and is one of the most commonly practiced winter sports. However, a potential side effect of this sport is the risk of injury, predominantly in the lower limbs (Flores et al., 2022), with fatigue being one of the most common contributing factors (Garouche et al., 2023). This study aims to determine muscle fatigue after skiing by utilizing superficial electromyography (sEMG) among amateur skiers who regularly engage in sports but do not undergo specific training.

METHODS. 8 amateur skiers spent two hours skiing, completing the Aloch slope eight times. This slope is moderately complex, with a vertical negative drop of 308 m and an average gradient of 27%. A giant slalom course was set up in the second section of the slope, designated for our activity. This course comprised 12 turns, each with an average distance of 24 meters. The chairlift ride to come up takes about 9 minutes. Before starting the experimental protocol, the subjects performed a warm-up slope under the supervision of a ski instructor. During the execution of the first and last slopes, sEMG signals from the rectus femoris and vastus medialis muscles were recorded. At the end of these slopes, an isometric squat test to exhaustion was conducted to determine the fatigue level. A lactate sample was taken from the earlobe, and a Rating of Perceived Exertion (RPE) assessment was requested on a scale from 0 to 100. Heart rate (HR) was recorded continuously and analyzed in the test course.

RESULTS. All the analyzed objective fatigue parameters (lactate, heart rate, electromyographic parameters, and duration of the isometric endurance test) showed no statistically significant differences between the two trials conducted on the sample. However, the data for RPE, the subjects' perception of fatigue, was significantly higher ($p=0.036$) following the second trial, i.e., after the training session.

DISCUSSION AND CONCLUSIONS. From the obtained data, we can infer that a relatively low level of fatigue is maintained with an appropriate balance between recovery time, in our case, the time spent ascending the slope, and skiing time. This is demonstrated by values of muscle fatigue (EMG and isometric fatigue) and parameters such as lactate and heart rate. On the other hand, perceived fatigue appears to increase, which may be attributed to the subjects' lack of familiarity with this type of training, which consequently demands greater mental and coordination effort.

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An approach to evaluate the "FIS ISPP – Course Design / Downhill Jumps" project to reduce injuries

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Keywords: ski racing, downhill jumps, landing impact, severe injuries, prevention

INTRODUCTION. Ski racing is a high-risk sport. Specifically, in World Cup downhill races, many injuries occur due to the high landing impact at jumps. To mitigate these injuries, the "FIS ISPP – Course Design / Downhill Jumps" project was initiated in the 2021/22 season. The shape of the jumps was measured and the takeoff speed was estimated. Subsequently, a specifically developed simulation software was used to predict jump distance and equivalent landing height as a measure for the landing impact [1]. Adjustments to takeoff inclination and/or speed were made, when the simulation indicated excessive landing impacts or jumping distances. This study aims to evaluate the effect of the "FIS ISPP – Course Design / Downhill Jumps" project on the incidence of severe injuries by comparing events that were supported by the project versus those that were not.

METHODS. Data from the FIS Injury Surveillance System (FIS ISS) was used to count serious injuries at jumps in World Cup downhill races spanning the seasons 2018/2019 to 2022/2023. This included a total of 132 training and 100 competition days. Jump predictions were made for 20 training and 19 competition days during the 2021/22 and 2022/23 seasons. Injuries caused by falls during landing were considered.

RESULTS. In the 112 training and 81 racing days not assisted by jump predictions, 17 male and female ski racers suffered serious injuries. This corresponds to an injury rate of 8.8% per downhill day, or about 1.47 severe injuries every 1000 runs. Conversely, in the 20 training and 19 competition days accompanied by the project no severe injuries occurred during jumps. A detailed list of the seasons is shown in Table 1.

season		2018/19	2019/20	2020/21	2021/22	2022/23
without jump prediction	downhill days	54	43	41	30	25
	severe injuries	9	2	2	0	4
with jump prediction	downhill days				19	20
	severe injuries				0	0

Table 1: Training and competition days in World Cup downhill racing and severe injuries with and without jump predictions from the seasons 2018/19 to 2022/23.

DISCUSSION AND CONCLUSIONS. Although the available injury data is insufficient for making a statistically valid statement, the data strongly suggests the effectiveness of the project. We were successful in preventing falls with extremely high landing impacts, which are unequivocally linked to serious injuries. However, also during races assisted by the FIS ISPP project, there were instances where athletes fell or nearly fell without suffering an injury. Future efforts will be made to extend this project to other races, such as European Cup events.

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SPORTS INJURIES AS AN ACCEPTED COMPANION OF THE ATHLETE

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Keywords: Sports injuries, alpine skiing, Tina Maze, biopower, biopolitics, health as the norm

INTRODUCTION

The transition in medical discourse from the 18th to the 19th century, from focusing on the manifestation of diseases to viewing the human body as a quantifiable organism, led to the establishment of health norms. Health is equated with normality, and illness is seen as a deviation from this norm. The formation of these norms, and the distinction between what is normal and abnormal, falls within the remit of medicine and state control, epitomized by Michel Foucault's concept of "biopolitics" This study seeks to explore the application of biopolitics to the understanding and analysis of sports injuries.

METHODS

In this study, a systematic literature review served as the method that formed the theoretical basis for the review of articles sourced from Slovene newspapers and magazines.

RESULTS

The transfer of health to the purview of the state means the implementation of mechanisms to control interventions that regulate biological systems and operate primarily at the population level, encompassing metrics such as births, deaths, and morbidity. Current medical and scientific trends suggest a paradigm shift in the study of sports injuries, which are viewed through the lens of the individual body as an amalgamation of optimizable and correctable biological functions, conceptualizing the body as a tool for achieving athletic goals. However, this perspective tends to overlook the normalization of sports injuries as a common condition for achieving peak performance. Discussions of sports injuries are embedded in widely accepted ideological frameworks and norms, with an intriguing paradox manifesting in elite sports—a discourse recognizing sports injuries as both necessary and integral, often referred to as a "necessary evil," and essential to achieving top results.

DISCUSSION

Tina Maze, who is celebrated as the most successful Slovenian alpine ski racer in the World Cup, is in the spotlight of the Slovenian public, and she is characterized by one remarkable aspect: She ended her career as the only Slovenian top alpine ski racer to be speared serious injuries that required surgery. The rarity of her achievement prompts the reflection on the prevailing notion that sporting excellence is always associated with serious sports injuries. The phenomenon results from the deviation from the established norm in which sports injuries are considered commonplace. This underscores the institutionalization of sports injuries as an inherent norm, even in the field of preventive medicine, and underlines the supposed sanctity of this norm.

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AN EXAMINATION OF OCCUPATIONAL INJURY RATES OF SNOW SPORTS RESORT WORKERS IN BRITISH COLUMBIA

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Keywords: Snowports; employees; instructors; injuries; resort management; risk management

INTRODUCTION The intent of this research is to investigate occupational injury claim rates associated with snow sports resort workers in the province of British Columbia (BC), Canada. Over the previous decades snow sports resort workers in BC have had one of the highest occupational injury rate classifications of all sectors. Classifications are based on the North American Industry Classification System (Statistics Canada, 2022; WorkSafeBC, 2021b). The average annual provincial claims cost over the five years preceding 2012 was $2.3 million, with an injury claims rate of 8.0 per 100 estimated person years of employment. This well surpassed the province's 2012 total average industry rate of 2.3 claims per 100 (Roberts, 2013b). Furthermore, although the snow sports resorts industry in British Columbia implemented new safety programs prior to 2012, neither the injury rates nor costs have significantly declined (WorkSafeBC, 2019).
Intentional outcomes of this research will be to identify the historical occupational injury claims rates for snow sports resort workers in BC, quantify occupational injury claims, and discuss the leading causes and injury classifications of workplace injuries at 36 British Columbian snow sports resorts.

METHODS A mixed methods approach with an interdisciplinary focus was used to demonstrate how this subject applies to real world situations impacting snow sports resort workers in the province of BC. The analysis utilized WorkSafe BC injury claims data, obtained through a Freedom of Information request, in combination with a systematic literature review.

RESULTS There were 6455 worker compensation claims accepted by WorkSafe BC from the 36 snow sports resorts in BC between the years 2000 and 2021. 2877 ski and snowboard instructors and program leaders are represented in the claims data, as are 1160 attendants/operators, meaning outside workers accounted for 63% of accepted claims. Traumatic sprains, strains and tears accounted for 49% of claims, while accidents due to obstacle avoidance maneuvers and loss of control while skiing or snowboarding account for more than 20% claims. 14.7% of snow sports accidents result from collisions. Lone skiers falls and crashes into obstacles on the ski slopes are further common causes of accidents. There is no one specific solution on how best to reduce occupational injury rates for snow sport resort workers in BC, but rather a unification of multiple methods and strategies of best practices for reducing the frequency and severity of injuries (Dickson & Terwiel, 2020).

DISCUSSION AND CONCLUSIONS In BC resorts, program leaders and instructors were the most likely workers to suffer an injury while working. Evaluating the severity, probability, and exposure of occupational injuries for snow sports resort workers helps facilitate risk controls through avoidance, loss prevention, and loss reduction. The analysis will also help identify a future research agenda that is informed by the insights from snowsport injury research. The agenda may suggest research questions about the role of personal protective equipment (PPE); the relationship between trail ratings and injury frequency and severity; risk-taking behaviours; and self-awareness when riding.

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Injury prevention in alpine ski racing: where do we come from and how could we go on?

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Keywords: athlete, skiing, performance, injury prevention, return to sport

The consistently high injury rates in alpine ski racing have increasingly become the focus of research in recent years. [1] In particular, the "epidemiology" and "aetiology" of traumatic and overuse-related musculoskeletal injuries have been investigated in more detail. In addition, a small number of studies on elite alpine ski racing have focused on suitable preventative measures and their effectiveness. However, little research has been conducted on preventative approaches aimed at youth athletes.

The aim of this scientific presentation is to provide participants with an in-depth and comprehensive overview of the current state of research on the topic of injury prevention in alpine ski racing. Therefore, current knowledge gaps will be highlighted, and a potential road map for future injury prevention studies will be suggested.

A particular focus will be given to the areas of racing-specific injury epidemiology, injury risk factors, injury mechanisms, injury prevention measures, and implementation issues. Regarding prevention approaches, both athlete-related and framework- and material-related aspects will be addressed. The target audiences are researchers and practitioners engaged in injury prevention with a particular interest in competitive sports.

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Implementation approaches of preventative strategies in FIS sports: Perspectives of the FIS Athlete Health Unit

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As the international governing body for most on-snow winter sports, the International Ski and Snowboard Federation (FIS) has the duty to provide rules and a framework, wherein athletes can perform in a professional, safe, and fair manner. The FIS Athlete Health Unit was established two years ago, to embed a structure in the organisation, with the duty of working on safety and prevention topics in a transparent and unbiased way.

Most sports within the FIS umbrella inherently consist of different risk factors. Besides their multi-faceted origin, modifiable and non-modifiable risk factors can be defined. For example, done in alpine ski racing [1, 2]. Based on the problem definition, either by scientific evidence, or by experts in the field (athletes, coaches, or race organizers), FIS AHU tries to set up a process to work on those risk factors and improve the situation for athletes. Focus must always be on the complexity and interaction of the situation. This could be in the context of risk factors´ interaction, or in the context of performance-prevention/safety interaction. Both need to be monitored carefully and provided with necessary evidence. Again, this evidence could come from the scientific community or experts´ experience.

In general, topics and issues are categorized in three main topic areas: “athlete related”, “equipment related”, and “framework related”. This general categorization is applied to all FIS disciplines, but with different areas being focused.

With each issue, the outcome must show an impact on the situation of athletes to better prevent and protect from injuries. But this outcome is not necessarily dictated by rules and regulations. The standard procedure includes a hierarchy of measures, including first information and education, in a second step recommendations, and in a third step rules and regulations. While the level of rules and regulations mostly affect athletes, recommendation and information strategies target also supporting staff like coaches, parents, or equipment producers, with the aim to build up awareness about certain topics and learn about potential preventative measures. Besides that, technological innovations must be introduced thoughtfully and targeted.

Topics on prevention and safety will always find its trade-off with performance driven aspects of the sport. At the same time, it will never be possible to prevent from all injuries in professional high-performance sports. But this multi-dimensional approach and structure in place should provide long-term benefits for athletes presenting their skills in FIS sports.

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ATOMIC

TUESDAY (12. 3. 2024)

10:15 SKIMO (Session chair: H.-C. Holmberg):

- **Keynote (30 min) H.-C. Holmberg: FROM ALPINE TRAILS TO OLYMPIC HEIGHTS: THE EVOLUTION OF SKI MOUNTAINEERING**
- S. Rauter, N. Verdel, M. Majerič, B. Pellegrini, L. Bortolan, H.-C. Holmberg, M. Supej: IMPACT OF POLE LENGTH ON PHYSIOLOGICAL PARAMETERS IN UPHILL SKI MOUNTAINEERING
- T. Debevec, G. Manferdelli, B. J. Narang, N. Bourdillon, G. P. Millet: ALTITUDE-RELATED AEROBIC CAPACITY DECREMENT: CONSIDERATIONS FOR SKI MOUNTAINEERING
- S.P. Eun, J.-Y. Jung: THE PATTERN OF THE BONE CONTUSIONS IN NON-CONTACT ACL INJURIES COMPARISON BETWEEN SKI AND GROUND SPORTS
- G. Zullo, P. Cibin, L. Bortolan, N. Petrone: FRONT/REAR ROLL MOMENT RATIO IS MUCH HIGHER IN SKI TOURING BINDINGS THAN ALPINE SKI BINDINGS

12:00 Lunch

13:30 SKI AREAS AND TERAIN PARKS (Session chair: Irving Scher):

- L. Ellenberger, I. H. Mannsåker, B. Heer, M. Gilgien: DEVELOPMENT AND VALIDATION OF IN-FIELD MEASUREMENT METHODS FOR TERRAIN PARK JUMP PROFILES
- M.-S. Linløkken, S. A. Vigane, F. Meyer, C. Högström, P. Jølstad, H. Spieker, S. Guillaume, S. Hoholm, F. Wolfsperger, M. Gilgien: A BIOMECHANICAL ANALYSIS OF HOW ATHLETE BEHAVIOR AND EQUIVALENT FALL HEIGHT AFFECT LANDING STABILITY FOR SKIERS AND SNOWBOARDERS IN A WORLD CUP BIG AIR COMPETITION
- Y. Urabe, T. Tashiro, S. Arima, R. Kaizuka, N. Maeda: TRENDS AND CHALLENGES IN THE SKIING AND SNOWBOARDING POPULATION IN JAPAN: A LITERATURE REVIEW AND FUTURE OUTLOOK
- T. J. Dickson, F. A. Terwiel: MOUNTAIN BIKE INJURIES IN SNOWSPORT RESORT MOUNTAIN BIKE PARKS: RESEARCH INSIGHTS AND A RESEARCH AGENDA FOR THE FUTURE

14:30 Coffee break

15:00 DESIGN OF SPORTS EQIPMENT (Session chair: Nicola Petrone):

- P. Carqueville, V. Wohlgut, V. Senner: INVESTIGATION OF LATERAL SKI BOOT TOE LIP DISPLACEMENT AND TWISTING TORQUE IN SKIING
- F. Biagi, D. Colombo, L. Crosetta, M. Parisi, G. La Fauci, A. Nanni and M. Colonna: RECYCLING PROCESSES FOR MORE SUSTAINABLE SAFETY SPORT EQUIPMENT
- G. Porter, L. S. Stepan, I. S. Scher: ASSESSING COMPATIBILITY OF SKI BOOTS AND BINDINGS USING ASTM F504
- T. Allen, N. Hamilto, G. Leslie and K. Winwood: REDUCING SNOWBOARDING WRIST INJURIES: PROGRESS AND RECOMMENDATIONS

16:00 PROTECTIVE EQUIPMENT (Session chair: Tom Allen):

- E. Baldoin, G. Zullo, P. Carraretto, N. Petrone: EVALUATING HELMETS ANTI-ROTATIONAL TECHNOLOGIES EFFECTS ON SKULL AND BRAIN KINEMATICS USING A BIOFIDELIC SENSORISED HUMAN HEAD REPLICA
- W. Wei, S. Bonte, P.-G. Champavier, J. Demasi, A. Thouze, P.-J. Arnoux, L. Thollon, N. Bailly: SAFETY EVALUATION OF A SNOWBOARDING BACK PROTECTOR: A FOCUS ON BACKWARD FALL PROTECTION
- L. S. Stepan, D. C. McFarland, G. Porter, I. S. Scher: THE EFFECT OF WINTER GLOVES ON GRIP STRENGTH AND HANG TIME
- G. La Fauci, D. Colombo, M. Parisi, L. Crosetta, F. Biagi, M. Colonna: A NOVEL METHOD TO EVALUATE THE PERFORMANCES OF ANTI-ROTATIONAL ACCELERATIONS SYSTEMS USED IN PROTECTION HELMETS

17:00 WINTER SCHOOL PRESENTATIONS (Session chair: Uwe Kersting)

FROM ALPINE TRAILS TO OLYMPIC HEIGHTS: THE EVOLUTION OF SKI MOUNTAINEERING

Prof. dr. Hans-Christer Holmberg

Luleå University of Technology, Sweden

Ski mountaineering (SkiMo) is a rapidly growing winter sport that involves alternately climbing and descending slopes and various racing formats that differ in length and total vertical gain, as well as their distribution of downhill and uphill sections. In recent years, both participation in and media coverage of this sport have increased dramatically, contributing, at least in part, to its inclusion in the 2026 Winter Olympics in Milano-Cortina. Despite its popularity, research on this discipline is scarce, but some general characteristics are already emerging. Pronounced aerobic capacity is an important requirement for success, as demonstrated by positive correlations between racing time and aerobic capacity. Moreover, due to the considerable mechanical work against gravity on demanding uphill terrain, the combined weight of the athlete and equipment is inversely correlated with performance, prompting the development of both lighter and better equipment in recent decades. In SkiMo, velocity uphill is achieved primarily by more frequent (rather than longer) strides due primarily to high resistive forces. Skis, boots, and bindings must be light enough to facilitate climbing uphill and, at the same time, provide stability and safety in often-challenging descents. Moreover, a skier must be able to easily and rapidly attach and remove the adhesive skins under the skis that provide grip while skiing uphill. Poles and their baskets must be designed optimally to transfer propulsive force and help maintain balance. Improvements of equipment in a number of areas could potentially advance both performance and safety. Such advances must be based on a better understanding of the sport´s biomechanics, which could be obtained with wearable technology and achieved via extensive collaboration between researchers, skiers and their coaches, and manufacturers of SkiMo equipment.

IMPACT OF POLE LENGTH ON PHYSIOLOGICAL PARAMETERS IN UPHILL SKI MOUNTAINEERING

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Keywords: Ski mountaineering, ventilatory efficiency, pole length, uphill

INTRODUCTION. Ski mountaineering, commonly referred to as SKIMO, is a sport that is gaining popularity. However, there is still a scarcity of research in this field and a lack of knowledge regarding the role of ski poles. Ski poles are crucial for maintaining balance and coordination and reducing physical strain, especially when moving uphill. While the use of poles during uphill portions is widely acknowledged in SKIMO, there is a lack of understanding related to the impact of pole length on propulsive force. Unlike trail running and cross-country skiing, there is a significant variation in the length of poles used in SKIMO among athletes. This study aims to investigate how various pole lengths affect uphill walking with skis at different intensities, focusing on ventilation parameters. The findings of this study could provide valuable insights for reducing fatigue and enhancing performance in SKIMO.

METHODS. The study involved 12 SKIMO athletes (181.6 ± 5.2 cm; 79.8 ± 9.2 kg; 51.3 ± 4.8 ml/min/kg). The study consisted of two parts on separate days. In the first part, an incremental test was conducted. The second part examined the effects of three different pole lengths (including the optimal length and variations of -5 % and +5%) on physiological parameters such as heart rate, ventilation, oxygen consumption, and oxygen utilization in relation to speed. The incremental test was performed using a K5 metabolic analyzer (Cosmed, Italy) on a treadmill (Rodby, Sweden). The athletes used standard SKIMO equipment, including the typical pole length. The test included a standardized warm-up phase of ten minutes at a 20% incline and a 3.4 km/h speed. Following the warm-up, a ramp protocol was initiated with a constant gradient of 24% and a speed of 3.4 km/h, increasing by 0.4 km/h every minute until volitional exhaustion (Lasshofer et al., 2021). For the ventilation thresholds (VT1 and VT2) calculations, we used a combination of the V-slope method and ventilation equivalences. Subsequently, the second part of the protocol involved six distinct performance tests with three different pole lengths at two intensities. Following a 10-minute warm-up, 5-minute exercise bouts interspersed with a 2-minute passive resting phase were conducted for each of the three pole lengths, randomly proposed, targeting VT1 and VT2.

RESULTS. The two-way analysis of variance revealed no statistically significant differences between pole lengths at intensity VT1 for VE ($p = 0.983$), VO2 ($p = 0.671$), HR ($p = 0.988$), and oxygen utilization in relation to speed ($p = 0.919$) and at intensity VT2 for VE ($p = 0.939$), VO2 ($p = 0.855$), HR ($p = 0.836$) and oxygen utilization in relation to speed efficiency ($p = 0.759$).

DISCUSSION AND CONCLUSIONS. The participants involved in the study conducted incremental and performance tests at different intensities and pole lengths to assess the effect on heart rate, ventilation, oxygen consumption, and efficiency. According to these initial findings, SKIMO athletes at the race intensities tested here, have the flexibility to select their poles based on snow and terrain conditions, resulting in improved balance and enhanced safety without any effects on physiological factors. In contrast to cross-country skiing, where the poles are primarily used for propulsion, in SKIMO the poles are used for both support and propulsion on the steeper climbs, similar to trail running. This highlights a particular aspect of SKIMO compared to cross-country skiing and suggests a complex relationship between pole length and performance that warrants further detailed investigation.

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ALTITUDE-RELATED AEROBIC CAPACITY DECREMENT: CONSIDERATIONS FOR SKI MOUNTAINEERING

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Keywords: Ski Mountaineering; Altitude; Hypobaric hypoxia; Aerobic capacity; Performance.

INTRODUCTION. The popularity of ski mountaineering is significantly increasing, both in recreational as well as in high-performance domains (1). The increase in the latter seems particularly relevant due to the inclusion of ski mountaineering in the competition programme of the upcoming Winter Olympic Games in Milano in 2026. While many different determinants underlie overall ski mountaineering performance, high aerobic capacity undoubtedly represents one of the key aspects, given that all disciplines involve uphill phases (2). Due to global warming-related lack of snow at lower altitudes, ski mountaineering, even at a competitive level, tends to be (or will soon need to be) conducted at higher terrestrial elevations (≥ 3000 m). Accordingly, the physiological and performance-related effects of hypobaric hypoxia need to be considered.

METHODS. To characterise the effects of altitude-related hypoxia on exercise performance, convective and diffusive oxygen transfer, and other physiological parameters – as described previously (3) - fifteen healthy young males underwent two incremental exercise tests to exhaustion, one near sea level (295 m; Ljubljana, Slovenia; barometric pressure ~737±2 mmHg) and the other after three days at high altitude (3375 m; Torino hut, Aosta Valley, Italy; barometric pressure ~503±3 mmHg). Both exercise tests were conducted on a cycle ergometer with a 5-minute rest period followed by a 2-minute warm-up (60 W) and subsequent increments of 40 W every 2 min until volitional exhaustion. Exhaustion was determined using standard criteria. Gas exchange, cardiac hemodynamics, muscle, and brain oxygenation were assessed continuously using a metabolic cart, transthoracic impedance, and near-infrared spectroscopy, respectively.

RESULTS. Peak power output was significantly reduced in hypoxia (279 ± 10 W) compared to normoxia (312 ± 12 W; $P < 0.05$). Similarly, exposure to hypobaric hypoxia significantly lowered peak oxygen consumption (NOR: 51.9 ± 1.9; HYP: 37.9 ± 1.1 ($mL \cdot min^{-1}/kg^{-1}$); $P < 0.01$) and augmented peak minute ventilation (NOR: 163.6 ± 6.9; HYP: 179.0 ± 5.8 ($L \cdot min^{-1}$); $P < 0.05$). No significant differences were noted between normoxic and hypoxic tests in peak cardiac output-related parameters. Similarly, muscle tissue saturation index – at peak exercise – was comparable between conditions.

DISCUSSION AND CONCLUSIONS. Overall, the present data – in line with previous work - show that exposure to 3375 m profoundly reduces maximal aerobic exercise capacity. The generalizability of the present work to ski mountaineering may be limited, considering the use of cycling as the exercise modality. However, together with our current understanding of altitude-related hypobaric hypoxia, it is clear that ski mountaineers should employ appropriate (pre)acclimatization strategies to mitigate the detrimental physiological effects on exercise capacity. As a result, ski mountaineering performance when acutely exposed to high altitudes may be optimized.

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The pattern of the bone contusions in non-contact ACL injuries - Comparison between ski and ground sports –

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Keywords: ACL, mechanism of injury, bone contusion, meniscus, MRI

INTRODUCTION

Acute non-contact ACL injuries are frequently combined with the meniscus, ligaments, and bone contusions. The combinations of those lesions differ among types of sports activities, and the differences in injury patterns may be related to the mechanism of injury. The purpose of this study was to characterize injury patterns in acute non-contact ACL injury, and to determine whether there are differences in patterns of the bone contusion between ski and other ground sports.

METHODS

“This is a preliminary data. Results with a full data set will be provided in the conference."
We reviewed the clinical record and MRI of the 82 patients with an acute non-contact ACL injury. All patients had undergone an arthroscopically assisted stabilizing procedure within 6 weeks after the injury. 37 of the patients were skiers, while the 45 patients were injured in other ground sports. The frequency, location, and severity of the bone contusions were analyzed based on magnetic resonance imaging, and compared between both groups. The association between bone contusion and frequency of injuries in meniscus and MCL were also analyzed.

RESULTS

91.5% of the acute non-contact ACL injury had bone contusions on magnetic resonance imaging. The Skier group(100%) had a higher prevalence of bone contusion compared to the other ground sports group(84.4%)(P=0.0127). For the location of the bone contusion, the ground sports group showed a higher prevalence of medical compartment than the skier group(P=0.008). For severity of the bone contusion by the ratio of contusion length to articular surface, the skier group was more severe than ground sports on the lateral femoral condyle (P=0.0325). 61% of the acute non-contact ACL injury had a combined meniscus injury, and 15.9% had a medial collateral ligament injury. With the progression of the bone contusion, the prevalence of the meniscus and MCL increased. For the location of the combined meniscus injury, 84.2% were the lateral meniscus for the skiers, 67.7% for the ground sports. 21.1% of the combined meniscal injuries were the medial meniscus for the skiers, 48.4% for the ground sports.

DISSCUSSION AND CONCLUSIONS

Bone contusions are strong indicator of the level of energy that causes the ACL injury. The ACL injury in skiers are combined with more frequent and severe bone contusions, especially on the lateral compartment than those in ground sports. Our results suggested that mechanism of ACL injury in skier causes more intense damage to the specific compartment of the knee as compared to that in patients with ground sports.

FRONT/REAR ROLL MOMENT RATIO IS MUCH HIGHER IN SKI TOURING BINDINGS THAN ALPINE SKI BINDINGS

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Keywords: ski bindings, ski boot, alpine ski, ski touring, ski mountaineering

INTRODUCTION. Skiing hardware is designed differently for each discipline. A first difference is that Alpine Ski (AS) gear focuses on strength, while Ski Touring (ST) equipment aims to minimize weight. This necessity, combined with the uphill technique of ST, had brought the working principle of ST bindings far from AS bindings. The static scheme of the bindings (in skiing mode) is very different too: AS bindings provide an hyperstatic torsional constraint to the boot, like a double fixed support; ST bindings instead are almost isostatic. Therefore, also boot loads distribution could be different, requiring the analysis of other load components [1]. Focus of previous works was on the twist release mechanism of ST bindings [2]. The aim of the present work is to compare the ski roll moment transmission between front and rear binding between ST and AS in outdoor skiing sessions.

METHODS. An instrumented set of touring and alpine ski and bindings were used for the study [3]. This system measures the ski Ground Reaction Force (GRF) with two six axis load cells between ski and bindings, also measuring GRFs under each binding. A ski instructor descended a groomed slope with ST gear and then with AS gear. Front and rear binding loads were collected at 1 kHz by a SoMat eDAQlite fitted in a backpack. Binding loads were referred to the ski reference system: X longitudinal; Y transversal; Z normal to the ski surface. Skiing data was segmented and then averaged within three repeated turns based on the roll moment (Mx): at each positive zero crossing the internal turn begins.

RESULTS. Figure 1 shows Mx for ST and AS. Ski touring Mx on the front binding is four times the rear binding (43.0 vs 10.1 Nm). Alpine skiing Mx is on the front binding 1.6 times the rear values (29.4 vs 17.8 Nm).

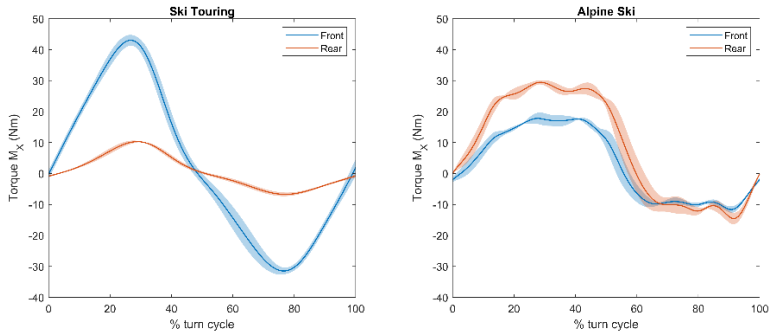

Figure 1. *Comparison of front/rear binding torque for ski touring (a) and alpine ski (b).*

DISCUSSION AND CONCLUSIONS. The study aimed to quantify differences in loading mechanisms of alpine and touring bindings, as well boots. Results confirmed that Mx distribution is extremely different between the two types of bindings. Therefore, this different loading distribution should be considered in boot design as well.

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Development and validation of in-field measurement methods for terrain park jump profiles

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Keywords: safety engineering, injury prevention, jump design, terrain park, accuracy, snow

INTRODUCTION. Skiing and snowboarding, enjoyed by 3.5 million Swiss residents annually, result in 62 000 injuries yearly, with nearly 10% occurring in terrain park environments. Injuries in terrain parks are likely more severe than those on ski slopes and predominantly affect young individuals. While the theoretical engineering knowledge on how to build safe terrain park jumps is available, a comprehensive method to measure the shape of existing jumps or jumps under construction in field is lacking. This study aimed to develop and compare methodologies enabling terrain park operators to swiftly, reliably and cost-effectively measure terrain park jump profiles, addressing a crucial need for accurate verification of terrain park constructions, with the goal of ensuring safety.

METHODS. During the winter 2022/23, measurements were conducted on a total of five jumps of varying sizes by up to three methods. A self-developed digital inclinometer based manual hand tool (BFU-tool) and an optic laser measurement device (Disto S910, Leica Geosystems), hereafter called Disto, were compared against a differential GNSS (Alpha-G3T, Javad). The accuracy of the Disto and BFU-tool was assessed through alignment of their profile data with the differential GNSS profile and a geometric profile deviation assessment. Furthermore, the handling and error susceptibility of the BFU-tool and the Disto were subjectively evaluated by two trained terrain park shapers.

RESULTS. The use of the Leica Disto resulted in a mean error of ≤ 5 cm across all measured jumps. To cover the entire jump profile, the Disto needs to be set up on the knuckle, at the start of the landing, where a 4 m range cannot be measured. On a medium-sized jump, this setup issue locally introduced a 15 cm error due to the absence of measured points, necessitating interpolation. In contrast, the application of the BFU-tool resulted in larger discrepancies, typically ranging from 5 to 10 cm, and in one instance when handled less diligently on a large jump, reaching 30 to 40 cm difference from the reference method (differential GNSS).

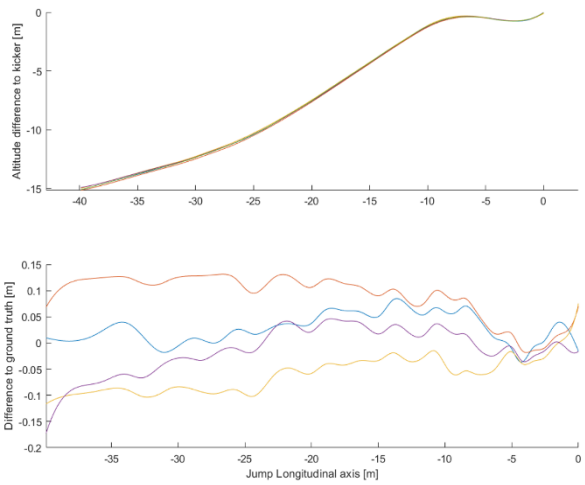

Figure 1: *Example of a terrain park jump. Top part: Profile view. Bottom part: Differences between Disto and BFU-tool and raters to the reference method (differential GNSS). Red: Disto (one rater). Blue, purple and yellow: three raters with the BFU-tool.*

DISCUSSION AND CONCLUSIONS. The Leica Disto and the BFU-tool both enable swift, reliable and cost-effective measurement of jump profiles in terrain parks. When the knuckle related issue is solved by interpolation for the Disto method, it exhibited slightly better accuracy and was favoured by practitioners due to its lower susceptibility to errors during use and more intuitive handling. With the development of suitable interfaces and analysis routines, future implementation could empower terrain park operators to measure their jumps independently and accurately. This capability not only facilitates efficient self-assessment but also enables prompt adjustments for safety considerations if necessary.

A Biomechanical Analysis of how Athlete Behavior and Equivalent Fall Height Affect Landing Stability for Skiers and Snowboarders in a World Cup Big Air Competition

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Keywords: Safety Engineering, Jump design, Injury risk, Athlete behaviour

INTRODUCTION. Big Air competitions show high injury rates [1], and there is an ongoing debate that questions whether the responsibility lies with organizers allowing jumps that induce high equivalent fall height (EFH) or with athlete actions during the flight. This study aimed to investigate athlete behaviour along with EFH to see how they impacted landing stability for World Cup Big Air athletes on freeski and snowboard, and further identify the predictive variables associated with EFH. Landing stability was used as a surrogate measure of injury risk.
METHODS. The data were collected on a step-down jump in a Big Air competition in Mönchengladbach using a geodetic video method. 3-dimensional models of the athletes' centre of mass trajectories were reconstructed, allowing the calculation of physical parameters such as EFH. A subjective assessment of the runs was conducted to extract landing stability and athlete behavioural factors, including airtime, degrees of rotations, average angular velocity, axial motions of manoeuvres performed, and athlete orientation during landing. Rotational direction for snowboarders was also assessed. Logistic regression analysis was used to investigate how EFH, and athlete behavioural factors impact landing stability, and linear regression was used to identify variable predictors of EFH.
RESULTS. Snowboarders exhibited a significantly higher incidence of failed landings (58.2%) compared to skiers (26.5%). This could be explained by differences in how skiers and snowboarders are attached to their equipment, leaving snowboarders with a limited ability to compensate for imbalances in the landing compared to skiers. None of the variables examined were found to be significant predictors of landing stability in either freeski or snowboarding. EFH ranged from 1.69 ± 0.55 m for male skiers, 1.48 ± 0.23 m for male snowboarders, and 1.20 ± 0.17 m for female skiers. Drop height and landing angle proved to be significant EFH predictors in both disciplines.
DISCUSSION AND CONCLUSIONS. Neither EFH nor athlete behaviour influenced landing stability, which is contrary to findings from a slopestyle competition [2]. However, the higher percentage of failed landings compared to earlier studies may imply that the high EFH values, all close to or exceeding the recommended maximum of 1.5 meters [3], allow little variability in control during landing, potentially resulting in failed landings across the entire range of EFH values. One can speculate whether the high EFH values mitigate the influence of athlete behaviour factors on landing stability. Since the step-down jump resulted in remarkable EFH values, the importance of designing a landing that aligns with the athlete's flight trajectory is important.

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Trends and Challenges in the Skiing and Snowboarding Population in Japan: A Literature Review and Future Outlook

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Keywords: Ski population, Ski outfit, Foreign visitors, Number of lifts, Climate change, Snowfall amounts

INTRODUCTION. This study aimed to summarize the declining trends in the skiing and snowboarding population in Japan, comparing them with global trends, and to make predictions about future developments.

METHODS. A literature review of past skiing and snowboarding populations in Japan and around the world was conducted.

RESULTS. The skiing and snowboarding population in Japan experienced a peak in the late 1990s to the early 2000s. The year 1998, when the Nagano Olympics were held, was the highest with 18 million participants (14 million skiers and 4 million snowboarders, with a snowboard/ski ratio of 28.6%), constituting 16% of the total population of Japan (126 million). However, the skiing and snowboarding population has steadily declined, reaching a low of 2.8 million in 2021 (2 million skiers and 0.8 million snowboarders, with a ratio of 40.0%). This represents only 16% of the population during its peak.
In 1987, a movie called "Take Me Skiing" (36 years ago) set off a ski boom throughout Japan. The peak of the skiing population was in 1993 (30 years ago) with 17.7 million participants, while snowboarding peaked in 2002 (21 years ago) with 5.4 million participants. The equipment market decreased from ¥287 billion in 1998 to ¥94 billion in 2021, marking a 32.8% decrease. Ski resort revenue also declined from ¥116 billion in 1998 to ¥44.8 billion in 2021, a decrease of 38.6%. Female participants constitute approximately half of male participants. In 2021, there is an increased number of skiers in their teens and those in their 70s (the Baby Boomer generation).
As for the number of lifts, the following countries are in order: France, USA, Austria, Italy, Japan (5th), Germany, Switzerland, Canada, Sweden, Czech Republic, Poland, China, Norway, Russia, Slovakia, Spain, Finland, Slovenia (ISSS host country), Korea, and Australia. In terms of the number of visitors to ski resorts in each country, in the following order: USA, Austria, France, Japan (4th), Italy, Switzerland, Canada, China, Russia, Sweden, Norway, Germany, Poland, Czech Republic, Spain, Korea, Slovakia, Finland, Andorra, and Australia. The percentage of participation in skiing was as follows: Liechtenstein (36%), Switzerland, Austria, Finland, Norway, Czech Republic, Andorra, Iceland, Sweden, Slovakia, Germany, Slovenia (ISSS host country), Poland, France, Italy, Netherlands, Canada, Denmark, Belgium, and Montenegro (10%). Japan is out of the rankings, with a participation rate of about 1.4%.

DISCUSSION AND CONCLUSIONS. Despite having a high number of lifts, Japan faces a challenge with a relatively low skiing population. Japan relies heavily on foreign visitors. With the cost of skiing being significantly lower in Japan compared to other countries, there is an expectation that international visitors will contribute to the industry. However, economic factors, such as inflation and disparities between those unable to afford skiing and those choosing not to participate, contribute to a continued decline in skiing and snowboarding interest in Japan. Further considerations, including climate change, snowfall amounts, and the number of foreign visitors, will be explored in subsequent phases of this study.

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MOUNTAIN BIKE INJURIES IN SNOWSPORT RESORT MOUNTAIN BIKE PARKS: RESEARCH INSIGHTS AND A RESEARCH AGENDA FOR THE FUTURE

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Keywords: Mountain biking; injuries; resort management; risk management; research agenda

INTRODUCTION. In the face of climate change many snowsport resorts around the world are looking to year-round operations to adapt to the impacts of climate change. One growth area over the last decade or more has been in lift-accessed mountain biking (MTB) that utilises existing infrastructure, such as chairlifts, for summer operations [1]. As at 23rd December 2023, *Trailforks* listed 638 Mountain Bike Parks around the world (https://www.trailforks.com/bikeparks/). In introducing their database, they state that "Many ski resorts run lift accessed bike parks in the summer. Lift-accessed bike parks are good because they offer the chance to make many more runs down a mountain than could be done without use of a lift. Most parks have a nice progression of trail difficulty for people to improve their skills on".
Despite operating in snowsports resorts that have a long tradition of researching injuries and injury mitigation there is little evidence that the same strategies are being applied to lift-accessed MTB. To address this gap in the literature and practice and to inform a MTB injury research agenda., this presentation will include analysis of an online data base of MTB parks, as well as the results of a systematic review of literature on MTB injuries, particularly within snowsport resort bike parks.

METHODS. With the crossover between snowsport resorts, with their long history of reporting and analysing injury events, and the growth in lift-accessed mountain biking in snowsport resorts over summer, this presentation will provide,

1. Analysis of the *Trailforks* database (n=638) to identify,
    a. How many are within snowsport resorts. Of these,
        i. The mix of uplift methods, e.g. chairlift, gondola etc.
        ii. The mix of trail ratings, e.g., green, blue etc...
2. Results of a systematic review of recent research articles (2014-2023) that explore the collection and reporting of injuries in lift-accessed mountain biking in snowsport resorts across the world. This will follow the PRISMA guidelines and will search relevant databases such as Scopus and Medline.
3. Recommendations for a research agenda for lift-accessed mountain biking in snowsport resorts.

RESULTS. Initial analysis of the *Trailforks* database indicates that the 638 parks are across 46 countries. Of the 14,533 reported trails, 13% were green, 25% blue, 10% black, 4% double black. The remainder were unrated (48.3%). The uplift methods included, 100 Shuttles, 247 Chairlifts, 97 Gondola, 53 T-bars, and 6 Magic carpets.

DISCUSSION AND CONCLUSIONS. The additional analysis of the database and results of the systematic will help to inform future risk management strategies in snowsport resorts and resort level injury reporting and analysis. The analysis will also help identify a future research agenda that is informed by the insights from snowsport injury research [e.g., 2, 3]. The agenda may suggest research questions about the role of personal protective equipment (PPE); the relationship between trail ratings and injury frequency and severity; and risk-taking behaviours.

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Investigation of Lateral Ski Boot Toe Lip Displacement and Twisting Torque in Skiing

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Keywords: Skiing, Mechatronic Binding, Boot Displacement, Partial Release, Hockey Stop, Carving

INTRODUCTION. This study is related to the "Mechatronic Ski Binding" project funded by the Bavarian Research Foundation until March 2023. To tackle the problem of high annual numbers of knee-related injuries, the prototype solution of the project dynamically adjusts the binding retention value within the specified DIN ISO 8061:2020 range. Background on this topic can be found in [1]. In this context, we address the tracking and correlation of the lateral toe lip displacement and twisting torque M_z to better understand the ski binding dynamics. Furthermore, this investigation is crucial for optimising injury risk-related false positives and false negatives of the control algorithm and, thus, refining the mechatronic binding solution.

METHODS. For this study, we show two ski runs, each involving different manoeuvres—carved turns and hockey stops—performed by a single subject on a soft ski slope surface. This study only regards sensors of the right ski prototype. The twisting moment M_z was measured with strain gauges in the heel part and the toe piece of the prototype and is calculated with respect to the tibial axis, as defined in DIN ISO 9462:2023. The binding's z-value was set to 6. To account for possible crosstalk due to ski bending, the twisting moment M_z measured by the binding components is symbolised below as M_{z*}. In addition, the partial release was measured using Hall sensors attached to the toe lugs, with angular changes translated into translational shifts of the boot's toe lip, as determined from laboratory tests. M_{z*} and the lateral toe lip displacement are sampled at 200 Hz. The turn sequence and speed are drawn from the right ski's Global Navigation Satellite System trajectory, sampled at 25 Hz.

RESULTS. Figure 1 depicts five instances of hockey stops to the left and carved turns, with emphasis on five left turns highlighted in blue. The minimal/maximal lateral toe lip displacements are -0.20/0.41 mm for carving and -0.42/ 0.18 mm for the hockey stops. Minimum and maximum M_{z*} values during carving were -4.99 Nm and 15.49 Nm, respectively, while during hockey stops, they were -3.67 Nm and 15.99 Nm.

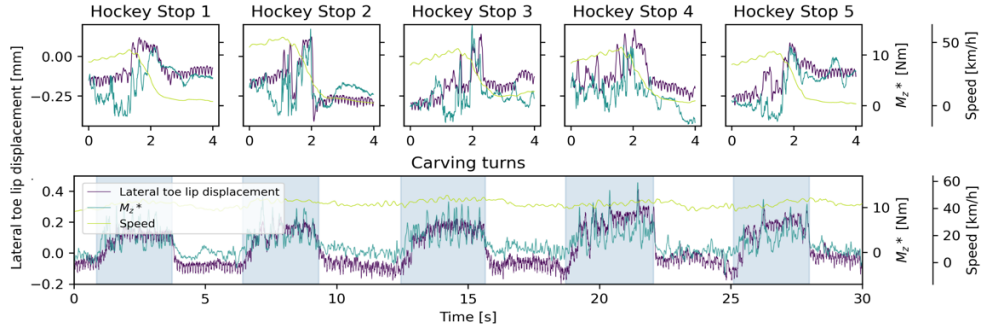

Figure 1: *Twisting moment M_{z*} and toe lip displacement during hockey stops and carved turns*

DISCUSSION AND CONCLUSIONS. The prototype's M_{z*} aligns well with the findings in [2]. Though minimal for both manoeuvres, lateral toe lip displacements show a strong correlation with the twisting moment M_{z*}, particularly during carving. Increased signal variation during hockey stops can be caused by increased flexion of the ski, resulting in partial interlocking of the boot and binding. Skiing scenarios and M_z magnitudes appear predictable through hall sensors integrated into the binding lugs. Our study provides crucial insights into ski binding dynamics, laying the groundwork for future advancements in sophisticated and cost-effective mechatronic bindings.

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RECYCLING PROCESSES FOR MORE SUSTAINABLE SAFETY SPORT EQUIPMENT

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Keywords: sustainability, recycling, helmets, body protectors

INTRODUCTION. Most sport equipment ends up in landfills due to significant challenges in recycling their complex, multi-material composition, thus impacting overall sports equipment sustainability. Since conventional separation techniques and recycling methods (e.g. chemical and mechanical recycling) have proved to be ineffective, particularly with multi-injected, glued, or foam materials, we have developed new advanced recycling methods for an efficient recycling of sport equipment. In particular, we have applied dissolution recycling, rebonding, and AIR-LAY processes for the recycling of end-of-life helmets and body protectors. Dissolution involves the use of solvents that selectively dissolve specific materials, allowing filtration and recovery without modifying their molecular structure. Rebonding consists in mixing the grinded materials with polyurethane monomers in a mold, while AIRLAY utilizes bicomponent fibers to create non-woven fabric binders through heating and compression. In this communication we report the recycling processes for ski helmets and back protectors, using eco-friendly solvents and applying rebonding and AIRLAY methods.

METHODS. Solvolysis-based recycling process has been applied to a ski helmet using Limonene and ethyl acetate as natural solvents. Limonene, derived from citrus fruit skin, dissolves the expanded polystyrene (EPS) in just 10 minutes at room temperature, that is then recovered through precipitation in ethanol. The ABS outer shell has been then selectively dissolved in in ethyl acetate at 60°C for 2 hours, and the polymer was recovered via solvent evaporation, with both solvents fully reclaimed for their reuse. Polycarbonate (PC) was separated from lenses by filtration, while the remaining parts of the helmet has been recycled using an air-lay binding process. Mechanical tests have been performed using ISO 527 and ISO 180 standards on injection-molded samples. Standard production methods have been used to create helmet parts with the recycled materials, evaluating the molecular weight through GPC analysis. D3O back protectors have been mechanical recycled by rebonding with a polyurethane pre-polymer at 200°C. AIR-LAY was performed using 10% of PP/PE bi component fibers, heated between 140 and 160 °C to melt the external layer of the fibers. Impact drop tests have been executed according to the EN 1621-1 and EN 1621-2.

RESULTS. EPS, PC, and ABS (which constitutes more than 85% of the helmet weight) have been recovered at 95% efficiency and 99% purity, as confirmed by FTIR and NMR analysis. The recycled polymers properties closely match those of virgin materials, indicating that no chemical degradation occurs during recycling. The materials obtained from the rebonding and AIRLAY processes have impact properties below those of virgin foams.

DISCUSSION AND CONCLUSIONS. The recycling from end-of-life helmets produces high-quality materials, that maintain mechanical and impact resistance performances similar to those of the virgin polymers and above the threshold used by industrial manufacturers for materials to be used for the construction of helmets. Therefore, we have used the recycled materials for the production of the parts of new helmets: ABS for shells, re-expanded EPS for helmet padding and PC for spoilers, thus demonstrating that a circular approach for the recycling of end-of-life helmets is possible. On the contrary, the mechanical proprieties of the recycled foams from end-of-life body protectors do not permit their re-use in the same application.

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Assessing Compatibility of Ski Boots and Bindings using ASTM F504

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Keywords: Ski bindings, ski boots, injury prevention, multi-norm

INTRODUCTION. Ski-binding-boot (SBB) systems were developed to reduce the likelihood lower leg fractures. Alpine SBB systems and their associated international standards have been credited with reducing significantly the incidence of tibia and fibula fractures [1]. On-piste loads measured at the binding-ski interface during falls are complex [2]; there are often large downward and lateral force components applied to a ski during a forward or backward twisting fall. Despite these data, ski bindings are required to meet only ISO 9462 or 13992 that model forward and backward twisting falls using basic preloads on the ski and pure twisting moments (couple); these standards require that the forward and backward preloaded releases be within 35% or 25% of the unloaded release torques. With the advent of touring and walking SBB systems, there has been concern that the ISO standards cannot determine compatible ski boots and bindings, especially for forward and backward twisting falls (when one would most need the SBB to work properly). Standard ASTM F504 is an alternative binding test method that offers more complex loading to model forward and backward twisting falls (Tests 1.6 and Test 1.10). In order to use ASTM F504 to evaluate SBB system compatibility, the acceptable release ranges for modeled forward and backward falls needs to be specified. We suggest using the ranges allowed by the alpine only SBB systems that have been so successful at reducing the incidence of mid-shaft tibia fractures. To this end, we tested alpine only bindings to determine their response in the forward and backward twisting falls modeled by ASTM F504.

METHODS. 10 new alpine ski bindings were tested using ASTM F504 and an ISO 9383 alpine test sole. Using the release setting for skier codes J, L, or N (chosen in a random order), an alpine ski binding was set to a release value and checked using a twisting release with no preloads and a pure couple (Test 1.1), both dry and wet. In a random order, simulated forward and backward twisting falls (Tests 1.6 and 1.10) were tested wet, with 9 tests in each condition.

RESULTS. 1116 tests were conducted. There was no significant difference between ASTM F504 Test 1.1 dry and wet; see Figure 1. For the modelled forward and backward twisting falls (Tests 1.6 and 1.10), the percent increase above Test 1.1 dry was less than 35% and 46% for the products tested (not considering outliers).

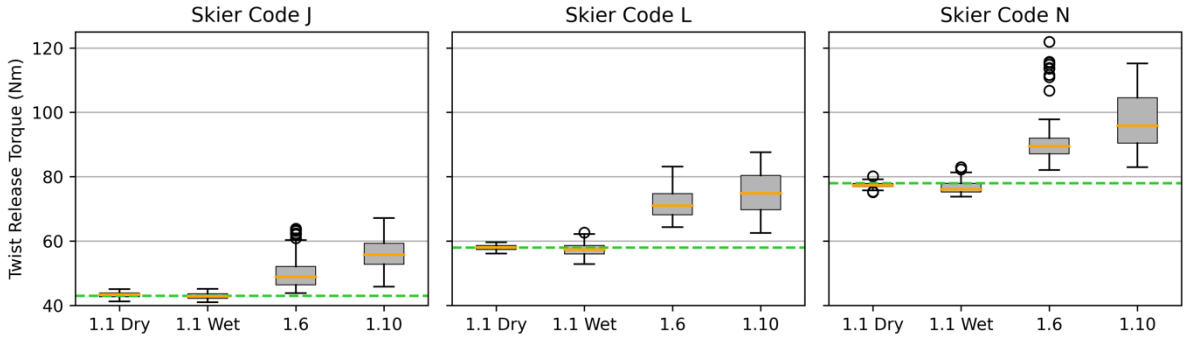

Figure 1. Box plots of twisting release torques for 3 indicator settings (related to skier codes J, L, and N) for ASTM F504 Tests 1.1, 1.6, and 1.10. The dashed green line is the reference release torque for the skier code.

CONCLUSIONS. Based on the response of alpine SBB systems, we recommend that all new SBB systems be evaluated with ASTM F504 and that the release torques for Tests 1.6 and 1.10 be within 35% and 45% of the Test 1.1 release value. This would apply to new touring, walking, and multi-norm SBBs.

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REDUCING SNOWBOARDING WRIST INJURIES: PROGRESS AND RECOMMENDATIONS

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Keywords: Certification, Injury, Impact Testing, Surrogate, Protective Equipment

INTRODUCTION. ISO 20320:2020 is the first standard for snowboarding wrist protectors (British Standards Institution, 2020). The International Society for Snowsports Safety formed a working group in 2011 to develop this standard (Allen *et al.*, 2019). This development was due to a prevalence of snowboarding wrist injuries (Michel *et al.*, 2013). Adoption of ISO 20320:2020 is needed to help reduce snowboarding wrist injuries. Here we summarise ISO 20320:2020, while outlining progress and making recommendations to maximise its impact.

METHODS. ISO 20320:2020 has a *Limitation of wrist extension* (5.8) test, where the product is fitted to a wrist surrogate, a torque is applied to the joint and the angle is measured. The torque is then increased, and the angle is remeasured. For each applied torque, the wrist angle must be within a specified range to pass. The standard also has an optional test termed *Impact performance* (5.7). For this test, the product is secured to an anvil with the palm facing up, a mass is dropped onto it and the force measured. The force must be below a specified limit to pass.

RESULTS. ISO 20320:2020 certified products are now available to snowboarders, e.g., German brand Ziener (Bavaria, Germany) show them on their website (e.g., MILO AS® GLOVE SB). The publication of ISO 20320:2020 has also helped to progress research on wrist protectors. Leslie *et al.* (Leslie *et al.*, 2023a) assessed the repeatability of a test based on ISO 20320:2020 *Limitation of wrist extension*. There has also been work on more realistic surrogates, such as the addition of soft tissue simulants (Leslie *et al.*, 2023a; Leslie *et al.*, 2023b) and exploring the feasibility of printing synthetic bones (Leslie *et al.*, 2023c).

DISCUSSION AND CONCLUSIONS. Having ISO 20320:2020 certified products available is a key step towards potentially reducing the risk of snowboarding wrist injuries. Future work should help bring more ISO 20320:2020 certified products to the market, raise awareness of them among snowboarders and monitor whether they effect injury rates. Researchers should continue to critique ISO 20320:2020 in preparation for its first review in 2025. For example, the *Limitation of wrist extension* test could be updated to ensure it is more repeatable (Leslie *et al.*, 2023a), and accessible to brands who are developing products.

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EVALUATING HELMETS ANTI-ROTATIONAL TECHNOLOGIES EFFECTS ON SKULL AND BRAIN KINEMATICS USING A BIOFIDELIC SENSORISED HUMAN HEAD REPLICA

E. Baldoin[1]*, G. Zullo[1], P. Carraretto[1] & N. Petrone[1]

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Keywords: TBIs, rotational impacts, helmet, protection effectiveness, Human Head Replica

INTRODUCTION. Modern helmets incorporate Anti-Rotational Technologies (ART) to mitigate Traumatic Brain Injuries (TBIs). The modern methodology to test helmets uses rigid headforms and numerical models of the human head to assess brain damage. However, standard rigid headforms lack biofidelity, and validating finite element models is challenging due to limited cadaver data availability. Hence, an Instrumented Human Head Replica (IHHR) equipped with sensorised cerebrospinal fluid-meninges-brain simulants is under testing at the Department of Industrial Engineering (DII) of Padua University [1] [2]. This study aims to use embedded sensors on the IHHR to evaluate the effectiveness of a motorcycle helmet in rotational impacts, with ART and balaclava.

METHODS. A tower setup (ECE22.06 standard) was used for drop tests onto a 45° inclined anvil, instrumented with a 44 kN load cell. Protected tests (Alpinestars, SM8) with the IHHR were conducted from three heights (1, 1.5, and 2 m), with and without MIPS^{TM} ART and balaclava. Data from a palate 6DX PRO-A accelerometer (±500 g) and gyro (±8000 °/s) and a brain CoM gyro (±2000 °/s) were recorded at 10 kHz. In addition to Brain Injury Criterion (BrIC), the skull-brain relative angular velocities (magnitude differences) and the PRA [rad/s^2] were computed. Statistical analyses explored the effect of height, ART, and balaclava on brain rotation assessment.

RESULTS. Statistical analyses suggested a significant impact on the BrIC for both ART and height (p-values<0.001, η^2=0.40), along with their interaction (p-value<0.001, η^2=0.13), with a negligible effect of the balaclava. Moreover, both ART (p-value=0.02, η^2=0.35) and drop height (p-value=0.03, η^2=0.62) apparently influenced the maximum skull-brain relative angular velocity, while their interaction and balaclava usage were deemed negligible. An example of ART effect on skull-brain relative angular velocities and skull PRA for the drop tests conducted from 2 m, without and with balaclava, is shown in figure.

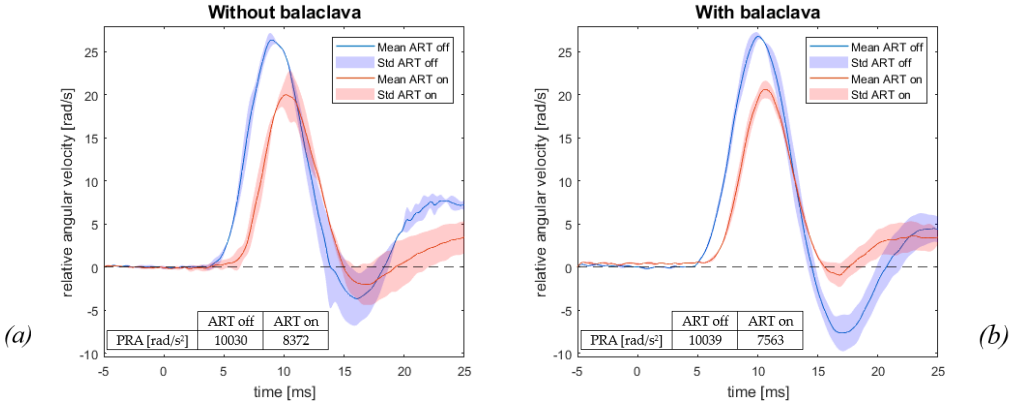

Figure *Assessment of skull-brain relative kinematics for drop tests from 2 m without (a) and with (b) balaclava.*

DISCUSSION AND CONCLUSIONS. The impact of the adopted ART on BrIC reduction appears to be affected by drop height. Moreover, the reduction of friction induced by a balaclava doesn't seem to be as effective as the ART. Since BrIC definition considers only skull kinematics, the influence of the factors on relative skull-brain motion was evaluated, showing that both ART and height seem to affect the relative angular velocity, whereas their interaction and balaclava usage don't appear influent. In conclusion, the tests provide valuable insights into the impact of different factors on TBIs. Next analyses will focus on brain stress and intracranial pressure to complete the overall evaluation of the ART, exploiting the full capabilities of the IHHR.

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Safety Evaluation of a Snowboarding Back Protector: A Focus on Backward Fall Protection

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Pierre-Jean Arnoux[1,2], Lionel Thollon[1,2], Nicolas Bailly[1,2]

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[3] *Decathlon SportsLab, Lille, France*

Keywords: snowboarding, back protector, injury, finite element, testing standard

INTRODUCTION. In winter sports, particularly snowboarding, the utilization of back protector (BP) devices has seen a notable upsurge as a proactive measure to mitigate spinal and back injuries [1]. However, no evaluation has been conducted to assess the effectiveness of BP devices in mitigating or preventing injuries specific to winter sports. Our prior investigation [2], utilizing numerical simulations, identified four scenarios of snowboarding backward falls resulting in spinal vertebrae and ribcage fractures. Building upon this foundational work, the objective of this study is to numerically model and assess the performance of a commercial winter sport BP in mitigating injuries across the previously-identified accident scenarios.

METHODS. Square-shaped foam samples, measuring 40*40*12.5 mm, were excised from a commercially available winter sport BP. These foam specimens underwent testing, subject to uni-axial compressions at nominal speeds of 0.01m/s, 0.10m/s, 1.00m/s, and 2.00m/s (Fig A), employing a servo-hydraulic Mechanical Test System (Landmark 370.10, MTS, Eden Prairie, MN, USA). Drop tower tests were also conducted to the foam samples at heights of 0.35m, 0.50m, 0.65m, and 0.80m, utilizing a 7.14kg drop mass. Finite Element (FE) modeling was executed to simulate these tests, wherein the foam was represented as Fu-Chang foam material exhibiting rate-sensitive loading behaviors. Stress-strain curves were calibrated to align with force time-histories within experimental measurement corridors. The BP was then modeled using the calibrated foam material properties and validated against drop tests from 0.6m and 1.5m, applied to three distinct impact regions (Fig B). The validated FE model of BP was finally integrated to four previous snowboarding backward fall simulations (a vertical impact velocity of 2.4m/s to the snow ground) [2] resulting in spine and ribcage fractures so as to identify whether the BP may mitigate impact loadings and protect snowboarders in such conditions (Fig C).

RESULTS. The BP mechanical responses were well modeled, aligning closely with the impact force time-histories within the experimental corridors of drop tests (Fig B). Wearing the BP significantly diminished the peak effective plastic strain (EPS) of the spinal cortical bones, demonstrating a notable reduction (0.037~0.118 with BP vs. 0.086~0.199 without BP) and resulting in only one case of spine fracture, in contrast to four cases without the BP, across the four simulated falls. However, the peak EPS of the ribcage consistently registered higher values when wearing the BP (0.500~0.169 with BP vs. 0.012~0.132 without BP), leading to three cases of ribcage fractures compared to a single case without the BP.

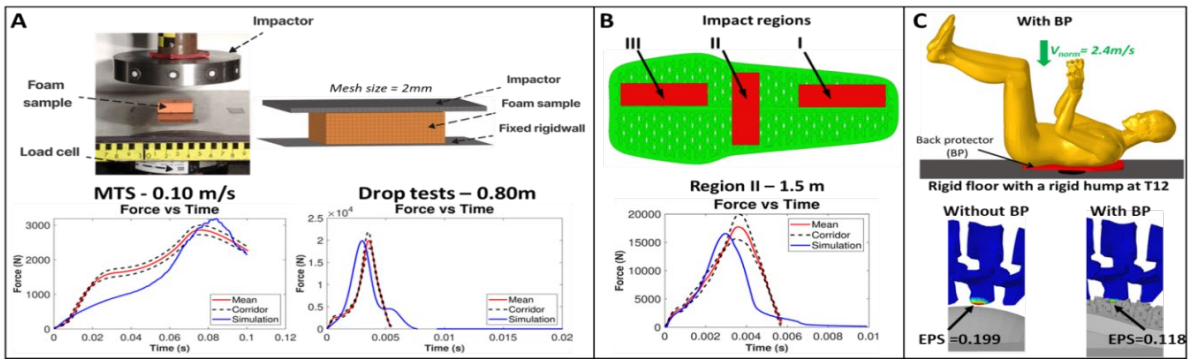

Figure FE modeling and safety evaluation of BP: *A) mechanical characterization of the foam, B) BP model validation against drop tests, C) reduction of impact loadings to the spine with BP in snowboarding backward falls*

DISCUSSION AND CONCLUSIONS. While the simulated BP effectively reduced impact loadings and mitigated injuries to the spine during these falls, the diminished loadings to the spine were seemingly transferred to other thoracic organs, such as the ribcage. This transfer of loadings may potentially elevate injury risks to corresponding organs. Consequently, there arises a need for further optimization of the BP's protective performance to strike a balance in injury mitigation across the entire thoracic region.

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The Effect of Winter Gloves on Grip Strength and Hang Time

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[2]*Department of Mechanical Engineering, University of Washington, Seattle, WA, USA*

Keywords: Grip strength, grip endurance, gloves, dead hang times, chairlift

INTRODUCTION. Ski areas transport regularly patrons on chairlifts; while falls from chairlifts are rare [1], there exists a potential for passengers to become unseated. In these situations, passengers may attempt to grab a chair structure (bale, armrest, restraint bar, etc.) to prevent or delay their fall. While extensive research exists on grip strength and endurance in cold and gloved conditions, there is sparse information in the scientific literature on the effect of ski specific gloves on grip strength and dead hang time [2]. To better assess how long a skier or snowboarder can reasonably support their weight while hanging from chairlift structure, we examined the effects of ski gloves on grip strength, grip endurance, and dead hang times.

METHODS. For each participant, their height, weight, and hand dimensions were measured, and their sex, age, dominant hand, and preferred glove size were documented. Participants selected their preferred size of men's or women's ski gloves for the testing. Dead hangs (DH) from a 3.5-cm diameter metal bar were conducted in both bare-handed and gloved conditions; DH time was measured with a stopwatch and verified by video. Each participant's maximum grip strength (MGS, kg) and 70% maximum grip strength endurance (70MGSE, sec) were measured using a dynamometer (G2000 Hand Grip Dynamometer, Biometrics Ltd) set at 3.5-cm and a stopwatch in bare-handed and gloved conditions. Between trials, participants rested to avoid fatigue. All tests were conducted at ambient temperatures. T-tests were performed to determine significant differences between the gloved and bare-handed conditions for males and females.

RESULTS. 38 subjects (19 females, 19 males, mean age = 35 ± 10 years) participated in the study. The mean MGS in the bare-handed condition was 23.2 ± 4.6 kg for females and 33.1 ± 6.4 kg for males ($p<0.001$); box plots of the results are provided in Figure 1. When gloved, MGS decreased 29.5% on average for females ($p<0.001$) and 24.2% for males ($p<0.001$). There was no significant difference between 70MGSE between females and males for the bare-handed or gloved conditions; ski gloves did not decrease significantly 70MGSE for males, but lowered 70MGSE for females by 47.5% ($p<0.001$). On average, females were able to dead hang for 44.4 ± 23.2 sec and males for 77.7 ± 37.4 sec when bare-handed. When wearing ski gloves, DH times decreased by an average of 67.7% for women ($p<0.001$) and 44.8% for men ($p<0.005$).

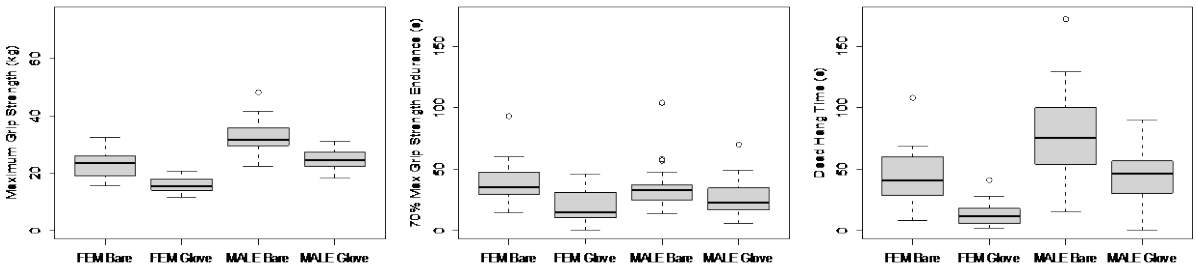

Figure 1. Box plots of MGS, 70MGSE, and DH time for females and males in the bare-handed and gloved conditions.

DISCUSSION AND CONCLUSIONS. Ski gloves decreased significantly MGS and DH times for both males and females. Ski gloves for females decreased MGS, 70MGSE, and DH times more than males; this may be due to differences in hand size relative to the ski glove thickness. DH times were decreased significantly with ski gloves, more so than would be expected by the percent decreases in MGS and 70MGSE. Ski gloves would likely significantly decrease the time a skier could hold onto a chair component after becoming unseated.

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A NOVEL METHOD TO EVALUATE THE PERFORMANCES OF ANTI-ROTATIONAL ACCELERATIONS SYSTEMS USED IN PROTECTION HELMETS.

Giuseppe La Fauci[1], Daniel Colombo[1], Mariafederica Parisi[1], Lorenzo Crosetta[1], Filippo Biagi[1] & Martino Colonna[1]

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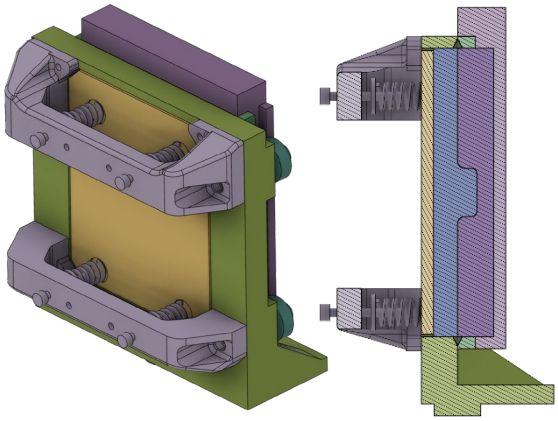
Keywords: Rotational Accelerations, Tangential Impacts, Helmet, Impact Test

INTRODUCTION.

The use of systems that protect the brain from rotational accelerations (hereinafter referred to as anti-rotational) in the case of tangential impacts, is rapidly spreading across all sectors of protective helmet applications. To effectively assess and compare the protective performance of these systems, it is necessary to develop a testing method able to evaluate their efficiency independently from the protective helmet on which they are installed.

METHODS.

A comparator for anti-rotational systems has been designed, using a frame composed of two parts: one fixed and one sliding aimed at simulating the interface between different protective layers. Both parts of the comparator feature a cavity designed to accommodate a rectangular specimen containing the system under test. The sliding motion of the two parts simulates the relative translation that occurs in the case of tangential impacts. Through the use of a drop weight machine and a platform with load cells, it was possible to impart a purely tangential movement and measure the amount of energy absorbed by the system following the impact.



To simulate the contribution of the orthogonal component, an adjustable preloading system has been integrated into the fixed part to allow the simulation of the pressure, and consequently the friction generated on the contact interface between the two specimens.

RESULTS.

This device allowed us to compare a commercial anti-rotational system (MIPS) with our in-development system (O-Damp) [1] under identical conditions. Three impacts of 15 J were applied to both systems, with a total preload of 760 N, and the load transmitted to the cells was measured. Consequently, the difference in energy absorbed between the two systems during impact was determined. Specifically, the O-Damp system exhibited a 7.5% reduction in the transmitted load.

DISCUSSION AND CONCLUSIONS.

The method has proven effective in determining the energy absorption performance provided by the tested systems, but it certainly requires further testing to establish its accuracy and repeatability. It should be noted that validation through comparison with impact tests on the complete helmet may provide additional data to assess the method's validity. We will proceed with the development of the device to refine it and ensure the reliability of the method in evaluating the performance of commercial anti-rotational systems. This effort will be accompanied by ongoing refinement of our proprietary system through tuning and optimization.

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WEDNESDAY (13. 3. 2024)

7:30 Skiing day in Nassfeld

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THURSDAY (14. 3. 2024)

8:30 TECHNOLOGIES (Session chair: Rick Greenwald):

- F. Bürgi, J. Rita Vetsch, L. Ellenberger: PREVIMAP – SYSTEMS THINKING IN INJURY PREVENTION
- C. Thorwartl, A. Tschepp, M. Zirkl, H. Holzer, T. Stöggl: VALIDATING PRINTED SENSORS FOR ALPINE SKI TORSIONAL DEFLECTION ANALYSIS IN THE LABORATORY
- S. A. Siddiqui, M. Hasler, J. van Putten, M. Mössner, W. Nachbauer: UNVEILING FRICTION-INDUCED LIQUID WATER USING HUMIDITY INDICATOR CHEMICAL
- D. Petrella, L. Ellenberger, F. Bürgi, M. Gilgien: ACCURACY OF SMARTPHONE GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)-DATA FOR ASSESSMENTS IN RECREATIONAL ALPINE SKIING
- J. Isaacs, J. Mortensen, K. O'Brien, S. Imler: WEARABLE DEVICES CAN DETECT DIFFERENCES IN ALPINE SKI ABILITY

10:00 Coffee break

10:30 BIOMECHANICS 2 (Session chairs: Flavia Bürgi & Nina Verdel):

- I. Steineck, U. G Kersting, N. Kurpiers: EFFECTS OF GUIDING VARIANTS ON THE BODY POSITION OF BLIND SKIERS
- B. Šimunič, K. Teraž: CORRELATION OF SKELETAL MUSCLE TENSIOMYOGRAPHIC PARAMETERS WITH THE AGE OF ALPINE SKIERS
- K. Teraž, B. Šimunič: TENSIOMYOGRAPHIC EVALUATION OF THE CONTRACTILE PROPERTIES OF SKELETAL MUSCLES IN CORRELATION WITH ANTHROPOMETRIC VALUES IN YOUTH ALPINE SKI RACES
- G. Nan, G. Jianqiao, R. Gexue, J. Huitong, Y. Chun: NUMERICAL ANALYSIS OF ALPINE SKIING WITH A BODY-GEAR-ENVIRONMENT INTERACTION MODEL
- I. Bon, M. Očić, V. Cigrovski, T. Krističević, M. Švegl: DIFFERENCES IN PRESSURE DISTRIBUTION BETWEEN THREE PHASES OF PARALLEL SKI TURN PERFORMANCE

12:00 Lunch

13:30 DIDACTIC SAFETY IN SNOWSPORTS (Session chair: Rado Pišot):

- **Keynote (30 min): R. Pišot, B. Lešnik, M. Lavrič, S. Pišot: DIDACTICS AND SKI INJURIES – SKI INSTRUCTORS' VIEWS ON THE IMPORTANCE OF A DIDACTIC APPROACH TO INJURY PREVENTION**
- M. Majerič, M. Andonovski, G. Nikovski, G. Jančar: SNOWBOARDING INJURIES AND RECOMMENDATIONS FOR THEIR PREVENTION IN PRIMARY AND SECONDARY SCHOOL PROGRAMS
- U. Marusic, B. Vadnjal, R. Pisot: NEUROPLAY INSIGHTS FOR SKIING: PREPARING YOUNG AND ELDER GENERATIONS FOR ENHANCED SKI EXPERIENCES
- A. Gobbi, R. De Filippi, S. Droghetti, L. Colleoni and M. Cristoforetti: SAFE INDEX: CLASSIFYING SKI INJURIES SEVERITY BASED ON AI
- V. Stijepovic, M. Markovic: ROLE OF SPORTS ON SNOW AS CULTURAL EDUCATION FACTOR IN CHILDREN AND YOUTH

15:00 coffee break

15:30-16:30 Round table – Didactic safety

17:00 SAFE RACE

19:00 SLOVENIAN NIGHT

PreviMAP – Systems thinking in injury prevention

Flavia Bürgi[1]*, Jolanda Rita Vetsch[1] & Lynn Ellenberger[1]

[1] *BFU – Swiss Council for accident prevention*

Keywords: systems approach, injury prevention, skiing and snowboarding

INTRODUCTION. The systems approach is a holistic method, examining interconnected components to understand and address complex issues comprehensively. It is therefore beneficial and widely used in developing more effective and sustainable solutions in fields such as engineering, management, ecology, and public health. The goal of this project was to adapt and apply the systems approach to injury research in snow sports, aiming to create a holistic prevention tool.

METHODS. Existing system thinking tools described in the literature, such as Rassmusen's AcciMap (Rasumssen 1997) or Salmon's adapted AcciMap for led outdoor activities (Salmon 2022) were used and further developed into the "BFU-PreviMAP", representing the setting "skiing and snowboarding on slopes in Switzerland". Further, the PreviMAP was consolidated with various snow sports experts.

RESULTS. The PreviMAP is a structured and systematic visualisation of factors influencing the occurrence of accidents, taking into account the entire system of skiing and snowboarding on slopes. The influencing factors are visualised in six different levels (Figure). Factors on the three lower levels describe the accident event. They directly affect the accident and are therefore also the most obvious, such as wearing a helmet. The three upper levels describe the prevailing framework conditions. The influencing factors on these levels affect the accident indirectly, and their contribution to the accident is often less obvious, such as regulation.

Figure: PreviMAP skiing and snowboarding on slopes (simplified)

Level	*Influencing factors*				
Society	Values and social norms	Economy and technology	Knowledge and interests	Social trends	
Regulation	Public regulation		Private regulation		
Services	Information	Training programmes	Led activities or products	Rescue	
Nature & Environment	Terrain	Conditions	Slopes	Other infrastructure	
Equipment	Sports equipment	Protective equipment	Resources	Emergency equipment	Other tools/devices
Humans/People	Individual preconditions	Situational factors	Social interaction		

DISCUSSION AND CONCLUSIONS. By the development of the BFU-PreviMAP a systems approach was applied to injury prevention in snow sports on slopes for the first time. This allows to identify and address the root causes and complex interactions that contribute to injuries, leading to more effective and sustainable prevention strategies. Rather than focusing on isolated factors, the PreviMAP considers the interrelated elements that influence the occurrence and prevention of injuries.

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Validating Printed Sensors for Alpine Ski Torsional Deflection Analysis in the Laboratory

Christoph Thorwartl [1], Andreas Tschepp [2], Martin Zirkl [2], Helmut Holzer [3]*, & Thomas Stöggl [4,5]

[1] *Salzburg Research Forschungsgesellschaft mbH* [2] *Joanneum Research Forschungsgesellschaft mbH*
[3] *Atomic Austria GmbH* [4] *Red Bull Athlete Performance Center* [5] *University of Salzburg*

Keywords: alpine ski, flexion, PyzoFlex, ski deflection, torsion sensors, torsional angle

INTRODUCTION. Recently, a PyzoFlex® ski prototype was developed to assess the curvature characteristics of alpine skis (Thorwartl et al., 2023a). This prototype not only measures curvature based on ski bending but also demonstrates potential in detecting torsional deformations (Thorwartl et al., 2023b). However, sensor calibration and a comparison with a gold standard have not yet been performed. Therefore, the objectives of this work were (i) to identify an appropriate printed sensor layout for torsional measurements, (ii) to calibrate the sensors with respect to torsional angle, and (iii) to assess validity of the sensor based torsional deformation concept.

METHODS. Three different sensor layouts (radial, cross, rectangular) were designed and instrumented at the same position on the ski (position 2, Figure 1). By the use of a pivot bearing the ski was torsional deformed, and the difference signal Δx, measured in volts (DAQ: Customized Dewesoft Sirius), was recorded for the corresponding sensor layouts: $\Delta x = (L_1 + R_2) - (L_2 + R_1)$. The sensor layout that showed the highest discrimination in terms of Δx was chosen and placed at positions 1, 2, and 3 according to Figure 1. The sensors were calibrated using a two-point method, with parameters derived from the initial measurements at position 2. The ski underwent deformation at three bending levels (0 N, 100 N, 230 N) and three torsion levels (4.5°, 9.5°, 14°), with bending applied to the ski centre and torsion applied to the ski shovel. All variations (bending and torsion) were measured three times. This series of measurements was conducted for both left and right-sided torsional deformations. The maximum value of Δx (in °), corresponding to the peak deformation, was detected. Pearson's correlation coefficient (*r*) evaluated the criterion validity between PyzoFlex® and the reference system (angle encoder). Furthermore, the agreement between the sensor system and the reference system was assessed using systematic bias, standard deviation (SD), and Limits of Agreement (LoA).

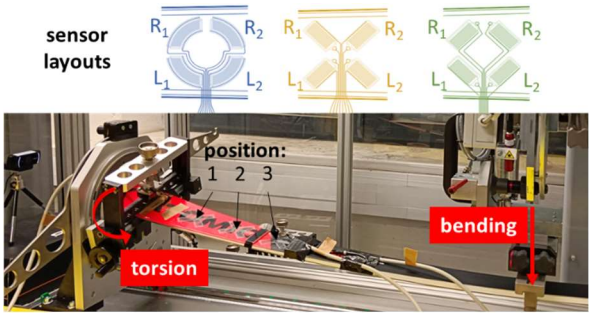

Figure 1. *Measurement setup*

RESULTS. In the initial measurements, the orange sensor layout (crossed, Figure 1) exhibited the best discrimination in terms of Δx. As a result, this sensor layout was selected for further investigations. The magnitude of the linear relationship between the angle encoder and the PyzoFlex® systems, expressed by *r*, was 0.998. The systematic bias measured 0.12°, while the SD was 0.42°, and the LoA ranged from -0.70° to 0.94°.

DISCUSSION AND CONCLUSION. High correlation (r = 0.998) between the sensor-derived and encoder-captured torsional angles confirms strong validity of the proposed concept. The sensor system demonstrated a high level of accuracy, with a systematic bias of 0.12°. The signal's precision, as indicated by SD and LoA, is suitable in the laboratory, where individual torsion levels are easily distinguishable (torsion range of ± 12°). Nevertheless, the question is whether the precision is adequate for field measurements, as field torsion angles can be very small and, consequently, more challenging to distinguish. Therefore, future snow measurements are needed to verify the approach described above. However, detecting ski deflection, both bending and torsional, is valuable not only for optimizing performance but also for ensuring safety when selecting the appropriate ski for product fitting.

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Unveiling friction-induced liquid water using humidity indicator chemical

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Keywords: ski friction, frictional meltwater, crystal violet, color histogram

INTRODUCTION. The fascinating friction properties of ice and snow providing exceptionally low friction coefficients is the basis of majority winter sports. The early theory of ice-slipperiness due to pressure melting [1] is disregarded and the frictional heating approach considering the formation of water layer is widely accepted [2]. Considering the ski-snow system, frictional meltwater formation [3] reduces the friction facilitating the easy gliding. However, conclusive evidence regarding the formation of this meltwater layer is contentious. We present a novel approach of applying a humidity indicator, like crystal violet, to the snow surface and detect the change in its color in response to the formation of meltwater. Crystal violet is a cationic dye and widely used as a purple dye for textiles and printers.

METHODS. The tests were performed at the snow lab of the Research Center Snow, Ski and Alpine Sports at the University of Innsbruck (Austria) on a linear tribometer with sliding surface 24 m length [4]. Three different snow temperatures of -1 ºC, -3 ºC and -5 ºC were selected. A XC ski (Salomon LAB WC Equipe 10 Skate, 192 cm) was moved at a sliding speed of 15 m/s. The normal load was 430 N. The experiment at different snow temperatures was repeated five times on each of the eight snow tracks.
The chemical crystal violet was sprayed over the snow surface using a pump sprayer. During the entire measurements the snow surface was filmed with a digital camera and regular monitoring and record of snow temperature was kept. The image taken before, during and after the run was analyzed through histogram that provides image's tonal information, statistical distribution delineating pixel intensities, frequencies enabling comprehensive characterization.

RESULTS. The histogram of the image before the start of ski gliding shows marked divergence from the after-run image indicating substantial alteration in pixel intensity distribution. The change in the spectrum of color distribution was most pronounced at -1 ºC (close to the melting point) where most water formation, presumably takes place as compared to the other lower temperatures (-3 ºC and -5 ºC). This change occurred due to the structural modification i.e., when positively charged carbon (in crystal violet) makes a covalent bond with the hydroxyl ion (OH^-). Due to the movement of the ski on snow surface, the water formation facilitated the chemical reaction resulting in the discoloration of crystal violet. The color change indicated water formation.

DISCUSSION AND CONCLUSIONS. The present study indicated the generation of frictional meltwater. We disregard the color change due to reaction between water present in snow and the used chemical. In our opinion, the color change is due to formation of meltwater caused by frictional heating. This approach offers a promising avenue for the detection of frictional meltwater. The phenomenon of color change of crystal violet due to reaction with hydroxyl ion is well-known. The response of crystal violet in contact with the formed liquid water provides good evidence for unraveling and further understanding the mechanism of ski-snow friction. The analysis is semi-quantitative and requires more precise techniques like thermal imaging using high resolution infrared cameras or measuring the dielectric properties of snow.

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Accuracy of Smartphone Global Navigation Satellite Systems (GNSS)-Data for assessments in recreational Alpine Skiing

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Keywords: position, tracking, kinematics, snow sports, alpine skiing, GNSS

INTRODUCTION. Current smartphones come with on-board GNSS units that allow for position and time logging. The position-time logging functionality is used by a variety of smartphone apps that were tailored to track alpine skiing and snowboarding activity. The apps typically provide information on the number of runs, their altitude drop, speed, and the position-time data is also used to visualise skiing activity on maps. Most of these apps are developed for entertainment purposes and to raise awareness of skiing/snowboarding. To evaluate whether the smartphone based GNSS tracking could also be used to describe the behaviour of recreational alpine skiers on public slopes in terms of slope preference and speed, this study examined the accuracy and precision of GNSS data obtained from tracking apps in alpine skiing collected by smartphones. A pre-study found that smartphone GNSS horizontal position error showed promise. To evaluate the impact of smartphone type and ski/snowboard app on accuracy, a variety of smartphones, apps, and settings were compared to a reference method for position and speed during recreational alpine skiing.

METHODS. A field study was conducted during three days in the winter of 2022/23 in ski resorts with representative GNSS conditions in terms of terrain and exposure (primarily north facing slopes in Davos and Saas Fee, Switzerland). Four different smartphone devices and six tracking apps were chosen for the GNSS accuracy assessment. Two recreational skiers were equipped with smartphones and an industrial-grade GNSS-aided inertial navigation system (GNSS/INS) (AsteRx-i S, Septentrio) which served as a reference. Differential GNSS/INS position time data were processed at 50 Hz from the GNSS/INS on the skiers and a local GNSS base station. Data were evaluated using MATLAB R2022b (MathWorks, Natick, MA, USA). The initial five minutes of each measurement were excluded from the analysis due to elevated errors attributed to the initial GNSS system's location optimization. The speed was calculated from the position-time data. Position, time and speed were calculated for each tracking app and smartphone type. For the accuracy assessment, the data was time synchronized using the systems' GPS time. Subsequently, the errors in position [m] and speed [m/s] were calculated by determining the norm difference between the smartphone/app data and the reference system.

RESULTS. Results revealed significant variations between all smartphone devices ($p < 0.001$). The mean (± SD) position error for the best devices was 2.8 ± 1.8 m, contrasting with the poorest performer at 8.1 ± 7.8 m. However, speed, calculated as position-time derivative, had satisfactory accuracy for all smartphones, with average errors ranging from 0.7 ± 0.7 m/s to 0.9 ± 1.0 m/s during skiing. Apps, on the other hand, demonstrated mean position errors ranging from 3.6 ± 4.1 m to 5.8 ± 6.0 m and mean speed errors ranging from 0.8 ± 0.9 m/s to 0.9 ± 0.9 m/s. Accuracy was substantially compromised during the first minutes of GNSS logging.

DISCUSSION AND CONCLUSIONS. Currently available smartphone GNSS-data exhibit significant potential to describe recreational skiing and snowboarding on snow sports slopes. Depending on the research question the absolute position accuracy may be comprised, since the horizontal plane position ranged from several meters to decameters. With appropriate processing, reliable velocity calculations can be obtained, allowing the data to be used to characterise the skier's or snowboarder's gross kinematic motion.

WEARABLE DEVICES CAN DETECT DIFFERENCES IN ALPINE SKI ABILITY

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Keywords: skiing, kinematics, inertial measurement units (IMUs), OpenSim, wearables

INTRODUCTION. The application of wearable technology to the use case of alpine skiing has been documented for a variety of factors including, but not limited to, speed determination, explicit training parameters, and overall performance (Fasel 2017, Supej 2021, Martinez 2021, Yu 2016). Largely, the focus to date has been quantifying data for high-performance athletes. In the current study, we addressed this constraint, using wearable technology to differentiate skiers of various abilities via comparison of quantifiable metrics informing whole-body kinematics.

METHODS. A pilot study was performed on a single day with 3 volunteer participants, with each being of a different self-reported ability level: novice, intermediate, or experienced. All testing was conducted at Wachusett Mountain in Princeton, MA, USA. A suite of sensors was worn by each participant including: 10 inertial measurement units (IMUs, Vicon BlueTrident) affixed to the skis, lower legs, thighs, sacrum, upper back, neck, and helmet; Polar H10 heart rate monitor; and Garmin ForeRunner 745 smartwatch. The participants took several runs along the same beginner-level trail and were instructed to ski as they nominally would for the conditions. The sensor-derived data collected for each participant during each of these runs was subsequently time-aligned, processed, and analyzed in MATLAB and OpenSim, from which, a series of explicit body dynamical metrics were generated and compared.

RESULTS. The IMU-derived metrics were considered for discretizing skier ability, as well as determining the minimum number of sensors required to do this successfully. It was determined that five IMUs (i.e., lower legs, thighs, and sacrum) was sufficient for this purpose. Using data from each participant for a common run, one such metric, the inter-ski distance, was quantified in OpenSim using the five IMUs, and the average distance over specific sections of the run were calculated (Fig. 1B). For these same sections of the run, the turn frequency was calculated in MATLAB using *only* the pelvis IMU (Fig. 1C). Finally, GPS data were used to determine skiing speed during these same sections (Fig. 1D). The inter-ski distance of the expert skier was substantially less than that of the other skiers, while both the intermediate and expert skiers demonstrated higher turn frequencies and speed over the given distance.

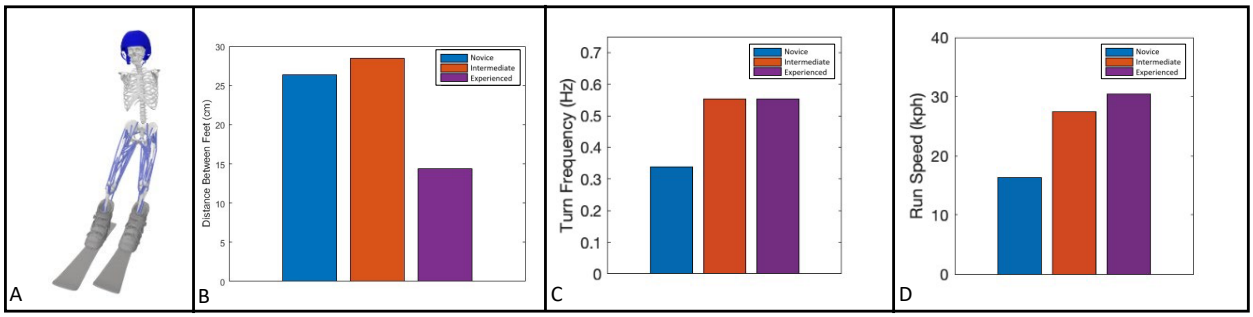

Figure 1: *(A) OpenSim model. Averages of the same run sections: (B) Inter-ski distance. (C) Turn frequency. (D) Speed.*

DISCUSSION & CONCLUSIONS. We were able to differentiate between the three levels of skiers based on kinematics utilizing five IMUs. This approach is extremely non-intrusive and allows for determination of skiing kinematics including visualization of technique in OpenSim. This technology can be utilized for skiers at all levels with minimal setup. Visual observation of technique allows for post-run feedback from instructors. While this pilot study allowed for a proof of concept, it was limited by three individual participants and further exploration requiring a larger cohort is needed to ascertain any conclusions from the data.

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Effects of Guiding Variants on the Body Position of Blind Skiers

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Keywords: Visual Impairment, Adaptive Skiing, Ski Guiding

INTRODUCTION. Experience shows that visual impairment does not keep us from skiing. However, an important factor for the visually impaired skier is the guide, who uses acoustic commands to provide orientation on the ski slope beyond the immediate surroundings (Scherer 2015a, Scherer 2015b). There are several ways of guiding, with the main distinction being that the guide rides in front of (GF) or behind the blind skier (GB). Assuming a proper body position on the skis is not only a necessary prerequisite for parallel alpine skiing, but also a crucial safety aspect. Only if skiers adopt an appropriate body position avoiding backward lean they will be able to control the skis at all times (Kurpiers & Eden 2021). The aim of the study was to investigate the possible effects of the guiding variants on the position of the center of gravity (CG) of blind skiers with respect to the anterior-posterior shift. The secondary aim was to gain insights into the effects of the ways of communication, via a speaker or by voice alone.

METHODS. The study had an explorative design as no scientific studies are known in this area to date. The data were collected in the field with a non-probabilistic sample. The present study comprises 20 participants who tried both guiding variants, allowing for a repeated measures design (GF-GB). The age of the participants ranged from 15 to 60 years and their skiing ability varied from slightly advanced to expert. Nine women and eleven men took part in the study. Data were collected using the Xsens motion capture system MVN Link and analyzed using the Xsens motion capture software MVN Analyze Pro (2023.2), Visual 3d, Excel and SPSS. For data evaluation, six turns were considered in the middle of the respective measurement run. A value of zero means that the CG is above a line connecting the ankles. Positive values show how far the CG is in front of the ankle in the direction of travel. The measurements were carried out on slopes with a slight inclination between 10° and 19°.

RESULTS. A descriptive analysis of the results showed that the averaged CG positions of the two instruction conditions differ by 4.72 cm. As the measured values were not consistently normally distributed, the Wilcoxon Test was additionally used for the analysis of the differences between the conditions which turned out significant (p = < .001).

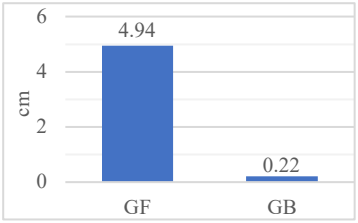

Figure 1: *Mean CG position according to guiding variant*

DISCUSSION AND CONCLUSIONS. This study marks the first effort of physiological field measurements in the area of skiing with blind people including various confounding variables. The results showed that the skiers who were guided from the front lean more towards the direction of motion than those who were guided from behind. These insights in the modification of motion patterns in blind skiers may have elementary implications on teaching approaches and curricula and gives pointers for follow up studies. In the future, the current results can serve as the basis for larger-scale experimental studies. In addition, it is interesting to biomechanically determine a reference value or continuum for the ideal body position independently of blind skiing. In conclusion, the results should be interpreted with care as the sample size was quite small which in turn was due to feasibility and availability reasons.

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Correlation of skeletal muscle tensiomyographic parameters with the age of alpine skiers

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Keywords: Alpine skiing, Tensiomyography, Contraction time

INTRODUCTION. Muscles of alpine skiers do not possess a distinct fiber type composition and, if anything, skiers tend to show a preponderance of slow twitch fibers. This concords with the recruitment of both muscle fiber types. However, older skiers have higher upper leg muscle torque than younger groups (in males and females) and that is generally dependent on age and biological developmental stage, but this dependence was considerably attenuated when body weight was considered. It seems that leg strength and leg muscle composition are independent factors of alpine skiing performance. Therefore, we aimed to show the correlation of muscle contractile parameters, when estimated from Tensiomyography, are correlated to the age of elite alpine skiers.

METHODS. We have assessed 63 elite alpine skiers (21 females), aged between 9 and 32 years. Tensiomyographic parameters (Tc – contraction time; Dm – lateral displacement; Td – delay time) were assessed in ten muscles (VL – vastus lateralis; VM – vastus medialis; RF – rectus femoris; BF – biceps femoris; AL – adductor longus; GL – gastrocnemius lateralis; GM – gastrocnemius medialis; TA – tibialis anterior; GT – gluteus maximus, and ES – erector spinae). We have correlated those parameters with participant's age. Furthermore, we have compared between those who reported their predisposition to speed disciplines or technical disciplines.

RESULTS. Although MANOVA revealed sex differences ($p = .023$) in tensiomyographic parameters between sexes, post-hoc analysis could not point out where those differences are. Therefore, we have decided to pool data for correlation analysis. Age was positively correlated with Td in ES ($r = .34$; $p = .006$), GL ($r = .55$; $p < .001$), VL ($r = .27$; $p = .046$) and GT ($r = .54$; $p = .004$). Further, Tc was positively correlated with Tc in GM ($r = .33$; $p = .020$), GT ($r = .33$; $p = .020$), VM ($r = .36$; $p = .004$) and negatively with BF ($r = -.27$; $p = .035$). No correlations were found in Dm. Participants in speed disciplines ($n = 10$) have longer Td in (ES, GL, GT, TA and VL; $p < .05$), longer Tc (VM and GL; $p < .05$) and lower Dm (GT, RF and TA, $p < .05$) than those of technical disciplines ($n = 21$ to 52, depending on muscle data availability).

DISCUSSION AND CONCLUSIONS. Out of ten muscles, we have confirmed longer Td in four muscles, longer Tc in three muscles, and shorter Tc in one muscle with increasing skier's age. This could be explained by longer training background in older skiers, as we know that skiing performance strongly relates to aerobic capacity of the muscles. Skiers in speed disciplines have longer Td in two out of ten muscles and longer Tc in three out of ten muscles as well as higher muscles tone in three out of ten muscles than skiers on technical disciplines. It seems that faster movement frequency in technical disciplines promotes faster muscle fibre phenotypes, which could be supported by lower muscle tone (higher Dm) than in speed discipline skiers. Furthermore, eccentric muscular work plays a large role in alpine ski racing, especially in slalom and giant slalom, and is well known that eccentric loading enhance maximal muscle strength and power as well as speed of contraction and therefore explains differences between technical and speed alpine skiing racers.

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Tensiomyographic evaluation of the contractile properties of skeletal muscles in correlation with anthropometric values in youth alpine ski racers

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Keywords: muscle properties, posture, youth sport, alpine skiing

INTRODUCTION: The differences between the sexes become more pronounced during adolescence, which has a particular impact on participation in sport. Scientifically, the differences in biological maturation affect the physiological performance of adolescent ski racers. Tensiomyography (TMG), a non-invasive technique, measures skeletal muscle contractile properties in isometric conditions. TMG-derived parameters, like contraction time (Tc), delay time (Td) and maximal displacement (Dm), correlate with intrinsic muscle characteristics. Previous studies indicates that TMG parameters are related to chronological and biological maturation stages in youth athletes and provide insights into the relationship between puberty, sex differences and muscle characteristics. The purpose of this study was to assess possible association between body height and muscle contractile properties.
METHODS: In the analysis we included youth Slovenian alpine skiers. Using multiple regression analysis, we test the association of body height (after controlling for sex) with TMG parameters (Td, Tc and Dm) in five muscles (*biceps femoris - BF, erector spinae - ES, rectus femoris - RF, vastus lateralis - VL, vastus medialis - VM*).
RESULTS: A total of 43 youth alpine skiers (168.8 ± 13.9 cm, 63.6 ± 15.7 kg, 15.3 ± 2.5 years) with age range of 9 - 18 years were included in analyses. It was found that body height, after adjusted for sex, significantly predicted Td for *Biceps Femoris* (R^2 = .148, (2,40) = 3.461, p = .041) and *rectus femoris* (R^2 = .160, (2,36) = 3.436, p = .043). Furthermore, body height, after adjusted for sex, significantly predicted Dm for *erector spinae* (R^2 = .454, (2,40) = 16.646, p < .001), *rectus femoris* (R^2 = .302, (2,36) = 7.770, p = .002), *vastus lateralis* (R^2 = .272, (2,40) = 7.467, p = .002) and *vastus medialis* (R^2 = .370, (2,40) = 11.758, p < 001).
DISCUSSION AND CONCLUSIONS: In this cross-sectional exploratory study, we found that higher body height is associated with higher Dm in four out of five muscles, explaining 27.2 to 45.4 % of Dm variance, and higher Td in two out of five muscles, explaining 14.8 to 16.0 % of Td variance. There was no association of body height with Tc. Higher posture yields longer muscles fibers and longer Td could indeed be expected. Whereas longer muscle fibers could also be reflected in higher Dm which could be interpreted as lower muscle stiffness (or tone). Further research that includes maturity status as a peak height velocity, could help young skiers and their coaches to select competition categories. Furthermore, additional research on the relationship between body characteristics such as height, mass and injury frequency in adolescents would provide important added value for coaches.

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Numerical Analysis of Alpine Skiing with a Body-Gear-Environment Interaction Model

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Keywords: alpine skiing simulation, multibody dynamics, ski-snow contact, musculoskeletal model

INTRODUCTION.
Alpine skiing, a thrilling winter pursuit, harmonizes control forces like muscle-skeleton strength with natural elements such as gravity, friction, and air resistance. Assessing skiing skills quantitatively holds substantial promise in elevating training outcomes for enthusiasts and athletes alike. To realize a precise numerical evaluation of skiing, a body-gear-environment interaction (BGEI) model has been established. By integrating a specially crafted wearable system that captures kinematic signals during each turn, this model accurately recreates skiing kinetics and kinematics, serving as a sport digital twin of alpine skiing. This virtual counterpart produces vital biomechanical parameters crucial for advancing techniques. This innovative approach transforms the skiing experience into a data-driven realm, offering a pivotal tool for refining and mastering the art of skiing.

METHODS. Two ski volunteers (a coach and a beginner) were recruited to complete the ski turns under the same conditions. Seventeen inertial sensors were attached to the volunteers limbs to capture their posture and movement during each ski turning (Figure B). The musculoskeletal model in the BGEI model was based on the Opensim full-body lumbar spine (FBLS) model [1]. The ski model was discretized by flexible beam elements. The interaction between the ski and snow was described by a dissipative contact model. Forward-inverse coupling dynamics simulations were performed by tracking the measured kinematics data. A global positioning system (GPS) collecting the skier's motion trajectory, a pair of plantar pressure measurement insoles measuring the ground reaction forces were adapted to evaluate the accuracy of the simulation results of the BGEI model.

RESULTS. The simulation results for the skier's mass center trajectories exhibited a high level of consistency with the actual measurements, yielding a correlation coefficient of r=0.97. Similarly, the normalized ski-snow contact forces aligned well with the measured plantar pressure, displaying a strong correlation coefficient of r=0.94 (Figure C). A comparative analysis between the coach and the beginner additionally highlighted the technical errors exhibited by beginners (Figure D): The simulation identified an abnormal activation of the psoas major muscle in the beginner, along with a delay in the left-right switch of the body mass center.

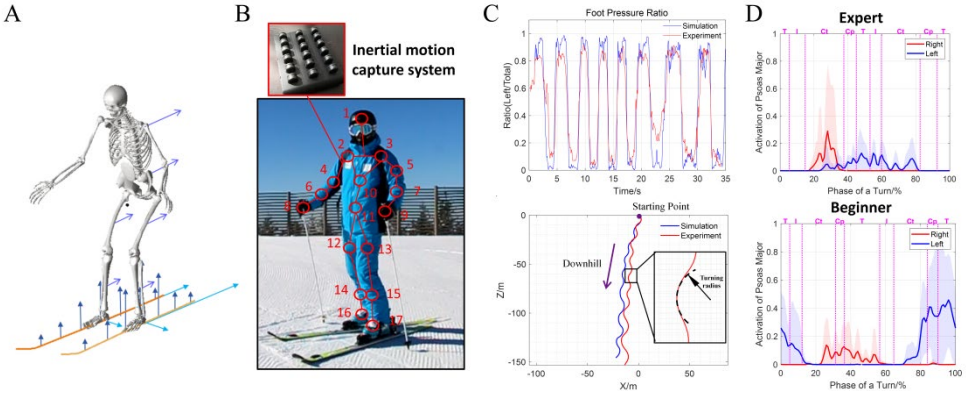

Figure *A Skier's musculoskeletal model; B Inertial sensors; C Validation of model; D Activation of psoas major.*

DISCUSSION AND CONCLUSIONS. Utilizing the BGEI model, we derived crucial parameters such as skiers' speed, body mass center trajectory, joint angles and moments, ski angles and positions, and muscle activations at each time point. With these parameters, this comprehensive model allows us not only to evaluate skiers' turning techniques accurately but also provides valuable scientific guidance for training and the selection of ski equipment.

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DIFFERENCES IN PRESSURE DISTRIBUTION BETWEEN THREE PHASES OF PARALLEL SKI TURN PERFORMANCE

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Keywords: kinetic analysis, pressure insoles, ski technique, teaching process

INTRODUCTION. For most recreational skiers, the ultimate goal is to acquire a level of skiing technique that allows them to independently and safely navigate all ski slopes. These recreational skiers typically conquer slopes by executing parallel turns (PT) because this technique is applicable in almost all snow conditions and on various slopes. During skiing, external forces effect skiers who must control them in certain phases of the turn to successfully execute it. To achieve this, skiers use internal forces by adopting an optimal position and adjust it as they move towards the final phase of the turn. Ground reaction forces and pressures can be observed through kinetic analysis, which allows the measurement of foot pressure on different regions during each phase of the turn. Kinetic analysis carried out in this study could provide a clear insight in the complexity of applying pressure during phases of the PT performance. It could also enable a better understanding of this ski element and help in adapting ski school teaching process.

METHODS. The sample consisted of 23 ski instructors. Analysis of kinetic parameters during performing PT was conducted, using insoles designed for pressure detection (Novel, Pedar). Testing protocol was carried out directly on the ski slope in defined corridor 15 m wide. Each ski instructor performed 12 turns in observed element. The following kinetic variables were measured: maximum force, force on the medial and lateral part of the foot and on the heel, for both inside and outside foot. The parameters were measured in 3 time points (phases) of the performed turn. One way ANOVA was used to determine differences in the pressure distribution between each phase of the PT.

RESULTS. Differences were observed between phases of executing turns in terms of maximum force values, for the inside and outside foot ($p < 0.01$). Observing the distribution by regions of the foot for both legs when initiating the turn, it is evident that the weight is predominantly distributed on the front part of the foot. In the second phase, the force ratio between the outside and inside foot is predominantly on the outside foot (73% vs. 26%). In the third phase the ratio between the force is similar, with the force predominantly distributed on the outside foot, mainly on the medial part. Differences between phases are determined in almost all variables, with exceptions as follows. When observing force on the medial part of the foot of the outside leg, no statistically significant difference was found between the 1st and 2nd phase ($p = 0.07$). The force on the lateral part of the foot of the outside leg does not differ statistically significantly between 2nd and 3rd phase ($p = 0.74$), the same as on the inside foot ($p = 0.81$). On the rear part of the foot (heel), a difference between phases was not found in the force of the outside foot between 2nd and 3rd phase ($p = 0.38$).

DISCUSSION AND CONCLUSIONS. While performing PT, the skier must learn how to control the center of mass, pressure distribution and edging angle. This ensures optimal control of direction and speed which could be crucial for enabling skiers to be independent in mastering complex skiing elements. Based on the gained results, it can be concluded that adequate pressure distribution on the surface from the beginning to the end of the turn is crucial. The pressure of the outside foot should be dominant throughout the whole turn with the highest values in the 2nd and 3rd phase of the turn. In everyday practice, instructors often ask ski school participants "to feel pressure" under specific parts of the foot during skiing to enhance their performance. To optimize the learning process and subsequently reduce the number of skiing injuries, it is necessary to fully understand the movements and actions skier must perform at specific moments. Our conclusions can serve as a guideline for adapting teaching process.

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Didactics and ski injuries – Ski instructors' views on the importance of a didactic approach to injury prevention

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Keywords: ski teaching, ski injuries, didactic approach, SKI EASY unified teaching model

INTRODUCTION. Alpine skiing, a dynamic and exhilarating sport, has garnered widespread popularity. However, the risks associated with the high-speed descents and challenging terrain require a comprehensive understanding of the factors that influence the occurrence of injuries. By understanding the mechanisms of injury occurrence, we can have a significant impact on reducing the incidence of injury, but due to many factors that we cannot control or predict, we will never be able to completely prevent them. We know a lot, and many references prove that the specifics of weather conditions, slope preparation, snow type, ski and protective equipment have a significant impact on the occurrence of injuries, but there is very little scientific evidence on the influence of the approach to ski teaching, the choice of didactic steps and models and the time we spend teaching the different ski elements. This study addresses a crucial aspect that is often overlooked: the didactic approach of the ski instructor. It's including the methods of teaching skiing, the teaching techniques, and the learning environments, that play a crucial role in developing the skills and decision-making ability of skiers. The aim of the study was to investigate how much importance ski instructors place on the individual elements of skiing when teaching and how much time they devote to some key triggers that we believe are important in the process of acquiring skiing skills. As a starting point, we have chosen the SKIEASY unified teaching model, which is based on the critical stages in the learning process, the Motor Skills Triggers (MST), and focuses on the specific movement skills that the individual must achieve, master and internalize in order to develop perfectly coordinated and safe skiing step by step.

METHODS. An international group of 214 ski instructors (male = 69%) from 25 countries provided self-reported demographic data, ski course participant's injury incidence, type of injury and instructional strategies over the course of their career. From December 1 to 23, 2023 an online survey entitled "Injury incidence factors in Snowsports" was conducted and aimed at ski instructors, ski teachers and coaches in snowsports. Descriptive statistics were compiled for all variables.

RESULTS. Overall, 66% of participants reported an injury during their ski instructor career (53% reported more than one injury). Most of them reported injuries in beginners (in children and adults), while in adolescents more injuries occur in advanced skiers. Speed and loss of control are cited as the most common reasons for the occurrence of injuries (59%). However, it is interesting to note that the majority of respondents do not attach great importance to the initial elements (gliding, speed control, change of direction), but to technique and skiing in a group. Although most (82%) believe that it is very important to spend time on speed control when learning the technical elements.

DISCUSSION AND CONCLUSIONS.

By examining the interplay between didactic strategies and injury outcomes, this study aims to provide valuable insights for the fields of sport didactics and injury prevention. The results have potential implications for refining teaching methods, improving safety protocols, and ultimately promoting a safer and more enjoyable experience for alpine skiers.

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Snowboarding injuries and recommendations for their prevention in primary and secondary school programs

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Keywords: injuries, snowboarding, school programs, recommendations, prevention

INTRODUCTION. In Slovenia, winter sports are still very popular among young people due to top athletes. This also applies to snowboarding. Students can learn about this sport in the educational system of primary and secondary schools according to the curriculum at sports days, outdoor schools and winter camps. In primary and secondary schools, participation in sports days, which last 5 hours, is mandatory for all students. Participation in nature schools and winter camps is voluntary. The recommendations for physical education teachers state that at schools where they have the opportunity to do so, they should organize at least one winter sports day in every grade of nine years Primary school. It should be intended for activities and sports in the snow (sledding, skiing, snowboarding, skating, etc.). During the sports days, public elementary schools must also organize a five-day outdoor winter sports school for students in the second trimester. They can also organize winter camps. In the gymnasium, regular physical education lessons are supplemented by two sports days per year in the first three years, and one winter sports day is planned in the last year. Usually one sports day lasts 5 hours. At the same time, the recommendations for physical education teachers stipulate that, as part of the mandatory optional content, students should be offered three more sports days each year, which the students can choose freely. Students can also be offered various optional sport courses. A review of the curricula of Slovenian public elementary and high schools shows that for learning to snowboard in public schools that have this option, a total of approx. from 60 to 100 hours is available. Physical education teachers in Slovenia must use formal curricula The students knowledge is required by knowledge standards. However, the choice of snowboard teaching is left to the autonomy of the teacher. Due to strict legislation, more and more teachers are avoids teaching winter sports because of the injury risk. Since we believe that with planned and systematic teaching, most injuries can be prevented, in the first part of the paper we analyzed the available sources on the injuries of young people while snowboarding; and in the second part, recommendations for their prevention were prepared.
METHODS. We searched the SportDiscus and Medline databases using the search string "injuries, snowboarding, youth". Only research with these sets is used in the paper.
RESULTS. Research has shown that the most common mechanisms of injury were falls and collisions. The most common types of injuries were impacts, fractures, sprains and strains. Most upper extremity injuries occurred at the wrist; on the lower limb and on the knee. Younger, less physically fit, with previous injuries, poorer movement skills and less experience were exposed to a higher risk of injury.
DISCUSSION AND CONCLUSIONS. Recommendations for injury prevention include planned and systematic preparation for lessons. This includes appropriate physical and mental preparation of the students, appropriate learning methodology, selection and adjustment of equipment, and teaching on suitable terrain in suitable weather, following all FIS safety instructions for safe skiing. The use of additional safety equipment (helmet, wrist and back protectors) is an additional prevention against injuries.

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NeuroPlay Insights for Skiing: Preparing Young and Elder Generations for Enhanced Ski Experiences

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Keywords: neuroplasticity, cognitive-motor programs, skiing, training

Introduction

The concept of "NeuroPlay" is an innovative strategy that combines physical activity (PA) with cognitively stimulating tasks in an intergenerational setting. This approach aims to promote neuroplasticity and cognitive competence in different age groups. The importance of an active lifestyle for physical and mental well-being is recognized from childhood to old age. However, a significant proportion of the population, from children to older adults, do not reach the recommended guidelines for physical activity. Physical activity is not only crucial for maintaining physical health, but is also positively related to cognitive functions such as memory, executive function and attention.

Methods

In this study, a systematic review is conducted to examine and consolidate the literature relevant to the NeuroPlay concept. The aim is to identify and summarize research findings that establish a link between physical activity and cognitive engagement in intergenerational contexts, with a focus on promoting neuroplasticity and cognitive health in different age groups.

Results

Recent research highlights the combined benefits of physical activity and cognitive engagement to improve cognitive performance, a synergy based on the principle of neuroplasticity – the brain's ability to form and reorganize synaptic connections. However, many of these studies are limited to controlled environments, which may limit the transferability of their findings to the real world. At the same time, intergenerational initiatives that bring different age groups together through shared activities have shown the potential to promote positive perceptions, break down age-related stereotypes and encourage knowledge sharing between younger and older people.

Discussion and conclusions

The NeuroPlay approach, as proposed in this article, seeks to address existing gaps by developing and evaluating intergenerational programs that combine PA with cognitive challenges. These programs are specifically designed for non-cohabiting grandchildren and grandparents and aim to improve cognitive functioning and well-being while strengthening family bonds. This article highlights the lack of intergenerational PA programs, particularly those that focus on strengthening family relationships. The NeuroPlay model offers a new way to promote physical and cognitive health across generations and promises individual and societal benefits. The European Commission has recognized the potential of the NeuroPlay approach, as demonstrated by the recent allocation of funds under the call for proposals for the Erasmus+ Sport program, underlining the innovation and likely impact of the approach.

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SAFE Index: classifying ski injuries severity based on AI

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Keywords: SAFE index, Artificial Intelligence, skiing safety, rescue data.

INTRODUCTION. SAFE is a platform used for mapping ski rescues that is already provided to 70% of Italian ski resorts. This contribution describes the development, validation, and systemization of the SAFE Index, an Artificial Intelligence (AI) component of the SAFE platform [1], for automatic severity injury classification. The index has been developed using an ad-hoc statistical model based on Machine Learning and over 140,000 ski rescues collected in the SAFE platform in the last five years. This model can assign an injury severity class to each rescue entered into the platform. The project is developed in the Trentino Innovation ecosystem, thanks to a collaboration between the MotoriaLab and Data Science for Industry and Physics (DSIP) unit of FBK's Digital Industry Centre.

METHODS. The SAFE Index is a predictive analytics tool composed of machine learning modules trained on geospatial data extracted from the SAFE platform. SAFE is a commercial platform used by over 1.000 patrollers in Italy, France, and Spain. In 5 years, the SAFE database has grown, hosting more than 140.000 geolocated reports on ski rescues. It is used by more than 150 ski resort managing companies to produce risk maps for risk mitigation through intervention, better patrolling, and research.

All the reports consist of two forms: one describing the location of the rescue and all the environmental variables linked to the event, and one describing the details of the person rescued and a brief report on the type of injury the person suffered. In the SAFE database, there are more than 15,000 forms of rescues operated by the White Cross of Bolzano. In every report, the operators at the time of the rescue indicate the assisted person's health assessment by selecting between 4 classes. The classes follow the indications given in the Ministry of Health's documentation in the document "Health care services in emergency-urgency" under the Functional Specifications of the 118 and First Aid tracks.

RESULTS. The SAFE Index is an eXtreme Gradient Boosting model (XGBoost,[4]) trained to predict health assessment based on reports. Low-represented categories are grouped, avoiding overdispersed samples that can lead to overfitting. The customizable splitting procedure produces train/validation/test datasets for testing the robustness of the trained model on a new ski resort or a new ski season. Finally, a feature importance study shows how the model's performance varies depending on the number of input features. Given the desired accuracy, it is possible to identify the minimum set of features required by the model. This information can be used to select the minimum set of mandatory fields filled out by the operators. Two case studies have been implemented simultaneously: a medium-size ski resort has been removed from the initial dataset (T1,2034 samples) and the last two ski seasons of the larger ski resort (T2, 2183 samples). The remaining dataset has been split randomly into train (9455) and validation (4658). Optuna [5] has been used to search for the best parameters for the XGBoost model running 1000 trials, maximizing the Mattews Correlation Coefficient (MCC) as a more suitable performance measure for high-unbalanced datasets [6]. On the validation set, we obtain 74.5% accuracy (MCC=0.46), in T1 75.1% (MCC=0.38), and in T2 74.3% (MCC=0.45), showing a good generalization of the model both on the new ski resort and on new ski season.

DISCUSSION AND CONCLUSIONS. The SAFE index will allow ski resort managers and ski instructors in Trentino, Italy, and internationally to use a data-driven approach to improve the safety of their customers and, in the not-so-distant future, skiers to receive helpful information on their safety and the insurance world to improve their estimates of the risk of injury to their policyholders.

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ROLE OF SPORTS ON SNOW AS CULTURAL EDUCATION FACTOR IN CHILDREN AND YOUTH

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[2] *2Institute for improvement of education Republic of Serbia*

Keywords: snow sports, education, physical education,, culture, children, youth

INTRODUCTION. Staying on the mountain is beneficial for their health, and if we still connect with snow sports, this certainly brings a special experience for each of them. The special importance of staying and applying sports on the snow has a health and hygienic effect on the child's organism as well as the socio-psychological development of the child.
For the plan and program of wintering, the Expert Council of physical and health teachers of each school is in charge

METHODS. An analysis of the 20 previous studies in the period from 1980 to 2018 has highlighted the important role of sports in the snow both in physical education and in the cultural development of children and youth.

RESULTS. In addition to educational tasks, the modern school has in its programs and certain forms of work outside the school which influence the achievement of the goals of education and attainment of the established ones. One of these forms of work is the organization of wintering of students envisaged by the program of teaching and learning of physical education. The new course program offers the possibility to organize wintering or excursions on the snow with the aim of linking physical and health education through interrelated competences with other subjects for the social and cultural development of young people. Even if the priority of teaching physical education is the development of physical abilities, the program does not neglect the socio-cultural component of personality development.
The results of the analysis of the works have shown that the snow disputes have multiple significance:

- Health-hygienic
- Psycho-social
- Sport-recreational
- Cultural-historical

DISCUSSION AND CONCLUSIONS. Activities in nature and winter also contribute to achieving the objective of the course Physical and health education, programs of these activities are realized by connecting with the physical and social environment, which results in the child developing comprehensively and versatile. All this is, of course, desirable, but the ultimate outcome of school wintering should be, in addition to a child-educated, richer and contented child.
Sufficient child is accomplished, motivated, confidently, confidently, self-respected, happy. Wintering and snow activities are well realized when a satisfied student returns to school.

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FRIDAY (15. 3. 2024)

SITEMSH

10:15 SNOWSPORT MEDICINE AND TRAUMA MANAGEMENT (Session chair: Matej Drobnič):

- **Keynote (30 min): M. Drobnič: SOFT TISSUE INJURIES OF THE LOWER LIMBS DURING WINTER SPORTS AND THEIR SEQUELAE**
- A. Vidal: ACL INJURIES IN LEISURE DOWNHILL SKIERS. EPIDEMIOLOGY AND SURGICAL RECONSTRUCTION
- J. Rius-Tarruella, C. Torrens, R. Soler, C. Torrens, A. Escoda, D. Orozco: LONG-TERM EFFECTIVENESS AND SAFETY OF CULTURED MESENCHYMAL STEM CELLS IN THE TREATMENT OF CHRONIC PATELLAR TENDINOPATHY IN ATHLETES PARTICIPATING IN SPORTS WITH HIGH ECCENTRIC QUADRICEPS LOADINGS, SUCH AS SKIING,
- W. Nachbauer, A. Barvinek, G. Innerhofer, M. Barth, A. Giger, P. Schröcksnadel: ACL REINJURIES OF ELITE ALPINE SKI RACERS
- A. Cherati, S. Fröhlich, J. Spörri: OVERUSE INJURIES IN THE KNEE, BACK AND HIP OF TOP ELITE FEMALE ALPINE SKIERS DURING THE OFF-SEASON PREPARATION PERIOD: PREVALENCE, SEVERITY AND THEIR ASSOCIATION WITH TRAUMATIC PREINJURIES AND TRAINING LOAD
- A. Vidal, S. Aguirre: KNEE INJURIES IN SNOW SPORTS. OUR EXPERIENCE IN A SKI RESORT

12:00 Lunch

13:30 EPIDEMIOLOGY AND ACCIDENTS (Session chair: Aleix Vidal):

- N. Bourganos, A. Zacharopoulos: COLLISIONS IN ALPINE SKIING AND SNOWBOARDING A FOURTEEN YEARS' EXPERIENCE IN GREECE
- K. Ryosuke, T. Tsubasa, A. Satoshi: WINTER HAZARDS IN JAPAN: BACKCOUNTRY INCIDENTS AND AVALANCHE SAFETY
- A. Kolarić, D. Kolarić, L. Ružić: HOW MUCH ALCOHOL DOES IT TAKE TO CAUSE A SKIING INJURY?
- S. Radovanović, A. Petrović, B. Delibašić, M. Suknović: ANALYZING DISPARITIES IN MACHINE LEARNING-BASED SKI INJURY PREDICTION: A LONGITUDINAL STUDY FOR MT. KOPAONIK SKI RESORT
- A.-K. Najda, P. Carqueville, V. Senner: ONE STEP TOWARDS ANOMALY DETECTION OF SKIING SCENARIOS USING IMU-DATA
- A. Zacharopoulos, N. Bourganos: CHILDREN'S INJURIES IN ALPINE SKIING AND SNOWBOARDING A FOURTEEN YEARS' CASE-CONTROL STUDY

19:00 Closing ceremony

SOFT TISSUE INJURIES OF THE LOWER LIMBS DURING WINTER SPORTS AND THEIR SEQUELAE

Prof. Matej Drobnič, MD PhD, consultant orthopedic surgeon

University of Ljubljana, Slovenia

Winter sports often lead to lower limb injuries, either as an acute event or as an overuse injury. The incidence of acute injuries varies between 0.44 and 1.68 in recreational athletes, but rises to 3.5 skier days in elite athletes. The lower extremity is affected in about half of the cases, the knee itself in about 1/3 of all injuries. On the other hand, overuse injuries are probably the most common type of injury suffered by skiers, but they are much less systematically studied. These injuries are common but, as they are usually minor, are often ignored by both novice and experienced skiers. As the symptoms of overuse injuries usually only become noticeable the next day, estimates of their frequency are imprecise. The most common overuse injuries are characterized by muscle discomfort and pain in the quadriceps femoris, gastrocnemius and paravertebral muscles of the back. A soft tissue injury is damage to muscles, ligaments and tendons throughout the body. Common soft tissue injuries are usually caused by a sprain, strain, a single blow resulting in a contusion, or overuse of a specific body part. Soft tissue injuries can lead to pain, swelling, bruising and loss of function. Most soft tissue injuries require temporary restriction of activity and treatment with analgesics/NSAIDs and physiotherapy (known as MEAT – Movement Exercise Analgesics Treatment) in order to return to sport within 3-8 weeks, depending on the intensity of the primary injury. On the other hand, severe ligament injuries, most commonly knee ligament injuries in practice, require surgical intervention for repair or reconstruction. The long-term outcome of knee ligament injuries in the joint area depends on the primary load and the biomechanical restitution of the injured joint. Despite proper joint reconstruction, early cartilage degeneration (osteoarthritis) is very likely.

ACL injuries in Leisure Downhill Skiers.
Epidemiology and Surgical Reconstruction.

Aleix Vidal MD PhD

Centro Medico Teknon, Barcelona.
Baqueira Beret Medical Centre, Pyrenees.

Keywords: anterior cruciate ligament, downhill leisure ski, ACL graft reconstruction.

INTRODUCTION. ACL injuries are commonly seen in downhill skiers. Mechanical factors have been described as a possible cause of injury. Gender has also been proven to be a factor.
In this study, the analysis of 4.415 ACL cases confirmed this prevalence for the female gender to suffer an ACL injury throughout 13 consecutive ski seasons.
We hypothesize that age is also a related factor to ACL injuries. Gender and group age prevalence justifies utilizing cortical suspension techniques for ACL reconstruction.

METHODS. Since 2010/11 we have been collecting data at Baqueira Beret Medical Center to analyze ACL injury epidemiology. During these 13 consecutive seasons we have recorded 11.082 leisure downhill knee injuries. ACL was involved in 4.415 of those knees.
We have studied: diagnosis and injury related factors for every knee lesion.
Endosteal graft fixation techniques have been used either with semitendinosus or quadriceps autologous tendons suspended with cortical mechanisms.

RESULTS. During thirteen seasons, ACL injuries represent 13% of our leisure population skiers. ACL injuries in females represented 65,38% compared to 34,56% in males. Mean age for ACL injuries was 41,74 years old.
In this period, incidence of evolution for ACL has fluctuated from 9,27% incidence to 16,52% compared to all sport injury in our ski resort.

DISCUSSION AND CONCLUSIONS. Mechanism of ACL injury have been largely investigated in the literature. Our study suggests that gender and group age distribution play also an important role in the ACL rupture mechanisms. These are important factors to be considered when graft reconstruction is planned.
In our ski resort, females over 40 years are the most frequently injured downhill skiers. Surgical procedures for ACL reconstruction have become a routine in our practice. When surgery is needed for ACL reconstruction, we advocate for endosteal graft fixation using suspension graft techniques to promote better osteoconduction/creeping substitution in bone-graft interface for both femur and tibia tunnel/socket.

Long-Term Effectiveness and Safety of Cultured Mesenchymal Stem Cells in the Treatment of Chronic Patellar Tendinopathy in athletes participating in sports with high eccentric quadriceps loadings, such as skiing.

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Keywords: regenerative medicine; mesenchymal stem cells; platelet-rich plasma; patellar tendinopathy; jumper's knee; sports injury

INTRODUCTION. Patellar tendinopathy, commonly known as "Jumper's Knee", is a prevalent issue in both elite and nonelite athletes, presenting challenges in management and resulting in prolonged pain, reduce function, and significant financial costs (1). This condition involves small tears in the patellar tendon, often observed in sports with intense jumping and high demands of leg extensors, causing localized tenderness. Sports like volleyball, track (jump), basketball, long-distance running, and skiing frequently exhibit this issue (2). Conventional treatments, including exercises and shockwave therapy, have limited efficacy, necessitating exploration of alternative biological treatments. This study investigates whether ultrasound-guided injections of autologous cultivated and expanded bone marrow mesenchymal stem cells (MSCs) or leukocyte-poor platelet-rich plasma (Lp-PRP), can enhance clinical outcomes in athletes with patellar tendinopathy.

METHODS. The study was a 12-month prospective clinical trial, involved 20 athletes' men with chronic patellar tendinopathy with Gap >3 mm. Participants were initially divided into two groups: MSCs (n=10) and Lp-PRP (n=10). After 6 months, the study was unblinded, and patients in the Lp-PRP group were transferred to receive MSCs treatment. The dose of cells supplied was $20x10^6$ cultured MSCs in two 5-mL syringes, one with $10x10^6$ cultured MSCs suspended in a 2-mL solution was injected into the tendon gap, and the other with $10x10^6$ MSCs suspended in a 4-mL solution was injected into lateral peritendinous area accounting for the Hoffa fat pad (3). The evaluation continued for an additional 6 months for the original MSCs group, while the original Lp-PRP group received cultured MSCs treatment for 12 months. The study assessed the 12-month follow-up results for cultured MSCs treatment in 20 patients with patellar tendinopathy (4).

RESULTS. Patient characteristics and procedural details were recorded, revealing a mean bone marrow volume of 101.00 ± 4.47 mL and a time lapse of 21.65 ± 2.89 days between bone marrow retrieval and ultrasound guided cultured MSCs implantation. The injection procedure, administered to all participants, demonstrated no complications. Clinical parameters, such as swelling and signs of inflammation, notably improved at the 12-month mark, with a reduction in pain on tendon palpation from 95.0% to 5%. Pain and function scores also exhibited positive changes, particularly in the cultured MSCs group, which displayed significant improvements in VAS pain and VISA-P scores. MRI findings revealed significant post-treatment improvements in lesion size (image). The analysis of lesion size and volume in all patients showed significant improvement ($P < .05$ for all), as observed in MRI scans and reflected in reduced VAS pain scores. By 12 months, there was notable tendon restructuring and significant tissue regeneration in all study participants. 95% percent of the men returned to sport activities after 90 days before treatment with MSCs, while 80% returned to sport competition at 6 months after MSCs treatment. Regarding safety, treatment with cultured MSCs was well-tolerated by all 20 patients, and no serious AEs were reported.

DISCUSSION AND CONCLUSIONS. In the 12-month assessment post-treatment, the administration of MSCs for patellar tendinopathy demonstrated both safety and a significant reduction in pain, enabling a secure resumption of sporting activities. In contrast to Lp-PRP, cultured MSCs were associated with substantial and favorable changes in tendon structure, as evidenced by imaging modalities. This observed structural improvement could be attributed to a more pronounced anti-inflammatory and analgesic effect compared to Lp-PRP. These results underscore the potential of cultured MSCs therapy to address refractory cases that do not respond to conventional interventions, providing a quick return to sports. Our experience also includes resolving other tendinopathies with cultured MSCs treatment, such as partial ruptures of the Achilles tendon, peroneal tendons, tibialis muscles (anterior, posterior, and longus), hamstrings, supraspinatus, and lateral epicondyle

tendons. Over than 250 cultured MSCs treatments for tendon pathologies supporting our results, this approach offers a new therapeutic avenue for tendon pathologies for athletes.

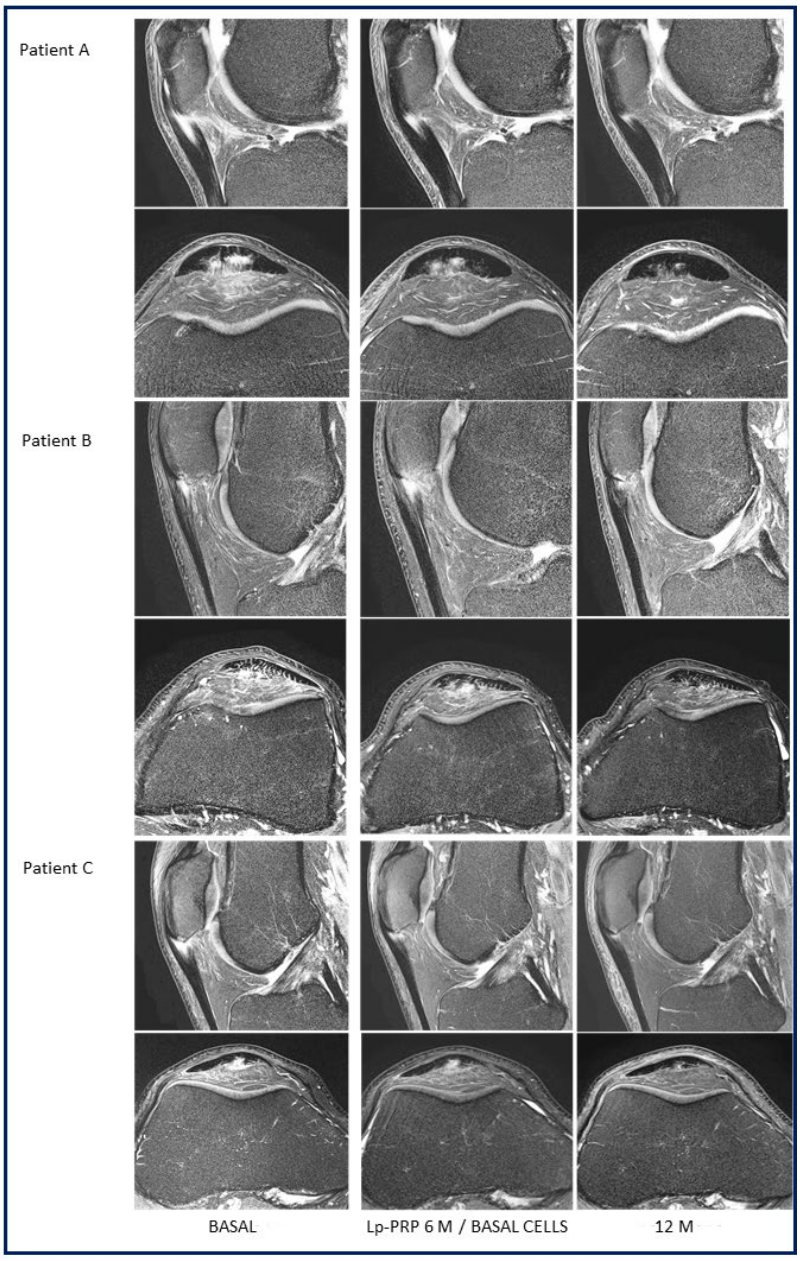

Figure: Sagittal (top row) and axial (bottom row) T2-weighted fat-saturated magnetic resonance imaging sequences of 3 patients who were initially treated with leukocyte-poor platelet-rich plasma (Lp-PRP) and then with bone marrow–derived mesenchymal stem cells (BM-MSCs). Shown are images from baseline, the 6-month follow-up (after Lp-PRP), and the 12-month follow-up (after BM-MSCs).

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ACL reinjuries of elite alpine ski racers

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Keywords: ACL rupture, reinjury, graft rupture, contralateral rupture, ski racing

INTRODUCTION. Anterior Cruciate Ligament (ACL) tears are very frequent injuries in alpine ski racing. Torn ACLs are commonly reconstructed with different types of grafts. Ruptures of the graft and ACL ruptures at the contralateral knee occur frequently. The purpose of this study was to determine the number of reinjuries as function of time after the primary ACL injury.

METHODS. The Injury Surveillance System of the Austrian Ski Federation was searched for ski team members with ACL ruptures. 177 athletes with primary ACL ruptures (58.2% females) were identified in the years 1992 to 2021. Interviews were conducted with 105 athletes to control the database information and to obtain surgery and return to competition data. Only those athletes were included in the analysis who were still active five years after their ACL rupture or suffered a reinjury within five years (n=63).

RESULTS. Five years after their primary ACL rupture, 33 (52%) of the 63 athletes were reinjured either by graft ruptures (27%, 17) or by contralateral ruptures of the ACL (25%, 16) (Fig. 1). In the first 13 months after the primary rupture, 8 of 17 graft ruptures occurred (Fig. 2) whereas only 2 of 16 contralateral ruptures happened. Females showed an exceptionally high number of graft ruptures (5 from 10) from the 8th to the 12th month inclusively after the primary rupture. At six months after the primary rupture, 49% of the athletes had completed their first snow training and 86% of the athletes were competing again within one year after injury.

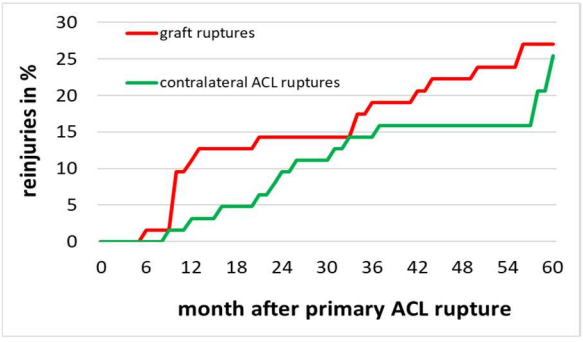

Figure 1: Graft ruptures and contralateral ACL ruptures over 5 years after injury (n=63)

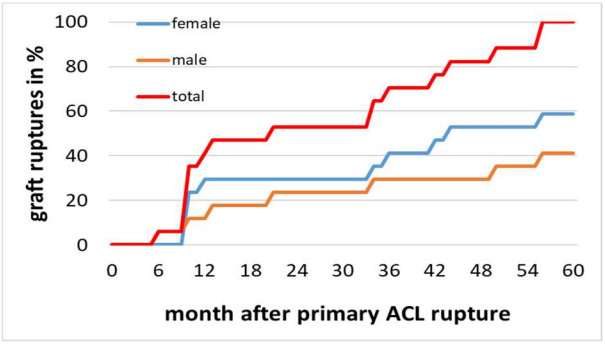

Figure 2: Graft ruptures for females (n=10), males (n=7) and total (n=17) over 5 years after injury

DISCUSSION AND CONCLUSIONS. The results showed that athletes, especially females, have the highest risk to suffer a graft rupture six to 13 months after the ACL rupture. Since this time span corresponds with the beginning of snow training and competitions, preventive measures may focus on reduced loading of the musculo-skeletal system during skiing. This obviously demands to start in competitions at a later time.

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Overuse injuries in the knee, back and hip of top elite female alpine skiers during the off-season preparation period: prevalence, severity and their association with traumatic preinjuries and training load

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Keywords: Overuse injuries, female alpine skiers, training load

INTRODUCTION:

To investigate knee, back and hip overuse injuries in top female elite alpine skiers during the off-season preparation, which has so far received little attention, and to assess their relationship with previous traumatic injuries and overall training load. Little is known on whether athletes are more susceptible to subsequent long-term complaints if previous traumatic injuries have occurred. Female skiers suffer from a relatively high number of traumatic knee injuries during the off-season preparation periods (intensive physical conditioning combined with extensive amounts, off/on-snow training)

METHODS:

All 26 female athletes of the Swiss Alpine Ski-Team (National, A, B and C squads) were asked to participate in a prospective 14 weeks cohort study during the off-season preparation period (Age (years) 20.91±2.67). Out of the 26 participating athletes, 15 were specialised in the technique disciplines (slalom and giant-slalom) and 11 in the speed disciplines. Previous injuries were classified as severe, when having resulted in an absence from training and/or competition of >28 days. An overuse injury was defined as any physical complaint caused by repeated microtrauma without a link to a single, clearly identifiable event. Overload was determined as Athletes' average total training hours per week and were calculated based on their biweekly self-reported accumulated training hours. For the prospective data collection, the Oslo Sports Trauma Research Centre (OSTRC) questionnaire on overuse injuries (specific questions tailored to the anatomical area of interest) was used.

RESULTS:

57.7% of the female skiers suffered from at least one severe traumatic knee injury during their preceding career. The average 2-weekly prevalence of overuse injuries was highest for the knee(n=52), followed by the back(n=37) and hip(n=19). Technique specialists (giant slalom and slalom) were more prone to back overuse injuries than speed specialists (super-G and downhill). The occurrence of knee overuse complaints was directly associated to previous severe traumatic knee injuries and athletes' total training hours.

DISCUSSION AND CONCLUSIONS:

In top female elite alpine skiers, knee, back and hip overuse injuries are relatively frequent. Moreover, discipline preferences, previous traumatic injuries and the overall training load may play an important role for their manifestation

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Knee injuries in snow sports. Our experience in a ski resort

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Keywords: Knee injuries. Evolution in ski resort.

INTRODUCTION. Knee injuries have been evolving through the years. We present our knee injury experience in our ski resort medical center. The aim of this study is to analyze our impression that some specific diagnoses are evolving throughout the seasons.

METHODS. Since 2005 we have been collecting data in Baqueira-Beret Medical Center in the Pyrenees for both downhill and snowboard injuries. During nineteen consecutive seasons we have recorded 12.133 knee injuries. We have analyzed the diagnosis and probability of injury for every knee lesion, and we have recorded in charts the diagnosis' trends for every diagnosis.

RESULTS.

1. We have analyzed the variability among different knee injuries since 2005 and we have found the following results: MCL at 40.56% of all knee injuries. ACL at 37.35% of all knee injuries. LCL at 4.81%. Sprain and contusions at 20.35% of all knee injuries. Tibia plateau fracture at 6.87%. Tibia eminence avulsion at 3.56%. Segond fracture at 2.13% Finally, PCL at 0.27%.
   Gender distribution shows predominance in females for all different knee injury diagnosis.
   ACL injuries in females represented 62.44% compared to 37.56% in males. Mean age for all ACL injuries was 41.32 years old.
   MCL injuries in females represented 59.50% compared to 40.46% in males. Mean age for all MCL injuries was 35.45 years old.
   Tibia Plateau Fractures in females represented 68.82% compared to 31.18% in males. Mean age for TPF was 44.58 years old.

2. In the evolutive trend analysis, ACL incidence in 2005 started at 6 per every 1000 total injured population and evolved to a maximum peak of 16/1000. Tibia plateau fractures started at 1.5/1000 in 2005 and augmented to 2.52/1000.
   MCL started at 15 per every 1000 of our patient population in 2005 and decreased to 12.66/1000 after 19 seasons. LCL started in a 3.25/1000 and decreased to 1,08 throughout the seasons.

DISCUSSION AND CONCLUSIONS.

When analyzing the statistical trend in our injured population for specific diagnosis, we have observed that Anterior Cruciate Ligament, and Tibia Plateau Fractures tend to increase through seasons.
Medial Collateral Ligament and Lateral Collateral Ligament injuries tend to decrease, or to stay constant.

COLLISIONS IN ALPINE SKIING AND SNOWBOARDING
A FOURTEEN YEARS' EXPERIENCE IN GREECE

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Keywords: Collision, Skiing, Snowboarding, Children, Epidemiology

Introduction: Collisions among Skiers and Snowboarders is an indefeasible phenomenon in every ski resort around the world. Unfortunately, their increased incidence and the harmful type of injuries that they cause, indicate the necessity for a thorough analysis in order to accomplish a more effective handling. In the current study we attempt to interpret the information we collected about the involved individual characteristics, the conditions under which these crushes occurred and the health outcomes of the sportspersons. Our aim is to identify the reasoning and mechanisms behind collisions and subsequently to propose realistic solutions in order to minimize their impact.

Methods: In a prospective case-control study, 4868 injured Skiers and Snowboarders were recorded, at Parnassus ski resort, using a multivariate protocol, during the years 2007-2023 (14 winter seasons). For the purpose of this study, we evaluated 470 collisions that occurred among individuals. At the same time a control group of 1974 uninjured skiers and boarders, randomly selected on the slopes, were also recorded on a similar protocol. The number of skier/boarder days was calculated from total tickets number. Statistical analysis was performed using t – test, x^2 - test and Fisher's exact test.

Results: Out of 523 collisions, we analyzed 470 individuals who engaged in collisions between persons and required medical treatment for 547 injuries. From them, 217 (46,2%) were involved in collisions that occurred among skiers, 64 (13,6%) among snowboarders and 189 (40,2%) between skiers and snowboarders. Only in 5,9% of the collisions both of the involved participants needed medical attention. The mean injuries rate from collisions, expressed in M.D.B.I. (Mean Days Between Injuries), was 2257 days. Skiers have by far the highest account of injuries with 397 (72,6%), contrary to snowboarders with 150 injuries (27,4%). Men comprise the majority with 267 of them injured (56,8% vs 61,5% of controls), but women are at higher risk for injury (43,2% vs 38,5% of controls), while the same is observed with children (27,2% vs 24% of controls). The most common injured anatomical region among skiers was the Lower Extremity (40,5%) but among snowboarders the anatomical regions of Lower Extremity, Upper Extremity and Head have almost similar proportions (30,6%, 28%, 27,3%). Collisions were the second most common cause of injury (9,65%) in total, after one's Own Mistake/Fall during free riding. Most importantly, it is the most possible mechanism of injury for a Skier to suffer a concussion (4,8%), even if wearing a helmet, with 20% of them requiring emergent transfer to the nearest hospital.

Discussion and Conclusions: Collisions may have a low injury percentage among Skiers and Snowboarders, but the impact in athletes, due to heavy consequences of the injuries, and ski resorts due to the urgent actions required, is significant. Skiers seem to collide in greater frequency than snowboarders, while females and children have the highest risk for injury. Careful considerations must be taken from all parts in order to diminish the collision incidence.

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Winter Hazards in Japan: Backcountry Incidents and Avalanche Safety

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Keywords: Distresses, Backcountry Accidents, Avalanche, Ski, Snowboarding

INTRODUCTION. During the winter season, the number of individuals skiing and snowboarding in areas known as backcountry increases. However, backcountry accidents occur frequently every year, necessitating urgent countermeasures. This study aims to provide a comprehensive overview of the current situation of backcountry accidents in Japan and to identify issues for future avalanche accident prevention.

METHODS. A literature review was conducted on backcountry incidents that occurred in Japan during the 2022-23 season. Incident data were collected from newspaper article databases provided by Japanese national newspapers (Asahi Shimbun, Yomiuri Shimbun and Mainichi Shimbun) and from a cross-sectional search service for local newspapers (G-search) for those that could not be fully investigated using these databases. Search formulae used for the extraction (skiing AND backcountry AND incidents, snowboarding AND backcountry AND incidents, boarding AND backcountry AND incidents, skiers AND backcountry AND incidents, boarders AND backcountry AND incidents). These data were analysed by simple aggregation. Geographical boundaries were clarified and used to help identify hazardous areas.

RESULTS. Information from media reports and the Internet was collected to ascertain the status of distress incidents. The total number of cases collected was 36 in December, 57 in January, 67 in February, and 9 in March, totaling 169. This represents a significant increase compared to the preceding years. In 2020-22, during the COVID-19 pandemic, there were 90-110 cases, and in 2019, just before the pandemic, there were approximately 150 cases. This season, with the diminishing impact of COVID-19 restrictions, there is an expectation that the enthusiasm for winter mountaineering has rebounded, leading to an increased number of incidents. The elevated number of incidents during the harsh winter months of December through March can be attributed to a rise in backcountry and low mountain hiking incidents, in addition to regular snow mountaineering. Based on the collected cases, 85 (approximately 50%) were related to snow mountaineering, 35 (approximately 20%) to backcountry incidents, and 32 (approximately 20%) to low-mountain hiking. Furthermore, there were 17 incidents (approximately 10%) occurring outside the management area near ski resorts. Out of the 35 backcountry distress cases, 8 individuals lost their lives, and 7 were victims of avalanches. Despite the prevalence of backcountry accidents, only a few were fatal, with the majority being rescued after getting lost or stuck.

DISCUSSION AND CONCLUSIONS. Distress cases clearly highlight avalanches as the most perilous hazard in the backcountry. Assessing and mitigating avalanche risks demands specialized and intricate measures. Aspiring backcountry enthusiasts should prioritize avalanche prevention. Therefore, individuals venturing into snow-covered mountains must mitigate risks to a level acceptable to all group members through meticulous planning and training, carrying appropriate equipment, obtaining weather and snow-cover information before entering the field, and judiciously assessing and managing their behavior in the field. It is important to note that not all backcountry accidents in Japan are reported, and only a fraction may be known. The future challenge will be to collect information on backcountry accidents and establish links to avalanche accident prevention.

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- National Police Agency of Japan

HOW MUCH ALCOHOL DOES IT TAKE TO CAUSE A SKIING INJURY?

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Keywords: alpine skiing, ski injuries, alcohol consumption

INTRODUCTION. Although there have been studies that reduce or even negate[1] the influence of alcohol consumption on injuries in alpine skiing, most studies note an increased risk of injury, considering that alcohol is detected in the blood of over 40% of seriously injured skiers [2]. The aim of this study was to determine the influence of alcohol consumption and alcohol amount on injury risk and severity.

METHODS. The study included injured recreational skiers (n=212) of all ages, skiing abilities, and both sexes who were treated in specialised rehabilitation clinics over a five-year period. A control group (n=206) who had never suffered an injury was also included in the study after skiing a full day at a resort. Only 204 injured and 196 uninjured skiers answered all of the questions concerning alcohol consumption, but considering the established level of statistical significance, the planned sample size was sufficient for a reliable analysis. Both groups completed a questionnaire. The question was "Did you consume alcohol on the day of the accident?" and if so, how much, and the control group "Did you consume alcohol today?" and if so, how much The amount of alcohol was measured according to international units (1 unit is equal to 1 dcl of wine or 0.33 dl of beer or 0.02 l of spirits).Using chi-square test, Fischer test and logistic regression, we calculated the influence of the consumption, and amount of consumption on the possibility of injury, and on injury severity via the ISS (Injury severity score).

RESULTS. The majority of skiers did not consume alcohol (82%). However, while one in ten injured skiers consumed alcohol, only 27% of uninjured skiers did so (Table 1). The logistic model showed that skiers who consumed alcohol were 3.7 times (OR=0,27; 95%CI=2,105-6,579) less likely to be injured while skiing. In addition, skiers who drank up to two units of alcohol were 13.9 times (OR=0,07; 95%CI=4,000-47,619) less likely to be injured than those who drank no alcohol at all. There was no statistically significant difference in the likelihood of injury between those who drank no alcohol and those who drank more than two alcohol units. In addition, neither alcohol consumption (chi-square test; p=0.529) nor the amount of alcohol consumed (Fischer test; p=0.552) was related to injury severity.

Table 1: The connection between alcohol consumption and injuries

Variable	Total	Injured	Uninjures	p-value[a]
Alcohol consumption	400	204	196	< 0,001
Yes	73	20	53	
No	327	184	143	
Alcohol unit number				< 0,001
0	327	184	143	
<=2	55	13	42	
> 2	18	7	11	

[a]P-value of chi-square test/Fisher's test to compare the distribution of characteristics between injured and uninjured groups of skiers.

DISCUSSION AND CONCLUSION. The stated results should be taken with great caution, considering that the group of injured skiers consumed alcohol only until the moment of injury, which was on average after three hours of skiing (between 12:00 and 13:00), and the control group until the end of the skiing day (around 16:00). Despite this, we can read from the results that alcohol consumption alone is not such a significant factor for injury, especially in a dose of up to two alcohol units.

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Analyzing Disparities in Machine Learning-based Ski Injury Prediction: A Longitudinal Study for Mt. Kopaonik Ski Resort

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Keywords: Ski injury prediction, Ski resort safety, Machine Learning.

INTRODUCTION. Using machine learning algorithms to predict the occurrence of ski injuries in recreational skiing is not a novel task (Delibašić, et al., 2018, Van Eetvelde, et al., 2021). Although the number of injuries during skiing is generally very low, the cost of injuries can be very high (Mueller, et al., 2019). The goal of this paper is to analyse disparities and errors discrepancies within the prediction model for a ski resort learned on multiple ski regions (include multiple slopes) and different periods of the day.

METHODS. The data originates from Mt. Kopaonik, Serbia. This ski resort has around 1.5 injuries per thousand skier days, which is similar to other ski resorts (Mueller, et al., 2019). The dataset comprises 605 skiing days, ranging over six consecutive seasons. Based on ski gate lift entrances, 38 attributes were extracted that describe ski regions on an hourly level. The goal of the prediction was to predict whether an injury will occur on the ski slope within the following hour. We used the data from one season to learn machine learning models and applied the model to the data from the following season. We measured AUC and inspected the differences in predictive performances between ski slopes and the time of the day.

RESULTS. Based on Random Forest algorithm we obtained the results presented in the Figure 1.

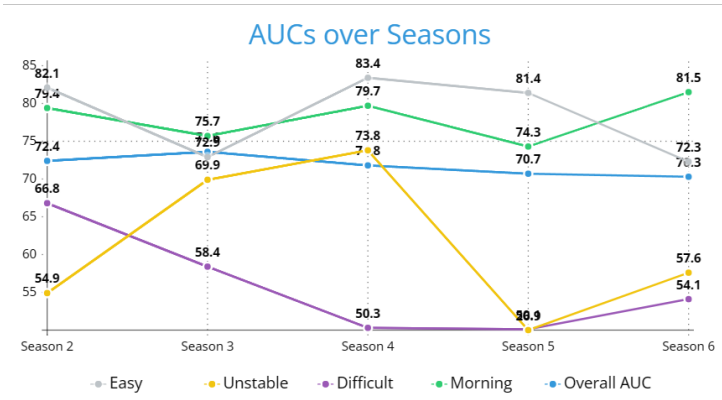

Figure 1. AUCs over time for the entire ski resort, morning hours of skiing, and selected ski slopes

DISCUSSION AND CONCLUSIONS. The results indicate a slight decline in the AUC over six seasons, moving from 72% to 70%. This decline is attributed to the AUC being inflated by many true negatives (Gneiting & Vogel, 2018). On a different note, the most popular ski regions consistently maintain AUCs that are relatively stable, hovering around the overall AUC values. This behaviour aligns with expectations, considering that injuries often occur due to crowded slopes featuring a mix of experienced and novice skiers (Weinstein et al., 2019), the presence of skiing groups (Delibašić et al., 2022), etc. However, ski slopes with fewer skiers exhibit different behaviour can be categorized into distinct clusters. Firstly, there are *easy to predict ski regions* mainly those with lower difficulty levels, some of which boast AUCs up to 79%. Conversely, *difficult to predict ski regions* make up a second group, with very low AUCs. Lastly, there are *unstable to predict ski regions* where AUCs are very unstable during the years. Additionally, these regions experience a significant performance drop in a single year, with abysmal AUCs. The explanation for this is rather easy. The easy to predict ski regions are regions where experienced skiers ski but which do not have high velocities of skiing. The difficult to predict regions are those where beginners learn to ski, while the unstable group to predict are those regions which have the highest oscillations in the number of skiers due to frequently changing conditions on the regions. Moreover, the analysis reveals that the best predictive performance (AUC = 78%) occurs in the morning hours of skiing, characterized by fewer skiers on the ski slopes. Around mid-day, AUC aligns with the overall average for the entire ski resort, while the worst performance is observed in the afternoon, where AUC drops to 65%.

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One Step Towards Anomaly Detection of Skiing Scenarios Using IMU-Data

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Keywords: IMU-Data, Gyroscope Data, Mechatronic Ski Binding, Safety, Alpine Skiing

INTRODUCTION. Each season, approximately 42.000 to 44.000 Germans experience injuries related to alpine skiing, with about one-third involving the knee joint (Schulz, 2018). Many lower limb injuries are caused by a binding that fails to release at the appropriate moment (Finch & Kelsall, 2012). One approach to improve this is to create a ski with a mechatronic binding system, as presented by Hermann in 2022. Hermann proposed a knowledge-driven control algorithm based on a fuzzy logic design. This study aims to explore to what extent a control algorithm based solely on an inertial measurement unit (IMU) is feasible. Ideally, the algorithm will receive enough information from the IMUs to detect an impending fall and release the binding at the precise moment. However, distinguishing between a genuine accident and certain deliberate movements can be challenging. To enhance the precision of this differentiation, this study utilizes an explorative data-driven approach to refine the algorithm.

METHODS. A field test was conducted using skis equipped with IMUs positioned in front of the ski binding. The IMUs have a sampling rate of 200 Hz. The primary focus of this study is the analysis of gyroscope data acquired from the IMUs with a specific focus on the angular velocity around the y-axis with the coordinate system according to DIN ISO 9462:2023. The recorded gyroscope data was analyzed with the 2D WinARace software and Python.

RESULTS. The data clearly shows different patterns for different skiing scenarios. Figure 1 depicts the angular velocity of selected right turns along one ski run, measured on the left ski. It is visible that during a fall, the angular velocity suddenly peaks with values almost five times higher than during "normal" behavior.

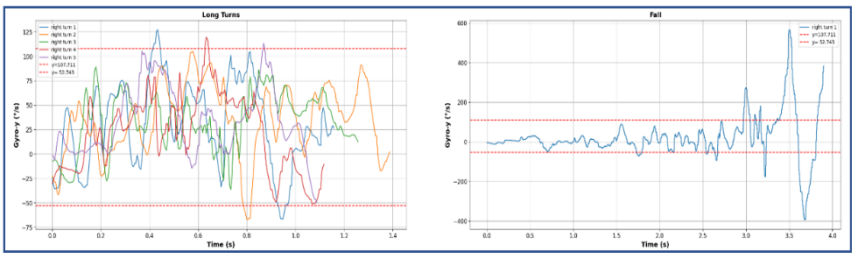

Figure 1 *Left: long turns that represent "normal" behavior. Right: Exemplary fall scenario that resulted in the release of the left binding. Dotted red lines: for reference at y=107.711 and y=-52.743, representing the 95th percentile of data during "normal" behavior*

DISCUSSION AND CONCLUSIONS. In summary, Figure 1 shows the contrasting behavior of the ski during a fall scenario compared to long turns. It is important to note that variations in the measured data may exist for different fall scenarios. Additionally, other skiing styles, such as short turns, need further examination. Relevant observations will also include the behavior of both skis with respect to each other. Nevertheless, this study shows very promising findings that have the potential to improve the algorithm in the mechatronic ski binding system. Especially the utilization of fuzzy logic and data-driven algorithms should help to classify skiing scenarios more effectively, distinguishing between "normal"- and critical skiing situations. The identified patterns can provide a basis for establishing decision criteria to ensure a safer binding release. It seems to be beneficial to investigate the approach further and focus on IMU data.

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CHILDREN'S INJURIES IN ALPINE SKIING AND SNOWBOARDING
A FOURTEEN YEARS' CASE-CONTROL STUDY

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INTRODUCTION. Injuries of children and adolescents in skiing and snowboarding is a developing field of research. Especially during the last two decades, alpine sports have demonstrated a steady growth in the preferences of little athletes worldwide. The purpose of this study is to determine the incidence and the types of these injuries and to identify the risk factors that may be associated with them.

METHODS. In a prospective case-control study, 4868 injured Skiers and Snowboarders with 5314 injuries were recorded, at Parnassus ski resort, using a multivariate protocol, during the years 2007-2023 (14 winter seasons). From these, 1168 injured were under 18 years old (842 skiers and 326 snowboarders). For our analysis and considering the different characteristics of the growing bony structure and mental maturation, we separated children in 3 age categories. These are the children of age 1-10 y.o., the age 11-14 y.o. and the adolescents of age 15-17 y.o. At the same time a control group of 1974 uninjured skiers and boarders, randomly selected on the slopes, were also recorded on a similar protocol. Out of them, 474 were under 18 years old (384 skier and 90 snowboarders). The number of skier/boarder days was calculated from total tickets number. Statistical analysis was performed using t – test, x^2 - test and Fisher's exact test.

RESULTS. The overall rate of injury was 3,94 injuries per 1000 skier days (IPTSD). The injury rate for both children (0-17 y.o.) and adults was 3.94 (3.5 vs 3.24 for skiers and 5.8 v 5.41 for snowboarders respectively). Almost 53,4% of injured children skiers and 77,6% of snowboarders were male. Referring to the children's study group, adolescents (15-17 y.o.) turn out to be twice as likely to be injured than other skiers (27,2% vs 14,06% of controls). According to gender, it is observed that male skiers age 11-14 y.o have high possibility for an injury (39,56% vs 31,08% of controls), while female skiers of the same age have the second lower possibility for injury (40,56% vs 51,85% of controls). As far as snowboarders are concerned, adolescent females have the highest possibility for injury (65,75% vs 44,44% of controls). In all age groups, the most common injured anatomical region among skiers was the Lower Extremity, except from the male skiers of age 15-17 y.o where the region of Upper Extremity predominates with 38,6% of the injuries. Simultaneously, while the most frequent injured anatomic location for snowboarders is the wrist joint, for male adult snowboarders the most frequent location is the shoulder with 33,25% of the injuries. In comparison with adults, children have increased probability for fractures (16% vs 12%) with the most frequent injury to be the wrist joint of male snowboarders. Beginner skiers are at high risk for injury (42,3% vs 36% of controls), while the same is observed to moderate snowboarders (41.2% vs 20%).

DISCUSSION AND CONCLUSIONS. Despite the factor that the risk for injuries among children and adolescents has reduced, compared to our previous experience, the male adolescent skiers still are twice as likely to be injured. The types and causes of these injuries are also different than those of adults. Understanding and addressing these factors provides safe pathways for injury risk reduction.

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